NATIONAL ECOSYSTEM ASSESSMENT OF ETHIOPIA

Syntheses of the Status of Biodiversity and Ecosystem Services, and Scenarios of Change

Ethiopian Biodiversity Institute
Addis Ababa, Ethiopia
2022

FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA

NATIONAL ECOSYSTEM ASSESSMENT OF ETHIOPIA

Syntheses of the Status of Biodiversity and Ecosystem Services, and Scenarios of Change

Ethiopian Biodiversity Institute

Addis Ababa, Ethiopia

2022

Comoros Street, Woreda 5, Yeka Sub-City
Addis Ababa, Ethiopia
P.O. Box 30726
Tel. +251-0116615607/0499
Fax. +2516613722/2542
E-mail. Info@ebi.gov.et
Website: www.ebi.gov.et

Editors

Debissa Lemessa (PhD)
Feleke Woldeyes (PhD)
Melesse Maryo (PhD)
Misikire Tessema (PhD)
Motuma Didita (Mr.)

Disclaimer

The publication has been produced by the **Ethiopian Biodiversity Institute (EBI)**, as part of the initiative on "Building capacity for national ecosystem assessments: linking science and policy and the Biodiversity and Ecosystem Services Network (BES-Net)". Financial support was provided by International Climate Initiative (IKI) of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) of the Federal Republic of Germany. The contents of this publication do not necessarily reflect the views or policies of the United Nations Environment Programme (UNEP), the United Nations Development Programme (UNDP) and their partners nor the Government of Germany. The designations employed and the presentations of material in this report do not imply the expression of any opinion whatsoever on the part of UNEP or contributory organizations, editors or publishers concerning the legal status of any country, territory, city area or its authorities, or concerning the delimitation of its frontiers or boundaries or the designation of its name, frontiers or boundaries. The mention of a commercial entity or product in this publication does not imply endorsement by UNEP or UNDP.

Acknowledgement

The Ethiopian Biodiversity Institute acknowledges that the successful implementation of the National Ecosystem Assessment Project has been materialized through the contribution of international partners and local stakeholders. Accordingly, our first and foremost thanks go to United Nations Environmental Programme World Conservation Monitoring Centre (UNEP-WCMC) for it has provided to benefit from this global project opportunity and also providing unreserved technical support during the implementation processes. Along with this, our sincere gratitude is also extended to International Climate Initiative (IKI) of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) of the Federal Republic of Germany for its financial support with which the present National Ecosystem assessment has been executed. Furthermore, the contribution of other international institutions that are affiliated to these two organizations and supported the process in one or another way is also well acknowledged.

We are grateful to our stakeholders, who basically belong to the policy making, scientific investigation and practically implementing realms, for they have actively engaged in consultative sessions contributing fruitfully throughout the project implementation processes. Moreover, we feel honoured to extend special thanks to the Authors, Editors, Reviewers, and project team who have been diligently participating in the assessments and evaluations of the outputs, subject and language editing, and the overall coordination of the project implementation, respectively. In this regard, arriving at the composite book would not have been possible without the relentless efforts and contributions of these experts of different categories and project team members.

Last, but not least, the administrations, financial and logistic facilitators of our Institute deserve our heartfelt thanks for their unreserved cooperation during the whole project implementation phases and the communication of outputs to stakeholders via appropriate modalities. Finally, we would like to thank all Ethiopian and international scholars who endeavored to gather information on Ethiopian biodiversity and Ecosystem Services and put it in a usable form and also local communities who have generated valuable knowledge for millennia. We are equally grateful to those responsible citizens who will be making use of the findings of the current national ecosystem assessment in improving biodiversity conservation and peoples’ wellbeing.

Foreword

Ethiopia is among the few megadiverse countries of the world. The topographic, agro-climatic and socio-cultural multiplicity of the country have contributed to the endowment of the rich biological diversity of the country. This also includes different ecosystems where parts of the two global biodiversity hotspot areas are situated in. Attributed to such physiognomic, ecological and cultural diversity, Ethiopia has become the center of origin and diversity for many genetic resources, including the domesticated crop species as well as wild forms.

Ecosystems, which represent biological communities of interacting organisms and their physical environment, supply us with the air, water, and food that are essential for life, with the raw materials for our industry and consumption, and other irreplaceable services including regulation of disease and soil erosion, purification of air and water, and opportunities for spiritual reflection. Nonetheless, the current status of biodiversity and the benefits we drive from ecosystem services are less known both locally and beyond.

Now there exists a general consensus that humans have changed ecosystems faster and more extensively in the last century than in any comparable period of time in human history. The situation in Ethiopia also aligns with this global reality. Predominantly, human-made direct drivers such as climate change, land use and land cover changes, environmental pollution, invasive alien species, and indirect drivers like production and consumption patterns, human population dynamics, the impact of technological innovations and trade, weak local governance system, policy and institutional frameworks, conflicts, migration, etc. remain the major causes of the witnessed changes. Cognizant of the direct consequences of changes in the status of biodiversity, the motto **"*By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people*"** was given a central position during the recent Post-2020 Global Biodiversity Framework formulation. The possibility of attaining a healthy planet in the presence of the aforementioned drivers, particularly in developing countries like Ethiopia where there is a low economy and an ever-growing population, seems difficult as suggested by many. However, professionals as well as many parties to the Convention on Biodiversity envisage that putting the transformational change approach into practice is a viable means to minimalize or curb the aforementioned complications. The transformational change could help implementing major strategic and cultural changes**,** and also adopting radically different technologies, making significant operating changes to meet the dynamic supply and demand aspects. To materialize such changes, bold plans and decisions, effective commitment, accountability, and a sense of responsibility are highly needed. Ethiopia has been known to have spearhead implementation of such initiatives ever since the ratification of the Convention on Biological Diversity in 1992.

The present Ecosystem Assessment, which has been undertaken at a national scale, is the first in its kind and offers a comprehensive picture of the natural as well as the human-modified Ethiopian environments, including the state of biodiversity and ecosystem services. The findings of this assessment hopefully establish the scientific evidences and bases for the actions required to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being. At this particular juncture of societal development where the need to ensure the conservation of biodiversity is a priority, and where the need to strengthen the science-policy interface to facilitate informed decision is high on the agenda, and generation of such knowledge on the environment is known to be of crucial importance.

As a largely agrarian society, the very existence of the Ethiopian population and our aspirations to emerge as a middle income country in the coming years are intimately linked to our achievements vis-à-vis conserving the country’s biodiversity wealth. In light of the progressive dwindling of this vital resource, there is a pressing need to jump into practical actions with the spirit of accomplishing transformative change in the area. I, therefore, take the outputs of this assessment as a starting point and fundamental input to the task ahead.

In line with this, government entities, particularly sector ministries and other institution, have to work hard with a strong motive to sustain the existing ecosystems and their services for the benefit of both the present and future generations. It remains the responsibility of various sectors both at Federal level and across different Regions in the country to engage the public through properly planned mobilization schemes. In this regard, the best practices and lesson learned from previous exercises including watershed development initiatives, the sustainable land management undertakings, and the Green legacy initiative need to be scaled up so as to minimize and halt the biodiversity loss as well as ecosystem degradation. Moreover, the issues of biodiversity have to be mainstreamed into sectors and sub-sectors targeting particularly at raising awareness and acting in environment friendly manner. Finally, effective monitoring, evaluation, reviewing, and reporting mechanisms have to be in place nationally. This will not only alert but also motivate us to take a proper action towards conserving and wisely utilizing our precious resources.

Non-governmental actors, and responsible citizens of Ethiopia, and the public at large are also called to earnestly use the outputs of the current assessment to contribute towards the national effort in achieving healthy environment and sustainable development. To this end, I sincerely invite our stakeholders and development partners to thoroughly read this comprehensive book which presents in a single package the diverse works of scholars from Ethiopia and abroad, and understand the current status of knowledge on biodiversity, ecosystem services and the existing science-policy gap.

Last but not least, I would like to thank those who have contributed their share by engaging in the Ecosystem Assessment, those who provided financial and technical support, and those who dedicated their time while guiding and coordinating multiple years long process which eventually culminated in this valuable book.

Oumer Hussein
Minister, Ministry of Agriculture
Federal Democratic Republic of Ethiopia

Preface

Ethiopia is situated in the northeast of horn of Africa lying between the geographical coordinates of 3°24′–14°53′ N latitudes and 33°00′–48°00′ E longitudes. The topography of Ethiopia is highly varied wherein globally recognized biodiversity hotspots, viz., the Eastern Afromontane, and the Horn of Africa exist. These biodiversity hotspot areas are comprised of a high level of endemism and diversity of flora, fauna, and micro-organisms. Moreover, Ethiopia is a megadiverse country in terms of natural ecosystems, farming systems and cultural diversity.

As an agrarian country and hosting a high human population where about 72% live in rural areas, Ethiopia is largely dependent on biodiversity resources for food production. Given the rich diversity of ecosystems and extensive agricultural practices, it is quite indispensable to obtain comprehensive data on the current status of biodiversity and future dynamics, and generate evidences that would be used to narrow the gap between science-policy interfaces. These evidences would also be used as inputs for policy and decisions makers in setting priorities and designing biodiversity conservation and sustainable development strategies. To this end, the World Conservation Monitoring Center (WCMC), which is an intergovernmental organization, globally supports countries to undertake their national ecosystem assessment following the conceptual and assessment frameworks of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). In this regard, Ethiopia has got the opportunity to undertake its national ecosystem assessment for which the Ethiopian Biodiversity Institute is a focal point and mandated nationally. Accordingly, the Institute has been collaborating with this global initiative since 2017 and nationally coordinating the assessment by identifying and nominating potential national scholars from universities, research institutes and non-governmental organizations.

The ecosystem assessment in Ethiopia has been implemented with the following approaches; (1) the technical team was established where the members were from Ethiopian Biodiversity Institute, Addis Ababa University, and Environment, Climate Change and Coffee Forest Forum, (2) the inception workshop was held to introduce the objective and the significance of the assessment for biodiversity conservation and enhancing the contributions of ecosystem services in improving human wellbeing, and (3) series of workshops with stakeholders were organized to identify the ecosystems and correspondingly validate the assessment activities.

Following the above steps, five ecosystems, namely, Mountain, Forest and Woodland, Aquatic and Wetlands, Rangelands, and Agroecosystem were recognized for the assessment at national level. To conduct the assessment, experts were identified and nominated by the assessment technical team based on their areas of expertise and experiences and approved by Ethiopian Biodiversity Institute. Guided by the IPBES assessment approaches, these experts were grouped into three categories of (a) authors consisting of contributing, lead and coordinating lead authors, (b) editors, and (c) external peer reviewers, and in total 35 experts were participated in the assessment. Before and during the implementation of the assessment, several consultations have been held especially with the authors on how to carry out the assessment and for evaluation of the progresses. This assessment work was entirely based on the secondary information from both published and grey literatures following the assessment framework of the IPBES. After the assessment was completed, evaluated by the external peer reviewers, editors, and the composite book was produced comprising of evidences from the five ecosystems.

The composite book consists of six ecosystem chapters, including a scenario chapter and is the first of its kind in Ethiopia as far as the ecosystem assessment is concerned at national scale. The overall executive summary and key findings were extracted from the summaries and key findings of each ecosystem chapter. The general introduction provides readers with the overarching goals, significance, challenges, and the paths forward for the effective conservation of biodiversity of the country and enhancing the contributions of nature to improving human wellbeing. The five ecosystems are the main bodies of the composite book. The respective chapters present the concepts, evidences on the current status of knowledge, drivers, challenges, and recommendations. The evidences in this book were validated at the Ethiopian biodiversity platform and hence will strongly complement in narrowing the existing gap at the science-policy interface in this face of land use and climate change. To this effect, the evidences will be further synthesized in the form of a summary for policymakers, scenarios to understand the future ecosystem dynamics. Moreover, communication and outreach materials will be produced and disseminated using various tools to stakeholders. Taking this opportunity, the Ethiopian Biodiversity Institute wishes to thank International Climate Initiative (IKI) of the Federal

Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) of the Federal Republic of Germany for its financial support and the World Conservation Monitoring Center, United Nations Environment Programme and the United Nations Development Programme for technical guidance; and authors, editors, external peer reviewers and stakeholders who have been engaged in the assessment and contributed to the production of this composite book. At last, it is our trust and belief that this book will be helpful not only for policymakers and conservationists but also in academic areas in the country and beyond.

Melesse Maryo (PhD)
Director General, Ethiopian Biodiversity Institute
CBD Primary NFP

Acronyms

ABoA	Amhara Bureau of Agriculture
ABS	Access and Benefit Sharing
ACB	*Acacia-Commiphora* Woodland and Bush land
ACC	Agricultural Commercialization Clusters
ACIAR	Australian Centre for International Agricultural Research
ADB	African Development Bank
ADLI	Agricultural Development Led Industrialization
AEZ	Agro Ecological Zone
AFD	Action for Development
AI	Artificial Insemination
ALDPP	Arero Livestock Development Pilot Project
AnGR	Animal Genetic Resources
ANP	Awash National Park
APAP	Action Professionals Association for the People
APDA	Afar Pastoralists Development Association
a.s.l.	above sea level
ATA	Agricultural Transformation Agency
AU	African Union
AUPPF	African Union Pastoralist Policy Framework
BBC	British Broadcasting Corporation
BCM	Billion Cubic Meter
BOD	Biological Oxygen Demand
BYDV	Barley Yellow Dwarf Virus
b.s.l.	below sea level
cal BP	Calibrated Years Before the Present
CBBP	Community Based Breeding Program

CBD	Convention on Biological Diversity
CCRDA	Consortium of Christian Relief and Development Association
CEA	Country Environmental Analysis
CEM	Commission on Ecosystem Assessment
CHGE	Center for Health and Global Environment
CNRS	Délégation Paris Michel-Ange
cpDNA	Chloroplast DNA
CPR	Common Property Regime
CRGE	Climate Resilient Green Economy
CSA	Central Statistical Agency
CSB	Community Seed Banking
CSO	Civil Society Organization
CTW	*Combretum terminalia* woodland and wooded grassland
DAF	Dry Evergreen Afromontane Forest and Grassland Complex
DPSIR	Drivers, Pressures, State, Impact and Response
DRSLP	Drought Resilience and Sustainable Livelihoods Project
DSS	Desert and Semi-Desert Scrubland
EAS	Ethiopian Academy of Sciences
EB	Ericaceous Belt
ECFF	Environment and Coffee Forest Forum
ECWP	Ethiopia Country Water Partnership
EFASA	Ethiopian Fisheries and Aquatic Sciences Association
EFCCC	Environment, Forest and Climate Change Commission
EGS	Ecosystem Goods and Services
EHRS	Ethiopian Highlands Reclamation Study
EIA	Environmental Impact Assessment
EIAR	Ethiopian Institute of Agricultural Research
EIBC	Ethiopian Institute of Biodiversity Conservation

ELD	Economics of Land Degradation
ELMZT	Enhance Livelihoods in the Mandera Triangle
ENSO	*El Nino* and the Southern Oscillation
EOTC	Ethiopian Orthodox Tewahido Church
EPA	Environmental Protection Authority
EPCC	Ethiopian Panel on Climate Change
EPD	Ethiopian Pastoralists' Day
ES	Ecosystem Services
ESIA	Environmental and Social Impact Assessment
ESIF	Ethiopian Strategic Investment Framework
ESRI	Ethiopian Soil Research Institute
ETB	Ethiopian Birr
EU	European Union
EU RESET	EU Resilience Building Program in Ethiopia
EWNHS	Ethiopian Wildlife and Natural History Society
EWNRA	Ethio-Wetlands and Natural Resources Association
FAO	Food and Agriculture Organization
FAWCDA	Forest and Wildlife Conservation and Development Authority
FCPF	Forest Carbon Partnership Facility
FDI	Foreign Direct Investment
FDRE	Federal Democratic Republic of Ethiopia
FEPA	Federal Environmental Protection Authority
FLV	Fresh Lakes-lake shore, marshes, swamps and flood plain Vegetation
Ga	Gega Annum (One Billion Years)
GB	Great Britain
GBS	Genotyping by Sequencing
GDP	Gross Domestic Product
GEF	Global Environment Facility

GERD	Ethiopian Grand Renaissance Dam
GFI	Governance Forest Initiative
GIS	Geographic Information System
GISP	Global Invasive Species Program
GLWD	Global Wetlands Database
GoE	Government of Ethiopia
GTP II	Growth and Transformation Plan II
GWAS	Genome-wide Association
HPC	High Potential Cereal
HPP	High Potential Perennial
HPR	House of Peoples' Representatives
IAF	Intermediate Evergreen Afromontane Forest
IAR	Institute of Agricultural Research
IAS	Invasive Alien Species
IBC	Institute of Biodiversity Conservation?
IBCR	Institute of Biodiversity Conservation and Research
ICRAF	International Centre for Research in Agroforestry
IDDRSI	IGAD Drought Disaster Resilience and Sustainability Initiative
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IGAD	Intergovernmental Authority on Development
IIRR	International Institute for Rural Reconstruction
IK	Indigenous Knowledge
ILK	Indigenous Local Knowledge
ILRI	International Livestock Research Institute
INSA	Information Network Security Agency
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

IPCC	International Panel on Climate Change
IPLC	Indigenous People and Local Communities
ITC	International Trade Center
ITCZ	Inter-Tropical Convergence Zone
IUCN	International Union for Conservation of Nature
IWMI	International Water Management Institute
JIRDU	Jijiga Rangeland Development Unit
km^2	Square Kilometer
LGM	Last Glacial Maximum
LPC	Low Potential Cereal
LULC	Land Use-Land Cover
LULCC	Land Use/Land Cover Change
MA	Millennium Assessment
MDGs	Millennium Development Goals
MEA	Millennium Ecosystem Assessment
MEF	Ministry of Environment and Forest
MERCEP	Ministry of Natural Resources Conservation and Environmental Protection
MERET	Managing Environmental Resources to Enable Transitions
MLN	Maize Lethal Necrotic virus disease
MoA	Ministry of Agriculture
MoANR	Ministry of Agriculture and Natural Resources
MoARD	Ministry of Agriculture and Rural Development
MoEFCC	Ministry of Environment, Forestry and Climate Change
MoFED	Ministry of Finance and Economic Development
MoLF	Ministry of Livestock and Fisheries
MoWE	Ministry of Water and Energy
MoWIE	Ministry of Water, Irrigation and Electricity
mtDNA	Mitochondrial DNA

MY	Million Years
MWe	Megawatt electric
NABU	Nature and Biodiversity Conservation Union
NAGII	National Animal Genetic Improvement Institute
NAHDIC	National Animal Health Diagnostic and Investigation Center
NAPA	National Adaptation Programme of Action
NARS	National Agricultural Research System
NASA	Network of African Science Academies
NEA	National Ecosystem Assessment
NERDU	North East Rangeland Development Unit
NISS	National Intelligence and Security Service
NMA	National Meteorological Agency
NPBCR	National Policy on Biodiversity Conservation and Research
NPC	National Planning Commission
NRM	Natural Resources Management
NTFP	Non-Timber Forest Products
NTTICC	National Tsetse and Trypanosomiasis Investigation and Control Center
NVI	National Veterinary Institute
NYZS	New York Zoological Society
OCHA	UN Office for Coordination of Humanitarian Affairs
OECD	Overseas Economic Cooperation and Development
PA	Peasant Association
PAP	Pastoral and Agro-pastoral
PASC	Pastoral Affairs Standing Committee
PASDEP	Plan for Accelerated and Sustainable Development to End Poverty
PBR	Plant Breeders' Right
PCoA	Principal Coordinate Analysis
PDC	Planning and Development Commission

PES	Payment for Ecosystem Services
PGRC	Plant Genetic Resources Centre
PGRFA	Plant Genetic Resources for Food and Agriculture
PRIME	Pastoral Area Resilience and Sustainable Livelihoods Project
PRSP	Poverty Reduction Strategy Paper
PSNP	Productive Safety Net Program
PSR	Pressure-State-Response
RARIs	Regional Agricultural Research Institutes
RBoA	Regional Bureau of Agriculture
RCP	Representative Consultation Pathways
$REDD^+$	Reducing Emissions from Deforestation and Forest Degradation, Plus Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks
RF	Riverine Forest
RPD	Rural Population Density
RPLRP	Regional Pastoral Livelihoods Resilience Project
RRC	Relief and Rehabilitation Commission
RS	Remote Sensing
RV	Riverine Vegetation
SDGs	Sustainable Development Goals
SDPRP	Sustainable Development and Poverty Reduction Program
SERP	South Eastern Rangeland Project
SLM	Sustainable Land Management
SLV	Salt water Lakes, lake shore salt marshes and pan Vegetation
SNNPR	Southern Nations, Nationalities and Peoples Region
SNNPRS	Southern Nations, Nationalities and Peoples Regional State
SNP	Single Nucleotide Polymorphism
SORDU	Southern Rangeland Development Unit

SSA	Sub-Saharan Africa
STRP	Scientific and Technical Review Panel
TLDP	Third Livestock Development Project
TLU	Tropical Livestock Unit
TRF	Transitional Rain Forest
TSS	Total Suspended Solid
TWNSO	Third World Network of Scientific Organizations
UN	United Nations
UNDESA	United Nations, Department of Economic and Social Affairs
UNEP	United Nations Environmental Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UN-EUE	UNDP Emergencies Unit for Ethiopia
USAID	United States Agency for International Development
USD	US Dollar
USPED	Unit Stream Power - based Erosion Deposition
VDFACA	Veterinary Drug and Feed Administration and Control Authority
WBISPP	Woody Biomass Inventory and Strategic Planning Project
WGG	Wooded Grassland of the Western Gambella Region
WHO	World Health Organization
WI	Wetlands International
WLRC	Water and Land Resource Centre
WSDP	Water Sector Development Program
WUA	Watershed Users' Association
WWF	World Wildlife Fund

Table of Contents

Contents	Pages

Executive summary

Ethiopia, the second most populous country in Africa, is located between 3°24' to 14°53'N latitude and 33°00' to 48°00'E longitude. Its 1.13 million km^2 total land area lies within the altitudinal range between 125 m b.s.l. and 4533 m a.s.l. The Country's diverse topographic features and associated environmental variations are comprised of varied habitats that house 12 vegetation types (well established) {3.1}.

Ethiopia is endowed with a variety of ecosystems (established but incomplete), the recognition of which is mainly based on the twelve vegetation types, and a newly established Intermediate evergreen Afromontane Forest: 1. Desert and semi-desert scrubland; 2. *Acacia-Commiphora* woodland and bushland; 3. Wooded grassland of the western Gambella region; 4. *Combretum-Terminalia* woodland and wooded grassland; 5. Dry evergreen Afromonane forest and grassland complex; 6. Moist evergreen Afromontane forest; 7. Transitional rain forest; 8. Ericaceous belt; 9. Afroalpine belt; 10. Riverine vegetation; 11. Freshwater lakes, lake shores, marshes, swamps and floodplains vegetation; 12. Salt-water lakes, lake shores, salt marshes and pan vegetation and the Intermediate evergreen Afromontane Forest {3.1}.

For the purpose of this National Ecosystem Assessment, the 12 vegetation-based ecosystems and their human-modified forms were broadly reclassified into five as: 1. Mountain Ecosystem; 2. Forest and Woodland Ecosystem; 3. Aquatic and Wetland Ecosystem; 4. Rangeland Ecosystem and 5. Agroecosystem. From among these five ecosystems, those mentioned from 2^{nd} to 5^{th} occur in more than one vegetation types. Moreover, the agroecosystem has evolved over the millennia through the conversion of the natural ecosystems by agrarian and agro-pastoral communities who have been interacting with the surrounding environment leading to the formation of heterogeneous agricultural landscapes, biophysical features and climatic regimes {1}.

This executive summary presents a brief synthesis of contents extracted from the summaries of the assessment reports of the five ecosystems, namely: Mountain ecosystem, Forest and Woodland ecosystem, Aquatic and Wetland ecosystem, Rangeland ecosystem and Agroecosystem. A more detailed information on these ecosystems can be obtained from the executive summaries of the respective ecosystem chapters {1}.

Each of the ecosystem has components that harbor unique biodiversity (well established). The recognized five ecosystems comprise part of the two of the 36 Global Biodiversity Hotspots (the Eastern Afromontane and the Horn of Africa) that support a large number of endemic and unique animal and plant species (well established). These ecosystems are reservoirs for several unique and domesticated and/or important wild plants and wild relatives such as *Coffea arabica*, Commiphora species and Boswellia species. They also house about 6000 higher plant species, 10% of which are endemic. There are also unique animal species in the various ecosystems. Some examples of the endemic species include the Endangered Walia ibex (*Capra walie*), the critically threatened Ethiopian wolf (*Canis simensis*), the gelada baboon (*Theropithecus gelada*); the Endangered Speke's gazelle (*Gazella spekei*) and the Critically Endangered Somali wild ass (*Equus africanus somaliensis*). The bird diversity and endemism is also extraordinary {2.3.3, 2.3.5, 3.1}. Moreover, Ethiopian Agroecosystem is are part of the Vavilovian centre of origin and/or diversity of crop species/varieties and livestock species/breeds, and are agrobiodiversity-rich systems (well established). In this connection, the promotion of agrobiodiversity conservation and diversification together with promotion of critically underutilized crops leads towards sustainable food production system {6.1, 6.3.2}.

The Ethiopian ecosystems provide various services such as provisioning, regulating, and non-material cultural, aesthetic, spiritual) services that contribute benefits to people. (well established). These ecosystems contribute to the national economy and local livelihoods: through income generation, by improving food and nutritional security and climate change adaptation {2.2.2, 2.2.3, 3.2.1, 4.2.1, 5.2.2, 6.3.1}, as tourist attractions {2.2.2, 2.2.3, 4.2.3, 5.2.2.3}; through their contribution in waste treatment and pollution prevention {4.2.2}; as habitat for pollinators and by providing cultural and spiritual services {2.2.2, 2.2.3.4, 3.2.1, 4.2.3, 4.2.4, 5.2.2, 6.1, 6.2.1}.

The Ecosystems in general are affected by direct drivers such as anthropogenic factors (including population growth) climate change, land use and land cover change and indirect drivers such as policy and governance systems at local, national and international levels. Extensive land use pressures and the increased demand for natural resources and products are the major causes of the degradation of ecosystems (well established). These major causes include excessive water abstraction, drainage agriculture, urbanization, pollution, introduction and expansion of invasive alien species {2.1.6.1, 2.3.3, 2.4.1, 2.4.2, 3.3.4, 3.5.1, 3.5.2, 4.3.2, 4.4.2, 5.4.1.1, 5.4.1.2, 6.4.1, 6.4.2}, and climate change {5.4.1.1}; bush encroachment and transformation of rangelands to other land use types {5.3.3.2}. Moreover, agricultural activities/practices expanding to new areas are resulting in habitat changes threatening animal and plant species by reducing their populations and associated gene pools (well established){2.4.1, 3.5.2, 4.3.2, 5.4.1.2}.

The spread of invasive alien species affects all ecosystems (well established). The introduction and the proliferation of these species such as water hyacinth, (*Eichhornia crassipes*), prosopis (*Prosopis juliflora*), parthenium (*Parthenium hysterophorus*), striga (*Striga hermonthica*, some species of which are native) and lantana (*Lantana camara*) weeds into the, forest and woodlands, water bodies, rangelands and agricultural production systems affecting biodiversity and ecosystem services including fishery industry, livestock watering, navigation and ecotourism, canals of hydroelectric power plants and irrigation; thus causing serious ecological imbalance and health hazards to humans and animals {3.3.3, 3.3.4, 4.4.1, 5.3.3.2, 6.4.1.2}.

Ethiopia has formulated and implemented several biodiversity related policies, laws, regulations and guidelines over the past several years to address conservation and sustainable use related challenges and to improve economic and societal benefits (well established). In this regard, the National Biodiversity Strategy and Action Plan 2015-2020 is an overarching framework on biodiversity for all stakeholders to value biodiversity and ecosystem services, reduce the pressures on biodiversity and ecosystems, improve the status of biodiversity and ecosystem services, and ensure access to genetic resources and fair and equitable sharing of benefits arising from their use. Ethiopia's Climate Resilient Green Economy strategy and the sustainable land management entail a mix of policies and instruments that together ensure nature conservation, ecological restoration and sustainable use, sustainable production (including of food, materials and energy), and climate change adaptation, and in so doing addresses the major drivers of biodiversity loss and nature deterioration {2.6, 3.7.1, 4.6, 5.6.4.1, 5.6.5, 6.6.1}. A number of international treaties and conventions that relate to biodiversity conservation were adopted over the last two decades {2.6.3, 3.7.1, 4.6.12, 6.6.1}. However, some of the policy and legal instruments of implementations are patchy to protect ecosystems; their implementation and enforcement are irregular, incompetent, and ineffective {2.6, 3.7.1, 4.6, 5.6.4.1, 5.6.5, 6.6.1}

Furthermore, the absence of a comprehensive land use policy, frequent changes in institutional setup and weak capacity of institutions, poor inter-sectorial coordination and lack of synergy between sectors, inadequacy of the legal frameworks and weak law enforcement, and unclear tenure system were some of the major challenges that have been affecting biodiversity of the country {2.6, 3.7.1, 4.6, 5.6.4.1, 5.6.5, 6.6.1}. These challenges resulted in degradation of ecosystem services and integrity of unique biodiversity in many of the ecosystems and, therefore, there is a need for concerted management interventions for sustainable uses of the natural resources and services; policy action needed to promote sustainable intensification in agriculture and limiting excess population growth {2.6.1, 3.7.1, 3.7.2, 4.6, 5.6.7, 6.6.2}

Local communities living in the various ecosystems have rich indigenous local knowledge developed over millennia to manage biodiversity and the ecosystem services (well established). These communities have unique natural resource management systems that contributed to the conservation of biological resources and ecosystem services, and use {2.5, 3.6.2, 4.5.1, 5.6.4.1, 6.1} and this needs to be tapped, enhanced and applied. Though there are efforts to conserve biodiversity resources in all ecosystems, there is a need to increase awareness and recognize and make use of the invaluable indigenous knowledge for the management of biodiversity and ecosystem services {2.5.2, 3.2.1, 3.6.1, 4.5.1, 5.6.4.1, 5.6.5, 6.5.1, 6.5.2}.

Key Findings

Ethiopia is ecologically diverse with the chain of highlands, midlands and lowlands that encompass familiar biomes and more than 13 major vegetation types and various ecosystems with diverse flora, fauna and rich belowground and aboveground microbial diversity {2.1.1, 2.1.2}. The topographic settings stretch over a high altitudinal range between 125 m b.s.l. and 4533 m a.s.l. covering high mountains, flat-topped plateaus, gorges, valley bottoms and aquatic and wetland environments. Rangelands and agricultural landscapes where population centres occur and people engage in animal husbandry, crop cultivation and other livelihood systems are distributed within the wide agroclimatic and spatio-temporal settings of the country (well established).

The Ethiopian mountains are among the unique centres of biodiversity, housing diverse endemic fauna and flora inhabiting this most sensitive and fragile ecosystem {2.1.6.1, 2.2.1, 2.3.4, 2.4.3}. Most of the mountains are well-known headwaters to major inland and Transboundary Rivers, holding great cultural values for connecting people with nature and serving the purposes of recreation and tourism in addition to the usual material goods and services (established but incomplete). This ecosystem is highly vulnerable to the adverse impacts of climate change with little or no documentation in most cases. The mountain ecosystem has entered a declining phase as manifested by shrinkage of coverage due to on-going human-driven land use and land cover changes with increasing vulnerability to climate change, further aggravated by increasing livestock populations and encroachment by agriculture and settlement.

Most of the endemic flora and fauna inhabiting isolated mountains have been assigned critically endangered status by the IUCN Red List Criteria {2.3.5}. The on-going changes are negatively impacting the rare and endemic plants, animals, the keystone species and the characteristics of the ecosystem (well established).

Local communities living inside and around the Ethiopian mountain ecosystem have developed millennia long, rich Indigenous and Local Knowledge (ILK) for the uses of a variety of plant species for traditional medicine and conservation of biodiversity resources (established but incomplete). Local communities in Menz Guassa Mountains, for example, use what is called ‘Qero’ natural resource management system for conservation of biological resources and ecosystem services, and communities in and around Bale Mountains use plants as a major sources of medicine for primary health care {2.5}.

The National Policy on Biodiversity Conservation and Research and other environmental conservation and sustainable development-related policies and strategies pay little attention to the mountain ecosystem as a unique environment of outstanding ecosystem services {2.6, 2.6.3}. This assessment, therefore, sends an important signal to the Ethiopian Biodiversity Institute (EBI) and all concerned institutions to dispense/allocate special consideration to the important biodiversity and ecosystem services (established but incomplete).

The forest and woodland ecosystem stretches over a large area of the country and hosts the highest magnitude of biodiversity of all the Ethiopian ecosystems with considerable economic and ecological importance to Ethiopia and the global climate {3.1}. The long history of human occupation with continued land degradation and deforestation have critically threatened the forest and woodland ecosystem and its biodiversity. These changes need enhanced protection, afforestation, restoration and rehabilitation actions with sustainable utilization (established but incomplete).

The Ethiopian government has long realized the importance of forests and woodlands as demonstrated by designation and safeguarding of protected area systems, though most of the protected areas are under huge pressure due to inadequate protection partly because they are viewed by some affiliated authorities as areas set aside for the protection of game and associated wild animals {3.1, 3.2.1, 3.6.1}. Direct and indirect anthropogenic and natural causes and drivers negatively impact the biodiversity and the services of this ecosystem. If the current trend is left unchecked, the biodiversity of the country's relatively pristine environments of the forests and woodlands will indisputably continue to decline and the associated livelihood systems will further deteriorate. Introduction and promotion of environmental marketing schemes that involve water, biodiversity, carbon and other resources as well as valorization of new forest products will be critical to enhance forest and woodland conservation and sustainable utilization (established but incomplete).

Analyses of policies and institutional arrangements relevant to biodiversity and ecosystem services of the forest and woodland ecosystem and their impacts show a huge gap between policy design and implementation and law enforcement {3.3.1, 3.5.2, 3.7.1,3.7.2}. Efforts have focused on developing policies and strategies while little has been done on strengthening institutional arrangements, implementation at field levels and enforcement of laws (established but incomplete). Frequent shifting of the institutional mandates needs to be minimized and collaborations have to be improved for stability and deliverance of outputs.

Not enough biodiversity conservation has been done in the forest and woodland ecosystem and this is hindering national efforts to halt deforestation and achieve the country's ambitious plan for fast-track sustainable development (well established) {3.3.1, 3.5.2, 3.7.1, 3.7.2}. Translation of policy and legal provisions relevant to the forest and woodland biodiversity and ecosystem services into implementation instruments through regulations, directives and guidelines must be reinforced by actions. Freely accessible, accurate and up-to-date comprehensive legal and spatial information and records about the forest and woodland biodiversity ought to be maintained centrally at regional and federal levels and this must be enshrined by law.

Ethiopia is endowed with substantial aquatic and wetland resources. The total area of lakes, reservoirs and rivers is estimated at 7,444 km^2 (0.07% of the country). There are 11 major freshwater lakes, nine major alkaline lakes and 12 major wetlands, which all together occupy about 1.5-2.0% of the country's landmass (well established) {4.1.3, 4.2}. Growing number of reservoirs have been constructed including the Great Ethiopian Renaissance Dam with an area of 1874 km^2 at full capacity. Fourteen major rivers crisscross the country, which is largely classified as a dryland area despite being the source of major inland and transboundary rivers including the world's longest river (the Nile). A growing number of human-made reservoirs are adding to the surface water storage potential of the country.

The Ethiopian aquatic and wetland ecosystem is a biodiversity hotspot accounting for about 10% of the country's floral diversity, holding habitats for about 25% of the avifaunal diversity and diverse megafauna (well established) {4.2.4}. This ecosystem provides key economic and cultural values that enhance the quality of life in addition to the provision of water and land critical for agriculture, albeit the lack of adequate empirical data on the number of pollinators and their contribution to the national economy.

The aquatic and wetland ecosystem has a potential to contribute to improving food security and surplus production so long as sustainable management is made the norm. The services

and values that accrue to the people of Ethiopia from this ecosystem play key roles in the cultural manifestations as well as affirmation of beliefs and identity of communities adding to the major material goods, functions and services {4.2.1, 4.2.3}. The roles of wetlands as kidneys for the aquatic system and adjoining drylands with benefits to nature and humanity coupled with their economic and biodiversity potentials are assets yet to be fully understood and recognized in development ventures (well established).

Ethiopia is rapidly losing its natural water bodies and wetlands due to factors such as over abstraction, pollution, changes in land use and habitats and climate change which result in water scarcity, increased vulnerability to drought, floods and loss of livelihoods {4.3.2, 4.4.2}. The biodiversity of this ecosystem is rapidly declining as the negative impacts threaten the wild flora, fauna and the ILK system. Growing socio-economic demands attributed to a multitude of internal and external factors drive the dynamics in the Ethiopian aquatic and wetland ecosystem and services. Direct drivers causing resource degradation include over-abstraction, invasive alien species, overgrazing and dominance of non-palatable forage plants (well established).

Low level of public awareness prevails in the face of growing threats to aquatic and wetland areas. The legislative and organizational reforms have played their role in reducing environmental challenges although their impacts to reverse damages are contested {4.3.2, 4.5.1}. The laws, policies and associated instruments lack implementation tools as well as confronting unclear and overlapping mandates (established).On the other hand, some issues pertinent to this ecosystem are included in other policy frameworks {4.6}. The existing legal instruments are patchy and irregular leading to incomplete implementation, compliance and enforcement. These legal frameworks are ineffective to protect the aquatic and wetland areas of the country thus calling for further interventions. On-going activities geared to developing regulations that help to delineate wetlands, buffer zones and for mounting awareness-raising drives are expected to redress some of the gaps.

The rangeland ecosystem in Ethiopia occurs widely and holds important biodiversity and provides key ecosystem services through the provision of sources of feed, food, medicine, energy, gum and incense among others and safeguards environmental health (well established) {5.2.2, 5.4.1.2, 5.4.2, 5.5.2, 5.5.3}. A major resource supplier in this ecosystem is livestock husbandry, which also contributes to soil nutrient cycling but may lead to land degradation and biodiversity loss in the absence of sustainable management. Vegetation in rangelands contributes to carbon storage, climate stability, air and water purification and control of the erosive forces. The habitats with the plants and animals create important sceneries, sites for large herbivores and carnivores and other wildlife and are highly valued as tourist attraction centres.

The rangeland ecosystem has roles of maintaining social identity, heritage values of cultural landscapes and provisioning of nature's spiritual services. Land use/land cover (LULC) changes in rangelands show the observable substantial changes made since the 1960s {5.3.2.2}. For example, many pastoral areas show increasingly fenced rangelands/grazing enclosures, an evident change in tenure with the growing shift from traditional communal grazing lands to private holding and curtailment of seasonal mobility between wet and dry season grazing areas. These changes led to the loss of vegetation cover aggravating soil erosion in wet season grazing areas. Anthropogenic pressures on rangelands coupled with changing climate have led to the deterioration of the ecosystem, increasing soil erosion, loss of palatable grasses and legumes, and increased bush encroachment (well established).

The shift towards sedentarization, crop cultivation and privatization of communal rangelands trigger conflicts over the use of grazing and water resources with boundary claims {5.3.2.2}. The major direct drivers of change in biodiversity and ecosystem services are climate change and variability, inappropriate extension services and management, land use changes, overexploitation, privatization and/or sedentarization, bush encroachment and population pressure with constrained mobility. Policy, governance and formal institutions indirectly contribute to the weakening of customary institutions leading to changes in biodiversity and ecosystem services (well established). Continued degradation of the rangeland ecosystem is leading to loss of the associated ILK and shifting livelihoods. Customary institutions that have traditionally been governing the rangelands are breaking down as formal institutions grow to dominance. Government programmes of pastoral areas emphasize poverty reduction and development focusing on resource extractions for short-term gains. The biophysical, socio-economic and political conditions in recent decades are also threatening the role and strengths of the traditional institutions and practices.

Lack of clarity in rangeland policy and development direction, limited knowledge and attention to the pastoral ILK and institutions and prevailing governance systems are causes of degradation linked mainly to inappropriate decision-making and misappropriation of resources (established but incomplete) {5.1, 5.6.4.1, 5.6.5}. There is no dedicated standalone organization responsible for rangeland development. Besides there is no a clear policy framework that recognizes and empowers customary institutions and ILK for resource governance, conflict management and other methods of traditional protection applicable to rangelands. This situation has led to the deterioration of biodiversity and ecosystem services of rangelands.

The rangeland sector needs strong institutional stature or alignment with the most relevant and mandated ministry (established but incomplete) {5.6.7}. Adequate research evaluating the effectiveness of policies, governance systems and institutional settings that can harmonize government plans with the interests of pastoral communities need to be put in place. The challenges could be addressed through the provision of training, awareness-raising, implementation of outreach programmes, developing knowledge management system suitable for diverse stakeholders and undertaking research on biodiversity and ecosystem services where consideration of the know-how on payment for ecosystem services (PES) that would engage and empower local communities needs to be designed. The evolution of a pastoral-friendly rangeland policy can pave the way towards building resilient livelihoods while maintaining the cultural, historical and economic characteristics of the system. A clear pastoral land tenure system and land use policy frameworks are necessary to sustain the productivity and viability of this ecosystem.

The agroecosystem in Ethiopia stretches over 32 major agroclimatic/agroecological zones with diversity in agricultural practices and farming complexes (established but incomplete) {6.1}. Fourteen distinct production-based agricultural systems, clustered into three major systems (pastoral and agropastoral, cereal/grain crop-based or seed farming, perennial crop-based), have varying designations and agrobiodiversity contents. They are widely distributed within the agroecological zones providing multiple agroecosystem services to people and nature.

The Ethiopian agroecosystem has various forms of uniqueness as it evolved within a Vavilovian centre of origin and/or diversity of crop and livestock species/varieties and

breeds under diverse socio-cultural settings in a biodiversity-rich country that falls within two of the global biodiversity hotspots (well established) {6.1}. It provides major ecosystem services benefitting people in Ethiopia and beyond. The agricultural systems have been shaped by millennia of perfection of the ILK for sustaining the biophysical, socio-economic and cultural assets of communities.

Crop and livestock varieties/landraces and breeds that are contributing to humanity's welfare are declining and the many wild useful plant species and orphan crops that could improve food security and livelihood systems of the people remain underutilized and vulnerable {6.3.1, 6.3.26.}. Wider knowledge and yield gaps prevail more in the cases of the underutilized species. There are several orphan crops and uncultivated useful plants that require increased conservation actions. Traditional agricultural practices have built-in agrobiodiversity conservation and livelihood support systems but the time-tested ILK on agroecological farming and polyculture practices are underutilized and underdeveloped (established but incomplete). Adequate documentation, valorization and effective socio-economic transformation efforts are lacking.

Agriculture is the largest sector of the economy in Ethiopia being backed by diverse agricultural systems and plentiful agrobiodiversity that supports diversified livelihood systems in pockets of agroecosystem {6.2.1, 6.2.3}. The country has diverse agroecosystem pockets upon which the economic and social systems are based. The types of crops cultivated indifferent localities are determined by the agroecology of the sites and the preferences of the people living in the areas. However, systematized scientific data are lacking and modernized use and management remain growing concerns. Agroforestry systems are likely to increase in coverage with increasing potentials to optimize agroecosystem services. Traditional agroforestry systems based on indigenous woody species and natural ecosystems adjacent to farmed landscapes are critical for safeguarding and enhancing agroecosystem functions and optimizing its services (well established). Planning and implementation of conservation need to consider pools of genetic resources in crops, crop wild relatives, livestock and associated biota including microbes.

The agroecosystem plays significant roles in supporting human wellbeing in Ethiopia; but it is threatened by natural and anthropogenic drivers resulting in the loss of agrobiodiversity and essential ecosystem services {6.4.1, 6.4.2}. Elements of climate change, recurrent droughts, floods and invasive alien species add to vulnerability of the agroecosystem in Ethiopia. Overexploitation of soil and water resources further compounded by acidification and salt accumulation heighten Ethiopia's major challenges in food production and productivity and efforts to reduce poverty, maximize agroecosystem services and maintain healthy human ecology and socio-economic wellbeing (well established).

In recent decades, increasing level of awareness and knowledge about nature's contributions, status and management of agrobiodiversity and agroecosystem services is observed (established but incomplete) {6.5}. Ethiopia has awareness-raising and education programmes, policies and planning frameworks that support conservation and sustainable management of agrobiodiversity and agroecosystem services. These are undertaken through mainstreaming agrobiodiversity and engaging local communities and farmers to enhance agrobiodiversity-enriched farming. Awareness raising and generation of knowledge need to focus on the trade-offs between the provision of material goods and non-material ecosystem services.

The government of Ethiopia has demonstrated commitment to agrobiodiversity conservation for better agroecosystem services through institutional capacity building and funding but more is needed to enhance the use of climate-smart ILK relevant to agriculture and the ecological processes at all levels given the gaps (established but incomplete) {6.5.2, 6.5.3}. Gradual increase of community participation in agrobiodiversity management is noticeable but the need to develop and implement new approaches that recognize and work with farmer conservators on documentation, valorization and incorporation of ILK is high.

1. Introduction

Biodiversity and healthy ecosystems provide the essential resources and ecosystem services that directly support a range of economic activities, such as agriculture, forestry, fisheries and tourism. All food systems depend on biodiversity and a broad range of ecosystem services that support agricultural productivity, soil fertility, and water quality and supply. According to Biodiversity and the 2030 Agenda for Sustainable Development, 2016, at least one-third of the world's agricultural crops depend upon pollinators. Ecosystem services and other non-marketed goods are estimated to make up between 50 and 90% of the total source of livelihoods among poor rural and forest-dwelling households (https://www.cbd.int/development/sdg1/). Healthy ecosystems help to mitigate the spread and impact of pollution by both sequestering and eliminating air, water and soil pollution. Forests, among other benefits, regulate water flow and improve water quality (https://www.cbd.int/development/). Many medicines have been derived from biological products and a substantial proportion of the world's population depends on traditional medicines derived from biodiversity.

Ethiopia is one of mega diverse countries in terms of biodiversity. This is due to the presence of different geographical features with varying temperature and precipitation. These topographic features provide habitats for plant and animal species, which had formed assemblages and larger ecosystem hierarchies. This has enabled the country to host two of the world's 36 biodiversity hotspots, i.e., the Eastern Afromontane and the Horn of Africa hotspots.

Despite this rich endowment, biodiversity is being lost and ecosystem are degraded at an alarming rate due to habitat conversion, unsustainable utilization of biodiversity resources, invasive alien species, replacement of local varieties and breeds, climate change and pollution. Specifically, conversion of natural forests, grazing lands, woodlands, and wetlands to agriculture and settlement are growing, causing severe ecosystems degradation and biodiversity loss in different parts of the country. Consequently, many wild plants and animals including endemic species are at risk of extinction. According to EBI (2014), some 103 tree and shrub species, 31 bird, one reptile, nine amphibian, two fish, and fourteen other invertebrate species are known to be under threat. Farmers' crop varieties and indigenous animal breeds are slowly disappearing.

The ecosystems in Ethiopia have been classified into 10 broad categories (EBI, 2015). According to the recent work by Friis et al. (2010), 12 vegatation-based ecosystem are recognized. For the purpose of this national assessment, however, these ecosystems are clustered into the following five major groups, based on the stakeholders consultations during the scoping phase.

1. **Mountain ecosystem:** this refers to the ecosystem on high mountains that support people who live within the mountain regions. The low land people also depend on mountain environments for a wide range of goods and services, including food, water, energy, timber, and other biodiversity resources as well as opportunities for recreation and spiritual renewal.
2. **Forest and woodland ecosystem:** this ecosystem type refers to natural forest and woodland which provides goods such as timber, food, fuel and other bio-products. Moreover, a healthy forest and woodland ecosystem functions as carbon storage and serves in nutrient cycling, water and air purification, and maintenance of wildlife habitat.

3. **Aquatic and wetland ecosystem:** this ecosystem refers to the aquatic and wetland areas where living organisms whose food, shelter, reproduction and other essential activities depend in a water-based environment. This consists of both running (lotic) and standing (lentic) inland water bodies, including rivers, lakes, reservoirs, swamps, wetlands and aquatic bodies with transient water contents during some time of the year. Aquatic and wetland ecosystem provides habitats, and breeding grounds for several plant and animal species. The ecosystem facilitates the recycling of nutrients, helps to purify water, recharges groundwater, mitigates floods, and serves as a habitat for aquatic flora and fauna.

4. **Rangelands ecosystem:** rangeland ecosystem refers to the land where grasses, forbs and shrubs are predominantly found. This ecosystem provides multiple functions as a habitat for a wide array of domestic and wild animal species as well as for a diverse and wide range of plant species. The Rangeland supports pastoral and agro-pastoral livelihoods and social values.

5. **Agroecosystem:-** this is the ecosystem upon which agriculture is based. It generally corresponds to the spatial unit of a farm and whose ecosystem functions are valued by

humans in the form of agricultural goods and services. The ecosystem harbours a diverse range of organisms that contribute, at various scales to, *inter alia,* nutrient cycling, pest and disease regulation, pollination, pollution and sediment regulation, maintenance of the hydrological cycle, erosion control, and climate regulation and carbon sequestration.

This National Ecosystems Assessment (NEA) is the first of its kind for Ethiopia. It was undertaken through a comprehensive systematic review of research findings reported in various journals and sectoral reports. The assessment process was based on the guideline of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). To conduct the assessment, senior experts were commissioned as coordinating lead authors, lead authors, contributing authors, editors and external peer reviewers at a specific ecosystem level. For each ecosystem assessment, a team of experts consisting of seven members was formed. Accordingly, a total of 35 experts took part in producing the national ecosystem assessment report. The assessment report produced for each ecosystem was reviewed by both subject editor and external peer reviewer conceptual correctness and information completeness. The report was enriched by incorporating the feedbacks. Finally,, the lead authors and project team members worked on the harmonization and compilation of the ecosystem chapters towards formulating the composite book.

The report shows the existing challenges and evidence gaps at science-policy interface and expected to lead to a better understanding of the need for taking into account biodiversity and ecosystem services related issues in policy development and decision making processes. As this is the first national ecosystems assessment, the experiences and lessons learnt will be used as a baseline to inform future assessments and processes in Ethiopia and elsewhere.

2. Mountain Ecosystem

Contributors

Corresponding Lead Author: Tigist Wondimu (PhD)

Lead Author: Sileshi Nemomissa (Professor)

Contributing Authors: Belay Simane (Professor)

Ermias Lulekal (PhD)

Mekuria Argaw (PhD)

Editor: Woldeamlak Bewket (Professor)

External Peer Reviewer: Desalegn Wana (PhD)

Table of Contents

List of Tables

List ot Figures

List of Boxes

Executive summary

In Ethiopia, mountains have three distinct vegetation types (Afro-montane, Ericaceous and Afro-alpine) that stretch in peculiar ranges of altitude forming belts around the high rising landmass. They also form distinct peaks and exhibit characteristic diurnal variations of temperature at their upper most vegetation type, the Afro-alpine, i.e., summer-type every day and winter-type every night. **Ethiopian mountains are among the most fragile and sensitive ecosystems to climate change** (established but incomplete). They are being affected at a faster rate than other terrestrial habitats, which is likely to have severe consequences for water provision and livelihoods in downstream regions {2.1.6.1, 2.2.1, 2.3.4, 2.4.3}.

Although the Ethiopian mountain ecosystem is among the unique centers of biodiversity that houses diverse endemic fauna and flora, limited information is available in majority of the cases (established but incomplete). For example, 340 medicinal plant species and 163 endemic plant species of Ethiopia occur in Bale Mountains, and 23 of the endemic plant species are confined to these mountains {2.3.3}.

Ethiopian mountain ecosystem is well-known as headwater to several national and transboundary rivers (well established). Populations of Ethiopia and the neighboring countries heavily rely directly and indirectly on Ethiopian mountain resources for freshwater supply. For instance, close to 80 percent of the total annual renewable surface water resource of Ethiopia leaves the country through its transboundary rivers {2.2.3.1}.

Ethiopian mountains have a great cultural value and are centers of recreation and tourism (established but incomplete). About 24% of the Protected Areas of Ethiopia are located in mountains (5 mountains fall in the National Parks conservation category covering about 10,110 square kilometers). A large number of tourists visit mountain ecosystem every year, e.g., 9,000 for Bale Mountains and 26,000 for Simen Mountains National Parks in 2014 and 2018, respectively. As the result, the Ethiopian mountain ecosystem directly contributes to the national economy and local livelihoods through incomes from tourists. Evidence based management plans as well as research based ecosystem service payment scheme may help to enhance sustainability of such ecosystem services {2.2.2, 2.2.3.4}.

Most of the endemic fauna of the Ethiopian mountain ecosystem have been categorized as critically endangered as per the IUCN RED List criteria (well established). However, the conservation status of many endemic plant species that are confined to mountain ecosystem has not been assessed by the same criteria despite the evident threat. For example, *Swertia macrosepala* subsp. *microsperma, S. volkensii var. baleensis* and *S. crassiuscula* subsp. *robusta* are known only from one to two populations on Afro-alpine belt of Bale Mountains {2.3.5}.

Mountain ecosystem exhibits a declining trend in its area coverage due to an on-going human-driven land use/land cover changes (well established). Agricultural activities are expanding into the steep slopes of this ecosystem, e.g. the growing of barley in the Afro-alpine belt of Simen Mountains, and settlements and cultivations in the Ericaceous belts of Bale Mountains. These anthropogenic effects on Mountain ecosystem of Ethiopia have threatened long-term persistence of animal and plant species through reducing their populations and associated gene pools {2.4.1}.

Mountain ecosystem is increasingly becoming vulnerable to climate change and increasing livestock populations and movement of people (established but incomplete). In this ecosystem, fire is used to manage traditional grazing practices in the Ericaceous belt and local communities move large herds of livestock to the Afro-alpine in search of pasture. Such effects threaten habitat quality and size, induce a decline of the integrity of biodiversity and trigger risks of cross breeding of domestic animals with critically endangered wild animals, e.g., the cross breeding between dogs and the Ethiopian Wolf {2.1.6.1, 2.3.3, 2.4.1, 2.4.2}.

The mountain ecosystem of Ethiopia is unique with regard to goods and services it provides, the ecology and diversity of fauna and flora; and has a high potential for development of ecotourism (established but incomplete). It exhibits a diversity of microclimates, e.g., pockets of habitats protected from prolonged sun radiation, high altitude swamps and alpine crater lakes, exposed rock cliffs, stream banks for range restricted plant species such as *Rosularia semiensis* and *Saxifraga hederifolia* {2.2.2, 2.2.3}.

Local communities living inside and around the Ethiopian mountain ecosystem have developed millennia long, rich Indigenous and Local Knowledge (ILK) for the uses of a

variety of plant species for traditional medicine and conservation of biodiversity resources (established but incomplete). Local communities in Menz Guassa Mountains, for example, use what is called 'Qero' natural resource management system for conservation of biological resources and ecosystem services, and communities in and around Bale Mountains use plants as a major sources of medicine for primary health care {2.5}.

The National Policy on Biodiversity Conservation and Research is an overarching policy document regarding the country's biodiversity resources, but it does not pay any special attention to mountain ecosystem as a unique environment with its outstanding ecosystem services (well established). The lack of policy focus on the Ethiopian mountain ecosystem could lead to a continued decline in the ecosystem services it provides and the integrity of unique biodiversity found therein. Concerted management interventions taken by the government and non-government organizations in some areas have demonstrated possibilities for sustainable uses of the natural resources and services of this ecosystem {2.6).

The Ethiopian Biodiversity Institute is the sole government body which oversees the conservation research and sustainable use of biodiversity; and equitable sharing of benefits accrued from the use of genetic resources (well established). There are also other government institutions, e.g. the Ethiopian Wildlife Conservation Authority, which focuses on the conservation, research and development of the diversity of fauna of the country. Although Ethiopia is known for its strong vertical links of institutions, horizontal linkages are generally weak {2.6.3}.

Key findings

1. Ethiopian mountains are among the most fragile and sensitive ecosystems prone to adverse impacts of climate change.
2. Although the Ethiopian mountain ecosystem is among the unique centers of biodiversity that houses diverse endemic fauna and flora, limited information is available in majority of the cases.
3. The Ethiopian mountain ecosystem is well-known as headwater to several national and transboundary rivers.
4. The Ethiopian mountains have a great cultural value and are centers of recreation and tourism.
5. Most of the endemic fauna of the Ethiopian mountain ecosystem have been categorized as critically endangered by the IUCN RED List criteria.
6. The country's mountain ecosystem exhibits a declining trend in its area coverage due to an on-going human-driven land use and land cover changes.
7. The mountain ecosystem is increasingly becoming vulnerable to climate change and increasing livestock populations and movement of people.
8. The mountain ecosystem of Ethiopia is unique with regard to its ecosystem goods and services, ecology and diversity of fauna & flora; and has a high potential for development of ecotourism.
9. Local communities living inside and around the Ethiopian mountain ecosystem have developed millennia-long, rich Indigenous and Local Knowledge (ILK) with respect to the use of a variety of plant species for traditional medicine and conservation of biodiversity resources.
10. The National Policy on Biodiversity Conservation and Research is an overarching policy document for the conservation and sustainable use of the country's biodiversity, but it does not pay any special attention to the mountain ecosystem as a unique environment with its outstanding ecosystem services.

11. The Ethiopian Biodiversity Institute is the sole government body which oversees the conservation, research and sustainable use of biological diversity; and equitable sharing of benefits arising from the use of genetic resources

2.1 Introduction

2.1.1 Definition of key terms

Mountain is defined as a landmass that has risen significantly above sea level and from the surrounding area, forming attitudinally defined vegetation zones. In Ethiopia, the upper most vegetation zone, the Afro-alpine, is characterized by summer every day and winter every night weather due to its remarkable diurnal variation of temperature (Hedberg, 1964). The mountain ecosystem is a more diverse than the surrounding lowlands due to climatic and habitat diversity along the steep elevation. With regard to vegetation types, mountains exhibit three distinct zones (i.e., Afro-alpine, Ericaceous Belt and Afro-montane) along the altitudinal gradient (Figure 1). In line with this, three distinct vegetation types that form the ground for naming of the different zones and that stretch in peculiar ranges of altitude forming belts around the high rising landmass were considered in this assessment (Hedberg 1951; Bussmann, 2006; Marino 2003; Gehrke and Linder, 2014).

The flora of the Afro-alpine vegetation includes geographically isolated vicarious taxa, e.g. the giant lobelia that are as renowned as the finches of Galapagos Islands (Hedberg, 1969). Although the pleistocene climate change has modified the vegetation zones of Ethiopian mountains, the Afro-alpine's vegetation zone is an isolated island since the origin of the mountains themselves. Despite the fact that pleistocene climate has considerably modified the altitudinal limits of these zones, it is highly unlikely that the afro-alpine vegetation zone of different mountains had been in contact.

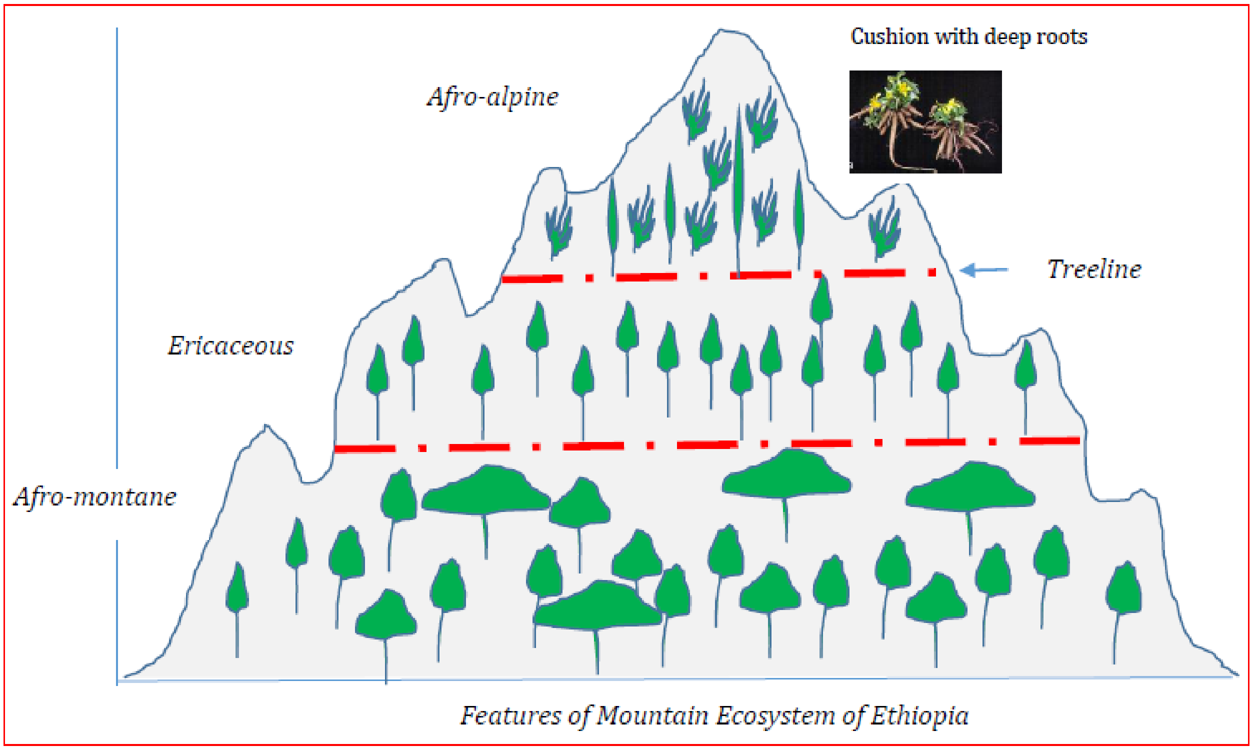


Figure 1 Features of mountain ecosystem of Ethiopia

The mountain ecosystem of Ethiopia is unique and serves as natural laboratory to study historical vegetation dynamics and evolutionary events of its plant biodiversity heritage. Whereas the Afro-montane forests have served as stepping stones by forming Afro-montane forest bridges to facilitate northward migration of certain species (e.g., *Lobelia gibberoa*, Kebede et al., 2007), the Afro-alpine has formed *sky islands* leading to *in-situ* speciation and long distance dispersal of its flora (Assefa et al., 2007). The highlands of Ethiopia are bisected by the Main Ethiopian Rift Valley (MERV), which has served as a barrier to plant and animal migration from one of its side to the other for some species (Figure 2). Although the MERV has no effect on some plant species, e.g. *Luzula abyssinica* (Juncaceae), it is an important barrier facilitating an on-going infra-specific *in-situ* speciation leading to genetic distinctions in *Cardamine obliqua* (Brassicaceae) (Figure 2).

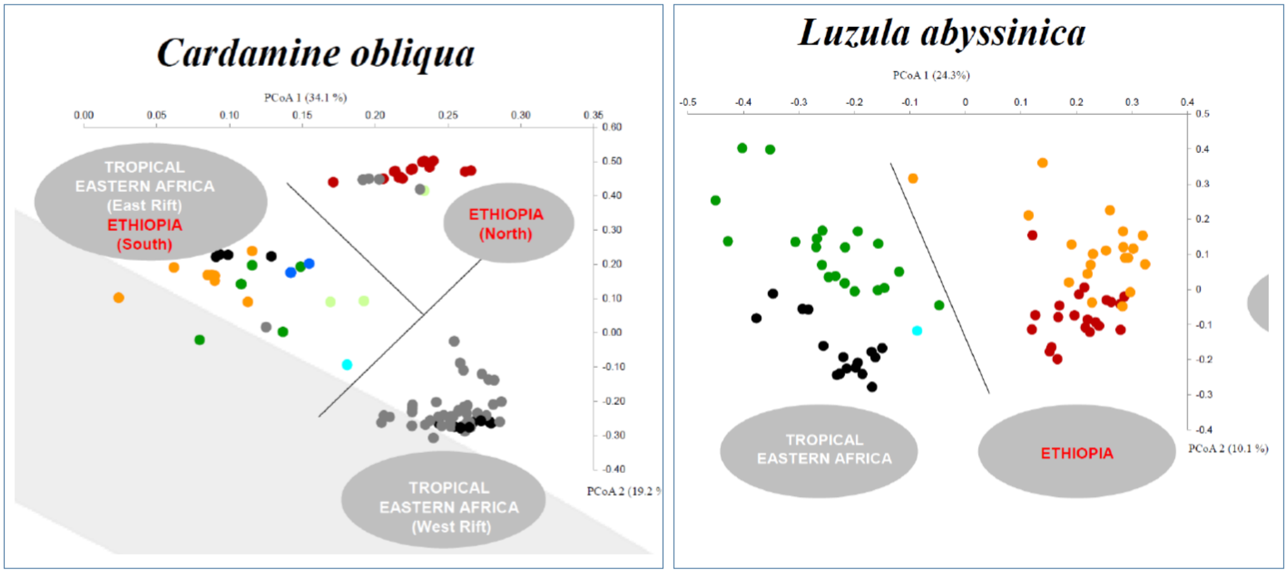


Figure 2. The role of the main Ethiopian Rift Valley in species migration (Source: Piñeiro et al., 2010). Solid line depicts Rift Valley; red dots, populations from Simen Mountains; orange dots, populations from Bale Mountains; other colors denote populations fr

2.1.2 Vegetation characteristics of the mountain ecosystem

At their lowermost zone, mountains are occupied by Afro-montane forest (Figure 1). Based on the moisture regime, two types of Afro-montane forest are found at this zone. These are dry and moist Afro-montane forests. The dry Afro-montane forest is characterized by plant species such as *Juniperus procera* and *Olea europea* ssp. *cuspidata*. The moist Afro-montane forest is comprised of characteristic species such as *Pouteria adolfi-friderici* and *Schefflera abyssinica*. At its most upper part, species such as *Hypericum revolutum* are dominant.

The second vegetation zone of a mountain ecosystem is the Ericaceous belt, which is dominated by *Erica arborea*. This vegetation belt is prone to fire, the source of which could be either natural due to drought or man-made to open spaces for the growth of grasses for livestock and control larvae that feeds on Erica leaves and lethal if consumed by cattle.

The uppermost vegetation belt of a mountain ecosystem is the Afro-alpine, which is characterized by its landmark plant species, *Lobelia rynchopetalum*. The Afro-alpine belt has different microclimates to which different species have adapted. These habitats are rock outcrops, *Carex monostachya* bog, alpine lakes, open grassland, open stream banks and patches of *Erica arborea*, which are believed to be relicts of previously extensive stands during the early quaternary period (McGuire and Kron, 2005). The Ericaceous vegetation zone occurring on the Eastern African mountains, including Ethiopia, form a belt and are considered as refugia.

On some mountains such as Bale Mountains, there are pure stands of *Alchemilla haumannii* in a rather patchy distribution. Areas disturbed by giant mole rat harbor species such as *Geranium sp*. and *Oreophyton falcatum* that are highly specialized to this highly disturbed habitat.

2.1.3 Biophysical conditions of Ethiopian mountains

As part of the Arabian-Nubian shield, the formation of the Ethiopian highlands has history that dates back to the Neoproterozoic epoch, having mean geologic age between 0.87 Ga and 2.1 Ga (Stern 2002; Kröner and Stern 2004). Historical evidences show that Ethiopian mountains have arisen about 70 to 75MY ago together with the Arabian plateau (Williams et al., 2004; Abbate et al., 2015). The predominant uplift of the Ethiopian mountains took place between 30 and 45 MY ago as a result of diverse volcanic activities and overlaid sequence of flood basal (Kieffer et al., 2004; Williams et al., 2004; Abbate et al., 2015). About 70% of Africa's highlands are parts of the Ethiopian mountains.

The characteristic ecoregions of Ethiopian high mountains exhibit distinct altitudinal ranges and vegetation types. Afro-alpine belt is found in areas of highest mountain peaks at above 3500 m asl, whereas the Ericaceous belt is found adjacent to Afro-alpine belt mostly between 3200-3400 m asl. Afro-montane forest forms the vegetation component of mountainous ecosystem stretching below this altitudinal range (between 2500 m and 3200 m asl).

2.1.4 Spatial extent and main mountains of Ethiopia

The mountain ecosystem of Ethiopia exhibits a fragment distribution across the country's landmass and separated by the Great East African Rift Valley (Figure 3). The mountains that are located in the northwest side of the Rift include: Simen Mountains, Mt. Choke (3900 m asl), Mt. Guna (4231 m asl), Mt. AbuneYosef (4191 m asl), and Mt. Birhan (4154 m asl). In the southeast side of the Rift are: Bale Mountains, Mt. Kaka (4190 m asl), Mt. Chilalo (4036 m asl), Mt. Bada (4139 m asl) and Mt. Gughe (4200 m asl).

Among all these, two are protected and designated as National Parks: the Bale Mountains National Park and the Simen Mountains National Park. These Mountains are also known for having multiple peaks. The Simen Mountains National Park (SMNP) represents one of the most marvelous natural places in the world. The presence of a large number of endemic species, unique biophysical features and its international significance has made SMNP to become a World Heritage Site since 1978 (Falch and Keiner, 2000). The Bale Mountains National Park (BMNP) conserves the largest area of Afro-alpine habitat on the African continent and covers 2,200 km^2. It encompasses a broad range of habitats between 1,500 and 4,377 m asl.

This report recognizes the following mountains as the major components of the mountain ecosystem of Ethiopia: Simen Mountains, Mt. Guna, Mt. Abune Yosef, Mt. Abuye Meda, Mt. Amba Farit, Choke Mountains, Gurage Mountains, Mt. Kaka, Mt. Chilallo, Galama Mountains, Bale Mountains, Gara Muleta and Mt. Gughe.

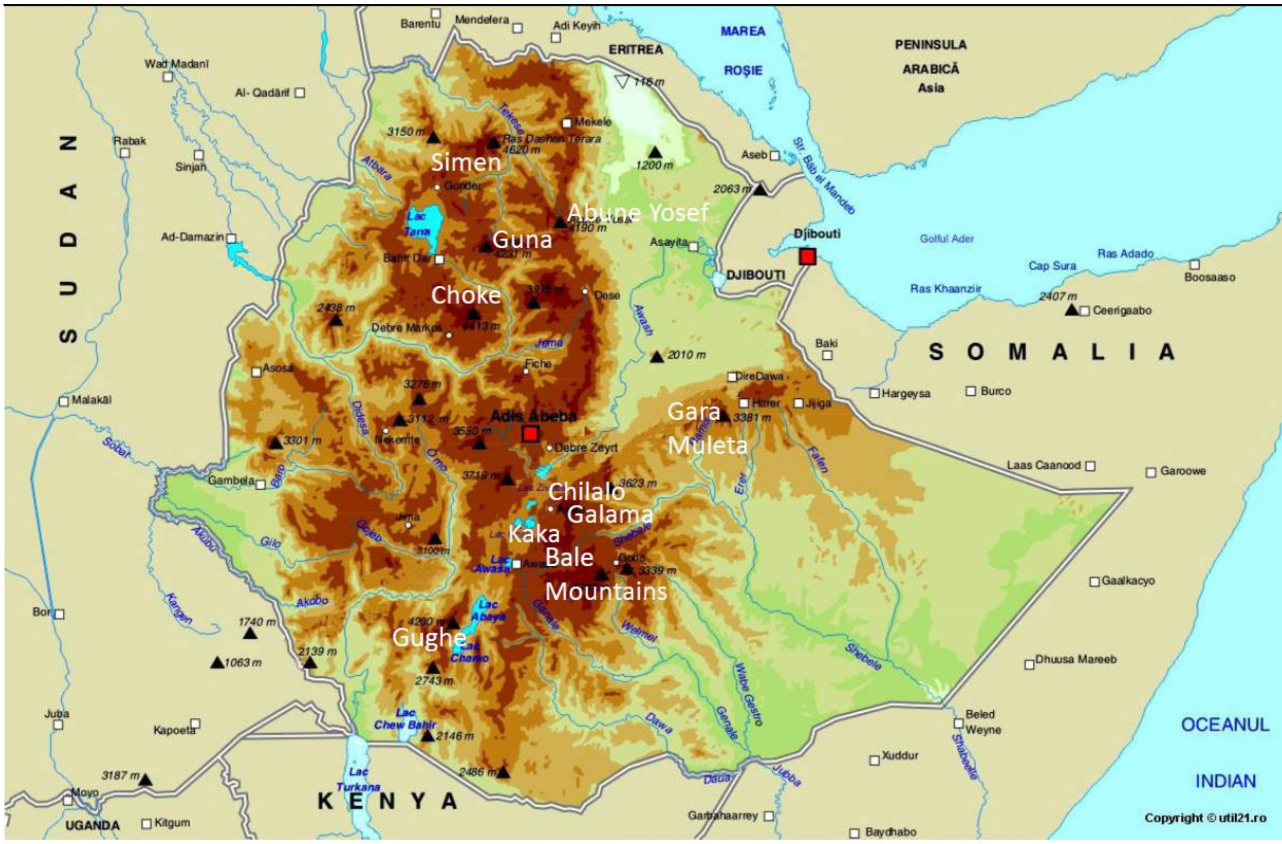


Figure 3. Mountain Ecosystem of Ethiopia ([Modified from etiopia.jpg (1178×765) (util21.ro)]

2.1.5 Unique plant life forms of Ethiopian mountain ecosystem

Ethiopia's mountain ecosystem is characterized by many unique plant life forms (Figure 4). The giant rosette plant is represented by *L. rhynchopetalum* where the young buds are protected from frost by layers of rosette leaves. The tussock grasses are represented by, e.g., *Festuca simensis* while *Haplocarpha rueppellii* and *Trifolum acaule* are the predominant plants of acaulescent groups. Cushion forming plants are represented by *Myosotis keniensis, Helichrysum citrispinum* and *Helichrysum gofense*.

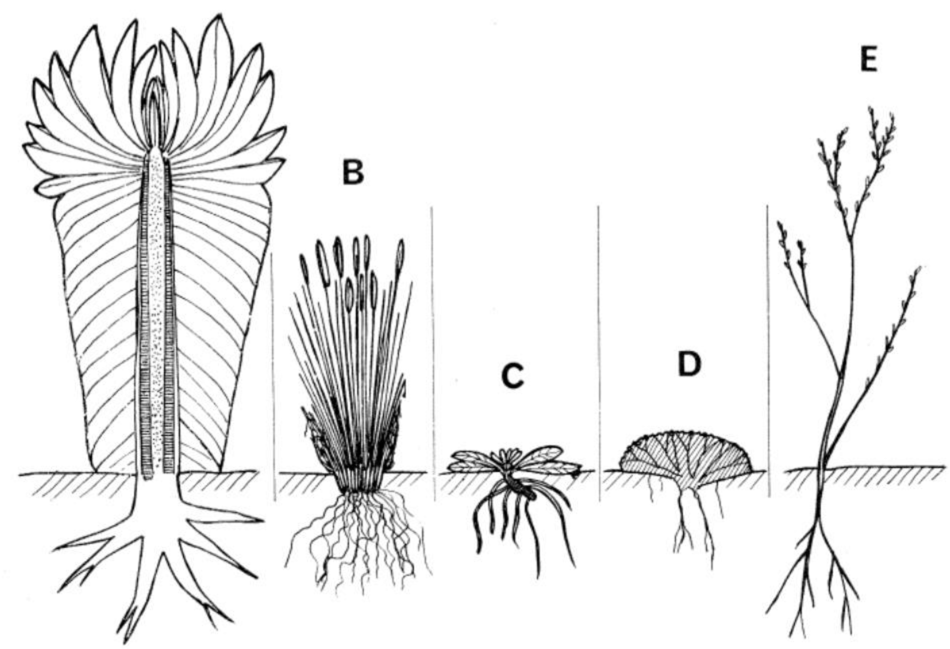


Figure 4. Plant life forms of mountain ecosystem. [A, giant rosette plants; B, tussock grasses; C, Acaulescent rosette plants; D, cushion plants; E, Scrolephyllous shrub. (Taken from Hedberg and Hedberg, 1979)].

2.1.6 Vulnerability and sustainability

2.1.6.1 Vulnerability

As mountain biota are adapted to relatively narrow ranges of temperature and precipitation, they are highly vulnerable/susceptible to climate change. Afro-alpine and Ericaceous vegetation belts are under pressure of growing human and livestock populations in the surrounding areas and subsequent expansion of agriculture.

The fragility of the mountain ecosystem is a considerable challenge to sustainable development. Its low resilience arises primarily from steepness, low temperatures, and isolation. Mountain biota are adapted to relatively narrow ranges of temperature and precipitation. In fragile mountain ecosystem, conditions of unsustainability emerge quickly and in a more pronounced manner than in relatively resilient lowland areas (Jodha, 1989). Increased landscape instability and degradation, reduced natural biodiversity, and loss of crop cultivars and livestock breeds are some of the indicators of the present ecosystem imbalance in mountains. Mountain ecosystem is sensitive to rapid global development (Schroter et al., 2005). The main pressures result from changes in land use practices, infrastructure development, unsustainable tourism, fragmentation of habitats and climate change (EEA, 2002).

In mountains, soils tend to be thin and highly erodible while the low temperatures cause vegetation growth and soil formation to occur very slowly. At higher altitudes, extreme diurnal temperature fluctuations require specialized survival adaptations. In this harsh environment for biological life, the time scale of ecosystem recovery may be hundreds of years (Messerli, 1983). Mountain ecosystem is not only subject to natural hazards, but also are more susceptible to human-initiated damage than other types of terrain. These range from volcanic events and flooding to global climate change, and the loss of vegetation and soils due to inappropriate agricultural and forestry practices. When mountain environments are affected because of any disturbance, deterioration occurs at a faster rate. In most cases, the damage is irreversible or reversible only over a long time (Poore, 1992).

2.1.6.2 Sustainability

Mountains maintain rich biodiversity along with their ecological and geophysical heterogeneity. They include as many as half of all global biodiversity hotspots and support a great deal of inhabitants as sources of livelihoods (Dax 2002; Spehn et al., 2010). The high species and genetic diversity of mountain ecosystem contributes to human well-being in various ways. They provide humans with food, feed to their livestock, medicinal resources to combat diseases and provide other cultural services (Payne et al., 2017). In many parts of the world, mountains also exhibit well maintained agrobiodiversity reflecting a rich history of human-nature interaction. This strong social-ecological interaction might have contributed to resilience of mountains to climate change and other disturbances.

Mountain ecosystem has received global attention since the 1990s due to the increased awareness about the importance of the ecosystem. The physical nature of mountain ecosystem is such that it is highly susceptible to soil erosion, habitat fragmentation and degradation. Hence, the ecosystem needs special attention otherwise loss of biodiversity would be an inevitable consequence. Agenda 21, Chapter 13 states that the mountain ecosystem is one of the most important and yet most fragile planetary ecosystems (UNCED, 1992). This highlights the need for sustainable mountain ecosystem development and management.

Ethiopia has a long history of conservation efforts with one of the oldest record of conservation area established on a mountain ecosystem. The Menagesha-Suba National Forest Park was established on Mount Wechecha in the 1450s by Emperor Zere-Yacob (Gilbert, 1970). This park and some of the trees planted during this period are still maintained. More remarkably, a historical community-based conservation area exists in Menz-Guassa District in central Ethiopia. This communal resource governance system is based on equitable use and distribution of natural resources in a sustainable way. It implements a period of closure system that prohibits use of resources and reopens when appropriate (Tefera, 2004). This regulated resource utilization and management system has effectively protected the biodiversity of the Afro-alpine vegetation of the Guassa-Menz area. This system could be taken as a kind of community-based adaptation that empowers people to plan and adapt to the impacts of resource scarcity as well as climate change (Pérez et al., 2010).

Mountain ecosystem benefits people living in the surrounding areas in several ways, being sources of food and feed, medicine, water, fuel wood and other services. However, the rapidly growing population induces an imbalance on social-ecological interaction causing severe impact on the natural system. Studies have shown that there is a rapid encroachment demonstrating a human induced land use change associated especially with agricultural expansion and overgrazing (Mezgebu and Workineh, 2017). This trend will affect the sustainability of the mountain ecosystem unless a proper action is taken. In addition to this root cause of natural resource depletion, inadequacies in community participation, training of local community members, local government commitment, farmers' capacity, extended bureaucracy are critical barriers of sustainability (Simane, 2013).

2.2 Mountain Ecosystem Services and Benefits

2.2.1 Pathways of ecosystem functions to human well-being

Ecosystem services are the benefits people obtain from ecosystems (Diaz et al, 2015). They are the direct and indirect contributions of ecosystems to human well-being (TEEB, 2010). These include provisioning, regulating, and cultural services, which directly affect people, and supporting services needed to maintain the other services (MEA, 2005).Changes in these services affect human well-being through impacts on food security, materials required for a good life, health, social and cultural relations. These constituents of well-being are, in turn, influenced by an influence on the freedoms and choices available to people (Diaz et al., 2015).

Ecosystems benefit people in the presence of people (human capital), their communities (social capital), and their built environment (built capital). Thus, ecosystem services need to be perceived as a contribution of the natural capital to human well-being which forms through interaction with human, social and built capital (Ruskule et al., 2018). The argument here is human capital, social capital and built capital need the presence of people as role player since ecosystem service is the interface between people and nature.

Ecosystem services contribute to human well-being by satisfying our needs. Some ecosystem services clearly relate directly to a particular human need like clean air to breathe. In contrast, other services help to satisfy many needs. For example, the provision of clean water allows satisfying human need for subsistence as well as the need for relaxation through fishing and swimming. Some services, such as the provision of food and water for irrigation, contribute to human subsistence needs for food, and also provide income to cover other important needs such as health, education and shelter. However, the income generated from some of these services also supports high level of material consumption, which may be unsustainable (Roberts et al., 2015).

Ecosystems provide innumerable services which has made human civilization possible. Unfortunately, many people believe these services are provided for free and have no direct economic value (Jordan et al., 2010). People may not pay directly for these ecosystem services but they do pay significantly for their loss through infrastructure and policy costs (e.g., construction and operation of wastewater treatment facilities, increased illness and losses in soil fertility as well as reductions in basic human well-being). Human life is dependent upon these ecosystem goods and services. These services also contribute to a “good” or “quality life” by influencing the well-being of individuals and communities (Daily, 1997). One of the greatest challenges is to maintain ecosystem while promoting economic growth and the quality of life (Summers et al., 2012). Ecosystem services such as cleansing, renewal and recycling coupled with ecosystem goods like food, fiber, timber and aesthetics have significant tangible and intangible values (Summers et al., 2012). Humans stress the environment by disrupting its natural functioning (Worm et al., 2005). Ecosystems have been changed massively in the last several decades in order to meet growing demands for freshwater, food and fuel (Daily, 1997). These changes have caused significant losses in ecosystem structure and function such as diversity loss and impoverished capacity for service generation (Summers et al., 2012).

Ecosystem services are perceived also as an interface between people and nature (Potschin and Haines-Young, 2016). This explains interrelations between ecosystems and human well-being. Here, the ecosystem is characterized by its biophysical structures and processes where the biophysical structure constitutes habitat type while processes refer to dynamics and interactions forming an ecological system such as primary production (Ruskule et al., 2018).

The final ecosystem services are the ones which can be harvested by humans (e.g., timber, grain, flood protection, beautiful landscape and others) whereas supporting or intermediate services are those that support an ecosystem to deliver the services (Figure 5).

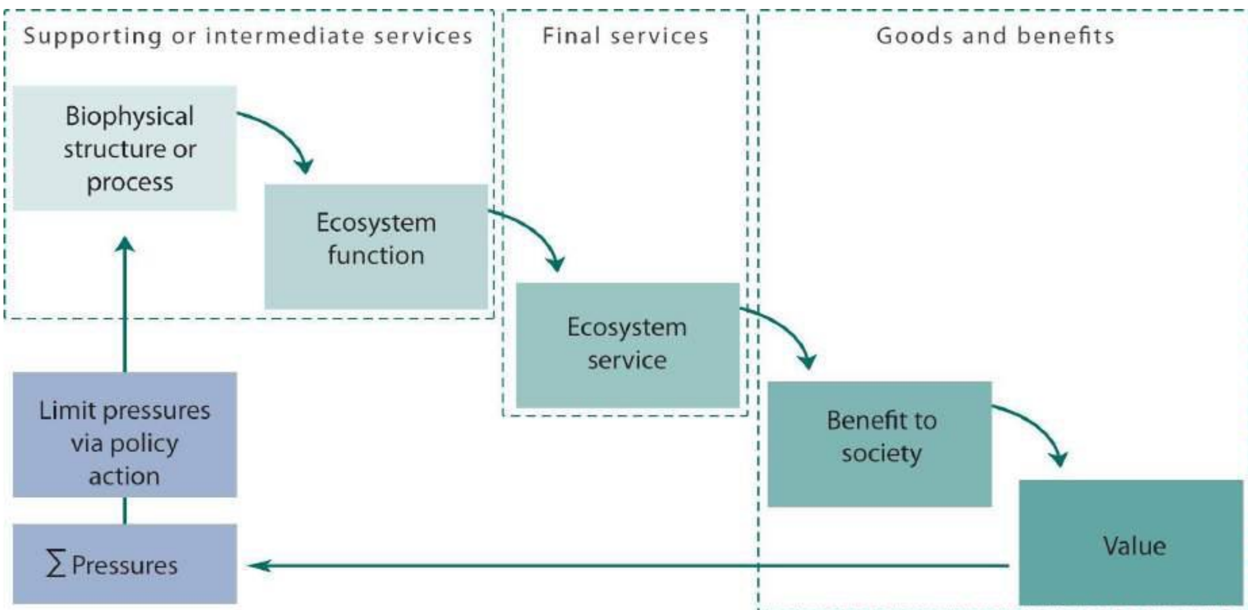


Figure 5. . The pathway from ecosystem structure and processes to human well-being (adapted from Potschin and Haines-Young, 2016)

The supply of ecosystem services to humans is dependent on structure and processes of the ecosystem. This normal functioning of ecosystems is altered by human activities such as changing land use type and influencing ecosystem service supply or link between different services. Ecosystem structure, processes and functions are responsible for its service supply where function is determined by interactions with socio-economic systems (Ruskule et al., 2018). The dependence of humans on ecosystem services reflects directly the profound co-evolutionary processes that underlie the origins of the Earth's biosphere. The effects of adverse ecosystem changes on human well-being can be grouped as direct and indirect. Direct effects occur with some immediacy through locally identifiable biological or ecological pathways. For example, impairment of the water purification capacity of wetlands may adversely affect those who use that water. The deforestation of hillsides can expose downstream communities to the hazards of flooding (Lemessa and Teka, 2017). Some of the categories of indirect drivers of change are demographic, economic, socio-political, scientific, technological, cultural and religious. Important direct drivers include climate change, land-use change, invasive alien species and agro-ecological changes. Collectively, these factors influence the level of production and consumption of ecosystem services and the sustainability of production. Both economic and population growth lead to increased consumption of ecosystem services. These factors interact in complex ways in different locations to change pressures on ecosystems and uses of ecosystem services (Ruskule et al., 2018).

Generally, human well-being can be enhanced through sustainable human interaction with ecosystems via the support of appropriate instruments, institutions, organizations, and technology. Creation of these through participation and transparency may contribute to people's freedom and choices so as to increased economic, social, and ecological security (Lemessa and Teka, 2017). However, when ecosystems are degraded, they are not resilient in the face of natural and technological disasters. As the result, safety and security of humans are affected due to further degradation of ecosystems, economic loss, increased dependence on social safety nets and recovery services (Roberts et al., 2015).

2.2.2 Mountain ecosystem and human well-being

Mountains provide a number of ecosystem goods and services for both upstream communities and downstream users. However, evidences in recent decades of escalating human impacts on ecological systems worldwide raises concerns about the consequences of ecosystem changes for human well-being (MEA, 2005). In a mountain ecosystem, the need for water is often a cause for concern, both in upstream and downstream locations. In many places, water availability and management has received increased attention due to projections of climate-induced changes to water production in mountain regions. Very small temperature changes can lead to very large changes in water volume, both in the short term and across seasons (Lemessa and Teka, 2017). The ecosystem services delivered by indigenous biodiversity and natural ecosystems contribute in a wide variety of ways to human well-being. Nutritious food from healthy ecosystems, and opportunities to spend time in recreation contribute to human physical and psychological health. The energy to power human lives from basic needs to high consumer life styles also comes from nature (Roberts et al., 2015).

Mountain ecosystem is a unique center of cultural diversity and an essential reservoir of biological diversity as well as the source of the world's great rivers and the providers of fresh water (FAO, 2002). It contains rich assemblages of species in a dense ecological community. Many endemic species have evolved over centuries of isolation from ancestral stock. Climatic variations including temperature, solar radiation, and wind as well as moisture availability occur over short distances. The dynamic and unstable nature of mountain environments leads to dramatic differences in succession stages of vegetation, as do variations in rock type and derived soils. Mountains act as refugia or a sanctuary for plants and animals that had become locally extinct long ago from transformed lowlands. Mountains serve as biological corridors; and their ranges connect isolated habitats or protected areas (Elizabeth and Sainju, 1994).

2.2.3 Benefits of mountain ecosystem

Mountains are important sources of vital ecosystem services and have a significant role in economic development, environmental protection, ecological sustainability, and human well-being (de Groot et al., 2002). Mountain environments are essential to the survival of the global ecosystem. They provide a direct life-support base for about one-tenth of mankind as well as goods and services to more than half of the world's population (Dax 2002; Spehn et al., 2010). For example, more than half of human race depends on freshwater that is captured, stored, and purified in mountain regions. Mountain regions are hotspots of biodiversity. They are used as key destinations for tourists and recreation activities (Sarvasova and Dobsinska, 2016).

While there are many classifications and characterizations of ecosystem services, the most commonly used categories (MEA, 2005) are provisioning services (food, water, fodder and timber), regulating services (climate regulation, rainfall interception, air quality regulation, erosion control, water purification, pest and disease control), supporting services (soil formation, photosynthesis, pollination, nutrient cycling, enhancement of biodiversity) and cultural services (aesthetic landscape, natural area tourism, cultural and environmental heritage). Each of these mountain ecosystem services makes specific contributions to lowland and highland economies.

2.2.3.1 Provisioning services

Provisioning services of Ethiopian mountains include the provision of genetic materials, fresh water, food and fiber, timber/fuel/energy, ornamental and medicinal materials (Table 1). The rating of provisioning services, as presented in Table1, is based on experts evaluation using qualitative criteria: Key contribution (if the services are well studied, documented and abundantly available); Some contribution, (if the services are well studied, documented but not abundantly available), No contribution (if the services are well studied, documented but its availability is limited) and Poorly known (if the services are not studied, and documented).

Table1. Provisioning services of selected Ethiopian mountains (KC= Key Contribution, SC= Some Contribution, NC= No Contribution, PK= Poorly Known)

Mountain	Genetic resources	Fresh Water	Food & fiber	Timber/ Fuel/energy	Ornamental resources	Medicinal	References
Simen mountains	KC	KC	KC	KC	KC	KC	Falch and Keiner, 2000
Abune Yosef	KC	KC	KC	KC	SC	SC	Saavedra, 2009
Guna	KC	KC	KC	KC	SC	KC	ANRS, 2005
Aboi Gara	KC	PK	PK	PK	PK	PK	Eshete et al., 2015
Borena-Sayint National Park	KC	PN	PK	PK	KC	KC	Ayalew et al., 2006
Menz-Guassa	KC	KC	KC	KC	KC	PK	UNDP, 2012
Choke	KC	KC	KC	KC	SC	SC	Simane et al., 2013
Gurage Mts	PK	KC	KC	KC	PK	PK	MOA, 2000
Gughe	PK	PK	KC	KC	PK	PK	-
Wochecha	PK	PK	PK	PK	PK	PK	-
Ziquala	PK	KC	PK	KC	PK	KC	-
Bale Mountains	KC	KC	KC	KC	KC	KC	Watson, 2007
Gara Muleta	PK	KC	PC	KC	PK	PK	Teketay, 1996
Chilalo- Galama	PK	KC	PK	PK	PK	PK	-
Kaka	KC	KC	KC	PK	PK	PK	-

Regarding services related to the provisioning of genetic materials, Ethiopian mountains are recognized to be a reservoir of genetic resources. Some of the characteristic plant species of this ecosystem include *Alchemilla ellenbeckii*, *A. haumannii*, *Erica arborea*, *E. trimera*, *Erica trimera* ssp *keniensis*, *Euphorbia dumalis*, *Festuca* sp, *Hagenia abyssinica*, *Hebenstreitia dentata*, *Helichrysum* spp, *Hypericum revoltum*, *Kniphofia foliosa*, *Lobelia rhynchopetalum*,. *Rosularia semiensis*, and *Thymus schimperi*. Endemic, rare and threatened mammals and birds are also the unique features of this ecosystem (Table 2). For instance, four of the seven endemic large mammals are represented in the Simen Mountains National Park (Ethiopian Panel on Climate Change, 2015).

Table 2. Biodiversity Resource of Ethiopian mountain ecosystem (PK = Poorly Known)

Mountain	No. Faunal spp.	No. Floral spp.	References
Bale mountains NP	78 mammals (22 endemic) 278 birds (16 endemic) 12 amphibians (4 endemic)	1321 (163 endemic spp)	Alers et al., 2007
Simen Mountains National Park	35 small and large mammals 180 birds	57 (20 endemic spp.)	Hurni and Ludi, 2000
Abune Yosef	43 spp. of mammals 221 spp. of birds (6 endemic)	PK	Saavedra, 2009
Borena Sayint National Park	23 spp. of mammals 77 spp. of birds	174(12 endemic spp.)	Chane and Yirga, 2014
Guna Community Conservation Area	30 small and large mammals (6 endemic) 139 spp. Birds (13 endemics)	96 plant species	
Abuye Meda	PK	PK	-
Guassa Community Conservation Area	18 spp. mammals 114 spp. Birds (14 endemic)	82 plant species (11 endemic)	UNDP, 2012
Choke Mountains	24 spp. of mammals 52 spp. of birds	>85 spp. of plant	EWNHS, 2011
Gurage Mountains	PK	PK	-
Gughe	PK	PK	-
Wochecha	PK	PK	-
Ziquala	PK	217 spp. of plant	-
Gara Muleta	PK	PK	-
Chilalo- Galama	PK	191 plant spp.	-
Kaka	PK	PK	-

In the Bale Mountain National Park (BMNP), there are at least 1321 species of flowering plants, of which 163 are endemic (23 to Bale alone) to Ethiopia. More than 340 medicinal plants are recognized in BMNP (Alers et al., 2007). The Afro-alpine belt of the BMNP falling above 3400 m asl is comprised of its landmark species, the giant *Lobelia* (*Lobelia rhyncopetalum*) and others such as patches of *Erica arborea*, *Helichrysum* spp., *Carex monostachya*, *Festuca* and *Alchemilla* species. The area is also regarded as one of the most important sites for gene stock protection of wild *Coffee arabica* and various medicinal plants in Ethiopia (Senbeta, 2007). A total of 78 mammal species have been recorded in BMNP, of which 22 are endemic to Ethiopia (Alers et al., 2007). In addition, 278 bird species have been recorded; of these 16 species are Ethiopian endemics (Alers et al., 2007). Out of this 57% are found in Bale Mountains. There are also 12 endemic amphibians of which four are BMNP endemic (Urban and Brown, 1971). Important faunal species that occur in the Bale Mountains National Park area are the endemic and endangered Ethiopian wolf (*Canis simensis*) and Mountain Nyala (*Tragelaphus buxtoni*), as well as the endemic Bale monkey (*Chlorocebus djamdjamensis)* and the giant mole rat (*Tachyoryctes macrocephalus*) (Datiko and Tiki, 2017).

The Simen Mountains National Park is a part of the Afro-alpine center of plant diversity with high level of endemism (Puff and Nemomissa, 2005). The common plant species include *Erica arborea*, *Lobelia rhynchopetalum*, *Solanum* spp., *Rosa abyssinica*, *Helichrysum citrispinum*, *Hagenia abyssinica*, *Myrsine mesanophloeos*, *Pittosporum viridiflorum*, *Ekebergia capensis*, *Allophylus abyssinicus*, *Hypericum revolutum*, *Festuca gelbertiana*, *Rosularia simensis* and mosses. In addition to these taxa, herbs like *Thymus* spp., *Trifolium* spp., *Geranium arabicum*, *Rumex nervosus*, *Otostegia minucci*, *Clematis simensis* and *Galium spurium* grow on the top of ridges and sides of gorges (Hurni and Ludi, 2000). There are over 20 endemic plant species within and in the buffer zone of the SMNP. Of these, three are exclusively endemic to the Simen Mountains. These include *Festuca gilbertiana*, *Rosularia simensis* and *Dianthus longiglumis* (Falch and Keiner, 2000).

Unique mammals of these mountains are Ethiopian Wolf, Gelada baboon, Walia Ibex, Giant Mole Rat, Grass Rat, Klipspringer, Golden Jackal, Serval Cat, Caracal, Rock Hyrax, Grey Duiker and Abyssinian Hare. Some of the characteristic avian species include Blue Winged

Goose, Wattled Ibis, Thick-billed Raven, White-collared Pigeon and many other rare and common birds (Awas et al., 2003; IBC, 2005).

Mountains are important not just for biodiversity, but also as water catchment areas. They play vital roles in providing freshwater services (Griffiths and McSaveney, 1983). Streams and rivers from mountains are the arteries that deliver water from the moist upper landscapes to the more heavily populated plateaus and downstream areas.

Several rivers rise in the Simen Mountains and form tributaries to the Tekeze River, which provides a source of water for millions of users downstream in Ethiopia as well as in the Sudan and Egypt. The Choke mountain range is the water tower of the region serving as catchment of the upper Blue Nile Basin. The area is the source of 59 rivers and 273 springs (Simane et al., 2013). Many of the tributaries of the Blue Nile originate from these mountain ranges.

Bale Mountains National Park forms a water tower of southeastern Ethiopia. It is the source of nine rivers and about 40 streams and springs (Mezgebu and Workineh, 2017). It is estimated that around 12 million people in the lowlands of southeastern Ethiopia, northern Kenya, and Somalia are dependent for water resources generated from the Bale ecoregion (OFWE et al., 2014).

Mount Guna, located in South Gondar Administrative Zone, is known to be the source of many rivers that drain to the Abay, Tekeze and Lake Tana basins (ANRS, 2005). Since rainfall generally increases with altitude, these upland areas receive a higher amount of precipitation relative to the land area they occupy (Griffiths and McSaveney, 1983). These high inputs, combined with high levels of vegetation cover and low densities of grazing animals, result in larger yields of high-quality water (Table 3).

Mountain ecosystem provides fuel wood and timber products. For instance, Choke Mountain communities depend on biomass for their fundamental needs like food, fuel, building materials and raw materials for various types of traditional crafts, most of which are collected freely from the immediate environment (Simane et al,. 2013). Forest products harvested in the Bale Mountain ecosystem are used for construction of houses and fuel wood. The direct consumptive use values of marketed and non-marketed forest products from the Bale Mountain, was estimated at US$ 407 per household per annum (Watson, 2007). Furthermore, firewood is the most commonly used forest product and it is valued at over US$ 165 per household annually. Firewood is an extremely important source of value to Bale Mountain Eco-region rural people with alternatives, such as kerosene, electricity, and liquefied petroleum gas, being in accessible and expensive to acquire (Watson, 2007). Although there is no sufficient data, the same holds true in other Ethiopian mountain ecosystem including SMNP, Guna Mountain Community Conservation Area, Guassa Community Conservation Area, Mt. Choke and others.

Table 3. Mountains as sources of rivers in Ethiopia

Mountain	Area km^2	Max. Altitude M asl	No of rivers/ streams originating	Number of potential beneficiaries	References
Bale mountains NP	2200	4377	9 rivers and 40 springs	12 million	Stephen et al., 2019
Simen Mountains National Park	412	4543	1 river and many streams		Nepal, 2000
Guna Community Conservation Area	46.16	4113	2 rivers and Over 41 streams		ORDA, 2016
Guassa Community Conservation Area	78	3700	26 Rivers		UNDP, 2012
Choke Mountains	250	4093	59 Rivers and 273 streams		Simane *et al.*, 2013

In Ethiopia, there exists a deep-rooted tradition of using plants resources for medicinal purposes; and this makes an important contribution for primary health care. Up to 80% of Ethiopians reportedly use medicinal plants; and a significant proportion of these come from mountains. For example, about 60% of the known medicinal plant species in Ethiopia are found in the Bale Mountains National Park encompassing a total of about 337 species, of which 24 are endemic (Watson, 2007). Regarding use categories, about 283 species are used as human medicine, 47 are used as livestock medicine while 76 species are used for treating both human and livestock ailments by communities (Bekele, 2007). The current annual value associated with medicinal plants in SMNP and BMNP is 2,732,243 and 15,458,078 Birr, respectively (Van Zyl, 2015).

2.2.3.2 Regulating services

The most important regulating services of mountain ecosystem include maintenance of climate regulation, soil conservation, hydrological regulation and hazard regulation (Table4). Ethiopian mountain ecosystem has substantial contribution to climate regulation. For example, carbon sequestration by vegetation reduces gas emissions through the capture and storage of atmospheric carbon. The carbon stock estimates for forests within BMNP and SMNP were 2,122,907 and 25,261,558 tones, respectively (Watson, 2013).

The trace gases and particles in the atmosphere are sources of air pollutants or their precursors, but can also have positive effects on air quality, primarily through interception, deposition and removal of pollutants. Deposition of pollutants to vegetation and soil from the atmosphere can significantly reduce airborne concentrations, and hence, reduce adverse effects on human health and other ecosystem services. The Ethiopian mountain ecosystem has contribution in regulating air quality through deposition of pollutants but there is no data on the level of air regulation for specific mountain ecosystem.

Mountain forests help in erosion control through rainfall interception, absorbing and storing rainwater and acting as buffers to protect from floods and droughts (Semwal et al., 2007). Forests help to keep soils intact and prevent sediment load into nearby water bodies. By intercepting rain, a forest canopy reduces the impact of heavy rainfall on the forest floor, reducing soil disturbance. Leaves and natural debris on the forest floor slow the rate of water runoff and trap soils washed from nearby fields. Tree roots hold soil in place and stabilize stream banks (Ayenew and Tesfay, 2015).

One of the roles of ecosystem service in particular and mountain ecosystem services in general is regulating natural hazards like flood, fire, drought and others. Natural hazard is a natural process or phenomenon occurring in the biosphere that could harm human beings and/or damage natural systems. Like other natural ecosystems, the Ethiopian mountain ecosystem regulates and mitigates impacts of natural hazards. However, there is no data on a particular mountain ecosystem of the country on the issue.

Mountain ecosystem regulates water flows in streams and rivers (Bosch and Hewlett, 1982) and also maintain hydrological balance through regulation of water quality and quantity (Eriksson et al., 2009). The SMNP has an important role in maintaining perennial river flow as it contains the uppermost catchment areas of the tributaries to the Tekeze River (van Zyl, 2015). Likewise, the BMNP also plays crucial role in this regard. However, there is no sufficient data on water flow regulation capacity of most Ethiopian mountain ecosystem.

Table 4. Regulating services of selected Ethiopian Mountains (KC=Key contribution, SC = Some contribution, NC=No contribution, PK=Poorly known)

Major mountains	Aspects of regulations					References
	Climate	Air quality	Erosion	Natural hazard	Water flow	
Simen Mountains	KC	KC	KC	KC	KC	Zyl, 2015
Abune Yosef	KC	KC	KC	KC	KC	Saavedra, 2009
Guna	KC	KC	KC	KC	KC	ORDA, 2016
Aboi Gara	PK	PK	PK	PK	PK	-
Borena Sayint	KC	KC	KC	KC	KC	Abayneh, 2012
Menz-Guassa	KC	KC	KC	KC	KC	Tefera and Williams, 2005
Choke	KC	KC	SC	KC	KC	Simane *et al.*, 2013
Gurage Mts	PK	PK	PK	PK	KC	MOA, 2000
Gughe	PK	PK	PK	PK	KC	-
Wochecha	PK	PK	PK	PK	PK	-
Ziquala	KC	KC	KC	KC	PK	www. http//:trip-to-zequala-mountain-monastery
Bale mountains	KC	KC	KC	KC	KC	Watson, 2013
Gara Muleta	KC	KC	KC	KC	KC	Teketay, 1996
Chilalo- Galama	PK	PK	PK	PK	KC	-
Kaka	PK	PK	PK	PK	PK	-

2.2.3.3 Supporting services

Supporting mountain ecosystem services like pollination, nutrient cycling, soil formation, and biological diversity are essential for maintaining the provision of all other ecosystem services (MEA, 2005). Litter decomposition is one of the most crucial aspects of nutrient cycling and is directly related to soil fertility (Rawat and Singh, 1989). Supporting services are essential for sustaining each of the other three ecosystem services. Thus, the link between supporting services and human well-being occurs indirectly (Spehn et al., 2005). The Ethiopian mountains like SMNP, BMNP, Guna Mountain Community Conservation Area, Guassa Community Conservation Area, Choke Mountains and others provide supporting services.

2.2.3.4 Cultural services

Mountain ecosystem also has importance for human well-being through the cultural services it provides, for example, unique species, scenic landscapes, geological formations or rivers and lakes (Table 5). These attributes and functions of ecosystems influence the aesthetic, recreational, educational, cultural and spiritual aspects of human experience (Spehn et al., 2005).

The sacredness of many mountains and mountain locations around the world are not only important for the conservation of certain species, ecosystems, and landscapes, but also they stimulate development of infrastructure into and through many mountains (Egan and Price, 2017). Ethiopian mountain ecosystem has spiritual and religious values due to the presence of sacred sites, caves, holly waters and so on. For example, in the Simen Mountains National Park there are spiritual and religious places like St. Yared Monastery, Ancient Churches and holly water (EWCA, 2009). Sacred sites like sacred forests and groves typically harbor high species richness, biodiversity and biomass than the surrounding land uses due to high conservation value (De Lacy and Shackleton, 2017).

Ethiopian mountains have global significance as destinations for tourist and recreation activities. In SMNP the number of tourist flow has been increasing and it has now reached over 26,000 tourist arrivals per annum (Teshome and Demissie, 2018). Bale Mountains National Park is another tourist destination site and one of the most important conservation areas in Ethiopia (Watson, 2013) having around 9,000 tourist arrivals in 2014 (Van Zyl, 2015). It is characterized by a wealth of biodiversity and ecosystem services. It is home to a large number of fauna and flora including the endangered and endemic species like mountain Nyala and the Ethiopian Wolf (FARM Africa, 2008). Also, areas like the Choke Mountains, Guna Mountain Community Conservation Area, Menz-Guassa Community Conservation Area, Mt. Aboi Gara and others are destinations to many tourists.

Many of the Ethiopian mountains contain sites that are important to the cultural life of local communities. The Simen Mountains National Park, for example, is a UNESCO World Heritage Site and contains the Walia Kend and Kidus Yared spiritual sites. As noted in the Park management plan, there is a legend that Saint Yared brought the Walia Ibex carrying his holy books to the Simen Mountains. As a result, the Walia Ibex is important in the folklore and oral literature of the Simen communities (Zyl, 2015). Bale Mountains National Park also contains important cultural sites including Abel Kassim, Alija and Gassuray. Some of these areas are still used by local communities for religious purposes and other important areas are known to exist but are not well documented (FZS, 2007).

The Ethiopian Mountains provide wonderful sceneries and hence of aesthetic values. The Simen Mountains National Park represents one of the most marvelous natural areas in the world. Because of its unique topography, wildlife and scenic beauty with broad undulating plateau, it is a major tourist destination site of the country (Falch and Keiner, 2000).

The Ethiopian mountains are important areas for conducting educational activities and research on various issues including investigations on biological, ecological, geological, climate change, agriculture and socioeconomic aspects. They also serve as a natural laboratory to university and high school students to grasp practical knowledge. Most of the Ethiopian mountains are rich in biodiversity resources, and a source of inspiration and have a great potential to be adventure destinations for people around the world if properly conserved, developed and managed.

Table 5. Cultural services (KC=Key Contribution, SC=Some Contribution, NC=No Contribution, PK=Poorly Known)

Mountain	**Spiritual & religious values**	**Recreation & ecotourism**	**Cultural heritage**	**Aesthetic values**	**Education & inspiration**	**References**
Simen Mountains	KC	KC	KC	KC	KC	Teshome and Demissie 2018
Abune Yosef	KC	SC	PK	KC	KC	Saavedra 2009
Guna	KC	SC	KC	SC	KC	ORDA 2016
Abuye Meda	PK	PK	PK	PK	PK	-
Borena Sayint	PK	SC	PK	SC	KC	Abayneh 2012
Menz-Guassa	PK	SC	KC	KC	KC	Tefera and Williams 2005
Choke	KC	NC	KC	KC	KC	Simane *et al*. 2013
Gurage Mts	PK	PK	PK	PK	PK	-
Gughe	PK	PK	PK	PK	PK	-
Wochecha	PK	PK	PK	PK	PK	-
Ziquala	KC	PK	KC	KC	PK	www. trip-to-zequala-mountain-monastery
Bale mountains	KC	KC	KC	KC	KC	Watson 2013
Gara Muleta	PK	KC	PK	PK	KC	Teketay 1996
Chilalo-Galama	PK	PK	PK	PK	PK	-
Kaka	PK	PK	PK	PK	PK	-

2.3 Status, trends and future dynamics of mountain ecosystem and biodiversity

2.3.1 The status of Ethiopian mountain ecosystem

Mountain ecosystem of Ethiopia is under different states with regard to the dynamics of vegetation zones and nature of anthropogenic impacts. Based on aspect, a given mountain may have different species composition and plant community types (Bussmann, 2006). The North side of Bale Mountains is relatively dry and mainly comprised of *Hagenia abyssinica* and *Hypericum revolutum* (Figure 6). On the other hand, the South face emerges from the *Acacia-Commiphora* woodland and is moist (receiving an annual precipitation ranging from 850 mm–3000 mm) with different vegetation composition at its lower limit (Figure 6). Species such as *Pouteria adolfi-friderici*, *Schefflera abyssinica*, *Olea welwitschii* and a dense growth of *Coffea arabica* as an understorey shrub are common.

The Simen Mountains are drier than the Bale Mountains (Bussmann, 2006) and are gateways to plant migration to and from the Arabian Peninsula and the Middle East (Assefa et al., 2007; Koch et al., 2006). In the southwest, the Afro-montane vegetation starts from the upper limit of the dry foot zone (Figure 7). On the other hand, the northeast face of the Simen Mountains is rather moist with well-developed Afro-montane forest. A total of 550 species of flowering plants were recorded and the species richness in these mountains decreases with increasing altitude (Puff and Nemomissa, 2001).

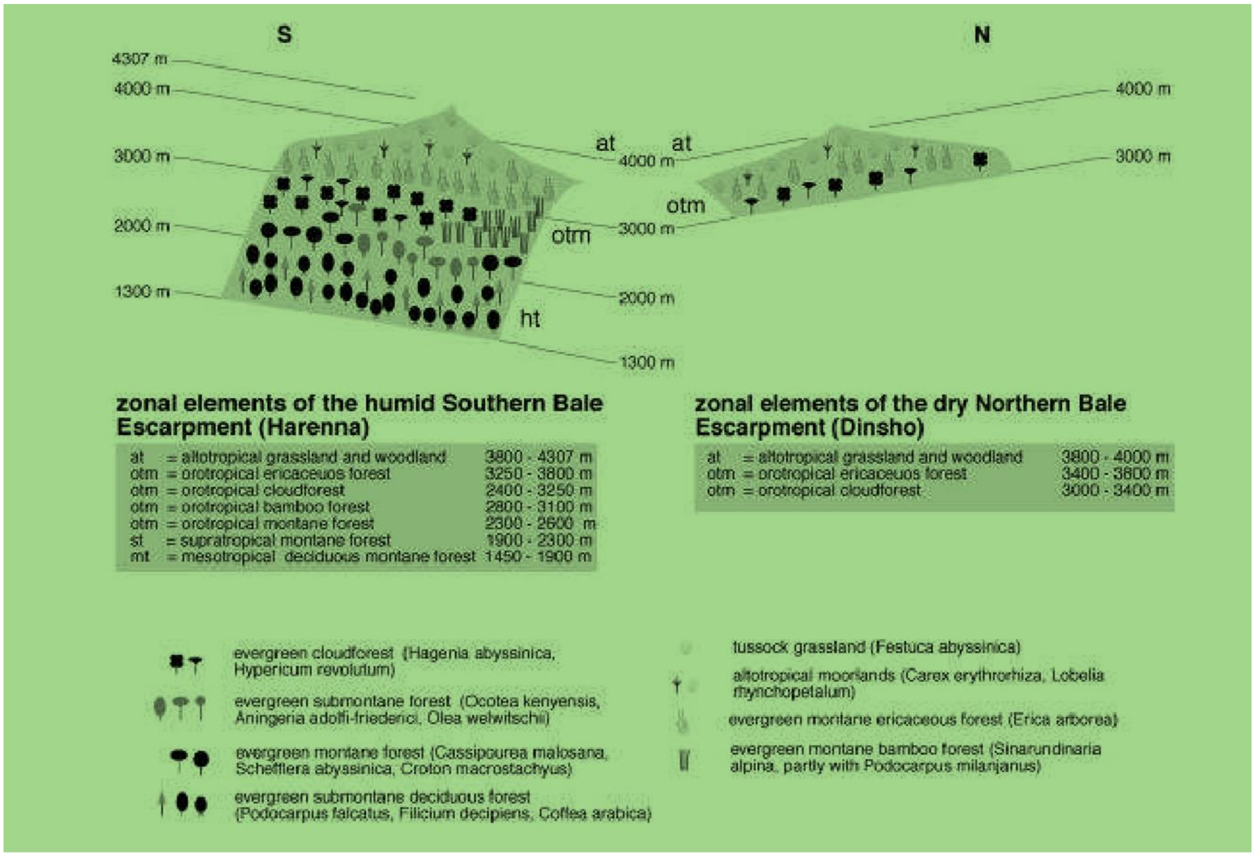


Figure 6. The State of the vegetation of Bale mountains (Source: Bussmann, 2006)

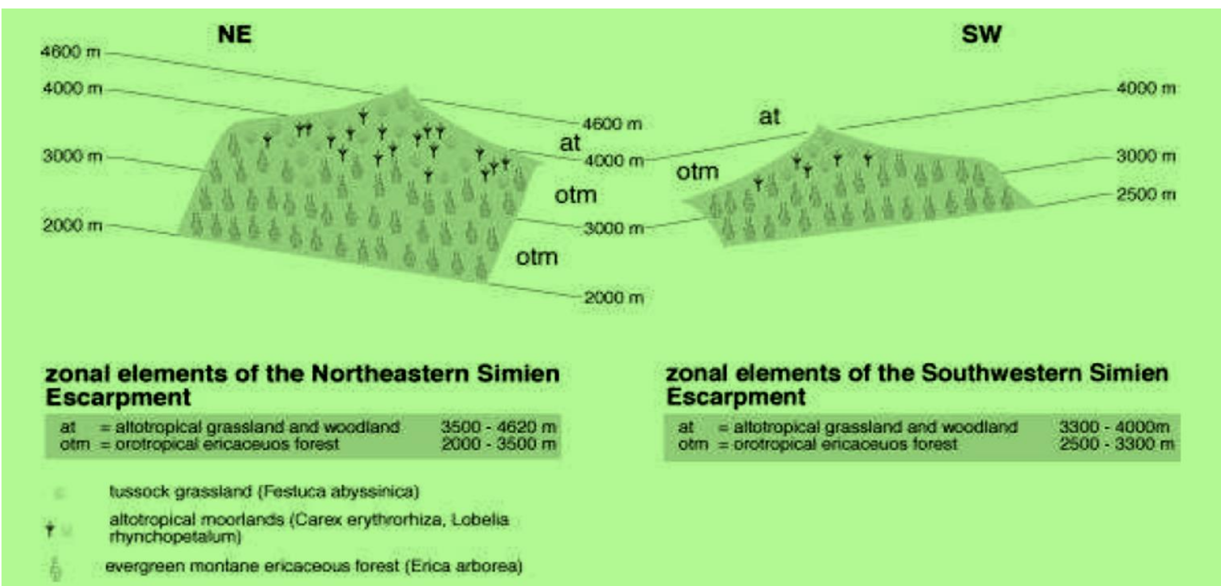


Figure 7. The State of the vegetation of Bale mountains (Source: Bussmann, 2006)

A detailed altitudinal cross-section of the Simen Mountains reveals the presence of a relatively less disturbed Afro-montane forest in inaccessible slopes with increased ruggedness (Puff and

Nemomissa, 2001). Both faces of the Simen Mountains are highly degraded due to settlement and agricultural expansion resulting in the continual shrinkage of the Afro-montane vegetation (Figure 8).

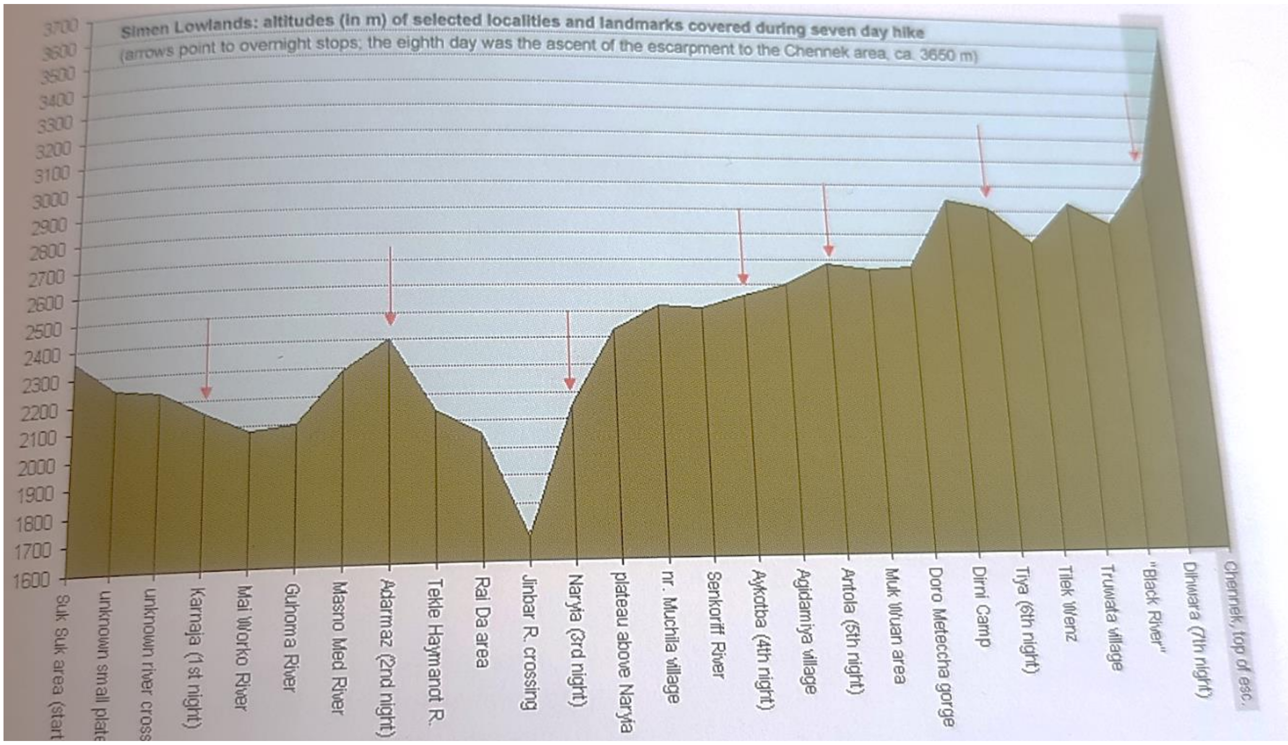


Figure 8. Altitudinal cross-section of the vegetation of Simen Mountains (Source: Puff and Nemomissa, 2005)

The mountain ecosystem of Ethiopia is under an increasing anthropogenic impact and little attention has been given to the conservation of this unique biophysical system. Although some of the mountains of Ethiopia have been designated as National Park and Community Conservation Area, most of them are not protected by law regardless of their unique position in preserving the highly valued biological heritage of Ethiopia. They are also important places for understanding biological dynamic processes such as historical evolutionary and speciation events under past climate changes, which serves as a clue to ensure long-term persistence of biodiversity under the ongoing global environmental change.

2.3.2 Origin, biodiversity dynamics and evolutionary processes in mountain ecosystem

During early Holocene, the Ericaceous vegetation belt of Bale Mountains has shifted upward extensively covering the Sanetti plateau due to increased moisture and temperature (Umera et al., 2007). Dried conditions after 4500 cal BP, i.e., reduced rainfall and short rainy season have triggered the development of *Juniperus* dominated forest on the northern slope of these mountains, a shrinking of the altitudinal limit of the Ericaceous vegetation and an expansion of the Afro-alpine vegetation belt. The human impacts during this period was minimal and the endemic biodiversity of the Ethiopian mountain ecosystem is the legacy of the natural Holocene vegetation change, i.e., repeated contraction and expansion of this ecosystem.

Mountain ecosystem of Ethiopia exhibits physical features where most of them are separated from each other by human dominated landscape and by the main Rift Valley. A long-standing debate with regard to the origin and evolution of the biodiversity of mountains is whether or not intermountain gene flow has entirely depended on long distance dispersal. During the Last Glacial Maximum (LGM), tree line was lower by 1000 m than the present and the Afro-alpine habits were eight times larger than that of today. The Ethiopian mountain ecosystem was interconnected except at the main Rift Valley. During the dry glaciations, species of the mountain ecosystem had extended distribution below the tree line and species have used these migration corridors for a gradual intermountain gene flow and under current climate before the transformation of low-lying landscapes by agriculture, Figure 9 (Chala et al., 2017). *Lobelia giberroa* occurs in the Afro-montane forest of the Ethiopian mountain ecosystem and has a low genetic diversity in Ethiopia, suggesting a gradual migration through the low-lying forest bridges connecting this ecosystem (Kebede et al., 2007).

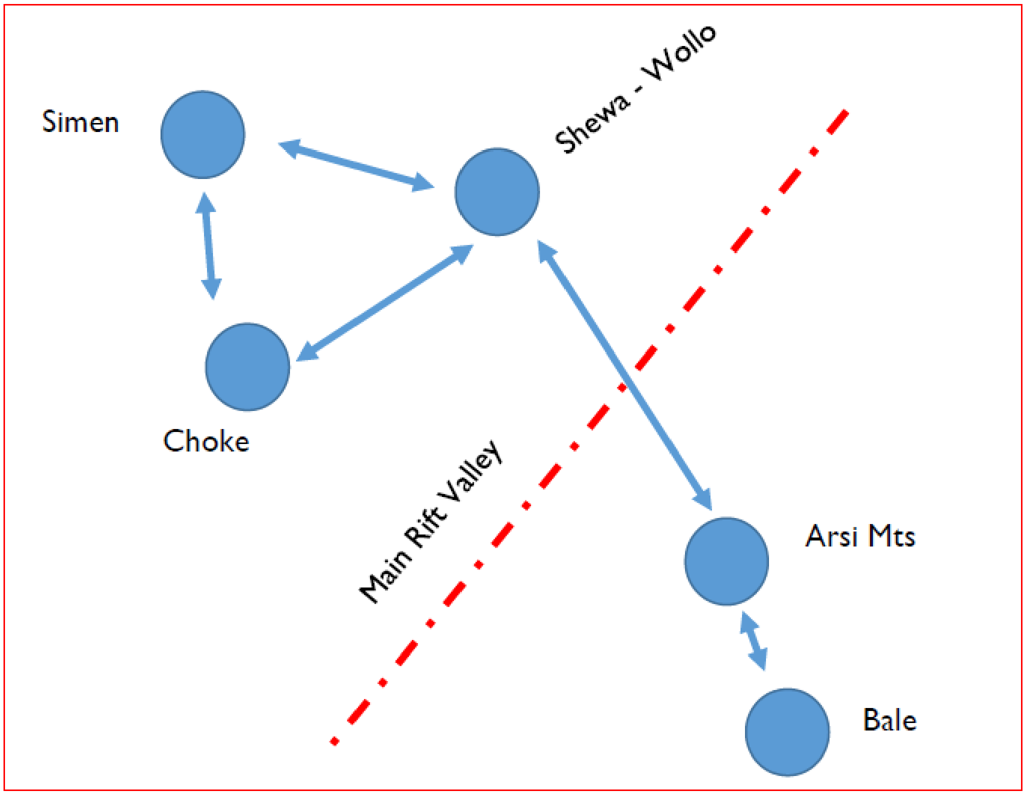


Figure 9. Potential habitat corridors of Ethiopian mountain ecosystem for species migration during the LGM (modified from Chala et al., 2017)

The main Rift Valley has played different roles for different species. Whereas it was permeable to some species, it has also served as an effective barrier to species migration leading to *in-situ* speciation (Figure 9). Plant species of the Ethiopian mountain ecosystem have different dispersal mechanisms, i.e., some lack distinct structure for dispersal (e.g. *Trifolium cryptopodium*) and others have well-developed structure (e.g. *Carduus schimperi*). Wondimu et al. (2014) have conducted a study to understand the impact of the main Rift Valley in shaping the current status of the genetic diversity of these two species. Populations from the opposite sides of the main Rift Valley have exhibited marked difference suggesting a long time isolation and genetic bottleneck effect. However, these populations of the species have a considerable genetic rarity (uniqueness) on each mountain. Long distance dispersal has also played key roles for shaping the current flora of the Ethiopian mountain ecosystem (Assefa et al., 2007; Gizaw et al., 2013). The geographic structure of the variation of the cpDNA of *Arabis alpina* supports long distance dispersal to the Simen Mountains from the Arabian Peninsula and its subsequent intermountain migration by the same mechanism across the Ethiopian mountain ecosystem (Assefa et al., 2007). Furthermore, populations from different mountains have unique cpDNA haplotype, e.g. those form Mt. Kaka.

A dominant species of the Ericaceous vegetation belt, *Erica arborea* has its cradle of genetic diversity in Ethiopian mountain ecosystem and has subsequently dispersed to other part of its current distribution range (Gizaw et al., 2013).

The extensive Afro-alpine habitats of the LGM has also facilitated the distribution of the Ethiopian wolf across the main Rift Valley (Gotteli et al., 2004). The molecular study based on the mtDNA diversity has revealed that genetic partitioning on both sides of the main Rift Valley at the onset of deglaciations (around 15 000 years ago) due to habitat reduction and fragmentation for this high-altitude adapted species. The genetic partitioning of the Ethiopian wolf has resulted in clusters that are found in three mountain groups, i.e., Arsi–Bale, Shewa–Wollo and Simen–Guna. Although there is a clustering of mtDNA haplotypes on the both sides of the main Rift Valley, a taxonomic distinction of two subspecies of the Ethiopian wolf was not supported by a phylogenetic analysis.

2.3.3 Biodiversity status of the Ethiopian mountain ecosystem

The Ethiopian mountain ecosystem is known for its high level of endemic plant species. Some endemic plants are confined to a single mountain, e.g. *Rosularia semiensis* while others are occurring on all mountains as landmark species, e.g. *Lobelia rhyncopetalum* (Puff and Nemomissa, 2005). The conservation status of plants of the Ethiopian mountain ecosystem was not thoroughly assessed although there is some information for certain species , e.g. *Helichrysum horridum*. There are some species known only from 2-3 populations occupying a very small area, e.g. *Swertia macrosepala* ssp. *microsperma* and *Saxifraga hederifolia* (Puff and Nemomissa, 2001). Still others are known only from a single locality (rare) such as *Rhytidosperma grandiflora* (rock outcrop on Mt. Silke, endemic to this Mountain), *Huernia macrocarpa* on the bank of Mai Shaha River valley on the way to Ras Dejen, *Ceropegia sobolifera* (Ericaceous scrub near Sankaber, Simen Mountains) and etc. (Figure 10). And yet, other plants species of the Ethiopian mountain ecosystem are known only from type collections, e.g. Swertia scotia which is endemic to Simen Mountains, from Mai Shah River valley (Nemomissa, 1994). The species has never been collected again, and might have become extinct. The locality which it was originally collected from has changed entirely due to deforestation and other human anthropogenic activities. Generally, the fragile mountain ecosystem of Ethiopia houses plant species of different conservation status and levels of threats to their long-term persistence.

Figure 10. Selected plant species of Ethiopian mountain ecosystem known from single locality (A, Huernia macrocarpa ssp. macrocarpa; B, Ceropegia sobolifera (Source: Puff and Nemomissa, 2005).

The Ethiopian mountain ecosystem is also known for its endemic flagship mammal species such as Walia ibex, Mountain Nyala and the Ethiopian wolf. Some of these flagship species are restricted to a single mountain separated by the rift valley. Besides, the big-headed giant mole rat (*Tachyorycetes macrocepahlus*), which is the main food source of the Ethiopian wolf, is endemic to Bale mountains. Others such as the Ethiopian wolf occurs on different mountains of Ethiopia. Though is the species was spotted on Mt. Guna in 1991 by a group of experts (Sileshi Nemomissa, personal communication) during a field work, current field observations suggest that it is no more extant and this exemplifies local extinction of populations due to extensive anthropogenic habitat degradation. Walia ibex, *Capra walie*, is restricted to Simen Mountains and it competes for resources with domestic goats, *Capra hirucus*, roaming the mountains, and this may compromise its long-term persistence (Gebremedhin et al., 2016). The DNA meta barcoding of the two species has revealed that most diets preferred by Walia ibex (*Alchemilla* sp., *Hypericum revolutum*, *Erica arborea* and *Rumex* sp.) are also the most preferred diets by domestic goats. Walia ibex has been separated for over 0.8 million years from its sister taxon, *Capra nubiana* and has a very low genetic diversity (mean heterozygosity = 0.35) compared to other endangered mammals (Gebremedhin et al., 2009). Such marked low genetic diversity of this species was attributed to a prolonged decline of its populations and small effective population size. A recent census of Walia ibex has recorded an increase in the number of this species (Ejigu et al., 2017). Whether such an increase in number of individuals is accompanied by an increase in genetic diversity is a question to be addressed in future studies.

With regard to raptors of the Ethiopia mountain ecosystem, there is some degree of overlap of their diets with the Ethiopian wolf on Bale Mountains (Clouet et al., 2000). Since there are abundant preys within 1 km^2 area on these mountains, there is no immediate effect on the survival of the Ethiopian wolf. Since there have been no detail studies so far, understanding trophic interactions in the Ethiopian mountain ecosystem could be useful for management plans of this ecosystem to foster sustainability.

The distribution of small mammals (e.g. shrew family) on different mountains of Ethiopia also exhibits patterns where mountains share common endemic species, e.g. *Crocidura glassi* and *C. Lucina* occur on both Bale Mountains and Gara Muleta, while some species are confined to a single mountain, e.g. *Crocidura baileyi* and one new species, *Crocidura* sp. indet. on Simen mountains, Figure 11 (Lavrenchenko et al, 2009) A high level of endemism of small mammals in Simen Mountains (54%) was also recorded by Craig, et al. (2020). Similarly, *C. aferworkei*, *C. harenna* and *C. bottegoides* are confined to Bale Mountains. As this has been the case for plant species, the Ethiopian main Rift Valley might be a zoogeographical barrier for some animal species but have caused no effect on others, which occur on both sides. But further studies are required to understand the details of the geographical distribution of their genes across the Ethiopian mountain ecosystem (phylogeography).

With regard to the threat status of the shrew family that are endemic to mountain ecosystem, some species are categorized as critically endangered (CR) such as *C. harenna*, (Lavrenchenko, 2016) and endangered (EN), e.g. the giant mole rat (Lavrenchenko and Corti, 2016) and others are endangered (EN), e.g. *C. bottegoides* (Lavrenchenko et al., 2009). On the other hand, *C.*

baileyi on Simen Mountains is of least concern (LC), while *C. glassi* occurring on Bale Mountains is vulnerable (VU). Currently, overgrazing of the habitats of these species and agricultural expansion are the main factors contributing to the continued decline in area, extent and quality of their habitats.

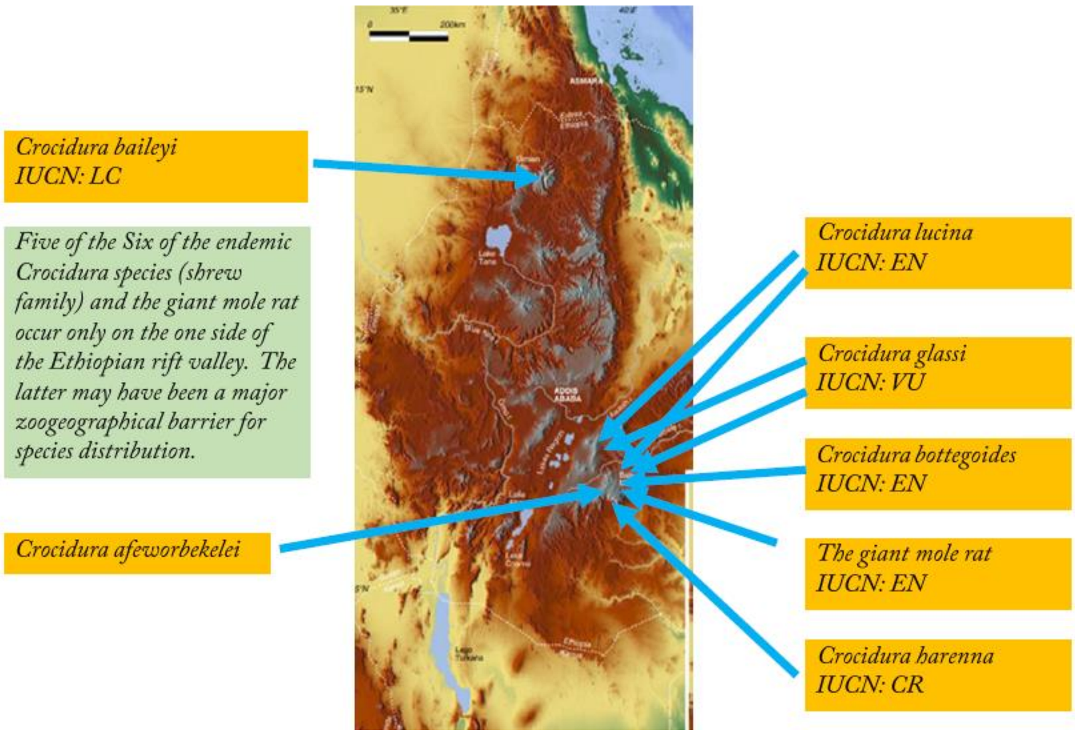


Figure 11. Location of endemic small mammals of the Ethiopian mountain ecosystem

There are limited studies on the geographical structure of the genetic diversity of the mammals of the Ethiopian mountain ecosystem. A recent study by Kostin et al. (2019) on the taxonomy and genetic diversity of endemic rodents of Arsi Mountains National Park has revealed a new, yet to be described species of *Dendromus* and the occurrence of endemic species such as *Lophuromys melanonyx* and *L. chrysopus*. Two mtDNA haplotypes of *L. melanonyx* have been recorded from Mt. Bada (Arsi Mountains National Park) and Bale mountains. On the other hand, two mtDNA haplotypes were recorded for *L. simensis* on Simen Mountains (North I and North II). A phylogenetic analysis based on these molecular markers have shown that the populations of the two species with haplotype II (Melanonyx II and North II) are closely related to each other than to other species occurring in different areas. On the other hand, populations of these species with haplotype I (Melanonyx I and North I) were differently grouped. Noteworthy is also that some taxonomic groups, e.g. *Stenocephalemys* spp. from the two mountain blocks (Arsi Mountains and Bale Mountains) have identical mtDNA haplotypes. Similar patterns of genetic diversity based on the cpDNA studies were also recorded elsewhere for plants (Assefa et al., 2007; Kebede et al., 2007; Wondimu et al., 2014). It is evident that some of the populations of different small mammals, e.g. *Lophuromys*, and *Arvicanthis*, have developed new mutations since the separation of the Arsi and Bale mountains.

In an Ethiopian context, little is known with regard to the taxonomic diversity and endemicity of amphibians. There are 32 species of endemic amphibian species in Ethiopia (www.amphibiaweb.org), based on few collections. A handful of these endemic amphibian species occur on the Ethiopian mountain ecosystem (Figure 12). Some of these endemic species are confined to a single mountain ecosystem, e.g. *Leptopelis susanae* to Gughe Mountain, *L. ragazii* and *L. gramineus* to Bale Mountains. On the other hand, others occur only on two mountains, i.e., *Paracassina kounhiensis* is endemic to Bale Mountains and Gara Muleta but absent from mountains across the Ethiopian main rift valley. An exception is the endemic *Afrixalus enseticola*, which occurs on Bale Mountains but also in Jimma area across the rift valley.

The endemic amphibian species of the Ethiopian mountain ecosystem have different level of threat status. Whereas *Leptopelis susanae* and *Afrixalus enseticola* are categorized as endangered (EN), *Paracassina kounhiensis* and *Leptopelis ragazii* are vulnerable (VU). On the other hand, *Leptopelis gramineus* and *L. yaldeni* are of least concern (LC) although they have fragmented ranges.

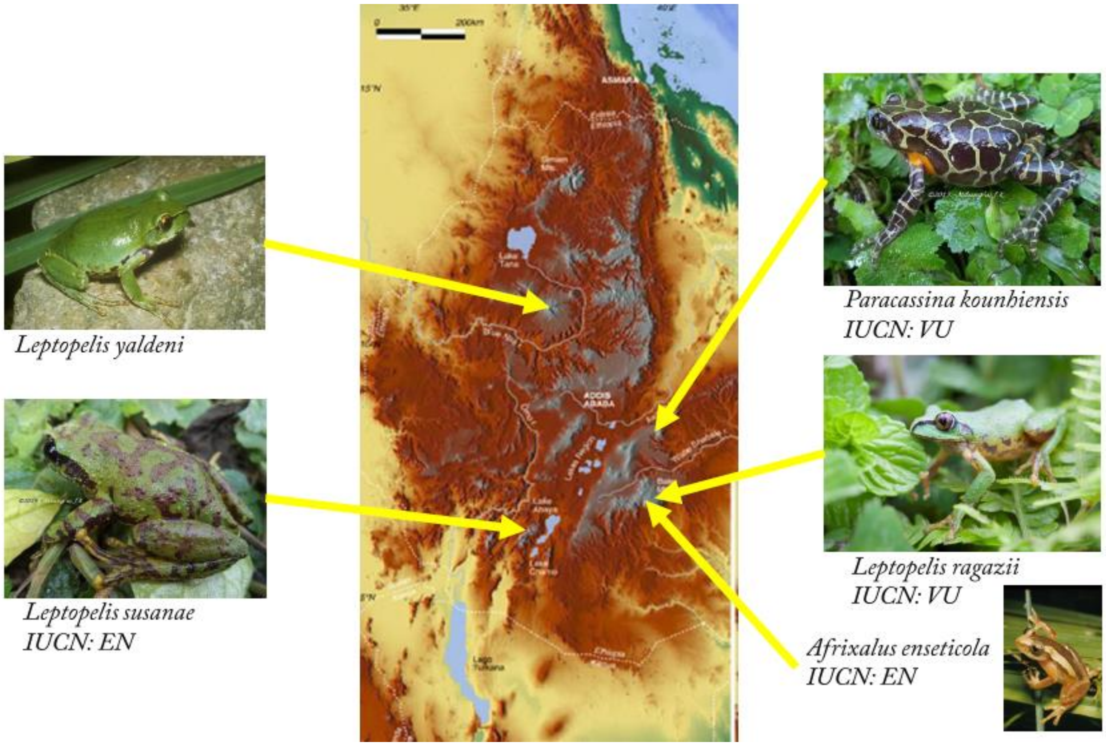


Figure 12. Endemic frogs of Ethiopian Mountain Ecosystem

There are very few records or a very limited study of reptiles from the Ethiopian mountain ecosystem. A recent study from Mt. Abune Yosef (Saavedra, 2009) has reported two species of lizards, i.e., *Mabuya* species (Family Scincidae) and *Acanthocerus annectans* (family Agamidae). Mabuya species has been recorded from above 3800 m asl, occupying diverse habitats. On the other hand, *Acanthocerus annectans* occupies altitudinal ranges up to 3300 m asl on the same mountain. Generally, the limited records of reptiles from the mountain ecosystem of Ethiopia do not allow comparative analyses to understand their zoogeography and the current status of species richness across the mountains.

The Ethiopian mountain ecosystem is a breeding place for several birds and hunting site for birds of prey (raptors). On Bale mountains, 25 species were recorded, i.e., 10 are resident, 8 are rare visitors and 7 are migrants (Clouet et al., 2000).

2.3.4 Future trend of plant and animal life of mountain ecosystem

The Ethiopian mountain ecosystem houses unique plant and animal species. These species are adapted to live under extreme diurnal variations of temperature and have restricted altitudinal ranges. Footprints of human activities since the Middle Stone Age on the glaciated Bale Mountains have been recently recorded (Ossendorf et al., 2019) where high-altitude rock shelters were repeatedly occupied by humans from 47 to 31 thousand years ago. Abundant food resources, namely rodents, in this cold and glaciated mountain have played key roles in facilitating the occupation of these high-altitude rock shelters by late Pleistocene hunter–gatherers. Human encroachment into the mountain ecosystem of Ethiopia is a common practice where people clear vegetation for agricultural expansion and settlement areas. The increasing trend of habitat degradation is one of the major threats to the long-term persistence of mountain biodiversity. The second main factor determining future species composition and richness of mountain ecosystem of Ethiopia is the human-driven global climate change.

The global climatic warming affects the responses of the biodiversity of mountain ecosystem of Ethiopia in different ways. Mountains could be refugia (Figure 13; 5), traps species in their existing microclimates-leading to local extinction (Figure 13; 3, 4), provides a chance to escape climate warming by topography effect (Figure 13; 6) and low altitude species may have to move a great distance to ensure their persistence (Figure 13; 1). Furthermore, population of species already living near mountaintops run out of space and are destined to extinction (Figure 13; 4).

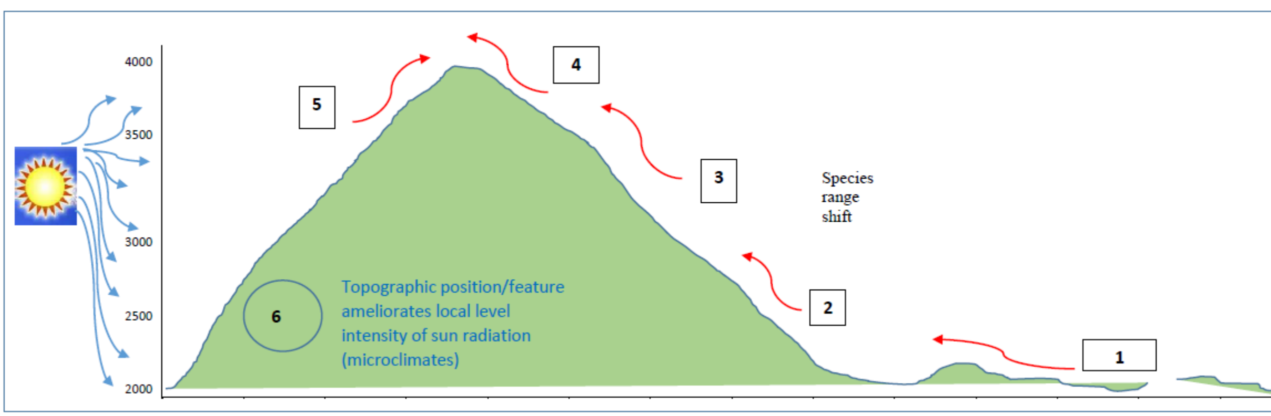


Figure 13. Species responses to climate change in mountain ecosystem

Recently, an interest in the responses of plants and animals in an Ethiopian mountain ecosystem to global climate change has grown (Chala et al., 2017; Evangelista et al. 2008). The study on the flagship of Ethiopian mountain ecosystem, *Lobelia rhyncopetalum*, has shown a significant shrinking of its current habitat and a potential extinction of this species under the current climate change (Chala et al., 2017). By 2080, only 3.4% of its current habitats could be considered suitable resulting in 82% loss of its genetic diversity. A study on the other Ethiopian mountain ecosystem flagship species, Mountain Nyala (*Tragelaphus buxtoni*), has predicted its suitable habitats and found a strong links between abiotic factors (temperature and rainfall) and its distribution range (Evangelista et al., 2008).

2.3.5 Trends in mountain ecosystem

In Ethiopia, accelerated deforestation has been taking place since the beginning of the 20th century (EFAP, 1993). Although forests were thought to have covered nearly 40% of the country's total area at the beginning of the 20th century (Breitenbach, 1961; EFAP, 1993), the high forest cover has reduced to almost less than 3% (EFAP, 1993) with annual rate of deforestation between 150,000 and 200,000 ha (Reusing, 1998). However, recent reports suggest that the forest cover of the country has increased to 15% (Ethiopian Mapping Agency, unpublished).

Recent studies on land use/land cover change and on the drivers of deforestation in the highlands of Ethiopia have documented historical trends that took place in the forests in general and mountain ecosystem in particular and reported increased human impact (Wondie et al., 2011; Alemu et al., 2012; Kidane et al., 2012; Fetene et al., 2014; Frankl and Nyssen, 2015; Jacob et al., 2014; Nune et al., 2016; Jacob et al., 2016 and Mezgebu and Workineh, 2017). For instance, Alemu et al. (2012) reported an increase of 1,467 ha (from 22,827 ha to 24,294 ha) in the Afro-alpine vegetation and a decrease in Ericaceous forest by 12,660 ha (from 249,636 ha to 236,976 ha) in the Bale Mountains from 1986 to 2006. Fire has been reported as a major factor for the increase of the grassland replacing the Ericaceous vegetation and shrub lands.

Another study by Kidane et al. (2012) assessed the spatio-temporal land use/land cover change of the Bale Mountains ecoregion using satellite imagery of the period between 1973 and 2008. The findings showed that drastic change of the landscape has taken place in these four decades, which could be summed up as a change of a natural landscape to a more cultural landscape. It has also shown an overall decline in the covers of the Afro-alpine grasslands, formations of Afro-montane dwarf shrubs and herbaceous, a decrease in grassland cover by more than half (from 19.3% in 1973 to 8.8% in 2008) in the Afro-montane grasslands while closed Erica forest shrank from 15.0% to 12.37%, and the Afro-alpine dwarf shrubs and herbaceous formations reduced from 5.2% to 1.56%, Figure 14 (Kidane et al., 2012).

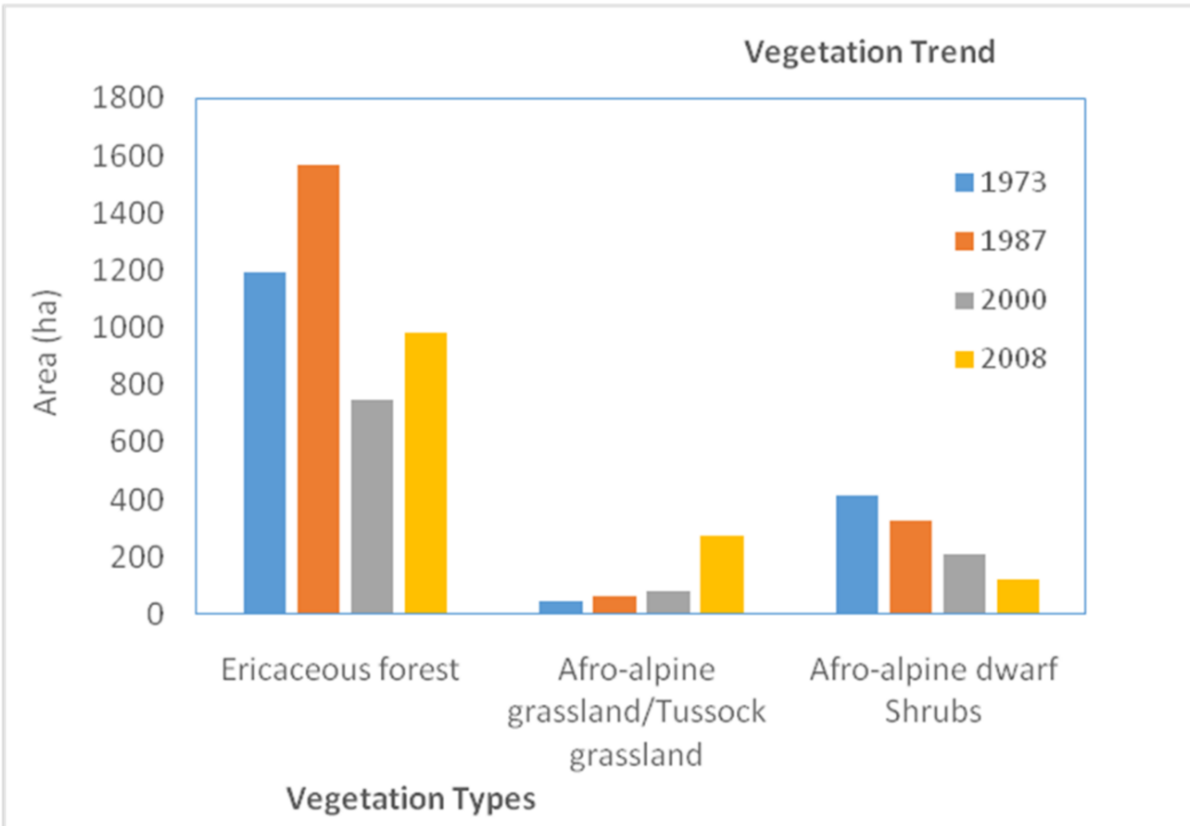


Figure 14. Trends of Afro-alpine and Ericaceous Vegetation in the Bale Mountains Ecoregion (1973-2008)

A similar study of the Bale Mountains ecoregion by Nune et al. (2016) reported a continuous decline in area of the Afro-alpine and the Ericaceous vegetation during the period from 1985 to 2015 using Landsat images (Figure 15).

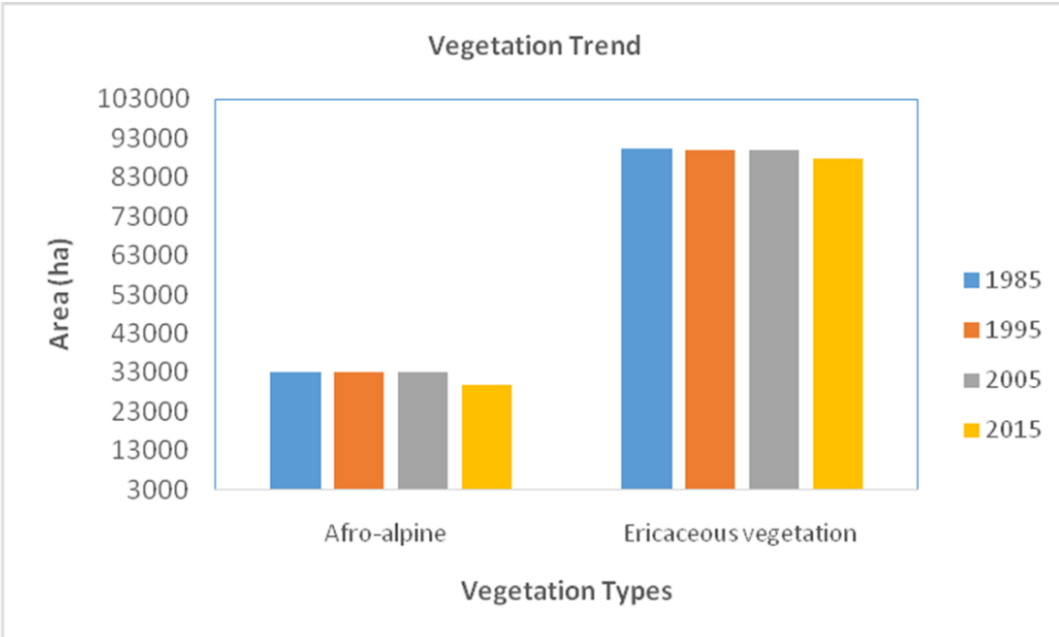


Figure 15. Trends of Afro-alpine and Ericaceous vegetation in Bale Mountains (1985-2015)

The study on LULC changes during a period of 48 years (1964-2012) at Lib Amba Mountain of northern Ethiopia (Tigray region) reported that a large scale deforestation has occurred in the Afro-alpine vegetation zones above 3500 m (Frankl and Nyssen, 2015). A severe decline of the Ericaceous vegetation has also occurred in the first 18 years (16% in 1964 to 4% in 1982), and, the decline continued even after 1982, although at slow rate. Land use intensification prevailed with a slight regeneration of the *Erica arborea* vegetation. Whereas eucalyptus plantation forest increased in the low altitude areas (below 3332 m asl) from a single patch in 1964 to several patches of woodlots in the higher altitude (above 3445 masl) in 2012. Moreover, in the higher altitudes of above 3700 m asl, plain bushland increased at the expense of mixed grass and bushland and grassland (Frankl and Nyssen, 2015).

On the other hand, in the analysis of the LULC on Lib Amba Mountain between the periods 1982-2012, cultivation was intensified and human settlements increased in the valleys below 3500 m asl. The trend showed that there has been a slight improvement in the regeneration of the *Erica arborea* vegetation in the high-altitude areas in recent years and a tendency of abandoning degraded farmlands on the steep slopes of the valleys. Interestingly, the study showed an increase in the elevation of the *Erica arborea* tree line by 7 to 15 meters in the period between

1965 and 2010, particularly in those areas where anthropogenic pressure decreased over the years (Jacob et al., 2014).

A study undertaken on the land use/land cover change in the Simen Mountains National Park by Wonddie et al. (2011) indicated an increase in the coverage of forest and shrub land between 1984 and 2003. This study further indicated that forest land alone has increased from 11.7 to 15.6% from the total land cover. The Ericaceous vegetation increased, particularly at the “Gich” plateau, due to better protection of the land from disturbance and interferences. Smilarly, the shrub land extensively expanded compared to the other land cover types covering 7.3% of the total area of the park in 1984. In 2003, the shrub land further expanded to 16.6%. The grassland remained relatively unchanged. However, agricultural land decreased with a net loss of 684 ha between 1984 and 2003.

The increase in forest cover and the decrease in agricultural land has positively contributed to the restoration of wildlife habitats during the study period (Wondie et al., 2011). The same study indicated also that between the period of 1984 and 2003, the forest cover has increased in the Simen Mountains National Park despite there was an increase in human and livestock populations. According to this report, agricultural areas and grasslands, which are sources of livelihoods for the people, had decreased and the trend remained relatively unchanged between 1984 and 2003.

As reported by Jacob et al. (2016), an increasing trend of forest cover by a magnitude of 20-40% was observed in the western and eastern edges (Sankaber and Imet-Gojo) of Simen Mountain from analysis of aerial photographs for the period 1966 to 2009. Besides, the tree line had shown uplift by more than 1 m per year in areas with low anthropogenic pressure, perhaps attributed to climate change impact. In another study by Bewket (2002), protection of the landscape by local communities contributed to the recovery and increment of natural forest cover, which has led to the regeneration of *Erica arborea* vegetation along the margins of the forest vegetation in the upstream of the Chemoga watershed.

Land use/land cover change and its effect on the extent and distribution of the Afro-alpine vegetation of Choke Mountain was studied by Aramde et al. (2014) using time series satellite images from 1986 to 2011. The results showed continuous increase of crop land by more than 200% while the Ericaceous forest, grasslands and shrub lands decreased by 79, 40 and 17%, respectively in the same period. Similarly, Birhanu et al. (2016) reported continuous decline of Ericaceous forest on Mount Guna because of clearing for agriculture and open grazing that dates back to the early 1970s. However, in an effort to curb the trend, local communities and local government institutions exerted concerted intervention in preventing the human and livestock pressure in the period between 2000 and 2014, which resulted in a successful recovery of the Ericaceous vegetation (Birhanu et al., 2016). The regeneration of the forest improved over the years after the involvement of Community Based Organizations (CBOs) in the landscape management. In a study of the Guraghe highland mountain by Sahle and Yeshitela (2018), constant shrinking of the Afro-alpine vegetation cover was observed in the period between 1986 and 2017. The magnitude of the loss of the Afro-alpine vegetation was reported as more than 50% in less than three decades. Significant proportion of the Afro-alpine vegetation (about 937 ha) was converted to grazing, cultivated and bare lands.

The changes in the land use/land cover of mountain ecosystem directly and indirectly affected biodiversity of the Afro-alpine and Ericaceous vegetation belts. In addition to impact on habitat quality, the decline in area cover restricts movement and limits availability of food for some range restricted species of wildlife. The population of such species may decline and their survival will also be threatened. On the other hand, targeted management interventions in the mountain ecosystem positively impacts some of the flagship endemic species and improve the population status. Examples of such targeted interventions are those of the Ethiopian wolf and Walia ibex. Despite there were management interventions, the population of Mountain Nyala in the Bale Mountains Afro-alpine area has been declining over the past decades (Atickem et al., 2011).

The Ethiopian wolf is much localized endemic species, confined to isolated pockets of Afro-alpine grasslands and heathlands where there is the typical prey, the Afro-alpine rodent. The Ethiopian wolf is found in the Bale mountains, Simien mountains, Arsi mountains, Mount Guna, Borena Saint, Menz-Guassa, and Aboi Gara Community Conservation areas (IBC, 2009; IUCN, 2011; EBI, 2014). The IUCN categorized the Ethiopian wolf as ‘Endangered’ in 2008, 2004, 1996, 1990, 1988, 1986), whereas the Wolf was categorized as ‘Critically Endangered’ in 1994

(Biodiversity Indicators Development National Task Force 2010). The Ethiopian Wolf Conservation Program (EWCP) has played significant role in Ethiopian Wolf conservation (Tefera & Sillero-Zubiri 2005, 2006). As a result of these interventions, the Ethiopian Wolf population has shown steady improvement since 1994 in the Bale Mountains (Figure 16).

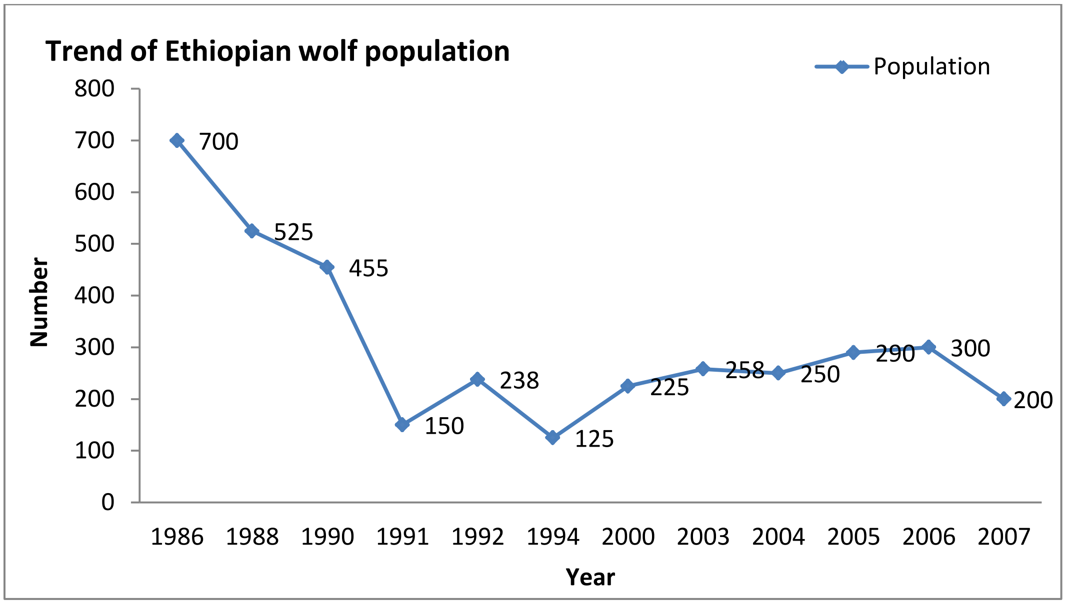


Figure 16. Population trend of Ethiopian wolf in Bale Mountains National Park (Source: IUCN and EWCA database)

Among the endemic species that have shown positive trend in population is the endemic Walia ibex (*Capra walie*). Walia ibex is listed as 'Endangered' in the IUCN RED list and it is confined to the Simen Mountains National Park and the surroundings. Although the species used to be spread over wide area of the Simen Mountains, the current remaining population is believed to be restricted within the boundaries of the Simen Mountains National Park. However, a report by the Biodiversity Indicators Development National Task Force (2010) recognized the presence of four small populations of Walia ibex outside of the protected area of the National Park. These are the areas around North of Werk Amba and towards the West of the park; an area between Silki and Walka North-east of the park; pocket area between Bwahit and Mesarerya; and an area in the North of Weynobar along the Ras Dejen escarpment.

In 2004, the population of Walia ibex was reported to be around 500, a figure that is slightly higher than earlier estimates of 200-250 individuals between 1994 and 1996. In 2008, the population was reported to be more than 700, though the species still remains as endangered (Figure 17). Although the population has been showing signs of increase over the past decade, the habitat continues to decline because of human encroachment (Biodiversity Indicators Development National Task Force, 2010).

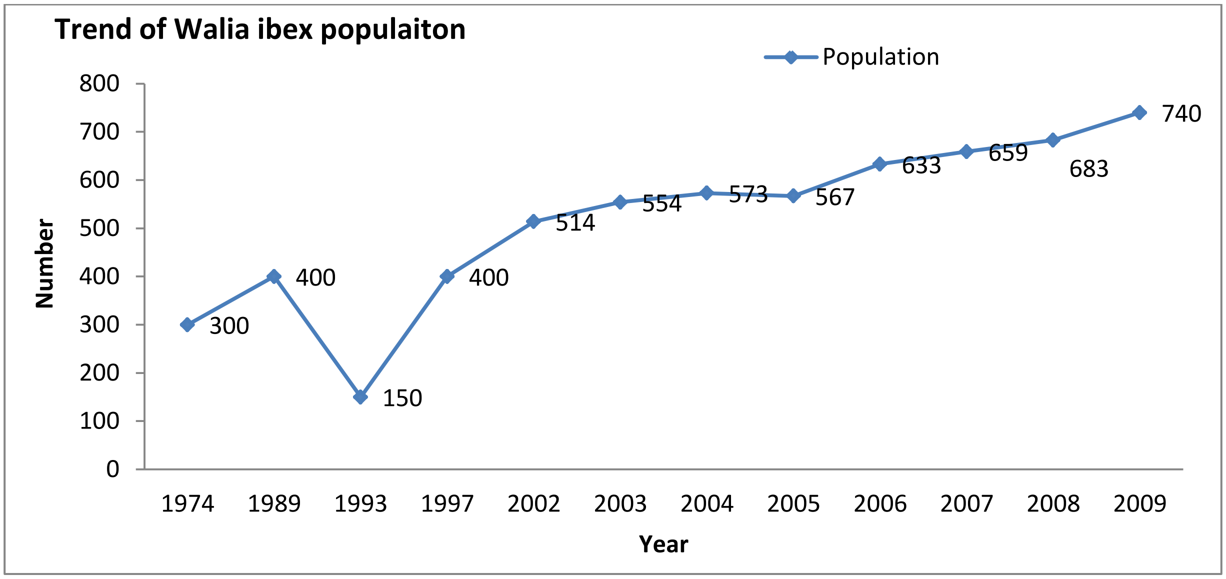


Figure 17. Population trend of Walia ibex in Simen Mountains National Park (Source: IUCN and EWCA)

Another endemic flagship mammal species of the mountain ecosystem is Mountain Nyala (*Tragelaphus buxtoni*). The distribution pattern, population status and habitat requirements of Mountain Nyala is relatively better documented in the Bale Mountains (Atickem & Loe, 2013), compared to other habitats as reported in intermittent observations and trophy hunters (Evangelista et al., 2007). It is the most important trophy species in Ethiopia. Records show that the population has been drastically declining in the past years mainly due to human and livestock encroachment to its habitat (Atickem et al., 2011). Even though Mountain Nyala is currently categorized as an endangered species by the IUCN (2007), the number of individuals in its habitat is believed to provide an opportunity to increase the population. In the early 1960s, the population was estimated to be 7000 to 8000 in fragmented habitat patches of the Bale and Arsi Mountains (Hillman, 1986). Estimates reported by Atickem et al. (2011) suggest that there are about 3800 individuals in the Bale Mountains. However, Sillero-Zubiri (2012) reported the total population to be between 1500-2000 individuals. Generally, the trend showed a continuous decline of the population that risks the survival of the species in its natural habitat.

2.4 Drivers of change in biodiversity of mountain ecosystem

Drivers are those factors exerting pressure on natural ecosystems resulting in, often negative but also positive, changes on the functions and services of ecosystems. The changes could be triggered by natural and anthropogenic direct and indirect drivers. There could be causal linkages among the direct natural and anthropogenic drivers that exacerbate the change process. Natural drivers might aggravate anthropogenic changes such as settlements along flood sensitive landscapes. This chapter explores the major drivers of changes in biodiversity of mountain ecosystem. Understanding the key drivers helps to make informed decisions in managing the negative outcomes on ecosystem goods and services.

2.4.1. Direct Drivers

Direct drivers are those drivers that directly exert pressures and threats to the ecosystem and its biodiversity. These are proximate causes that result in direct impacts. The impacts could be negative or positive, emanating from either natural or anthropogenic causes. The effects or impacts of these direct drivers of change can be identified, measured and monitored (Nelson et al., 2005; Ash et al., 2008; Díaz et al., 2015) for informed decision making.

Natural direct drivers

The natural direct drivers are those natural phenomena occurring with minimum or no human influence, although the impacts on humans may be exacerbated by people. The natural direct drivers include disasters (e.g., floods, droughts, and volcanic eruptions), natural fire hazards, climate change (temperature rise, decline of precipitation), outbreak of diseases and pests (e.g., locusts, army worms, crop diseases).

Natural Fire

Natural fires are most important direct drivers of change in mountain ecosystem. Studies suggest that a pattern of recurrent natural fires is presumed to be very common in the mountains of Ethiopia, altering the vegetation dynamics (Johansson, 2013). The change in vegetation dynamics and cover loss result in range restriction for some species, causing habitat shrinkage, degradation of habitat quality, disrupting food chain and causing prey-predator imbalance. Natural fires are main drivers of change in the Bale Mountains ecosystem. The Afro-alpine and Ericaceous belts have been affected, and as a result Ericaceous belt has been reduced. Similarly, in Simen mountains, fires have modified the composition of grassland in the Afro-alpine belt. According to Hedberg (1971), the woody vegetation in such ecosystem has been burnt by wild fires and cleared for years, degrading the naturally fragile environment.

Climate change

Climate change alters the natural ecological process in the mountain ecosystem due to changes in the spatial and temporal pattern of temperature and precipitation gradients. The Ethiopian Academy of Sciences (2015) reported that human induced climate change is a cause for deterioration of biodiversity resources in mountain ecosystem due to temperature rise, droughts, natural fires, soil erosion and invasive species. The degradation in vegetation and soils obviously implies great losses in valuable genetic materials. Some lower altitude species may adapt to the changing temperature regime while higher altitude species find it difficult to survive in increased temperatures. The impact of temperature regime change can likely cause upward migration of species (flora and fauna) towards the cold and dry plateau belt. This will affect the structure and cause an impact on the provisioning, regulating, cultural and aesthetic values of the ecosystem.

Drought

Cyclic droughts associated with *El Nino* and the Southern Oscillation (ENSO) affect wide regions of the country. Over the years, the frequency of these climate episodes has increased and resulted in high temperatures and moisture stress during dry years. Although high mountain climates are cold and dry, the changing temperature regimes trigger occurrence of natural fires. There have been records of recent fire incidents (Mezgebu and Workneh, 2017) in the Bale Mountains National Park, directly associated with extended drought due to the effect of *El Nino*.

Diseases and pests outbreaks

Diseases and pests are often caused by changes in the climate pattern and human encroachment of wildlife habitats, agricultural intensification and urbanization. Plant species are attacked by root rot bacteria, leaf rust fungus, and parasitic pests such as leaf scales, stem borers, and weevils. Human encroachment is also a cause for various types of zoonotic diseases to wildlife. Commonly known domestic animal diseases such as rinderpest, rabies, trypanosomiasis, canine distemper, and anthrax have been known to be transmitted domestic animals to wildlife due to anthropogenic factors, with serious impact on wildlife populations. For instance, rabies is known to have been transmitted from dogs to Ethiopian fox in Bale and Simen Mountains National parks.

Anthropogenic direct drivers

Anthropogenic direct drivers are purely an outcome of human activities such as clearing of land for settlement or agriculture. Human activities have a direct effect on biodiversity and ecosystems, causing either positive (e.g., through restoration) and/or negative (e.g., deforestation) impacts enhancing/reducing nature's benefits to people. The anthropogenic direct drivers include land use/land cover change (i.e., deforestation, land conversion), overexploitation (overgrazing, excessive wood extraction, overfishing), invasive alien species, and pollution (e.g., release of gasses, solid and liquid wastes).

Land use land cover change

Land use land cover change, especially conversion of natural vegetation to farmlands, grazing lands, infrastructure and human settlements contributes significantly towards loss of biodiversity and disruption of ecosystem functions. Land cover changes can also be caused by a number of natural driving forces (Meyer and Turner, 1994) in addition to human factors. However, the effects of the natural factors such as climate change on land use are felt after long periods of time while the human impacts are immediate and radical. The highlands of Ethiopia were widely covered with Afro-alpine moorlands and grasslands until 10,000 years ago (Messerli et al., 1977).

Agricultural expansion and wood extraction

Agriculture is recognized as the most important direct driver of ecosystem change (Mezgebu and Workineh, 2017). Agricultural land expansion, demand for fuel wood and construction materials as well as overgrazing have contributed to ecosystem degradation in Ethiopia (FAO, 2010). The intensification of farming and livestock grazing has resulted in environmental degradation and conflicts with wildlife, negatively affecting conservation of the Afro-alpine areas (Tefera and Leader-Williams, 2005). In the Choke Mountain range, there is extensive agricultural activity up to 3380 m, including on steep slopes (Hurni, 1990). Intensive cultivation is accelerating deforestation, soil erosion and land degradation of the fragile ecosystems in the mountains. For instance, a study in the Choke Mountain by Abelineh (2011) revealed that about 132,069 households live on traditional farming in the mountain and about 4,500 of the youth were reported to be landless. This was found to be the main reason for conversion of vast area of the Afro-alpine vegetation into cropland. Another study by Fetene et al. (2014) in the same area reported that cropland increased by 206%, whereas the Ericaceous forest, grasslands and shrub lands declined by 79%, 40% and 17%, respectively, in the Afro-alpine region of the mountain range between 1986 and 2011. Similarly, Teferi et al. (2010) reported loss of 607 km^2 wetlands and 22.4 km^2 water body in the Choke Mountains in the period between 1986 and 2005.

Conversion of natural habitat to farmland, overgrazing by livestock and unsustainable fuel wood and timber extraction are also major problems in the Bale Mountains (Nune et al., 2015). The floral composition and structure of the vegetation in the Bale Mountains are said to be threatened by disturbances mainly from overgrazing, fire and conversion to agriculture (Nigatu and Tadesse, 1989; Evangelista et al., 2007; Johansson, 2013). For example, Nigatu and Tadesse (1989) reported severe impact on vegetation composition and structure in the Bale Mountains National Park due to deforestation driven by expansion of agriculture, settlement and wood extraction. The spill-over effect of expansion of cultivation into the marginal and steep slope areas warrants gradual encroachment to the Afro-alpine belts. In the Simen Mountains, the woody vegetation belt, particularly the giant heather, *Erica arborea*, has been burnt and/or cleared in many areas further threatening the naturally fragile environment (Hedberg, 1971).

Land Degradation

Almost 75% of the highland areas in Ethiopia are known to have been degraded (FAO, 1986). Soil erosion is rampant due to the combined effects of the rugged configuration of the topography and the torrential rains, deforestation, cultivation of steep slopes and centuries of mis-management. Land degradation is widespread in the high mountain areas and it has become a major threat to various ecosystems in general (Hurni, 1986). The northern highlands are one of the most severely affected areas by land degradation with 71% of the land being vulnerable to soil erosion (Adenew and Abdi, 2005). The high intensity of rainfall, deep erodible types of soil and steep topography are the major natural factors driving land degradation in mountain ecosystem. The impacts on ecosystem services emanate from land conversion and/or absence of proper land management practices (Foley et al., 2005).

According to Hurni (1986), the annual soil loss from cultivated lands inside the Simen Mountains National Park was 80 tons per hectare. For instance, in 1989, about 3,326 ha of the Simen Mountains National Park was cultivated and an estimated 360,000 tons of soil was washed away. The continuous cultivation by local people leads to further degradation of soil depth and reduced moisture retention capacity. Reduced soil depth leads to less infiltration of water and higher surface runoff, while increasing soil erosion rates in the upper course of rivers and leads to higher sediment concentrations further downstream, and decreased water quality. Every year more and more land is lost to land degradation, seriously affecting livelihoods of farming communities and economy of the country. If current trends in land degradation continue, farmers who depend on the most vulnerable lands of the mountain ecosystem will be highly affected.

Overgrazing

In the Ethiopian highlands, overgrazing is one of the major drivers of land degradation and accounts for 20% of the country's annual soil erosion (Aregu et al., 2015), and vital plant species are disappearing from pastures mainly because of open-access grazing. Du to livestock grazing and browsing, palatable species are gradually replaced by non-palatable species. Moreover, overgrazing leads to the replacement of soft grasses with hard ones, prevention of tree regeneration and accelerates soil erosion (Klotzli, 1975).

Livestock encroachment has been common in dry evergreen Afro-montane belts (Teketay, 1992), Ericaceous vegetation (Miehe and Miehe, 1994; Johansson, 2013), and Afro-alpine vegetation types (Wesche et al., 2000). Excessive grazing, browsing, and trampling pressure on young seedlings and saplings were reported to alter vegetation dynamics (regeneration). These disturbances have also been reported to affect the cover and food requirements of the endangered endemic Mountain Nyala (*Tragelaphus buxtoni*) and other wildlife species in the Bale Mountains, ultimately affecting their survival (Evangelista et al., 2007; Mamo and Bekele, 2011; Mamo et al., 2012; Girma, 2016). Mekonnen et al. (2017) reported overgrazing, human settlement, agricultural expansion, pastoralist movement, illegal cutting of trees, human–wildlife conflict, habitat fragmentation, scarcity of water, migration of wild animal, and unmanageable cut-carry scheme of grass use, fire, mining activities and illegal hunting of wildlife as threats to biodiversity and the ecosystem in Harrena forest, which is partly in the Afro-alpine part of the Bale Mountain National Park.

In Simen Mountains National Park, cattle population is high, which has resulted in overgrazing. Livestock density throughout the Afro-alpine area of the Simen Mountains National Park was estimated to be 2.5 heads of livestock/ha (FZS, 2007). Monitoring program that was conducted in the Bale Mountain National Park Afro-alpine area between 2010 and 2014 showed that an estimated 563,000 heads of livestock accessed the area for grazing. The intensified use of the highland plateau for livestock grazing and farming are major disturbances in the Simen Mountains, which has led to the restriction of Walia Ibex to a narrow belt on the steepest cliffs (Hurni, 1986).

Population pressure

Population growth is the most important human factor driving ecosystem change in Ethiopia as it generally is the case in developing countries (Hurni, 1993; Mortimore, 1993). The highlands are inhabited by humans in the earlier times and hence, ecosystem changes are more severe in the highlands than in the lowlands (Eshetu and Hogberg, 2000). This is because of high population pressure and repeated cultivation without fallow (Kindu et al., 2013). The highlands contain about 90% of the total cultivated lands and are occupied by 90% of the human and 60% of all livestock populations (Hurni et al., 2010). The demographic trend shows a doubling of the population every 25 years since the 1950's, resulting in scarcity of land, shortening of fallow periods, and deforestation in the last remnants of natural forests (Hurni, 1986). For instance, the Choke Mountain range is densely populated, with an average of 260-270 people per km^2. Settlements are fairly common up to 3600 m of the mountain. Poverty is rampant and most people live below the national poverty line. As a result, they try to survive by eking out the land, resulting in overgrazing of fragile grasslands and cutting of forest stocks for firewood. In the context of short-term needs of individuals, each decision seems rational; in the long-term and wider context, however, the effects are disastrous. Hence, poverty is both a cause and an effect of environmental degradation (Durning, 1989).

Population pressure has pushed farmers onto steeper slopes in the Simen Mountains National Park (SMNP), which can only give yields for a few years before the soil is washed away. On such inhospitable environments, farmers could hardly produce crops with the same amount and rate as below the tree line, since the growth rate could be hampered by the unsuitable climatic conditions. About 86% of the Simen Mountains National Park is used by humans at various levels of intensity. Grazing is not as such significant, but farming causes much more harm (Falch and Keiner, 2000). According to Nepal (2000), almost 5,000 households with a total population of about 28,000 live in and around SMNP. Some 10,000 people either live on, or use land and other resources inside the park. However, large numbers of people are translocated recently from the core area of the park to the surrounding areas. Similarly, Bale Mountains National Park (BMNP) is under increasing threat from a growing human population, fire, and rapid illegal and unrestricted settlement (SOS Sahel Ethiopia, 2010). Over 40,000 people live within the BMNP boundary and has posed pressure on the natural resources (Taylor, 2015).

2.4.2 Indirect Drivers

Indirect drivers are often rooted from policy decisions that influence societal behavior. Indirect drivers of mountain ecosystem change are drivers that cause alteration of the rate at which direct drivers impact biodiversity and nature's contribution to people (Nelson et al., 2005). The decisions made by society, whether influenced by leaders in the public or private sector, and the influence of those decisions on human behavior have major consequences for nature and nature's contributions to people. Indirect drivers of change in ecosystems are often called underlying drivers, which result from the complex interactions of social, economic, political, cultural and technological developments, ultimately triggering the direct drivers to set off. The indirect drivers (Figure 18) include changes in economic and environmental policies, economic systems, population growth, migration and urbanization, technology development and application, insecurity, corruption and cultural practices and spirituality. The indirect drivers operate at national (e.g. economic development, population growth, domestic markets, national policies, governance) and local circumstances such as livelihoods, poverty, and unclear land tenure (Kissinger et al., 2012).

Population growth is the most important human factor driving ecosystem change in Ethiopia as it generally is the case in developing countries (Hurni, 1993; Mortimore, 1993). The highlands are inhabited by humans in the earlier times and hence, ecosystem changes are more severe in the highlands than in the lowlands (Eshetu and Hogberg, 2000). This is because of high population pressure and repeated cultivation without fallow (Kindu et al., 2013). The highlands contain about 90% of the total cultivated lands and are occupied by 90% of the human and 60% of all livestock populations (Hurni et al., 2010). The demographic trend shows a doubling of the population every 25 years since the 1950's, resulting in scarcity of land, shortening of fallow periods, and deforestation in the last remnants of natural forests (Hurni, 1986). For instance, the Choke Mountain range is densely populated, with an average of 260-270 people per km^2. Settlements are fairly common up to 3600 m of the mountain. Poverty is rampant and most people live below the national poverty line. As a result, they try to survive by eking out the land, resulting in overgrazing of fragile grasslands and cutting of forest stocks for firewood. In the context of short-term needs of individuals, each decision seems rational; in the long-term and wider context, however, the effects are disastrous. Hence, poverty is both a cause and an effect of environmental degradation (Durning, 1989).

Population pressure has pushed farmers onto steeper slopes in the Simen Mountains National Park (SMNP), which can only give yields for a few years before the soil is washed away. On such inhospitable environments, farmers could hardly produce crops with the same amount and rate as below the tree line, since the growth rate could be hampered by the unsuitable climatic conditions. About 86% of the Simen Mountains National Park is used by humans at various levels of intensity. Grazing is not as such significant, but farming causes much more harm (Falch and Keiner, 2000). According to Nepal (2000), almost 5,000 households with a total population of about 28,000 live in and around SMNP. Some 10,000 people either live on, or use land and other resources inside the park. However, large numbers of people are translocated recently from the core area of the park to the surrounding areas. Similarly, Bale Mountains National Park (BMNP) is under increasing threat from a growing human population, fire, and rapid illegal and unrestricted settlement (SOS Sahel Ethiopia, 2010). Over 40,000 people live within the BMNP boundary and has posed pressure on the natural resources (Taylor, 2015).

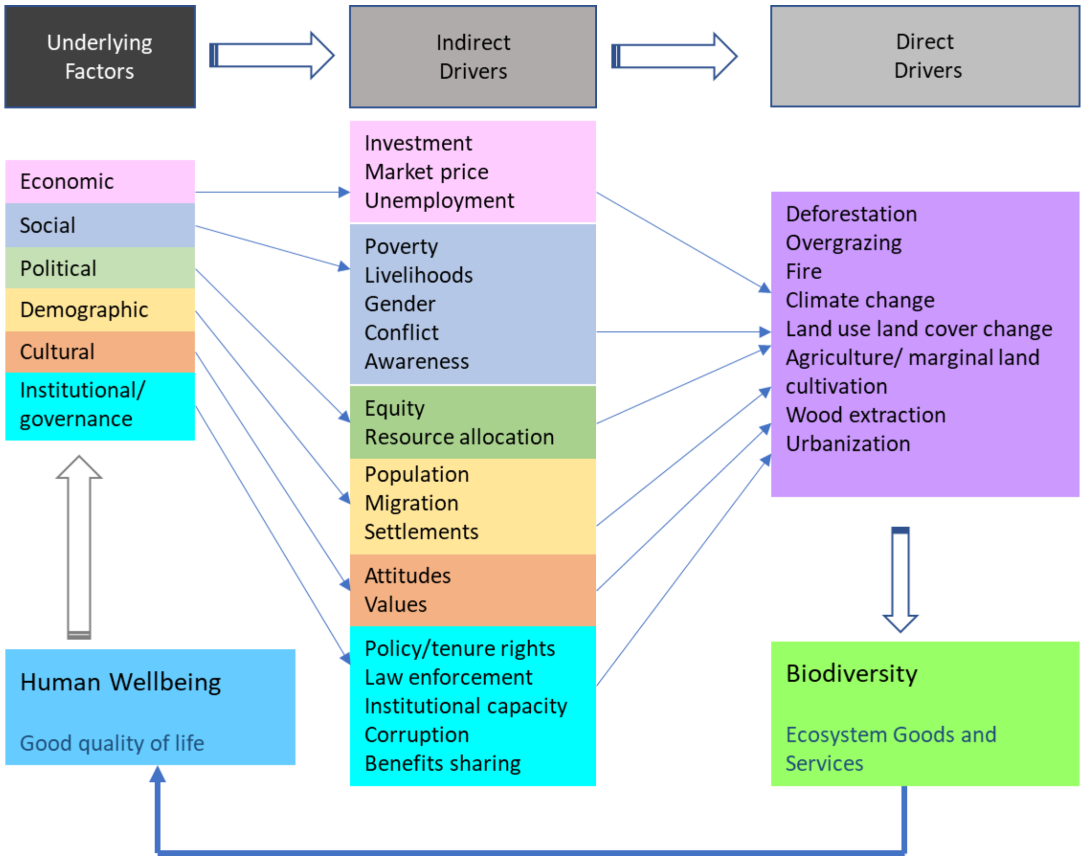


Figure 18. Linkages between underlying factors, indirect and direct drivers of change in mountain ecosystem

The majority of problems faced by the Simen and Bale Mountain National Parks emanate from the national policy on protected areas management and institutional setup related matters. The policy decisions, particularly the frequent restructuring of the organizational structure, resulted in institutional memory gaps, ownership confusions and relaxation of restrictions on access. Consequently, the efforts by the state and non-state actors to manage the parks are less effective in conserving the parks from degradation. For instance, immigration of people from the surrounding lowlands has not been controlled, and this exerted great pressure on the parks and the Afro-alpine habitats. Local people lack sufficient awareness about importance of the parks to people and nature. Hence, enhancement of awareness, and community involvement, linking conservation activity with livelihood improvement through ecotourism and allowing of activities such as beekeeping in the parks are important. Solutions need to be interrelated and holistic as much as possible (Gashaw, 2015).

2.4.3 Perspective outlooks on mountain ecosystem of Ethiopia

Ethiopia's mountain ecosystem is under extreme pressure from the ever growing human and livestock populations. Continued encroachment by local people into steeper slopes has become very common to expand agricultural cultivation and intense burning of the woody vegetation to encourage pasture and grass for roof thatching. Although these activities are rampant in the lower belts (below the tree line), evidences indicate the Afro-alpine and Ericaceous vegetation belts are seriously affected through loss of cover and habitat quality. The outlook on fire is more serious compared to conversion to agricultural land. This is because climate (low temperature) limits crop cultivation in the higher altitudes and hence less risk for conversion to cultivation (Gebregziabher, 1991; EBI, 2009; Ethiopian Academy of Sciences, 2015). Hurni (1986) reported high rate of soil erosion (as high as 123 t/ha/yr) on cultivated fields in the village of Argin along the boundaries of the Simen Mountain National Park. As agricultural land use continued intensively, soil erosion rates increased and soil depth decreased. As cultivation expanded towards the marginal areas, the Erica-*Hypericum* woodland in the mountain ecosystem has been reduced significantly in the past three decades (Hurni, 1986).

Not only cultivation expansion but also wood extraction for fuel and construction by local communities is a serious challenge in the mountain ecosystem. In the Simen Mountain, if the trend of utilization of wood resources continues at the same pace for the coming decades, the more easily accessible part of the highland, which is the *Erica-Hypericum* woodland, might disappear in the near future (Ethiopian Academy of Sciences, 2015). The vegetation loss in mountain ecosystem is expected to be exacerbated in Ethiopia due to future climate change (Kreyling et al., 2010). For instance, a study by Jacob et al. (2016) indicated an upward increase of the tree line by more than one meter per year, in the areas with low anthropogenic pressure in the Simen Mountains, which might be potentially related to increasing warming of up to 1.5°C over the past 50 years. These are indicators of the future trend of changes in the mountain ecosystem in the face of mounting anthropogenic and natural drivers of such changes.

The involvement of government and non-governmental organizations in the management of the mountain ecosystem in the past few years has resulted in positive outcomes in habitat improvement and population increase for some of the endemic mammals. For instance, legalization and demarcation of the parks and preparation of management and business plans have been undertaken to implement effective protected area protection system for the Bale Mountain National Park (BMNP). The Simen Mountain National Park has also been re-demarcated by expanding the previous size of the park. Additional community managed protected Afro-alpine and Ericaceous vegetation belts like Guassa and Abune Yosef are demarcated and legalized. On the other hand, Mount Choke and Mount Guna have become designated protected areas (proposed parks), and demarcation and legalization processes are underway.

In the past few years, emphasis has been given to ecosystem and faunal research, monitoring and conservation, reducing the negative incidence of interactions between humans and the critically endangered Afro-alpine and Ericaceous wildlife, strengthening of traditional grassland management systems (e.g., in Menz Guassa Mountain), awareness raising campaigns to local communities, and feasibility studies in Wello in two National Parks (e.g., Borena Sayint and Abune Yoseph) so as to assess their tourism potential. Activities aimed at alleviating poverty, developing and managing environmental and natural resources of the parks have been conducted (EBI, 2014). These efforts have improved populations of threatened and endemic mammals such as Walia ibex in the Simen Mountains National Park and the Ethiopian Wolf in Bale Mountains National Park and Guassa Community Conservation Area (EBI, 2014).

Throughout the country there are many designated protected areas of land including National Parks, Wildlife Reserves, National Forest Priority Areas, Biosphere Reserves and Community Conservation Areas. These not only act as biodiversity ‘banks’, but also provide important spiritual places and centers for traditional ecological knowledge. These protected areas can also have direct economic benefits by generating revenues from tourism and carbon trading. Protected areas in the country are increasingly degraded. Land is being converted for subsistence and commercial agriculture; timber is increasingly used for fuel wood and construction; and protected grasslands are used for livestock grazing. The loss of forests and other protected lands is primarily caused by a growing population size, unsustainable natural resource management practices, weak law enforcement, land tenure related challenges and low public awareness about importance of biodiversity and ecosystems.

Despite the protection guaranteed to National Parks in the most recent Wildlife Proclamation, parts of Omo and Mago National Parks have been given for sugar plantations, agricultural expansion threatens part of Gambella National Park, and permanent human settlements in Bale Mountains, Simen Mountains, Awash and Abijata Shala National Parks increasingly disrupt ecosystem functions and services. Conservation of Ethiopia's biodiversity and maintaining sustainability of ecosystem services are vital to ensure sustainable economic growth, to mitigate effects of climate change and to avoid the collapse of life support systems. Unless Ethiopia rapidly increases the protection of its biodiversity, the combination of the effects of climate change and unsustainable development will cause an environmental disaster that will assuredly result in increased levels of poverty.

Sustainable development and conservation of the mountain ecosystem and its biodiversity requires sound qualitative and quantitative data. Unless threats such as livestock grazing, fire, and wood collection are managed in a sustainable way, rare and threatened plant species that are ecologically, economically, and culturally important could be lost without being known to the scientific community.

2.5. Indigenous and local knowledge on biodiversity and ecosystem services in mountain ecosystem

Indigenous and Local Knowledge (ILK) refers to the understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings (UNESCO, 2017). Local communities residing in and around mountains have developed their own indigenous and local practices based on millennia old interactions with their natural environment. For example, a local knowledge-based utilization of traditional medicinal plants of the Bale Mountains for treating human and livestock ailments are evidences to the rich indigenous knowledge of the people residing in the mountain system. It was reported that the local community in the Bale Mountains were using 101 different species of traditional medicinal plants to treat 56 different types of human ailments in the area (Yineger et al., 2008). They also have indigenous wisdom to identify and use 74 different species of traditional medicinal plants in the mountain system to treat more than 25 veterinary ailments. About 5% (20 species) of the medicinal plants used by the local people residing in the Bale Mountains are strictly endemic to Ethiopia (Yineger et al., 2008). The deep-rooted indigenous and local knowledge of plant use for successive generations living in the Bale Mountain system has played a role for the sentimental adherence of the community to ancestral medical traditions which are still held as highly valued heritage of the mountain community.

The other notable example pertinent to indigenous and local knowledge practices of the Ethiopian mountain community is that of the Mount Menz-Guassa area in north central Ethiopia. The Menz-Guassa Mountain community members are well-cited for their indigenous and local knowledge system widely applied for conserving the mountain biodiversity and ensuring continuous access for the ecosystem services. The community has sustainably conserved the Menz-Guassa Mountain ecosystem for over four hundred years through a local knowledge system called the Qero system (UNDP, 2012). The system they developed for generations involved establishing well-defined indigenous common property resource management strategy which has enabled them to conserve the mountain biodiversity while living in harmony with nature.

The Ethiopian mountain ecosystem possesses diverse ethnic, economic, agricultural, environmental faunal and floral wealth. Local people inhabiting mountain ecosystem have their own knowledge pertinent to conservation and sustainable use of nature in the system (Mamo and Wube, 2018). A study conducted in the Bale Mountains, a globally important centre of endemism in southeastern Ethiopia, reported that about 43% of people living in the mountain ecosystem have developed knowledge and exhibited positive attitudes towards biodiversity conservation (Asmamaw and Verma, 2013).

Supporting the effort of indigenous and local communities in conserving mountain biodiversity encourages their participation in resource management decisions, besides empowering them to undertake sustainable management initiatives. A community conservation resilience assessment conducted in three *Kebeles* (smallest administrative units in the Ethiopian administration system) of the Bale Mountains indicated the tremendous value of indigenous and local knowledge of the community in conserving biodiversity (Tola and Traynor, 2015). The study indicated that local communities of the Bale Mountains practiced a strong conservation culture and biodiversity protection in selected sacred natural sites of the mountain system (*see case study 1*).

Case study 1: ***Value of Indigenous and Local Knowledge for Biodiversity Conservation***

Community Conservation Resilience Initiative (CCRI) in Bale Mountains, Ethiopia
(Tola and Traynor 2015, pp. 6-27)

A CCRI assessment was conducted in the Bale Mountains covering three different communities living in Aberkare, Dinsho-02 and Mio *Kebeles* of the Bale Zone, Oromia region, Ethiopia. The selected Kebeles belong to the Dinsho District which is composed of gentle slopes and high mountain massifs with altitudinal ranges between 2800 and 4000 m. Both quantitative and qualitative data were used for the CCRI assessment. Results from mapping of historical Sacred Natural Sites (SNS) identified 18 SNS covered by indigenous trees and shrubs within the 3 *Kebeles*. These SNS were found to cover a total of 217 ha. All the SNS were also found strongly associated with biophysical features such as springs, wetlands, streams, and wildlife on the mountain system. All of the historical SNS were also identified as important sites for their cultural, social, economic and/or ecological roles.

The study identified that the SNS are beautiful landscapes linked with rich natural resources, reflecting the presence of a local and indigenous approach to conserve biodiversity. The indigenous people referred to the SNS as '*Awlia*' which is translated as lover of God or place of peace. The SNS sites in the study area were reported as exceptional examples where deep relationships exist between the communities and nature.

The study also identified that the communities have been worshipping at the SNS for over ten generations, and those who worship in the sacred areas have a strong moral obligation to conserve all living things within the boundary of the SNS. The indigenous and local knowledge system in the area obliges the community to live in harmony with nature. Thus, the finding depicted that the communities in the study *Kebeles* have been actively practicing biocultural conservation for generations.

The study also reported that the flora and fauna found within the identified SNS are referred to locally as '*woyoma'*, which means 'respect' reflecting that the sites are bases of harmonious living with respect to biodiversity. It was also interesting to note that the identified SNS were clearly demarcated and the harvesting of young trees and live plants or plant parts within the boundaries is prohibited, while the collection of dry wood is permitted only for ritual ceremonies. The research also indicated that there are clear rules prohibiting hunting wildlife within the SNS, and animals which escaped hunting from the surrounding and entered to the SNS were allowed to live. Plants and wildlife found within the SNS boundaries are protected by customary laws of the indigenous people. Thus, the SNS acted as breeding areas for wildlife and also sources of seeds for indigenous trees, as these areas are largely undisturbed. The research also showed that indigenous people of the area reported that human-wildlife conflict is uncommon within the SNS. Transgressing the customary laws for the SNS is considered sinful and people doing so are regarded as *mujaza* (a person who carried out unethical or unacceptable actions) and they would be cursed or banned by the entire community, demonstrating the full support of the community for the SNS rules and regulations.

Local communities resident to Ethiopian mountains use indigenous knowledge to tap provisioning services provided by this ecosystem. This can be exemplified by the tradition of using plant resources for primary health care as in the case of communities in Bale Mountains (*see Case study 2*).

Case study 2*: Indigenous Utilization of Healing Plants in Mountain Ecosystem*

Plants used in traditional treatment of human ailments at Bale Mountains National Park, Southeastern Ethiopia. (Yineger et al., 2008, pp.132-153)

The study was conducted in 16 selected *Kebeles* found in three districts in and around the Bale Mountains, Bale Zone, southeastern Ethiopia. Ethnobotanical data were collected to identify indigenous traditional medicinal plants used to treat human ailments in the area. A total of 43 informants were involved for this research. In total, 56 different human ailments were reported to be managed by traditional healers using various medicinal plant species of the Bale Mountains ecosystem. A total of 101 medicinal plant species distributed in 88 genera and 51 botanical families were recorded.

Traditional healers reported to process remedies mainly through concoction (23.47%), crushing (22.38%), decoction (18.05%), and powdering (14.08%). Substances like cold water, honey, coffee, butter, olive oil, salt, sugar, kerosene, ash and milk were reported to be mixed with the plant materials during the preparation of remedies. The processed remedies are mostly administered through oral (50.72%) and dermal (37.68%) routes.

Generally, the Bale Mountains ecosystem was found to have high diversity of ethnomedicinal plant species useful to manage human ailments. Most of the ethnomedicinal species were reported to be collected from wild sources. Results of this study also revealed that most ethnomedicinal plant species used by traditional healers of the study area to manage human ailments had multiple uses in addition to their medicinal values. This was indicative of the degree of threat that medicinal plant species were facing from different angles in the Bale Mountains ecosystem.

The other example that relates to the use of local knowledge in making use of provisioning services comes from the practice by the communities in identifying and harvesting fodder species for their livestock in the mountain systems. A study conducted on indigenous practices of using fodder plants by the local communities residing in the mountain systems revealed the utilization of more than 29 indigenous fodder tree and shrub species (Kindu et al., 2006). The criteria for selecting indigenous fodder species of the mountain systems are totally based on local knowledge. The commonly reported selection criteria for fodder species of the mountain system were palatability, harmlessness to animals, availability during the dry season, coppicing ability, high biomass, and fast to intermediate growth (Kindu et al., 2009).

It was noted that among the different fodder species of the mountain systems, farmers prefer *Hagenia abyssinica* (Bruce) J.F. Gmel., as the best livestock fodder tree species. In congruence with this, an investigation on fodder values of *Hagenia abyssinica* also confirmed the presence of useful micro-and macronutrients in the species within the recommended range of nutrient concentrations as in many standard animal feed. Moreover, the crude protein content of the foliage and flower bud of *Hagenia abyssinica* species was confirmed even to be higher than the minimum required level for a standard livestock feed (Kindu et al., 2009). This indicates that indigenous people of the mountain system possess a remarkable knowledge pertinent to provisioning services.

The indigenous practices of local people related to regulatory services of the Ethiopian mountain ecosystem such as water flow regulation, erosion prevention and climate regulation are critical to bring overall biodiversity conservation. These indigenous knowledge and practices of local communities, in one way or the other, are related to the type of agro-ecological zone where they reside. In this regard, the UNESCO registered indigenous knowledge of the Konso people pertinent to the regulatory ecosystem services of the mountain terrains of the Konso landscape is well-recognised globally (*See case study number 3*).

Case study 3: ***A UNESCO Registered Indigenous Knowledge on Soil Conservation by Konso People***

Ethnobotany and indigenous people of the southern Rift valley and south western Ethiopia: Konso and Hamar. A project report for Christensen's Fund, USA (Woldu et al. 2006, pp. 85-100).

The Konso landscape is characterized by a very fragile soil having variable fertility. The mountainous and stony terrains of the Konso region with harsh climatic conditions necessitated the community to practice indigenous ways of securing regulatory services of the ecosystem mainly water flow regulation and prevention of soil erosion. The millennia old indigenous and local knowledge of the Konso people related to monitoring water flow regulation and soil erosion is seen through an existing elaborate terracing system using walls of stone gravels sometimes as high as 10 m and as long as several Km. However, the length and height of the stalls depend on the terrain. The advantages of this indigenous stonewall terracing include higher water retention and infiltration, reduced soil erosion, increment of soil fertility and biodiversity conservation.

The indigenous elaborate terracing systems developed by the Konso people are also backed up by extensive manuring and mulching systems, and rarely by fallowing practices. The mulching, irrigation, integration of trees into farming systems are also part of the traditional Konso agricultural system. Dung is not used as fuel in Konso unlike many parts of Ethiopia since it is needed for manuring the fields. Use of trash lines (contour lines of crop residues) is also a commonly practiced indigenous land management system in Konso. Moreover, multiple cropping systems including the use of a wide range of leguminous and non-leguminous plants and trees characterize the indigenous soil management and conservation system of the Konso people. Laying crop residues horizontally along the contour is also practiced by the people to reduce stalk borer infestation of maize and sorghum in the next cropping season.

Though the vegetation in Konso is highly influenced by anthropogenic factors, indigenous practices of the community have helped to maintain remnant patches in different parts of the area. In the mountainous highlands, the remnant patches are designated as community forests, plantations, cultural forests and King's forests. Such traditional designations help to maintain the biodiversity, and secure related ecosystem services. In Konso, community conservation systems are maintained through traditional clan leaders and the community. These community conservation practices are best observed in the remnant patches of forests called *Murras* (forests in Konso language) which serve as refugia of plant biodiversity.

A study conducted in the Choke Mountain area also showed that the indigenous people of the area have a good knowledge pertinent to ecosystem services of the mountain. The community reported that the Choke Mountain is a source of water, fodder, fuel wood and traditional medicine for treating people and their livestock (Simane et al., 2013). According to community leaders of the Choke Mountain, the natural resource base (land, water and biodiversity) of the area is under intense pressure from population growth and erosion-inducing farming and management practices (Simane et al., 2013). Soil erosion in the Choke mountain watersheds is a well-recognized problem, identified as a priority by local community members. The local community also reflected that their livelihoods face severe constraints related to intensive cultivation, overgrazing, deforestation, soil infertility, water scarcity, livestock feed and fuel wood demand. Thus, using the age old indigenous and local knowledge of the community in the area should be taken as a major part of the solution in any effort to avert the fast declining mountain ecosystem and related diverse services.

Similarly, findings of key informant interviews and focus group discussions conducted with indigenous communities of the Bale Mountains showed that local people residing in the area acquire knowledge on the physical and anthropogenic drivers that have resulted in a change of the Afro-Alpine ecosystem (Mezgebu and Workineh, 2017). The same authors have also reported that the local community has identified agricultural expansion, forest fire, illegal logging, fire wood extraction, overgrazing and expansion of unplanned rural settlements at forest corridors as the five major direct drivers of change in the Bale mountain areas. The experience of local community members is limited not only to identifying the drivers of change of the mountain ecosystem but also to maintaining the diverse ecosystem services.

The Menz-Guassa community members who are practicing a communal biodiversity conservation activity are also cited for their knowledge related to the regulatory services of the mountain system that they inhabit. The indigenous system they have established for managing the Menz-Guassa ecosystem is based on local knowledge related to the regulatory ecosystem services such as local flood and erosion control for generations (UNDP, 2012).

Local people at Mount Abune Yosef, North Wolo, are also known to share large communal land within the mountain ecosystem managed by their millennia old community knowledge (Eshete et al., 2015). They practice their own system of water flow regulation and erosion prevention so as to protect the ecosystem. The same authors have reported that people living in the area have positive attitudes towards conservation of plants, besides reflecting their sense of ownership of the Ethiopian wolf residing in the mountain system.

Generally, the long term association of local people of the Ethiopian mountain ecosystem with their natural environment and the reported commitments of the people to remain in their local areas ensure a prudent management of existing natural resources (UNDP, 2012). Living in harmony with the mountain ecosystem also helps the local community to secure all types of ecosystem services from their local areas where they have resided for millennia.

Ethiopian mountain ecosystem delivers tremendous cultural services such as serving as aesthetic, spiritual, educational and recreational sites for the public (Teshome and Demissie, 2018). Cultural ecosystem services are also important for raising public awareness and secure support for protecting and conserving ecosystems (Daniel et al., 2012).

The study conducted on attitude of the local community towards the benefit of the Guassa Mountain depicted that 85% of the respondents had knowledge and positive attitude towards the benefits that can be derived from this ecosystem (Tadesse and Teketay, 2018). This report was further elaborated in the box below (see Case study number 4).

Case study 4. ***Indigenous and Local knowledge on Cultural Services of a Mountain Ecosystem***

Attitudes of local people towards the Guassa Community Eco-Lodge in Menz-Gera Midir District, North Shewa Administrative Zone, Ethiopia. (Tadesse and Teketay, 2018 p. 279-289)

The study was carried out in Guassa Community Eco–Lodge (hereafter GCEL) which was established in 2005, and it belonged to the local people who live in different *Kebeles* around the Menz Guassa Mountain. The GCEL is found in the Guassa Community Conservation Area (GCCA) which lies between 10°15′–10°27′ N and 39°45′–39°49′ E. A structured questionnaire comprised of closed–and open–ended questions was developed to examine the attitudes of respondents towards the Guassa Mountain 'Eco–Lodge's was administered to a total of 165 randomly selected households.

Results of this study indicated that most of the respondents (98%) confirmed that they knew the Eco–Lodge and its significant services in the area. A majority of the respondents (81%) noted that the trend of the biodiversity status after the establishment of the Eco–Lodge is improving in the area. For example, while 77% of the respondents argued that strict law enforcement was a major reason for the increment in the trend of biodiversity after the establishment of Eco-Lodge, 61% argued that punishment of those who committed illegal encroachment into the compound was the major reason for the observed improvement.

Moreover, 85% of the respondents confirmed that they obtain benefits from the Eco–Lodge. The most prominent benefits to the local people include employment opportunities, wood products (e.g. fuel wood and construction materials), provision of fodder for livestock through cut and carry system, provision of medicinal plants, traditional beekeeping, access to free grazing during periods of fodder scarcity, and means of income from touristic activities.

Tola and Traynor (2015) have also reported the presence of Sacred Natural Sites in the Bale Mountains areas, delivering cultural services to the community. The report shows that local people of the Bale Mountains actively participated in worship, ceremonies and rituals within the Sacred Natural Sites, and these activities were composed of a variety of cultural aspects performed in the local language. Development of strong spiritual and emotional attachments with the Sacred Natural Sites in the mountain ecosystem is also underlined as the cultural significance of the area.

A report on the benefits of Abune Yosef Mountain areas as a basis for community resource revealed the knowledge of people on the cultural importance of the mountain ecosystem. The report explains that the proximity of Mount Abune Yosef to the Holy city of Lalibela, one of Ethiopia's top tourist attraction sites, initiated a community-based ecotourism activity in the area. Moreover, it was noted that the estimated annual financial benefit of households in the area reached to US$ 300 from tourist revenues alone (tourist guiding, renting pack animals and selling locally made items) (Eshete et al., 2015).

Generally, Ethiopia's mountain ecosystem plays a great role in provision of diverse cultural services. Beside their aesthetic, recreational and ecotourism roles the mountain ecosystem are also used for various educational activities. The number of university students travelling to the Bale Mountains and the Simen Mountains (from Ethiopia and abroad) to write their theses/dissertations is enormous as exhibited on published MSc and PhD research outputs from these areas. Local people of the mountain ecosystem are involved in different activities such as field guides, renting of pack animals and renting houses for visitors, thus benefited from the continual travel of students, researchers and tourists from different corners of the world to the areas.

2.5.1. Indigenous and local Knowledge on supporting ecosystem services

People residing on mountains practice their indigenous and local knowledge to run traditional manuring and mulching so as to foster soil formation, and even nutrient cycling (Woldu et al., 2006). The local knowledge based usage of dung for manuring is practiced by both highlanders and lowlanders in Ethiopia. It is also noted that many mountain communities have local knowledge of using crop residues as trash lines to bring back nutrient losses of over utilised agricultural lands.

The indigenous practice of multiple cropping systems by using a mix of leguminous and non-leguminous crops among communities of the Bale Mountains, the Simen Mountains, the Chilalo Mountains and the Choke Mountains depict the indigenous and local knowledge of the people on improved land use systems to improve soil fertility of their agricultural lands. The traditional soil burning practice locally called "Guie" is also another notable local practice mentioned for its value in improving soil properties among the local people residing on mountains of Ethiopia though it affects soil microbes and some useful nutrients (Amare et al., 2013). Detailed studies on evaluating the knowledge of local people on diverse supporting systems of the Ethiopian mountain biodiversity are lacking and thus call for investigation in the coming years.

2.5.2 Role of Indigenous and Local Knowledge in biodiversity conservation and ecosystem services

Understanding local community's awareness about mountain biodiversity conservation helps policymakers and development managers to plan local development, conservation strategies and policies harmonized with the interest of the people. Biodiversity conservation and related development efforts that build on indigenous and local knowledge would result in a more self-reliant pattern of development. Such trend of development system is harmonious with people's needs being congruent with available resources, reliable as well as economical (Fassil, 2003). Moreover, investigating the level of awareness of indigenous and local people about their environment and related services will create an opportunity to make the people involve enthusiastically in conservation activities (Xun et al., 2017).

Local communities in the Ethiopian mountain systems are concerned with conserving the biodiversity resources. However, their level of understanding about conserving the biodiversity wealth of their surrounding varies based on their personal characteristics, family characteristics, level of interaction with the resources of the mountain system, and even their subjective attitudes (Mamo and Wube, 2018). Despite their importance, Ethiopian mountain biodiversity and the related knowledge systems are declining due to natural and anthropogenic threats. A local knowledge linked with biodiversity of the mountain system declines when the biodiversity wealth of the area drops. In addition, indigenous and local knowledge related to biodiversity conservation and ecosystem services are prone to loss at each point of transfer since the community knowledge passes verbally across generations (Ayele and Teketay, 2018). Thus, the millennia old community knowledge linked with the rich biodiversity of the mountain ecosystem of Ethiopia needs to be investigated and documented.

Similarly, another research conducted on the Menz Guassa Mountain to measure attitudes of indigenous and local people of the area towards biodiversity conservation of the mountain ecosystem revealed that 100% of the study participants (140 males and 20 females) showed positive attitude to the subject. The same study also indicated that 82.5% of the respondents had direct participation on indigenous conservation activities of the Menz Guassa Mountain ecosystem (Mamo and Wube, 2018). The finding underlined the community has a tremendous sense of ownership of the biodiversity of the mountain from which they derived diverse benefits.

According to UNDP (2012), the Menz Guassa community has its own traditional system of conserving the biodiversity resources. (*see case study number 5*).

Case study 5: ***Indigenous Natural Resource Management System***

An important local resource, sustainably conserved by indigenous system (UNDP 2012, pp. 4-11)

For over four hundred years, the Menz-Guassa Mountain area's grassland has been sustainably conserved by a well-defined indigenous common property resource management system known as Qero. This institution entailed each of the two user communities in the area, Asbo and Gera, democratically electing an elder as a headman, called the Abba Qero. The Abba Qero is then responsible for protecting and regulating the use of the Guassa Mountain area. This Qero system would entail the closure of the Guassa area from any use by the community for between three to five years. The length of closure largely depended upon the growth and recovery of the grass, community requirements for resources, success of the local crop harvest and on the frequency of drought in the Guassa area. When the two Abba Qeros felt that the grass was ready for harvest, they would announce the date of the opening to the community. Closure periods were strictly enforced by the users themselves. This system also had substantial benefits for the biodiversity of the region, providing a healthy environment that supported endemic and endangered species.

Following the 1974 Ethiopian revolution, however, all rural land was nationalized in a process of agrarian reform, leading to the end of the Qero indigenous resource management institution. Private and communal land ownership was transformed into state or public land tenure. The area was essentially treated as an open access resource as it became available to a wider number of communities, leading to unsustainable use and overexploitation through the 1990s: livestock grazing continued year-round, while grasses were cut until they became too short to be of use. Attempts to reintroduce community-based management of the area's natural resources in tandem with the new local government authorities were less successful, and the land was substantially degraded by the late 1990s.

By 2003, support from international partners enabled the Guassa Committee, a body made up of representatives from local peasant organizations, to establish the Guassa Conservation Council, and reinstall the traditional resource management institution. This began with a three-year moratorium on natural resource use within the Guassa Mountain area, from 2003 to 2006. In its modern form, closure periods banning harvesting within the conservation area are declared by the Guassa Conservation Council. The ecological health of the area is monitored by local villagers trained as community scouts and community ecological monitors, while all human incursions are punishable by local courts.

The daily management of the area and supervision of community scouts is conducted by the Guassa Conservation Council, which comprises five representatives from each of the nine local Kebeles, or village administration units, as well as representatives from the Woreda (district-level) administration, judiciary, police, agriculture office, environmental protection office, and militia and security offices. The nine Kebeles that make up the Guassa

Committee are home to approximately 9,000 households. In addition to securing the long term natural resource-based livelihoods of the local population, this community management system has created opportunities for ecotourism, currently being developed with support from international partners. A general management plan was drawn up for the period 2007-2012, outlining the aims of the community-managed Guassa Mountain Area of Menz, and the initiative has successfully sought official recognition as a Community Conserved Area (CCA).

2.6. Policy and institutional framework for mountain ecosystem and biodiversity conservation

The National Policy on Biodiversity Conservation and Research (NPBCR) issued in 1998 by the government has been serving as the key policy document for governing biodiversity conservation activities in the country. In this document, ensuring biodiversity conservation, sustainable development and sustainable utilization of genetic resources and essential ecosystems were stated as the major policy objectives. Moreover, this policy consists of key conservation guidelines underlining the need for ensuring the country's sovereignty over its genetic resources, enriching the country's biological resources through restoration, integrating biodiversity conservation with sectoral and cross-sectoral strategies and programs, recognizing and protecting community knowledge, ensuring benefit sharing for local communities from biodiversity resource use, and promoting regional and international cooperation pertinent to biodiversity conservation (EBI, 2015). Although this policy consists of these contents, specifically, it fails to show the policy framework for mountain ecosystem and the biodiversity therein.

The need to conserve the declining biodiversity resources and related ecosystem services has given birth to the establishment of the Ethiopian Biodiversity Institute (EBI) by Proclamation No 120/1998. Then after, EBI has been nationally mandated to lead activities pertinent to the conservation of biodiversity (plant, animal and microbial) and their respective ecosystem services. In the recent times, EBI has established regional biodiversity units and seven different biodiversity centers in Metu, Hawassa, Harar, Mekele, Goba, Bahrdar and Asosa representing biogeographical regions of the country. Nevertheless, none of these regional biodiversity units are working on the mountain ecosystem of the country.

The National Biodiversity Strategy and Action Plan (NBSAP, 2015-2020) had targets on the involvement of several stakeholders and mainstreaming of biodiversity conservation activities into sectoral plans to strengthen biodiversity conservation. However, it was observed that there is no obvious system of horizontal linkage among the institutions at different levels. In this context, not only governmental institutions, recognizing the roles of non-governmental organization in biodiversity conservation and collaborations for the common goal should also come onboard.

2.6.1. The need for policy and institutions for conservation of Ethiopian mountain biodiversity

Ethiopia has set out policies and established institutional structures and legal frameworks that govern the country's biodiversity. The country is among the signatories of international and regional treaties including the Convention on Biological Diversity (CBD), The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Convention on Migratory Species (CMS), World Heritage and African-Eurasian Water bird Agreement (AEWA), and also acceded to the Nagoya protocol which focus on biodiversity conservation and related services (EBI, 2015). The commitment of the country in developing the first National Biodiversity Strategy and Action Plan and implementing it successfully between the years 2005 and 2010 shows the commitment the country has for biodiversity conservation. The second National Biodiversity Strategy and Action Plan (2015-2020) of Ethiopia is also in effect since 2015 showing good effort in line with conserving the country’s biodiversity and related ecosystem services. A well-established policy and strong legal, institutional and functional frameworks are mandatory to bring about sound biodiversity conservation. This section reviews in some detail the policies, legal and institutional frameworks related to conservation of biodiversity and ecosystem services focusing on the mountain ecosystem.

2.6.2 Policy framework

2.6.2.1 Policy on biodiversity conservation and mountain ecosystem services

The first recorded biodiversity conservation-oriented activity in Ethiopia dates back to the reign of Emperor Zere-Yacob (1434-1468) (Vreugdenhil et al., 2012). The Emperor noticed the declining of forest cover on the Wachecha Mountain ecosystem near Addis Ababa and took an inspiring action of collecting seeds and seedlings from other *Juniperus* forests and run replanting activities around Menagesha, and established the Menagesha State Forest. According to Pankhurst (1989) the Menagesha State Forest is the oldest conservation area in Africa, or the oldest formalized conservation effort in the continent. Currently, the country has several policies and different strategies pertinent to biodiversity conservation.

The Ethiopian Forestry Action Program (EFAP) comes among one of the documents indicating Ethiopia's commitment to conserve biodiversity (EFAP, 1994). According to FAO (1998) the EFAP was initiated in 1990 and became available in December 1994. It was also widely disseminated to different stakeholders including donors, NGOs and other relevant government agencies with the support of UNDP. Despite these efforts, the implementations of the projects and programs of EFAP were not successful as expected. In this regard, FAO (1998) explained that the major weakness in implementing the EFAP was the poor capacity of responsible stakeholders.

Among the most popular policy and strategies in Ethiopia related to biodiversity conservation was the Conservation Strategy of Ethiopia (CSE) which was approved by the Council of Ministers in 1996 (EBI, 2015). The CSE mainly gives attention to the importance of incorporating environmental factors into development activities. It delivers a rational approach to environmental management covering national and regional strategies, sectoral and cross-sectoral policies, action plans and programs. It also provides ways for developing appropriate institutional and legal frameworks for integrating environmental planning into new and existing projects and policies (EBI, 2015).

The other important document related to biodiversity was The Ethiopian Environmental Policy which dates back to 1997. The goal of this policy was promoting sustainable, social and economic development of the public by adapting environmental management principles and the need to run Environmental Impact Assessments before the development projects are implemented in the country (EBI, 2015).

In 1998, the Ethiopian government developed a key policy document entitled The National Policy on Biodiversity Conservation and Research in 1998. This policy had guidelines and objectives to ensure conservation, development and sustainable utilization of genetic resources and essential ecosystems of the country, though does not specifically treat the mountain ecosystem.

A significant milestone in Ethiopia's biodiversity conservation is the development of the first National Biodiversity Strategy and Action Plan in 2005 (IBC, 2005). The aim of this Strategy and Action Plan was to serve as a roadmap to enhance the conservation of biodiversity. The action plan outlined the status of the country's biodiversity and identified root causes of biodiversity loss and its impacts (IBC, 2005). According to EBI (2015), the major activities planned for the first National Biodiversity Strategy and Action Plan include afforestation, area closure, collection of germplasm, provision of policy and legislations as well as awareness creation at federal, regional and local levels. However, these activities have not been implemented as deemed because of the constraints related to budget, lack of clarity on implementations systems, absence of monitoring and evaluation and reporting mechanisms (EBI, 2015).

Recently, Ethiopia has developed the second National Biodiversity Strategy and Action Plan (NBSAP, 2015-2020) taking lessons from strengths and weaknesses of the first NBSAP. The vision of the current NBSAP states that:

> ″By 2020, awareness of the general public and policy makers on biodiversity and ecosystem services is raised, biodiversity and ecosystem services are valued, pressure on biodiversity and ecosystems are reduced, status of biodiversity and ecosystem services are improved, and access to genetic resources and fair and equitable sharing of benefits arising from their use is ensured″ (EBI, 2015, P. 13).

This NBSAP (2015-2020) has five major strategic goals and 20 different targets pertinent to biodiversity conservation. Strategic Goal 'D' gives emphasis on enhancing the benefits from biodiversity and ecosystem services. The technical rationale under 'target 10' of the stated strategic goal clearly underlines on the need to maintain different ecosystems including the mountain ecosystem to ensure biodiversity conservation and sustainable ecosystem services.

The Aforementioned policy and strategies of biodiversity conservation have been serving as the basis for development of laws, regulations and procedures. For example, laws, regulations, legislations and procedures were developed from the National Policy on Biodiversity Conservation and Research (1998) and the National Biodiversity Strategy and Action Plans of

2005 and 2015. The laws provided legal basis while the regulations and procedures delivered ways of implementation and technical activities pertinent to Ethiopia's biodiversity.

2.6.2.2 Legal tools for biodiversity conservation

Ethiopia has formulated legal tools and frameworks which govern conservation, sustainable use, and access to genetic resources and fair and equitable sharing of the benefits arising from the utilization of the genetic resources and associated community knowledge. The major laws and regulations relevant to biodiversity are listed below:

A. Proclamation on Environmental Impact Assessment (Proclamation No. 299/2002)
B. Rural Land Administration and Use (Proclamation No. 456/2005)
C. Plant Breeders Right (Proclamation No. 482/2006)
D. Development, Conservation and Utilization of Wildlife (Proclamation No. 541/2007)
E. Federal Forest Proclamation (Legislation 542/2007)
F. Access to Genetic Resources and Community Knowledge, and Community Rights (Proclamation No. 482/2006) and (Regulation No. 169/2009)
G. Proclamation on Biosafety (Proclamation No. 655/2009)
H. Forest development, Conservation and Utilization Proclamation (Proclamation No. 1065/2018)

These NPBCR policy and proclamations provide a legal basis for conservation and sustainable utilization of the country's biodiversity and related ecosystem services. Although these policy and legal frameworks are relevant to the mountain ecosystem, policy and proclamation specific to this ecosystem have not been in place yet.

2.6.2.3 Effectiveness of the national policy on biodiversity conservation and research

The effectiveness of the NPBCR (IBCR,1998) was assessed based on the principles, criteria and indicators (PCI) analytical framework (Bird et al., 2013) as indicated in Table 6.

Table 6. Policy-related effectiveness principles, criteria and indicators (PCI) used for this assessment (Source: Bird et al., 2013)

Principles	Criteria	Indicators
NPBCR is designed for ease of implementation	NPBCR objectives are clearly expressed	• Targeted objectives are listed in the NPBCR documentation • Timelines to achieve the set NPBCR objectives are articulated in the relevant policy documents • The method for mobilizing financial resources to implement the NPBCR is contained within the NPBCR document
	Subsidiary instruments for implementation accompany the NPBCR document	• Subsidiary instruments to achieve specific NPBCR objectives are identifiable within the document • Timelines are in place to establish appropriate subsidiary instruments. • Appropriate subsidiary instruments are legally gazetted
The legitimacy of NPBCR shall be recognized by stakeholders	Key stakeholders' interests are represented in NPBCR strategy-designing processes	• Strategy-designing platforms exist, where key strategic decisions are made (e.g. NPBCR working groups, expert working groups, sector working groups). • Existing policy platforms provide for representation of key stakeholders from both government and civil society • Existing policy platforms provide opportunities for stakeholders to contribute to the policy-making process
	NPBCR Policy-making is evidence-based	• The NPBCR policy formulation process was preceded by, and benefited from background analytical work • Policy think tanks and research institutions provide evidence-based analysis to support the policy process • Relevant policy documents contain explicit references to background analytical work and contributions from policy think tanks.
NPBCR shall be coherent with national development policies	NPBCR statements on Biodiversity conservation acknowledge national development goals	• Reference is made to national development in the National Policy on Biodiversity Conservation and Research
	Biodiversity conservation actions are consistent with strategies and planning processes for national development	• The National Policy on Biodiversity Conservation and Research documents and the national development goals refer to each other

NPBCR shall promote transparency in biodiversity conservation task delivery	NPBCR provides clear statements for the establishment and operationalization of mechanisms and modalities to promote transparency	• Mechanisms and modalities exist to promote transparency of biodiversity conservation tasks

From the relevant stakeholders, four, namely, the Ministry of Agriculture, Ethiopian Wildlife Conservation Authority, Higher Learning Institution (Addis Ababa University, Department of Plant Biology and Biodiversity Management) and Commission for Environment, Forest and Climate Change were purposefully selected for the evaluation of the effectiveness of NPBCR. From each of these institutions, three experts, in total twelve experts, were consulted during this evaluation. The summary of the output of this PCI analysis is shown in Table 7.

Table 7. Summary of experts' opinion on ease of implementation, legitimacy, coherence and transparency of NPBCR (IBCR, 1998)

NO	Evaluated principles based on specific criteria listed in table 12	**Experts' opinion (%)**				
		Do not know	**Disagree**	**Somewhat agree**	**agree**	**Strongly agree**
1	NPBCR is designed for ease of implementation		5	10	45	40
2	The legitimacy of NPBCR is recognized by stakeholders			65	35	
3	NPBCR is coherent with National development policies			13	87	
4	NPBCR promotes transparency in biodiversity conservation task delivery			75	25	

The overall result of the PCI analysis indicated that 40% of the stakeholders strongly agree on the ease of NPBCR implementation and 87% of the stakeholders strongly agree that the NPBCR is coherent with national development goals. However, there is no strong agreement on the legitimacy and transparency of NPBCR due to the lack of key stakeholders representations during the designing phase of NPBCR.

2.6.3 Institutional arrangement for biodiversity conservation

2.6.3.1 Government institutions involved in biodiversity conservation

The establishment of the Institute of Biodiversity Conservation and Research with Proclamation (No 120/1998), now called the Ethiopian Biodiversity Institute (EBI), has paved the way to address biodiversity conservation and related ecosystem services based on the institutionally mandated approach. Recognizing the key role of EBI, the Ethiopian government has further enacted to revise the Proclamation no 120/198 and formulate a new Proclamation (No 381/2004) in 2004.

EBI is nationally a mandated institute to coordinate the implementation of biodiversity conservation in consultation with relevant stakeholders and Regional States of the country (EBI, 2015). To this effect, EBI has established regional biodiversity units and centers in nine regions and Dire Dawa City council. According to NBSAP (2015-2020), the relevant stakeholders such as the Ministry of Agriculture, Ethiopian Institute of Agricultural Research, Ethiopian Wildlife Conservation Authority, Commission for Environment, Forest and Climate Change, higher learning institutions, Ministry of Culture and Tourism and Regional bureaus of agriculture, environment and forests need to strongly collaborate in biodiversity conservation. However, the lack of clear or overlapping mandates among these institutions has hampered the effectiveness biodiversity conservation in the country.

2.6.3.2 Contributions of NGOs and other institutions in conservation of biodiversity

International, regional and local NGOs and other civic societies have been engaged in Ethiopian biodiversity conservation. However, their contributions were not fully recognized by NBPCR. For instance, the Ethiopian Orthodox Tewahdo Church (EOTC) is among the local institutions housing the largest share of relict patches of indigenous trees found in the country. According to Wassie et al. (2005) the relict forest patches found in Monasteries and Churches of EOTC which are mainly built on hills are important conservation patches of the relic of the former or ancient vegetation types of the country. Therefore, recognizing the efforts of such institutions and supporting them to practice continuous conservation activities is essential. However, undertaking further analysis of the status of the contributions and keeping the documentations of the NGOs such as Farm Africa which has been instrumental for initiating and implementing participatory forest management in Ethiopia; Concern Ethiopia, SOS/Sahel and others which have also been involved in natural resource management and biodiversity conservation is required.

2.6.3.3 Stakeholders' understanding of the NPBCR (IBCR, 1988)

All Ethiopian institutions involved in conserving biodiversity resources need to be horizontally and vertically integrated and work in collaboration to save the rapidly declining biodiversity resources of the country including the neglected mountain biodiversity. The analysis of key stakeholders (i.e., Ministry of Agriculture, Ethiopian Wildlife Conservation Authority, Higher Learning Institutions, and Commission for Environment, Forest and Climate Change) on the policy document NPBCR, 1998 is summarized in Table 8. In this analysis, twelve experts (three from each institution) were interviewed.

Table 8. Experts' opinion (%) on NPBCR (IBCR, 1998) from stakeholder institutions

NO	Indicators for understanding	Experts' opinion (%)				
		Do not know	Disagree	Somewhat agree	agree	Strongly agree
1	Does your institution work in collaboration with EBI for the implementation of Ethiopian National Policy on Biodiversity Conservation and Research (NPBCR)?			25		75
	Do you think that the NPBCR objectives are clearly stated?				100	
	Does NPBCR contain subsidiary instruments to achieve specific objectives which are clearly identifiable within the document for proper implementation?		5	5	90	
2	Are stakeholders' interests represented in NPBCR designing processes?			100		
	Do you feel that the NPBCR making is evidence-based?			30	70	
3	Do NPBCR statements on biodiversity conservation acknowledge the national development goals of Ethiopia?				100	
	Are biodiversity conservation actions consistent with the strategies and planning processes set for national development			25	75	
4	Does NPBCR provide clear statements for the establishment and operationalization of mechanisms and modalities to promote transparency?			75	25	
5	Do you think that the existing NPBCR needs modification?					100

The majority (75%) of respondents agreed that their institutions have been working in collaboration with EBI on the implementation of NPBCR. However, about 25% of the respondents revealed that there is some degree of partnership although there is lack of clear institutional arrangement in collaborations. All the respondents stated that there is low agreement on the representation of stakeholders' interest in designing of NPBCR (IBCR, 1998). This policy was issued before twenty years and the respondents strongly agree that it has to be revised based on adequate representations of the stakeholders viewpoints.

2.6.4 Conclusions

Mountain is a landmass that has risen significantly above sea level and the surrounding areas with distinct peak or peaks and it is the most fragile ecosystem. In mountains there are three distinct vegetation zones following altitudinal gradient. These are the Afromontane, Ericaceous and Afro-alpine vegetation belts. Mountains are refugias and sanctuaries for plants and animals which are migrated from lowland areas due to land use changes.

Mountain ecosystem harbours rich biodiversity that provide enormous services to people living in the surrounding areas. In this aspect, although there is an increasing awareness, anthropogenic pressure is the main river of the declining of biodiversity in this ecosystem. Moreover, mountains are highly susceptible to soil erosion which causes habitat fragmentation and biodiversity loss.

The ecosystem goods and services provided by mountains benefit both upstream communities and downstream communities. Mountains provide a direct life-support goods and services for more than half of the world's population. These ecosystem services include: provisioning, regulating, supporting and cultural services. The provisioning services that Ethiopian mountain ecosystem provides are genetic materials, fresh water, food and fiber, timber/fuel/energy, and ornamental and medicinal materials. The regulating services include purification of air, fresh water, flood and drought regulation, stabilization of local and regional climates.

Although the flora is identified and better recorded in the last decades, the conservation status of most of the Afro-alpine and Ericaceous plants (including grasses and herbs, shrubs and trees) are not assessed as per the IUCN criteria to examine the impact of human and natural stressors. This is mainly due to absence of adequate data of the flora. Wildlife resources diversity and endemicity is reported to be high in the highlands of the country. This is because of the large extent of the areas and the isolation of the highlands within the Afro-tropical ecoregion. Large scale drastic change of the natural landscapes to cultural landscapes has taken place in last the four decades. Changes in land use/land cover of mountain ecosystem directly and indirectly affected biodiversity of the Afro-alpine and Ericaceous areas. In addition to impact on habitat quality, decline in area cover restricts movement and limits the availability of food for some range restricted species of wildlife. The population of such species may decline and their survival will be threatened.

The changes in the mountain ecosystem are caused by both direct and indirect drivers. Direct drivers can be caused by either natural phenomena or anthropogenic impacts. Among the natural drivers, natural fires and climate change are most important direct drivers of change in mountain ecosystem. Studies suggest that recurrent natural fire has become common in the mountains of Ethiopia, altering the vegetation structure. Human induced climate change is a cause for deterioration of biodiversity resources in mountain ecosystem due to temperature rise, droughts, natural fires, soil erosion and effects of invasive species. The anthropogenic direct drivers include land use/land cover change (i.e., deforestation, land conversion), overexploitation (overgrazing, overharvesting, overfishing), invasive alien species, and pollution (e.g., release of gasses, solid and liquid wastes).

Indirect drivers of change in ecosystems are often called underlying drivers, which result from the complex interactions of social, economic, political, cultural and technological developments, ultimately triggering the direct drivers to set off. The majority of the problems faced by the Simen and Bale Mountain National Parks were commonly emanated from the changes in the national policy on protected areas management. For instance, human immigration from the surrounding lowlands is not controlled and this exerts pressure on the parks and the Afro-alpine areas.

Mountain ecosystem is under extreme pressure from the ever growing human and livestock populations. Continued encroachment by local people into steeper slopes has become very common to expand crop cultivation on steep slopes and intense burning of the woody vegetation to encourage growth of pasture for livestock and grass for roof thatching.

Sustainable development and conservation of mountain ecosystem and their biodiversity requires sound qualitative and quantitative botanical data in addition to socioeconomic and biophysical data. Unless factors such as livestock grazing, fire, and wood collection are managed in a sustainable way, rare and threatened plant species that are ecologically, economically, and culturally important could be lost without being known to the science.

Sustainable natural resource management and conservation need effective policy and regulations. The Ethiopian government has issued The National Policy on Biodiversity Conservation and Research (NPBCR) in 1998. The document still serves as the key policy document for biodiversity conservation activities. Ensuring conservation, development and sustainable utilization of genetic resources and essential ecosystems of the country are the major objectives stated in the policy document. The policy consists of key guidelines for conservation, development and sustainable use of biodiversity resources of Ethiopia. In addition it underlines the need for ensuring the country’s sovereignty over its genetic resources, enriching the country’s biological resources through restoration, integrating biodiversity conservation with sectoral and cross-sectoral strategies and programs, recognizing and protecting community knowledge, ensuring benefit sharing for local communities from biodiversity resource use, and promoting regional and international cooperation pertinent to biodiversity conservation. However, it does not specify how to treat the rich biodiversity resources and ecosystem services of the country's mountain ecosystem.

Understanding the local people’s viewpoints about mountain biodiversity conservation may help the policymakers and development managers to plan local development, and formulate conservation strategies and policies harmonized with the interest of the local communities. Biodiversity conservation and related development efforts that build on indigenous and local knowledge is likely to result in a more sustainable path of sustainable development. The area coverage of the Ethiopian mountain ecosystem and the services it provide is significant. Yet, little attention has been given and, therefore, a policy framework specific to mountain ecosystem is of quite importance to ensure biodiversity conservation and optimize the associated services for in this ecosystem.

2.7 References

Abayaneh, A., (2012). The status and sustainability of conservation in threats of biodiversity of Boreana Sayint. Boreana Sayint National Park Office.

Abbate E., Bruni P. and Sagri, M., (2015). Geology of Ethiopia: A Review and Geomorphological Perspectives. In: Billi P. (eds) Landscapes and Landforms of Ethiopia. World Geomorphological Landscapes. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-8026-1_2.

Abelineh, A., (2011). Community Based Watershed Development for Climate Change Adaptation in Choke Mountain: The Case of Upper Muga Watershed in East Gojjam of Ethiopia; Addis Ababa University: Addis Ababa, Ethiopia.

Adenew, B. and Abdi, F., (2005). Land Registration in Amhara Region, Ethiopia Research Report SOS Sahel, Addis Ababa, Ethiopia. Russell Press, Nottingham, UK.

Alemu, M., Suryabhagavan, K.V. and Balakrishinan, M., (2012). Assessment of cover change in Harena Habitats in Bale Mountains, Ethiopia, Using GIS and Remote Sensing. *International Journal of Ecology and Environmental Sciences*. **38**, 39-45.

Alers, M., Bovarnick, A., Boyle, T., Mackinnon, K. and Sobrevila, C., (2007). Reducing threats to protected areas: lessons from the field. IOP World Bank and UNDP. http://siteresources.worldbank.org/INTBIODIVERSITY/Resources/ReducingThreats-web.pdf.

Amare, T., Yitaferu, B. and Hurni, H., (2013). Effects of ‘‘Guie’’ on Soil Organic Carbon and Other Soil Properties: A Traditional Soil Fertility Management Practice in the Central Highlands. *Journal of Agricultural Science*. **5**, 236-44.

ANRS (Bureau of Culture, Tourism and Parks Development). (2005). Socioeconomic situation, tourism potentials and biodiversity study report on Guna proposed community conservation area. Wildlife study, Development, Protection and utilization process, Bahir Dar, Ethiopia. 65 pp.

Aregu,L. and Darnhofer, I., (2015). Enhancing social-ecological resilience through social learning: A case study of communal pasture management in the Highlands of Ethiopia. *African Journal of Agricultural Research*, **10**, Pp. 4681-4698. DOI: 10.5897/AJAR2015.10318.

Ashet, N., Lucas, N., Bubb, P., Iceland, C., Irwin, F., Ranganathan, J., and Raudsepp-Hearne, C., (2008). Framing the link between development and ecosystem services. In J. Ranganathan, C. Raudsepp-Hearne, N. Lucas, F. Irwin, M. Zurek, Bennett, K., Ash, N., & P. West (Eds.), *Ecosystem Services: A guide for decision makers* (pp. 13–28). Washington, DC, USA: World Resouces Institute. Retrieved from http://pdf.wri.org/ecosystem_services_ guide_for_decisionmakers.pdf.

Asmamaw, D. and Verma, A., (2013). Local attitudes towards environmental conservation and ecotourism around Bale Mountains national park. *Ethiopia Journal of Agricultural Science*. **3**, 506-514.

Assefa A., Ehrich D., Taberlet P., Nemomissa S. and Brochmann C., (2007). Pleistocene colonization of afro-alpine 'sky islands' by the arctic-alpine *Arabis alpina*. *Heredity*. **99**, 133-142.

Atickem A., Loe L.E., Langangen Ø., Rueness E. K., Bekele A. & Stenseth N.C., (2013). Population genetic structure and connectivity in the endangered Ethiopian mountain Nyala (Tragelaphus buxtoni): recommending dispersal corridors for future conservation. Conservation Genetics 14: 427-438.

Atickem, A, Loe, L.E., Langangen, Ø., Rueness, E.K, Bekele, A.,and Stenseth, N.C, (2011). Estimating population size and habitat suitability for mountain nyala in areas with different protection status. *Journal of Animal Conservation*. **14**, 409-418.

Awas, T., Gashaw, M., Tesfaye, G. and Tihune, A., (2003). Ecosystems of Ethiopia. National Biodiversity Strategy and Action Plan (NBSAP) Project, IBCR, Addis Ababa, Ethiopia.

Ayalew, A., Bekele, T. and Demissew, S., (2006). The undifferentiated afromontane forest of Denkoro in the central highland of Ethiopia: a floristic and structural analysis. Sinet: Ethiopian J Sci. 29(1): 45–56.

Ayele, S. and Teketay D., (2018). Attitudes of local people towards the Guassa Community Eco-Lodge in Menz-Gera Midir District, North Shewa Administrative Zone, Ethiopia. *International Journal of Avian & Wildlife Biology*. **3**, pp 2018.

Ayenew, B. and Tesfay, Y., (2015). Economic Valuation of Forest Ecosystems Service’s Role in Maintaining and Improving Water Quality. *Economics*. **4**, 71-80.

Bekele, E., (2007). *Study on Actual Situation of Medicinal Plants in Ethiopia*.Japan Association for International Collaboration of Agriculture and Forestry.

Bewket, W., (2002). Land cover dynamics since the 1950s in Chemoga watershed, Blue Nile Basin, Ethiopia. *Mountain Research and Development*. **22**, 263-269.

Biodiversity Indicators Development National Task Force, (2010). Ethiopia: Overview of Selected Biodiversity Indicators. Addis Ababa.

Bird, N., Tilley, H., Canales, T. N., Tumushabe, G., Welham, B., and Yanda, P., (2013). Measuring the effectiveness of public climate finance delivery at the national level. London: Overseas Development Institute. [online] Available at: http://www.odi.org.uk/publications/7342- measuring-effectiveness-public-climate-finance-delivery-national-domestic-level. [Accessed 7 June 2019].

Birhanu, A, Frankl, A., Jacob, M., Lanckriet, S., Hendrickx H., and Nyssen J., (2016) Afro-alpine forest cover change on Mt. Guna (Ethiopia). *Geophysical Research Abstracts.*

Bosch, J.M and Hewlett, J.D., (1982). A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. *Journal of Hydrology*. **55**, 3-23.

Breitenbach, F.V., (1961). Forest and woodlands of Ethiopia: a geobotanical contribution to the knowledge of the principal plant communities of Ethiopia, with special regard to forestry. *Ethiopian Forestry Review*. **1**, 5–16.

Bussmann, W.R., (2006). Vegetation zonation and nomenclature of African Mountains – An overview. *Lyonia*. **11**: 41-66.

Chala, D., Ximmermann, N. E., Brochmann, C. and Bakkestuen, V., (2017). Migration corridors for alpine plants among the ‘sky islands’ of eastern Africa: do they, or did they exist? *Alpine Botany*. **127**, 133-144.

Chane, M and Yirga, S., (2014). Distribution and diversity of small mammals In Borena-Sayint National Park, South Wollo, Ethiopia: Implications of habitat specialization. International J of Biodiversity and Conservation 6(5): 415-421.

Clouet, M., Barrau, C. and Jean Louis, G., (2000). The diurnal Afro-alpine raptor community of the Ethiopian Bale Highlands. *Journal of African Ornithology*. **71**, 380-384.

Craig, E. W, Stanley, W.T., Peterhans, J.C. K., Bryja, J. Meheretu, Y., (2020). Small terrestrial mammal distributions in Simien Mountains National Park, Ethiopia: a reassessment after 88 years. Journal of Mammalogy, 101(3):634–647.

Daily, G. (ed)., (1997). Nature's Services: Societal Dependence on Natural Ecosystems. Washington, DC: Island Press.

Daniel, T. C., Muhar, A., Arnberger, A., Aznar, O., Boydd, J.W., Kai M. A., Costanza R, Elmqvistg, T., Flinth, C.G., Gobsteri, P.H., Grêt-Regameyj, A., Lavek, R., Muharl, S., Penkerm, M., Riben, R.G., Schauppenlehnerb, T., Sikoro, T., Soloviyp, I, Spierenburgq, M., Taczanowskab, K., Tame, J. and von der Dunk, A., (2012). Contributions of cultural services to the ecosystem services agenda, *PNAS*. **109**, 8812–8819.

Datiko, D. and Tiki, L., (2017). Challenges of human settlement on wildlife in Bale Mountains National Park, Southeast Ethiopia. *International Journal of Biodiversity and Conservation*. **9**, 107-114.

Dax, T., (2002). Research on Mountain Development in Europe: Overview of Issues and Priorities. Federal Institute for Less-Favoured and Mountainous Areas. Vienna.

De Groot, R.S., Wilson, M.A. and Boumans, R.M.J., (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics*. **41**, 393–408.

De Lacy and Shackleton, C., (2017). Woody plant species richness, composition and structure in urban sacred sites, Grahamstown, South Africa. *Urban Ecosystems*. DOI: 10.1007/s11252-017-0669-y.

Diaz, S. et al., (2015). The IPBES Conceptual Framework—connecting nature and people. www.sciencedirect.com. 14,1–16.

Durning, A.B., (1989). Poverty and the Environment: Reversing the Downward Spiral. Worldwatch Inst., Washington, D.C, 92 pp.

EBI (Ethiopian Biodiversity Institute), (2015). The National Biodiversity Strategy Action Plan (2015-2020). Addis Ababa, Ethiopia, Ethiopian Biodiversity Institute.

EBI (Ethiopian Biodiversity Institute). (2015). National Biodiversity Strategy and Action Plan, Government of the Federal Democratic Republic of Ethiopia, Addis Ababa, Ethiopia:

EBI. (2014). Ethiopia’s Fifth National Report to the Convention on Biological Diversity, Addis Ababa, Ethiopia. 86pp.

EBI. (2015). Ethiopia’s Revised National Biodiversity Strategy and Action Plan (ERNBSAP). Addis Ababa.

EEA (European Environment Agency). (1999). Environment in the European Union at the turn of the century. Environmental assessment report No 2, Office for Official Publications of the European Communities, Luxembourg.

EEA. (European Environment Agency), (2002). Europe's biodiversity—Biogeographical regions and seas. Biogeographical regions in Europe: The Alpine region—Mountains of Europe. European Environment Agency, Copenhagen.

EFAP (Ethiopian Forestry Action Plan). (1993). The Challenge for Development. Volume II. Addis Ababa, Ethiopia: Ministry of Natural Resources Development and Environmental Protection.

EFAP. (1994). The Challenge for Development, Volume III.. Ministry of *Development* and Environmental Protection, Addis Ababa.

Egan, P., and Price, M.F., (2017). Mountain ecosystem services and climate change: A global overview of potential threats and strategies for adaptation. Paris: UNESCO.

Ejigu, D., Bekele, A. and Powell, L., (2017). Walia ibex have increased in number and shifted their habitat range within Simen Mountains National Park, Ethiopia. *Journal of Mountain Ecology*. **10**, 27-44.

Elizabeth, B. and Sainju, M., (1994). Mountain ecosystem and Women: Opportunities for Sustainable Development and Conservation Vol. 14, No. 3, University of California Press for the International Mountain Society and United Nations University. pp. 213-228.

EPCC (Ethiopian Panel on Climate Change). (2015), First Assessment Report, Working Group II Biodiversity and Ecosystems, Published by the Ethiopian Academy of Sciences, Addis Ababa, Ethiopia. 210pp.

Eriksson, M., Jianchu, X., Shrestha, A. B., Vaidya, R. A., Nepal, S., and Sandstrom, K., (2009). The changing Himalayas impact of climate change on water resources and livelihoods in the greater Himalaya. Kathmandu: International Centre for Integrated Mountain Development (ICIMOD).

Eshete, G., Tesfay, G., Bauer, H. Ashenafi, Z.T. de Iongh, H., Marino, J., (2015). Community Resource Uses and Ethiopian Wolf Conservation in Mount Abune Yosef. *Environmental Management.* **56**, pp. 684–694.

Eshetu, Z.and Högberg, P., (2000). Effects of land use on ^{15}N natural abundance of soils in Ethiopian highlands. *Plant and Soil.* **222**, 109-117.

Ethiopian Academy of Sciences. (2015). Ethiopian Panel on Climate Change (EPCC). Climate Change Impact, Vulnerability, Adaptation and Mitigation. Biodiversity and Ecosystems First Assessment Report.

Evangelista, P., Swartzinski, P. and Waltermire, R., (2007). A profile of the Mountain Nyala (Tragelaphus buxtoni). *African Indaba*. **5** www.africanindaba@co.za.

Evangelista, P.H., Norman, J., Berhanu, L., Kumar, S., Alley, N., (2008). Predicting habitat suitability for the endemic mountain nyala (Tragelaphus buxtoni) in Ethiopia. Wildlife Research 35: 409–416.

EWCA (Ethiopian Wildlife Conservation Authority). (2009). The Value of the Ethiopian Protected Area System: Message to Policy Makers.

Falch, F. and Keiner, M., (2000). Simen Mountains National Park Management Plan, final draft.

FAO (Food and Agriculture Organization). (1986). Highlands Reclamation Study. *Ethiopia. Final Report, Volumes 1 and 2.* Food and Agriculture Organization, Rome.

FAO. (1998). National Forestry Action Plan Update, FAO, Rome, Italy.

FAO. (2002). Mountains and the law – emerging trends. FAO legislative study. 98 pp.

FAO. (2010). Global Forest Resources Assessment. FAO Forestry Paper 163. Rome, pp., 217–326.

FARM Africa. (2008). Bale mountains eco-region sustainable development plan: report phase I and II planning workshops. FARM Africa, Addis Ababa.

Fassil, H., (2003). "We do what we know": Local health knowledge and home-based medicinal plant use in Ethiopia. PhD Thesis, International Development Centre, Queen Elizabeth house, Oxford University.

FDRE Constitution. (1995). Constitution of the Federal Democratic Republic of Ethiopia, Addis Ababa, Ethiopia.

Fetene, A., Alem, D. and Mamo, Y., (2014). Effects of Landuse and Land Cover Changes on the Extent and Distribution of Afroalpine Vegetation of Northern Western Ethiopia: The Case of Choke Mountains. Research Journal of Environmental Sciences 8: 17-24.

Fetene, A., Alemu, D. and Mamo, Y., (2014). Effects of Landuse and Land Cover Changes on the Extent and Distribution of Afro-alpine Vegetation of Northern Western Ethiopia: The Case of Choke Mountains. *Research Journal of Environmental Sciences*. **8**, 17-28.

Foley J.A., (2005) Global Consequences of Land Use. *Science*. **309**, 570. DOI:10.1126/science.1111772.

Frankl, A. and Nyssen, J., (2015). Land Use and Cover Dynamics Since 1964 in the Afro-alpine Vegetation Belt: Lib Amba Mountain in North Ethiopia. Land Degradation and Development. https://www.researchgate.net/publication/276074065.

Friis, I., Demissew S. and Breugel P., (2010). Atlas of the Potential vegetation of Ethiopia. The Royal Danish Academy of Sciences and Letters. 306 pp.

FZS (Frankfurt Zoological Society). (2007). Bale Mountains National Park general management plan (2007-2017). Frankfurt, Germany: Frankfurt Zoological Society.

FZS. (2007). Bale Mountains National Park. General Management Plan 2007 – 2017. Compiled by the Frankfurt Zoological Society. Institute of Biodiversity Conservation (IBC).

Gashaw, T., (2015). Threats of Bale Mountains National Park and solutions, Ethiopia. *Journal of P*hysical *Science and Environmental Studies*. **1**, 10-16.

Gebregziabher, T., (1991). Management of mountain environments and genetic erosion in tropical mountain systems: The Ethiopian example. *Mountain Research and Development*. **11**, 225–230.

Gebremedhin, B., Flagstad, Ø., Bekele, A., Chala, D., Bakkestuen, V., Boessenkool, S. Popp, M., Gussarova, G., Schrøder-Nielsen, A., Nemomissa, S., Brochmann, C., Stenseth, N. C. and S. Epp, L. S., (2016). DNA Metabarcoding Reveals Diet Overlap between the Endangered Walia Ibex and Domestic Goats - Implications for Conservation. PLOS ONE. **11**, 1-18. doi:10.1371/journal.pone.0159133.

Gebremedhin, B., Rezaei, H. R., and Naderi, S., (2009). Combining genetic and ecological data to assess the conservation status of the endangered Ethiopian Walia ibex. *Animal Conservation*. **12**, 89-100.

Gehrke, B. and Linder, H. P., (2014). Species richness, endemism and species composition in the tropical Afro-alpine flora. *Alpine Botany*. **124**, 165-177.

Gilbert, E.F., (1970). Mount Wachacha: A botanical Commentary. *Walia*. **2**, 3–12.

Girma, Z., (2016). Habitat Use, Diet and Conservation of the Mountain Nyala and Menelik's Bushbuck in Arsi Mountains National Park, Ethiopia [PhD dissertation]. Buea, Cameroon: University of Buea.

Gizaw, A., Kebede, M., Nemomissa, S., Ehrich, D., Bekele, B., Mirré, V., Popp, M. and Brochmann, C., (2013). Phylogeography of the heathers Erica arborea and E. trimera in the afro-alpine 'sky islands' inferred from AFLPs and plastid DNA sequences. *Flora-Morphology, Distribution, Functional Ecology of Plants*. **208**, 453-463.

Gotteli, D., Marino, J., Sillero, C. and Funk, S. M., (2004). The effect of the last glacial age on speciation and population genetic structure of the endangered Ethiopian wolf (*Canis simensis*). *Molecular Eco*logy. **13**, 2275-2286.

Griffiths, G. A. and McSaveney, M. J., (1983). Distribution of mean annual precipitation across some steepland regions of New Zealand. NZ. *Journal of Science*. **26**, 197-209.

Hedberg, I. and Hedberg, O., (1979). Tropical alpine life forms of vascular plants. *Oikos.* **33**, 2097-307.

Hedberg, O., (1951). Vegetation belts of the east African mountains. *Svensk Botanisk Tidskrift*, **45**: 140-202.

Hedberg, O., (1964). Features of afro-alpine plant ecology. Acta phytogeographical Suecica. 144pp.

Hedberg, O., (1969). Evolution and speciation in a tropical high Mountain flora. *Biological Journal of the Linnean Society*. **1**: 135-148.

Hedberg, O., (1971). The high mountain flora of the Galama Mountain in Arus-si province, Ethiopia. *Webbia*. **26**, 101-228.

Hillman, J.C., (1986). Bale Mountains National Park Management Plan. Ethiopian wildlife conservation organization, Addis Ababa, Ethiopia.

Hillman, J.C., (1988). The Bale Mountains National Park area, southeast Ethiopia, and its management. *Mountain Research and Development*. **8**, 253–258.

Hurni, H, Abate, S. Bantider, Debele, B., Ludi, E., Portner, B., Yitaferu, B. and Zeleke, G., (2010). Land degradation and sustainable land management in the Highlands of Ethiopia. Perspectives of the Swiss National Centre of Competence in Research (NCCR) North South, University of Bern, Bern, Switzerland.

Hurni, H. (1993). Land degradation, famine and land resource scenarios in Ethiopia. In: D. Pimentel, ed., *World Soil Erosion and Conservation*. Cambridge: Cambridge University Press, pp. 27–61.

Hurni, H., (1986). Management plan: Simen Mountains National Park and surrounding rural area. Addis Ababa: UNESCO World Heritage Commission and EWCO.

Hurni, H., (1990). Degradation and Conservation of Soil Resources in the Ethiopian Highlands. In: *African Mountains and Highlands: Problems and Prospective*, pp. 51-63. (Messerli, B. and Hurni, H. eds.).Marceline Mo: Walsworth Press for the African Mountains Association.

Hurni, H., Ludi, E., (2000). Reconciling Conservation with Sustainable Development: A Participatory Study Inside and Around the Simen Mountains National Park, Ethiopia. Bern, Switzerland: Centre for Development and Environment (CDE).

IBC (Institute of Biodiversity Conservation). (2005). National Biodiversity Strategy and Action Plan, Addis Ababa, Ethiopia.

IBC. (2009). Convention on Biological Diversity (CBD) Ethiopia's 4th Country Report. Addis Ababa, Ethiopia.

IBC. (2009). Ethiopia's 4th Country Report to Convention on Biological Diversity (CBD), November 2009, Addis Ababa, Ethiopia.

IBCR (Institute of Biodiversity Conservation and Research). (1998). The National Policy on Biodiversity Conservation and Research (NPBCR). Addis Ababa, Ethiopia: Brana Printing Press.

IUCN (International Union for Conservation of Nature). (2007). Red List of Endangered Species. http://www.iucnredlist.org/search/details.php/ 3748/summ.

IUCN. (2011). Strategic Planning for Ethiopian Wolf Conservation. Canadian Specialist Group.

Jacob, M., Annys, F. A., De Ridder, M., Beeckman, H., Guyassa, E. and Nyssen, J., (2014). Tree line dynamics in the tropical African highlands – identifying drivers and dynamics. Journal of Vegetation Science. https://doi.org/10.1111/jvs.12215.

Jacob, M., Frankl, A., Hurni, H., Maaike, L Ridder, D., Guyassa, E,, Beeckman, H. and Nyssen J., (2016). Land Covers Dynamics in the Simen Mountains (Ethiopia), Half a Century After Establishment of the National Park.

Jodha, N.S., (1989). Mountain Agriculture. Search for Sustainability. MFS Series No. 2, ICIMOD, Kathmandu.

Johansson, M., (2013). Fire and grazing in subalpine heathlands and forests of Bale Mountains, Ethiopia: Fire ecology and traditional use of fire. PhD thesis, Swedish University of

Agricultural Sciences, Uppsala, Sweden. Accessed September 10, 2018. http://urn.kb.se/resolve?urn=urn:nbn:se:slu:epsilon-e-841.

Jordan, S.J., Hayes, S.E., Yoskowitz, D., Smith, L.M., Summers, J.K., Russell, M. and Benson, W.H., (2010). Accounting for natural resources and environmental sustainability: Linking ecosystem services to human well-being. *Environmental Science and Technology*. **44**, 1530-1536.

Kebede, M., Ehrich, D., Taberlet, P., Nemomissa, S. and Brochmann, C., (2007). Phylogeography and conservation genetics of a giant lobelia (*Lobelia giberroa*) in Ethiopian and tropical east African mountains. *Journal of Molecular Ecology*. **16**, 1233-1243.

Kidane, Y., Stahlmann, R. and Beierkuhnlein, C., (2012). Vegetation dynamics, and land use and land cover change in the Bale Mountains, Ethiopia. *Environmental Monitoring and Assessment*. **184**, 7473-89.

Kissinger, G., M. Herold, V. De Sy., (2012). Drivers of Deforestation and Forest Degradation: A Synthesis Report for REDD+ Policymakers. Lexeme Consulting, Vancouver, Canada.

Klotzli, F., (1975).Simen - A Recent Review of its Problems. *Walia*. **6**, 18-19.

Koch, M.A., Kiefer, C., Ehrich, D., Vogel, J., Brochmann, C., Mummenhoff, K., (2006). Three times out of Asia Minor: the phylogeography of *Arabis alpina* L. (Brassicaceae). *Molecular Ecology*. **15**, 825–839.

Kreyling, J., Wana, D., and Beierkuhnlein, C., (2010). Potential consequences of climate warming for tropical plant species in high mountains of southern Ethiopia. *Diversity and Distributions*. **16**, 593-605.

Kröner, A. and Stern, R.J., (2004). Africa/Pan-African Orogeny, North African Phanerozoic Rift Valley. *Encyclopedia of Geology*. **1**, 1-12.

Lavrenchenko, L. A. and Corti, M., (2016). “Stenocephalemys griseicauda”. IUCN Red List of Threatened Species. IUCN. e.T20741A115159785. http://dx.doi.org/10.2305/IUCN.UK.2016- 3.RLTS.T20741A22428816.en

Lavrenchenko, L. A., Bannikova, A. A. and Lebedev, V. S., (2009). Shrews (Crocidura spp.) endemic to Ethiopia: Recent adaptive radiation of an ancient lineage. *Doklady Biological Sciences*. **424**, 57-60.

Lavrenchenko, L.A., Voyta, L.L. and Hutterer, R., (2016). Diversity of shrews in Ethiopia, with the description of two new species of Crocidura (Mammalia: Lipotyphla: Soricidae). *Zoo taxa*. **4196**, 38–60.

Mamo Y., Bekele A., and Mengesha G., (2012). Habitat use of mountain nyala (Tragelaphus buxtoni, Lyddeker, 1911) in the Bale Mountains National Park, Ethiopia. *International Journal of Biodiversity and Conservation*. **4**, 642–651.

Mamo, G. and Wube, T., (2018). Local People's Attitude and the Impact of Community-based Conservation Practice at Menz-Guassa Community Conservation Area, Ethiopia. *Developing Country Studies*. **8**, 1-15.

Mamo, Y. and Bekele, A. (2011). Human and livestock encroachments into the habitat of Mountain Nyala (*Tragelaphus buxtoni*) in the Bale Mountains National Park, Ethiopia. *Journal of Tropical Ecology*. **52**, 265-273.

Marino, J., (2003). Spatial ecology of the Ethiopian wolf, *Canis simensis*. Ph.D. Thesis, Linacre College, University of Oxford.

McGuire, A.F. and Kron, K.A., (2005). Phylogenetic relationships of European and African Ericas. *International Journal of Plant Sciences*. **166**, 311-318.

MEA (Millennium Ecosystem Assessment). (2005). Ecosystems and human well-being: current state and trends, Volume 1. Island Press: Washington, DC. 917 pp.

Mekonnen, K., Glatzel, G., and Sieghardt, M., (2006). Evaluation of common indigenous tree and shrub species for soil fertility improvement and fodder production in the highland areas of western Shewa, Ethiopia. In: Glatzel G., Habermann, B., ed. Gemeinsam Forschen gemeinsam Lernen-Forschungspartnerschaften in der Entwicklungszusammenarbeit. Vienna, Austria: O¨ sterreichischen Akademie der Wissenschaften, pp 99–106.

Mekonnen, K., Glatzel, G., and Sieghardt, M., (2009). Fodder Values of 3 Indigenous and 1 Exotic Woody Plant Species in the Highlands of Central Ethiopia. *Mountain Research and Development*. **29**, 135-142.

Mekonnen, K., Schneider, T., Teketay, D. and Knoke, T., (2013) Land use/land cover change analysis using object-based classification approach in Munessa-Shashemene landscape of the Ethiopian highlands. *Remote Sensing*. **5**, 2411–2435.

Mekonnen, S., Chinasho, A.,Berhanu, K., and Tesfaye, S., (2017). Threats and conservation challenges of wildlife in Harenna Forest, HarennaBuluk District, South East Ethiopia.*International Journal of Biodiversity and Conservation*. **9**, 246-255.

Messerli B, Hurni H, Kienholz H, Winiger M., (1977). Bale Mountains: Largest Pleistocene mountain glacier system in Ethiopia. XINQUA Congress, Birmingham, Abstracts.

Messerli, B., (1983). Stability and Instability of Mountain Ecosystems. *Mountain Research and Development*. **2**, 81-94.

Meyer, W.B, and Turner B.L, (1994). Changes in Land Use and Land Cover: A Global Perspective. Cambridge: Cambridge University Press.

Mezgebu, A and Workineh, A., (2017). Changes and drivers of Afro-alpine forest ecosystem: future trajectories and management strategies in Bale eco-region, Ethiopia, *Ecological Processes*. **6**, 42-55.

Mezgebu, A. and Workineh, G., (2017). Changes and drivers of afro-alpine forest ecosystem: future trajectories and management strategies in Bale eco-region, Ethiopia. Ecological Processes 6: 42. DOI 10.1186/s13717-017-0108-2.

Miehe, S., and Miehe, G., (1994). Ericaceous Forests and Heathlands in the Bale Mountains of South Ethiopia: Ecology and Man’s Impact. Hamburg, Germany.

MoA (Ministry of Agriculture). (2000). Agroecological Zonations of Ethiopia. Ministry of Agriculture, Addis Ababa.

Mortimore, M., (1993). Population growth and land degradation. *Journal of Geography*. **31**, 15–21.

Nelson, C. G., Bennett, E., Berhe, A., Cassman, K. G., DeFries, R., Dietz, T., and Zurek, M., (2005). Drivers of change in ecosystem condition and services. In S. R. Carpenter, P. L. Pingali, E. M. Bennett, and M. B. Zurek, (Eds.), Ecosystems and human well-being: Scenarios: findings of the scenarios working group, Millennium Ecosystem Assessment (pp. 173–222). Washington, DC: Island press. https://islandpress.org/book/ecosystems-and-human-well-being-scenarios.

Nemomissa S., (1994). *Swertia* L. (Gentianaceae) in North East Africa. Unpublished PhD Thesis. University of Vienna, Austria.

Nepal, S. J., (2000). Simen Mountains National Park, Ethiopia. *Case Study*. **6**, 79-85.

Nigatu, L., and Tadesse, M., (1989). An ecological study of the vegetation of the Harenna Forest, Bale, Ethiopia. *SINET*: *Ethiopian Journal of Science*.**12(1)**, 63–93.

Nune, H., Soromessa, T. and Teketay, D., (2015). Non-carbon benefits for effective implementation of REDD+: the case of Bale Mountains eco-region,southeastern Ethiopia. *African Journal of Environmental Science and Technology*. **9**, 747–764.

Nune, S., Sormesa, T., and Teketay, D., (2016). Land Use and Land Cover Change in the Bale Mountain Eco-Region of Ethiopia during 1985 to 2015. Land 2016, 5, 41; doi:10.3390/land5040041 Accessed online [22 march 2019 www.mdpi.com/journal/land]

OFWE, FARM Africa and SOS Sahel Ethiopia. (2014). Bale Mountains eco-region reduction of emission from deforestation and Forest degradation (REDD+) project-Ethiopia. FARM Africa and SOS Sahel, Addis Ababa.

ORDA (Organization for Rehabilitation and Development in Amhara). (2016). Guna Mountain Community Conservation Area General Management Plan (2017-2026).

Ossendorf, G., Groos, A., R., Bromm, T., Tekelemariam, M. G., Glaser, B., Lesur, J., Schmidt, J., Akçar, N., Bekele, T., Beldados, A., Demissew, S., Kahsay, T. H., Nash, B. P. Nauss, T., Negash, A. Nemomissa, S., Veit, H., Vogelsang, R., Woldu, Z., Zech, W. Opgenoorth, L. and Miehe, G., (2019). Middle Stone Age foragers resided in high elevations of the glaciated Bale Mountains, Ethiopia. *Science*. **365**, 583-587.

Pankhurst, R., (1989). Some notes on deforestation and afforestation in Ethiopia prior to World War I. *Walia.* **12**, 10-20.

Payne, D., Spehn, E.M., Snethlage, M. and Fischer, M., (2017). Opportunities for research on mountain biodiversity under global change. *Current Opinion in Environmental Sustainability*. **29**, 1-222.

Pérez, A.A., Fernandez, H.B. and Gatti, C.R., (2010). Building Resilience to Climate Change: Ecosystem-based adaptation and lessons from the field. Gland, Switzerland: IUCN. Pp 164.

Piñeiro, R.,Popp, M., Nemomissa, S., Gizaw, A., Masao, C., Mugizi, F., Wondimu, T., Pimentel, M., Mirré, V., Linder, P., Eilu, G.7, Munishi, P., Mwachala, G., Taberlet, P., Brochmann, C. (2010). Which factors influence genetic diversity in the Afro-alpine ecosystem in eastern Africa? AETFAT, Madagascar.

Poore, D., (1992). Guidelines for Mountain Protected Areas. IUCN Protected Area Programme Series No. 2, Commission on National Parks and Protected Areas, IUCN, Gland, Switzerland and Cambridge, UK.

Potschin, M. and Haines-Young, R., (2016). Defining and measuring ecosystem services. In: *Handbook of Ecosystem Services*, pp 25-44. (Potschin, M., HainesYoung, R., Fish, R. and Turner, R.K. (eds), Routledge, London and ä New York.

Puff, C. and Nemomissa, S., (2001). The Simen Mountains (Ethiopia): comments on plant biodiversity, endemism, phytogeographical affinities and historical aspects. *Systematic and Geography of Plants*. **71,** 975-991.

Puff, C. and Nemomissa, S., (2005). Plants of the Simen: a flora of the Simen Mountains and surroundings, northern Ethiopia. *National Botanic Garden of Belgium*, Belgium. 258pp.

Rawat, Y.S. and Singh, J.S., (1989). Forest floor biomass, litter fall and nutrient return in central Himalayan oak forests. *Vegetation*. **82**, 113-125.

Reusing, M., (1998). Monitoring of Natural High Forests in Ethiopia. Internal Report, Ministry of Agriculture, Addis Ababa, Ethiopia.

Roberts, L., Brower, A., Kerr, G., Lambert, S., McWilliam, W., Moore, K., Quinn, J., Simmons, D., Thrush, S., Townsend, M., Blaschke, P., Costanza, R., Cullen, R., Hughey, K., and Wratten, S., (2015). The nature of well-being: how nature's ecosystem services contribute to the well-being of New Zealandand New Zealanders. Department of Conservation, Wellington. pp145.

Ruskule, G.A., Vinogradovs, I. and Pecina, M.V., (2018). The guidebook on "the introduction to the ecosystem service framework and its application in integrated planning" university of latvia, faculty of geography and earth sciences.

Saavedra, D., (2009). The Abune Yosef Massif: Birds and Mammals of a Hidden Jewel of Ethiopia. Publicacions del Centre de Recursos de Biodiversitat Animal, Volum 2, 131pp.

Sahle, M. and Yeshitela, K., (2018). Dynamics of land use land cover and their drivers study for management of ecosystems in the socio-ecological landscape of Gurage Mountains, Ethiopia. Remote sensing applications: society and environment, 12: 48-56.

Sarvasova, Z. and Dobsinska, Z., (2016). Provision of ecosystem services in mountain forests – case study of experts' and stakeholders' perceptions from Slovakia. *Journal of Forest Science*. **62**, 380–387.

Schroter, D., Cramer, W., Leemans, R., Prentice, I.C., Araujo, M.B., Arnell, N.W., Bondeau, A., Bugmann, H., Carter, T.R., Gracia, C.A., de laVega-Leinert, A.C., Erhard, M., Ewert, F., Glendining, M. and Hause, J.I., (2005). Ecosystem service supply and vulnerability to global change in Europe. *Science*. **310**, 1333–1337.

Semwal, D.P., Saradhi, P.P., Nautiyal, B.P. and Bhatt, A.B., (2007). Current status, distribution and conservation of rare and endangered medicinal plants of Kedarnath Wildlife Sanctuary, Central Himalayas, India. *Current Science*. **92**, 1733 – 1738.

Senbeta, F., Denich, M., Boehmer, H.-J., Woldemariam, G., Teketay, D., Demissew, S. 2007. Wild *Coffea arabica* L. in Afromontane rainforests of Ethiopia: distribution, ecology and conservation. Sinet: Ethiopian J Sci. 30: 13 – 24.

Sillero-Zubiri, C., (2012). Tragelaphus buxtoni MOUNTAIN NYALA (GEDEMSA). In: Mammals of Africa Volume VI: Hippopotamuses, Pigs, Deer, Giraffe and Bovids (Kingdon and Hoffman, eds). Bloomsbury Publishing Plc. London. Pp68.

Simane, B., (2013). The Sustainability of Community-Based Adaptation in the Choke Mountain Watersheds, Blue Nile Highlands, Ethiopia, *Sustainability [online]* 5, 1-x manuscripts. Available from: doi:10.3390/su50x000x.

Simane, B., Zaitchik, B. F. and Ozdogan, M., (2013). Agroecosystem analysis of the Choke Mountain Watersheds, Ethiopia. *Sustainability*. **5**, 592-616.

SOS Sahel Ethiopia. (2010). Annual Accomplishment Report for 2009: Submitted to Charities and Societies Agency (CSA). SOS Sahel Ethiopia: Addis Ababa. Annual_Report. Accessed from http://www.sossahel.org.et/publications/2009_SOS_Sahel_ Ethiopia.

Spehn, E., Berge, E., Bugmann, H., Groombridge, B., Hamilton, L.,Hofer, T., Ives, J., Jodha, N., Messerli, B., Pratt, J., Price, M., Reasoner, M., Rodgers, A., Thonell, J. and Yoshino, M., (2005). Mountain Systems. In: Hassan, R., Scholes, R. and Ash, N. eds. *Ecosystems and Human Well-Being: Current State and Trends*, pp. 681-717, (.), Condition and Trends Working Group, Island Press, Washington.

Spehn, E.M., Rudmann-Maurar, K., and Körner, C., (2010). Mountain Biodiversity- a global heritage. In: *Mountain Biodiversity and Global Change*, pp. 7-15, (Spehn, E.M., Rudmann-Maurar, K., Körner, C. and Maselli, D. eds.), GMBA-DIVERSITAS, Basel.

Stephen M. C., Melinda J. L., Nicholas E. Y and Paul H. E., (2019) Afroalpine Wetlands of the Bale Mountains, Ethiopia: Distribution, Dynamics, and Conceptual Flow Model, Annals of the American Association of Geographers, 109:3, 791- 811, DOI: 10.1080/24694452.2018.1500439.

Stern, R.J., (2002). Crustal evolution in the East African Orogen: a neodymium isotopic perspective. *Journal of African Earth Science*. **34**, 109-117.

Summers, J.K., Smith, L.M., Case, J.L. and Linthurst, R.A., (2012). A review of the elements of human well-being with an emphasis on the contribution of ecosystem services. *Ambio*. **41**, 327-340.

Tadesse, S.A. and Teketay, D., (2018). Attitudes of local people towards the Guassa Community Eco-Lodge in Menz-Gera Midir District, North Shewa Administrative Zone, Ethiopia. *International Journal of Avian & Wildlife Biology*. **3**, 2018.

Taylor, S., (2015). African Mountainous Countries and Their Mountains. Federal Democratic Republic of Ethiopia. University of Pretoria. 21pp.

TEEB (The Economics of Ecosystems and Biodiversity). (2010). The economics of ecosystems and biodiversity: ecological and economic foundations. Earthscan: London and Washington, DC.

Tefera, Z. and Leader-Williams, N., (2005). Indigenous common property resource management in the Central Highlands of Ethiopia. *Human Ecology*. **33**, 539–563.

Tefera, Z. and Sllero-Zubiri, C., (Walia 2005-6). Aflagship species for Afro-alpine conservation: An Overview of the status and Conservation of Ethiopian Wolf.

Tefera, Z., (2004). Community management of Afro-alpine highlands in Ethiopia. *Leisa Magazaine*, pp 10-11.

Teferi, E., Uhlenbrook, S., Bewket, W., Wenninger, J. and Simane, B., (2010). The use of remote sensing to quantify wetland loss in the Choke Mountain range, Upper Blue Nile Basin, Ethiopia. *Hydrology and Earth System Science*. **14**, 2415-2428.

Teketay, D., (1992). Human impact on a natural montane forest in South-eastern Ethiopia. *Mountain Research and Development*, **12**, 393–400.

Teketay, D., (1996). Floristioc composition of Gara Muleta and Kundudo mountains, south-eastern Ethiopi: implications for the conservation of biodiversity: In van der Maesen et al. (eds), The Bodiversity of African Plants, pp. 345-350.

Teshome, E. and Demissie, E., (2018). Tourist Services Quality in the Simen Mountains National Park, World Heritage Site, Ethiopia. *African Journal of Hospitality, Tourism and Leisure*. **7** (2), 2223-814X.

Tola, T. and Traynor, C., (2015). Country report on Ethiopia Community Conservation Resilience Initiative (CCRI). Global Forest Coalition Asunción, Paraguay.

Umera, M. Lambb, H.F., Bonnefillec, R., Le´zined, A.-M., Tierceline, J.-J., Gibertf E., Cazetd, J.-P. Watrind, J., (2007). Late Pleistocene and Holocene vegetation history of the Bale Mountains, Ethiopia. Quaternary Science Reviews 26 2229–2246.

UNCED (United Nations Conference on Environment and Development). (1992). *Agenda 21, United Nations Conference on Environment and Development*. United Nations Sustainable Development, Rio de Janerio, Brazil.

UNDP (United Nations Development Programme). (2012). Guassa-Menz Community Conservation Area, Ethiopia. Equator Initiative Case Study Series. New York, NY.

UNDP. (2012). Guassa-Menz Community Conservation Area, Ethiopia. Equator Initiative Case Study Series. New York, NY.

UNESCO (United Nations Educational, Scientific and Cultural Organization). (2017). What is Local and Indigenous Knowledge? http://www.unesco.org/new/en/natural-sciences/priority-areas/links/related-information/what-is-local-and-indigenous-knowledge/

Urban, E.K., and Brown, L.E., (1971). A checklist of the birds of Ethiopia. Addis Ababa: Haile Sellassie I University Press.

Van Zyl, H., (2015). The Economic Value and Potential of Protected Areas in Ethiopia Technical Report · September 2015 DOI: 10.13140/RG.2.1.2151.1449.

Vreugdenhil, D. M., Vreugdenhil, A. D., Tamirat, T., Anteneh, S., and Zelealem, T., (2012). Gap analysis of the protected area systems of Ethiopia with technical contributions from Nagelkerke, In: Gedeon, K., Spawls, S., Yalden, D., Lakew B., Siege, L. eds. *World institution for Conservation and Environment*, USA.

Wassie, A., Teketay, D., and Powell, N., (2005). Church forests in North Gonder Administrative Zone, Northern Ethiopia. *Forests, Trees and Livelihoods*. **15**, 349-373.

Watson, C., (2007). Direct Consumptive Use Valuation of Ecosystem Goods and Services in the Bale Mountains EcoRegion, Ethiopia. MSc Thesis, Centre for Environmental Policy, Imperial College London.

Watson, C., (2013). Forest Conservation for Communities and Carbon: The Economics of Community Forest Management in the Bale Mountains Eco-Region, Ethiopia. Doctoral thesis. London School of Economics and Political Science: London.

Wesche, K., Miehe, G., and Kaeppeh, M., (2000). The significance of fire for Afro-alpine vegetation. *Mountain Research and Development*. **20**, 340–347.

Williams, S., Vivero Pol, J.L., Spawls, S., Shimelis, A. and Kelbessa, E., (2004). Ethiopian Highlands. In: Hotspots revisited (Mittermeier, R.A., Gill, P.R., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C.G., Lamoreux, J. and Da Fonseca, G.A.B. (eds.)). CEMEx Publisher, Washington.

Woldu, Z., Asfaw, Z., Demissew, S., Getu, M. and Korme, T., (2006). Ethnobotany and indigenous people of the southern Rift valley and South western Ethiopia: Konso and Hamar. A project report for Christensesn's Fund USA. Unpublished.

Wondie, M., Schneider, W., Melesse, A.M., and Teketay, D., (2011). Spatial and temporal land over changes in the Simen Mountains National Park, a World Heritage Site in Northwestern Ethiopia. *Remote Sense*. **3**, 752–766. doi:10.3390/rs304075.

Wondimu, T., Gizaw, A., Tusiime, F. M., Masao, C. A., Abdi, A. A., Gussarova, G., Popp, M., Nemomissa, S. and Brochmann, C., (2014). Crossing barriers in an extremely fragmented system: two case studies in the afro-alpine sky island flora. *Journal of Plant Systematics and Evolution*. **300**, 415-430.

Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson. J.B.C., Lotze, H.K., Licheli, F., Palumbi, S.R., Sala, E., Selkoe, K,A., Stachowicz, J.J. and Watson, R., (2005). Impacts of biodiversity loss on ocean ecosystem services. *Science*. **314**, 787-790.

Xun, F., Hu , Y., Lv, L. and Tong, J., (2017). Farmers' Awareness of Ecosystem Services and the Associated Policy Implications.*Sustainability*. **9**, 1612 doi:10.3390/su9091612.

Yineger, H., Kelbessa, E., Bekele, T. and Lulekal, E., (2008). Floristic Composition and Structure of the Dry Afromontane Forest at Bale Mountains National Park, Ethiopia. SINET: Ethiop. J. Sci., 31(2):103–120.

3. Forest and Woodland Ecosystem

Contributors

Corresponding Lead Author: Abiyot Berhanu (PhD)

Lead Author: Professor Sebesebe Demissew (Professor)

Contributing Authors: Feyera Senbeta (Professor),

Alemayehu Negassa (PhD)

Alemayehu H/Michael (PhD)

Editor: Tadesse Woldemariam (PhD)

External Peer Reviewer: KumlachewYeshtila (Professor)

Table of Contents

List of Tables

List of Figures

Executive summary

Ethiopia is located between 3° 24' to 14° 53' N latitude and 33° 00' to 48° 00' E longitude; and within the altitudinal range of between 125 m bsl and 4533 m asl (well established). Topographically, the country possesses an extensive area of highlands, surrounded by lowlands in all directions. The Great Rift Valley system runs from northeast to southwest through eastern Africa toward Mozambique and divides the country into the northwestern and southeastern highlands {3.1}.

Owing to these diverse topographic features, Ethiopia is endowed with a variety of ecosystems (established but incomplete), which are mainly based on the vegetation types, of which the forest and woodland ecosystem of the country comprise: Dry Evergreen Afromontane Forest and Grassland Complex (DAF), Intermediate Evergreen Afromontane Forest (IAF), Moist Evergreen Afromontane Forest (MAF), Transitional Semi-evergreen Bushland (TSB), *Acacia-Commiphora* Woodland and Bushland (ACB), *Combretum-Terminalia* Woodland and Wooded Grassland (CTW), and the Transitional Rain Forest (TRF) {3.1}.

Ethiopia's forest and woodland ecosystem contributes various benefits to people such as regulating, material and non-materials services (established but incomplete). However, people's perception of benefits and changes of forest and woodland ecosystem vary from people to people. Many perceive the nature's benefit as free goods but failed to conserve owing to struggle for survival and improving livelihood. The traditional management and the benefit obtained from this ecosystem is highly recognized in traditional people. However, their role in governance and conservation of this ecosystem is commonly overlooked. Though, there are efforts to conserve forest and woodland biodiversity resources, more is expected in terms of creating awareness and recognizing the traditional forest management systems of indigenous communities {3.1, 3.2.1, 3.6.1}.

Extensive land use pressures and increased demand for forest and woodland products have put and are still putting immense danger on the natural ecosystems of the country (established but incomplete). Deforestation estimates show that the country is losing around 92,000 ha of forest cover each year. The diverse pressures that bring about changes in forest and woodland biodiversity and ecosystem services could be of direct or indirect nature. A direct driver unequivocally influences ecosystem processes whereas indirect driver operates more diffusely, by altering one or more direct drivers. Identifying drivers that cause pressure or changes in forest and woodland ecosystem at all levels is important to address the challenges. The magnitude of the impact and its recovery from shock depends on the nature of the pressure and the ecosystem in which it operates {3.3.4, 3.5.1, 3.5.2}.

The underlying legal and institutional factors that contributed for deforestation and forest degradation in Ethiopia include: absence of comprehensive land use policy, institutional instability and low capacity of forestry institutions, poor inter-sectorial coordination and synergy , inadequacy of the forestry legal framework, weak law enforcement, and unclear tenure and forest user rights (established but incomplete) {3.3.1, 3.5.2, 3.7.1, 3.7.2 }.

Ethiopia has formulated and implemented several forest and biodiversity related policies, laws, regulations and guidelines to address the persistent challenges and to fulfill the economic and societal benefits expected from these sectors over the past several years (established but incomplete). Ethiopia has also adopted several international treaties and conventions related to forest management and biodiversity conservation over the last two decades {3.7.1}.

Key findings

Ethiopia possesses diverse ecosystems with various floral, faunal and microbial resources. One of these ecosystems is the forest and woodland ecosystem. This ecosystem is affected by diverse anthropogenic and natural causes. The mode of pressure to drive change could either be of direct or indirect origin. The most important drivers degrading the forest and woodland ecosystem are habitat fragmentation due to agricultural expansion and energy demand (e.g. firewood). These major drivers (habitat fragmentation, fire wood demand, and agricultural expansion) which cause woodland ecosystem destruction need special strategy to halt their effects. Understanding of the network and interrelationships among direct drivers of change in both natural and manmade environments would help to look for effective management plan. Moreover, peoples' perception on forest management and their role in traditional governance is overlooked. Although there are efforts to conserve the forest and woodland biodiversity, much is required to be done in creating awareness and recognizing the traditional forest management systems of indigenous communities.

On the other hand, analysis of the impacts of policies and institutional arrangements on biodiversity conservation and ecosystem services shows a gap between legal and policy design and implementation. Efforts exerted so far have focused on developing policies and strategies while little has been done to strengthen institutional arrangement and implementation on the ground. Regulations and directives have not been developed to implement forest and biodiversity related proclamations, which resulted in a weak legal framework and poor law enforcement. For example, the Ethiopian Forest Development, Conservation and Utilization proclamation (2018) defined major types of forest and biodiversity related infractions, those definitions are not properly translated into regulations, directives and guidelines. Lack of proper implementation instruments not only undermine forest and biodiversity conservation but also hinder national efforts to halt deforestation and achieve the country's ambitious plan for fast and sustainable development. Policies and laws pertinent to forest and biodiversity are more inclined towards protection by giving less emphasis to the customary access rights of the local people to the resources.

Generally, the following are the key findings:

- Ethiopia is rich in biodiversity and being recognized as one of the top 25-biodiversity rich countries in the World,
- The forest and woodland ecosystem of the country contains the highest biodiversity and have a considerable economic and ecological importance to the nation,
- The long history of deforestation and forest degradation has critically threatened forest and woodland ecosystem of Ethiopia,
- Ethiopia has established many Protected Areas but most of these Protected Areas are currently under huge pressure and inadequately protected,
- The continuous impacts on biodiversity and ecosystem services will indisputably deteriorate environmental health and human well-being,
- Environmental marketing schemes (e.g., water, biodiversity, carbon trading, etc.) should be introduced to enhance conservation and sustainable use of forest and woodland ecosystems,
- Analysis of the impacts of policies and institutional arrangements on biodiversity conservation and ecosystem services shows a huge gap between legal and policy design and implementation,
- The existing efforts have focused on developing policies and strategies, while little has been done to strengthen institutional arrangement and implementation on the ground,
- Lack of proper implementation instruments not only undermine forest and biodiversity conservation but also hinder national efforts to halt deforestation and achieve the country's ambitious plan for fast and sustainable development,
- Government need to translate policy and legal provisions regarding forest and biodiversity into implementation instruments such as regulations, directives, and guidelines, and
- Accurate and up-to-date information and records that contain comprehensive legal and spatial information about forest and biodiversity conservation areas should be maintained centrally both at regional state and federal level and should be freely accessible by the public.

3.1 Introduction

Ethiopia is located between 3° 24’ to 14° 53’ N latitude and 33° 00’ to 48° 00’ E longitude; and within the altitudinal range of between 125 m bsl and 4533 m asl. Topographically, the country possesses an extensive area of highlands, surrounded by lowlands in all directions. The Great Rift Valley system runs from northeast to southwest through eastern Africa toward Mozambique and divides the country into the northwestern and southeastern highlands.

Ethiopia is endowed with unique ecosystems and biodiversity that provide considerable contribution to people at local, regional and global levels. A great proportion of these biodiversity and ecosystem services are mainly prevailing in forest and woodland ecosystem of the country. According to various sources (e.g., Logan, 1946; von Breitenbach, 1963; EFAP, 1994; Darbyshire et al., 2003; Nyssen et al., 2004; Bishaw, 2009), the Ethiopian high forests and woodlands used to cover about 60% of the total land area of the country a century ago. This ecosystem is a reservoir for several economically important wild plants, e.g., *Commiphora* and *Boswellia* species and wild gene pools of *Coffea arabica* (Senbeta, 2006; EBI, 2014). Specifically, they contribute regulating, material and non-materials services although the monetary values of the services are not yet accurately estimated.

Forests and woodlands play vital roles in ensuring food security and sustainable livelihoods for millions of households throughout Ethiopia. According to a study report (UNEP, 2016), Ethiopia’s forests generated economic benefits in the form of cash and in-kind income equivalent to USD 16.7 billion, or 12.9% of the measured value of GDP in the year 2012-13. Recent estimates indicate that about 26-30% of the total coffee production of the country originates from wild and semi-managed coffee forests and the value of wild coffee is estimated at USD 130 million/annum (Tesfaye, 2006; Lemenih, 2009). Furthermore, Ethiopia has also earned USD 12.68 million from the export of gums and incense in the year 2009/10 (MoFED, 2010).

Since the 1960s, much effort has gone into designating protected areas in Ethiopia with the hope of saving areas of crucial importance for biodiversity conservation. As a result, Ethiopia has established many conservation areas in forest and woodland ecosystem that include biosphere reserves, forest priority areas, national parks, sanctuaries, reserves and controlled hunting areas that cover over 14% of total land surface area of the country (EWNHS, 1996; UNDP, 2017;

MEFCC, 2018). Although a complete biodiversity survey is lacking, this ecosystem possesses unique genetic, species and ecosystem diversity and have huge economic value. For example, protected areas that are managed by Ethiopian Wildlife Conservation Authority (EWCA) are estimated to generate about 1.5 billion USD per year (EWCA, 2009).

Despite the ecological and economic benefits it provides, the forest and woodland ecosystem of Ethiopia has been and is still heavily exposed to severe degradation over the years. In recent decades, unregulated agricultural expansion, unsustainable harvesting and weak institutional capacity have led to the devastation of forests and woodlands and their associated biodiversity. With the increasing population pressure, the natural vegetation is still being cleared at an alarming rate to open up land for agriculture and human settlements. The reduction of forests which have a remarkable capacity of preserving the land from degradation, together with factors such as civil war, ethnic conflict and drought, has placed the country in a position where its people cannot even feed themselves (Berisso, 1995). Deforestation and degradation of Forest and woodland ecosystem is more pronounced in the northern part of the country compared to its south and southwestern parts. While it is the northern part that suffered the most, the southern part of the country is also going through rapid environmental changes.

All these dynamics/impacts call for the promotion of eco-friendly living which is strongly linked to biodiversity. Environmental friendly living exists within the socioeconomic value of biodiversity. Biodiversity conservation, cultural survival and the search for new products are intractably linked. Unless such an integrated conservation, protection and wise utilization of resources are applied, the future of biodiversity will be unsustainable and countries like Ethiopia will face adverse food insecurity, health-related hazards, social, economy and political problems. As Ethiopia's economy is heavily relies on natural resources, the decline in biodiversity and ecosystem services will have serious implications for economic growth, human well-being and livelihood security of the nation.

Vegetation types of forest and woodland ecosystem

There are twelve major vegetation types in Ethiopia (Friis et al., 2010) (Figure 1). These include: 1. Desert and Semi-desert Scrubland (DSS) which occurs in areas with an altitude of < 400 m; 2. *Acacia-Commiphora* woodland and bushland, found in areas between 400 and 1800 m altitude; 3. Wooded grassland of the western Gambela region (WGG), found between altitudes of 450 and

600 m; 4. *Combretum-Terminalia* woodland and wooded grassland (CTW), occurring in areas between 400 and 1800 m; 5. Dry evergreen Afro-Montane Forest and Grassland complex (DAF), found in areas between 1800 and 3000 m altitude; 6. Moist Evergreen Afro-Montane Forest (MAF), found in areas with elevation between 1800 and 3000 meter; 7. Transitional Rain Forest (TRF), occurring in areas with an altitude of 500-1500 m; 8. Ericaceous Belt (EB), found in areas between 3000 and 3200 m altitude; 9. Afro-alpine vegetation (AA), found in areas at altitudes > 3200 m; 10. Riverine Vegetation (RV), found along rivers below 1800 m altitude and with variable width depending on topography and edaphic conditions, but typically is 20-50 m wide; 11. Freshwater lakes, lake shores, marshes, swamps and floodplain vegetation (FLV), found in areas identified in the Global Wetlands Database (GLWD) and the lakes for Africa layer as lakes or all shorelines of the freshwater lakes; and 12. Salt water lakes, lake shores, salt marshes and pan vegetation (SLV), occurs in areas in the GLWD database. Of the 12 Ecosystem/vegetation types, seven of them have forests and woodlands. Two additional vegetation types were recently described, namely Transitional semi-evergreen bushland (van Breugel et al., 2016) and Intermediate evergreen Afromontane forest (Berhanu et al., 2018); which were previously described as part of the Dry and Moist evergreen Afromontane forests (Friis et al., 2010).

The forest and woodland ecosystem is found in the Dry Evergreen Afromontane Forest and Grassland complex (DAF); Intermediate evergreen Afromontane Forest (IAF), Moist Evergreen Afromontane Forest (MAF); Riverine Forest (RF) and Transitional Rain Forest (TRF). The woodlands, on the other hand, occur mainly in *Acacia-Commiphora* woodland and bushland; *Combretum-Terminalia* woodland and wooded grassland (CTW) and Wooded Grassland of the western Gambela region (WGG) (Table 1).

The forest and woodland ecosystem encompass eight vegetation types of Ethiopia (Friis et al., 2010). Figure 1 gives the geographical distribution of these vegetation types.

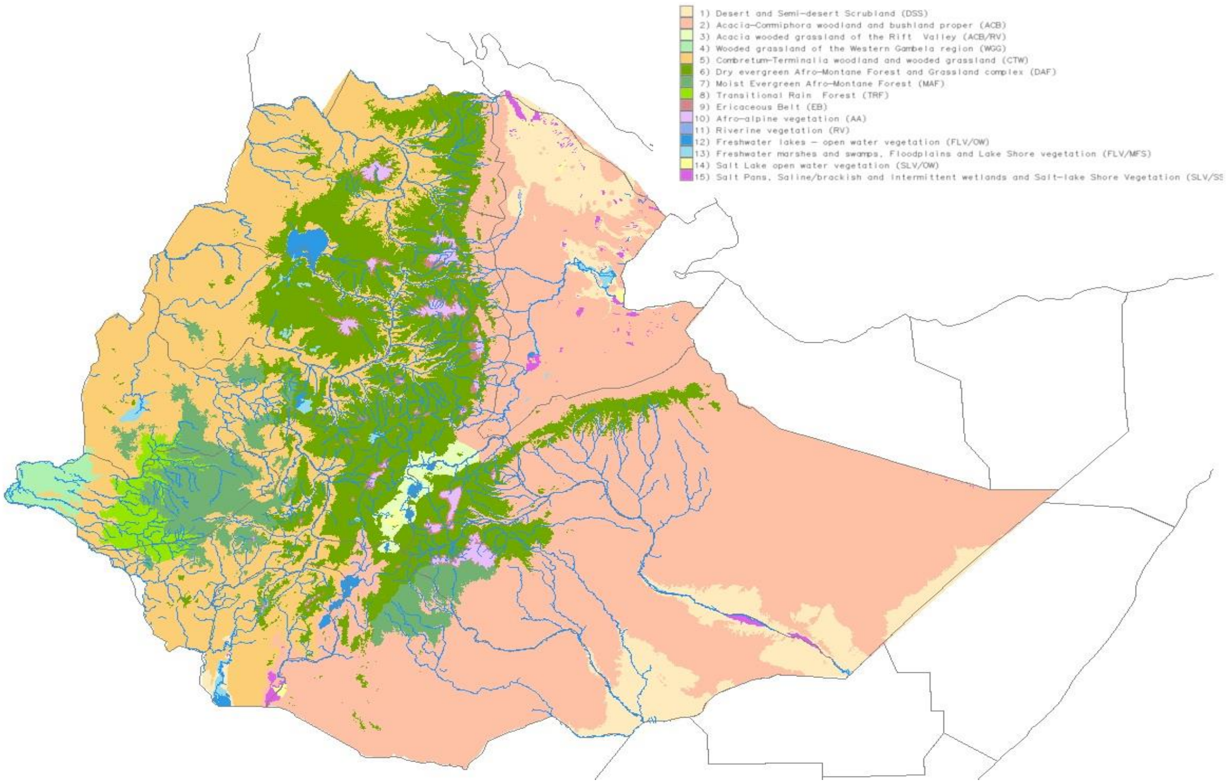


Figure 1. Atlas of Potential Vegetation types in Ethiopia (Source: Friis et al., 2010). Note that the newly described vegetation types (IAF & TSB) are not shown on the map.

Table 1. Details of the salient features and similarities of these vegetation types

Vegetation types	**Biological characteristics**			**Physical characteristics**
	Vegetation characteristics	Family	Species	
Dry Afro-montane Forest and Grassland complex (DAF)	Canopy dominated by *Podocarpus falcatus, Juniperus procera* and *Olea europea* subsp. *cuspidata* Comprises Afro-montane woodland and wooded grassland with Acacia *abyssinica, A. negri*[1], *A. pilispina, A. bavazanoi* and *A. montigena.*	Cuperssaceae		DAF occurs from 1800 – 3200 m asl. Its spatial distribution includes National Region States of Oromia (Shewa, Arsi, northern Bale and western Hararge), Amhara Region (Shewa, Gojam, Wello and Gonder), Tigray Region (Tigray) and SNNP region (Sidamo and Gamo Gofa).
		Podocarpaceae	*Podocarpus falcatus*	
		Fabaceae	*Acacia abyssinica, A. negeri, A. pilispina, A.*	

[1] Some of these species are endemic to the highlands of Ethiopia

			bavazanoi and *A. montigena.*	
Moist Evergreen Afro-montane Forest (MAF)	Canopy dominated by *Pouteria adolfi-friderici, Olea welwitchii, Albizia gummifera* and *Albizia schimperiana*	Sapotaceae	*Pouteria adolfi-friderici*	MAF occurs from1500 – 2600 m asl Its geographic distributions include southwestern part of the Ethiopian Highlands mainly in Oromia, SNNPR and Gambella (some part of Godere Forest) and on the southern slopes of the Bale Mountains in Oromia (Harenna Forest).
		Oleaceae	*Olea welwitchii*	
		Fabaceae	*Albizia gummifera* and *Albizia schimperiana*	
Intermediate Evergreen Moist Afro-montane Forest (IAF)	Share certain characteristics of MAF and DAF Closed evergreen strata of one of more *of Albizia gummifera, A. schimperiana* and *Celtis africana, Prunus africana*	Fabaceae	*Albizia gummifera A. schimperiana*	What are these intermediate climate It occurs from 1500 – 2800 m asl Its spatial extent includes West Gojam Zone (Bahirdar Zuria, Zege Peninsula); Gondar (western Farta on the west-facing slope of Mt. Guna); Awi Zone (most parts of Awi); Metekel Zone (on the plateau of eastern Wenbera, on the massive Mt. Belaya of Dangur, and smaller areas in Bullen and Mandura)
		Ulmaceae	*Celtis africana*	
		Rosaceae	*Prunus africana*	
Transitional Forest (TRF)		Sapotaceae	*Manilkara butugi* *Pouteria altissima* *Pouteria alnifolia*	TRF is found in the western parts of Ethiopia in Oromia (Wellega and Illubabor), Gambella (Godere and Abobo Forests) and in SNNPR (Kafa, Bench-Skeko and Sheka)
		Logianaceae	*Anthocleista schweinfurthii* *Strychnos mitis*	
		Moraceae	*Ficus mucuso* *F. exasperata* *Milicia excelsa* *Morus mesozygia*	

			Trilepisium madagascariense	
		Apocynaceae	*Alstonia boonei*	
		Euphorbiaceae	*Croton sylvaticus*	
		Ulmaceae	*Celtis toka* *C. zenkeri* *C. gomphophylla*	
		Ebenaceae	*Diospyros abyssinica*	
		Sapindaceae	*Zanha golungensis* *Lecaniodiscus fraxinifolius*	
		Meliaceae	*Trichilia dregeana*	
		Rutaceae	*Zanthoxylum leprieurii*	
		Fabaceae	*Albizia schimperiana* *A. grandibracteata*	
Riverine Forest (RF)		Ulmaceae	*Trema orientalis*	This vegetation type occurs along several major systems of rivers and tributaries such as Abay (Blue Nile), Awash, Baro, Omo, *Oncoba spinosa* Tekeze and Wabi Shebele Their tributaries have riverine forests in areas below approximately 1800 metres altitude Riverine forest vegetation is highly variable in structure and density, and the floristic composition is dependent on altitude and geographical location
		Flacourtiaceae	*Oncoba spinosa*	
		Annonaceae	*Uvaria* sp.	
Acacia – Commiphora Woodland and Bushland (ACB)	Characteristic species are drought resistant trees and shrubs, i.e., with deciduous or small, evergreen leaves	Fabaceae	*Acacia bussei* *A. drepanolobium A. hamulosa* *A. ogadensis* *A. prasinata* (endemic)	It occurs in the northern, eastern, central and southern part of the country mainly in Oromia, Afar, Harari, Somali, and SNNPR
		Burseraceae	*Boswellia microphylla* *B. neglecta,* *Commiphora alaticaulis* *C. albiflora* *C. ancistrophora, C. boiviniana* *C. boranensis*	
		Balanitaceae	*Balanites aegyptiaca* *B. rotundifolia*	

		Capparidaceae	*Boscia minimifolia* *Cadaba ruspolii* *C. rotundifolia* *Capparis tomentosa*	
		Combretaceae	*Combretum aculeatum* *Terminalia orbicularis*	
Combretum – Terminalia Woodland and wooded Grassland	Characteristic species have small to moderate-sized trees with fairly large deciduous leaves	Burseraceae	*Boswellia papyrifera*	It altitude ranges from 500 – 1900 m asl It occurs in the Tekeze valley, western parts of Benshangul- Gumuz and North to the village of Gelego and south of Metema
		Araliaceae	*Cussonia arborea*	
		Combretaceae	*Anogeissus leiocarpa* *Combretum Vitex doniana adenogonium* *C. hartmannianum* (near endemic) *C. mole* *C. rochetianum* (near endemic) *C. collinum,* *Terminalia laxiflora* *T. macroptera* *T. schimperiana*	
		Fabaceae	*Lonchocarpus laxiflorus* *Pterocarpus lucens* *Dalbergia melanoxylon* *Piliostigma thonningii*	
		Balanitaceae	*Balanites aegyptiaca*	
		Bignoniaceae	*Stereospermum kunthianum*	
		Anacardiaceae	*Lannea barteri* *L. fruticose* *L. schimperi* and *L. schweinfurthii Ozoroa insignis, O. pulcherrima* *Sclerocarya birrea* subsp. *birrea*	
		Lamiaceae	*Vitex doniana*	
		Fabaceae	*Acacia hockii*	
		Tiliaceae	*Grewia mollis*	
		Bombacaceae	*Adansonia digitata*	
Wooded		Fabaceae	*A. seyal*	It occurs between 450-500 m

Grassland of the Western Gambella Region (WGG)		*A. nilotica*	asl Dominant vegetation in western Gambella Region.
	Arecaceae	*Hyphaene thebaica* *Borassus aethiopum*	

This chapter of the National Ecosystem Assessment provides published information on the forest and woodland ecosystem of Ethiopia with regard to its current status, drivers of changes, future trends and an analysis of the policies and legal instruments. Furthermore, indigenous and local knowledge pertaining to this ecosystem will also be reviewed.

3.2 Forest and woodland ecosystem services and benefits to people and quality of life

According to the FRA (2010), 'Forest' is defined as land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10% or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use. On the other hand, 'Woodland' is land not classified as "Forest" spanning more than 0.5 hectares with trees higher than 5 m and a canopy cover of 5-10% or trees able to reach these thresholds; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use.

3.2.1 Benefits of Forest and Woodland ecosystem

The benefits obtained from forest and woodland ecosystem fall into the four major categories (provisioning, regulating, supporting and cultural) services. However, under this chapter presented as Regulating, Material, and Non-material contributions).

3.2.1.1 Regulating contributions

Regulating contributions are "functional and structural aspects of organisms and ecosystems that modify environmental conditions experienced by people, and/or sustain and/or regulate the generation of material and non-material contributions" (Diaz et al., 2018). These are also referred to as environmental benefits. Among the many ecosystem regulating services identified, forests provide what are referred to as the "big three". These include climate change regulation (carbon storage), watershed protection services and biodiversity conservation (FAO, 2007). As these are not directly traded on the market, at times it is often difficult to put monetary value. Nonetheless, there are several attempts to quantify the values of the services using various approaches. The first comprehensive attempt to value global ecosystem services was the work of Costanza et al. (1997) that estimated the ecological benefits of forests to be USD 33 trillion, a number nearly twice the then global gross product. Other estimates also attach similar values to the services of forests and woodland ecosystem provide (Krieger, 2001; Rojahn, 2006). For instance, Rojahn (2006) estimated the pharmaceutical value of 18 global biodiversity hotspot sites to lie between USD 231- 900 per ha per year (Table 2).

Table 2. Global average estimates of values of selected ecosystem regulating services (Source: Costanza et al., 1997; Krieger, 2001)

Ecosystem service	Estimated Value (USD/ha/yr)
Climate regulation	223
Water quality regulation	6
Water supply	8
Erosion control and sediment retention	245
Soil formation	10
Nutrient recycling	922
Biodiversity conservation (genetic resources conservation)	41
Recreation	112
Cultural	2

Forests and woodlands contribute to Climate regulation. However, due to increased human and livestock population in Ethiopia, the forest and woodland coverage is decreasing in size with negative implications to climate change and affecting its ability to regulate leading to negative consequences mentioned below.

- Increases in seasonal mean temperatures have been observed across Ethiopia over past 50 years, and the length of the growing season is reduced by ~15% in the region,
- Increased rates of warming are associated with all greenhouse gas emissions scenarios. Under a business as usual scenario, median temperature increases of approximately 4^{o}C are projected. With ambitious reductions in emissions, warming may be contained within the 2^{o}C threshold associated with dangerous climate change,
- Increased rainfall intensity is likely to result in greater likelihood of flood events. Greater extreme hot events are also expected. The impact of climate change on drought is unclear

and depends on the balance between increased rainfall and increased evaporation losses,

- Climate change will reduce agricultural production and output in sectors linked to agriculture and is likely to reduce GDP by ~10%. At an individual level climate change is likely to raise income inequality, reduce household wealth and fuel poverty,
- Food production is expected to be consistently and negatively impacted and compound challenges of food security. Changes in rainfall will make critical problems at household level such as dates for preparing and planting more difficult. Large decreases in the productivity of major cereals have been projected. Coupled with small and decreasing farm sizes adaptation to future impacts will be challenging,
- Benefits of potentially increased rainfall will be compromised by increased floods and soil erosion, which are associated with increased sediments and pollutants in fresh water bodies. A number of studies of the response of major rivers suggest decreasing river flows towards the end of the century due to increasing temperatures and associated evaporation losses,
- Rising temperatures and increases in rainfall intensity may shift or extend the areas affected by vector borne diseases. Increased occurrence of floods and heat waves will also have implications for health, as will impacts on food production,
- Women are more reliant on agriculture than men and are therefore likely to be more adversely affected by climate change. In addition water access also has important gender dimensions with young girls in particular being more vulnerable to changes in water availability and competition, and
- Historically drought has been a major driver of population movements in Ethiopia. Research is also highlighting that issues with land tenure, coupled with increases in climatic extremes are acting as important drivers of rural-urban migration in the northern highland of Ethiopia under present conditions. Increases in the frequency of extreme events is likely to reducing coping capacities and increase rates of migration with social and cultural impacts in both sending and receiving areas.

3.2.1.2 Material contributions

Material contributions are “substances, objects or other material elements from nature that directly sustain people’s physical existence and infrastructure” (Diaz et al., 2018). These are also referred to as Economic benefits. These are mainly material that one obtains from nature that directly allow people to sustain themselves (food, energy, medicinal plants, spices) and acquire material assets. Ethiopian forests and woodlands are depositories and gene pools for several domesticated and/or important wild plants and wild relatives of domesticated plants. For example, Coffee (*Coffea arabica*) is found in the wild in the Moist Evergreen Afromontane forests and Transitional Rain forests of western and southwestern parts of Ethiopia (IBC, 2005) (Figure 2). The following are some of the facts about coffee and coffee systems in Ethiopia (Williams et al., 2017):

- Ethiopia can be considered as the biological and cultural home of coffee. In its wild state, Arabica coffee (*Coffea arabica*) is a forest plant restricted to the highlands of Ethiopia and a small area in neighbouring South Sudan (Davis et al., 2012),
- An estimated 525,000 hectares (5,250 km^2) of coffee are planted in Ethiopia (Tefera, 2015),
- Contributing around one quarter of its total export earnings in 2014/15, Ethiopia exported around 180,000 metric tonnes of coffee at a value estimated to be in excess of 800 million USD (International Coffee Organization, 2015), and
- Coffee farming provides a livelihood income for around 15 million Ethiopians (16% of the population), based on four million smallholder farms (Tefera, 2015; Minten et al., 2014; Tefera and Tefera, 2014).

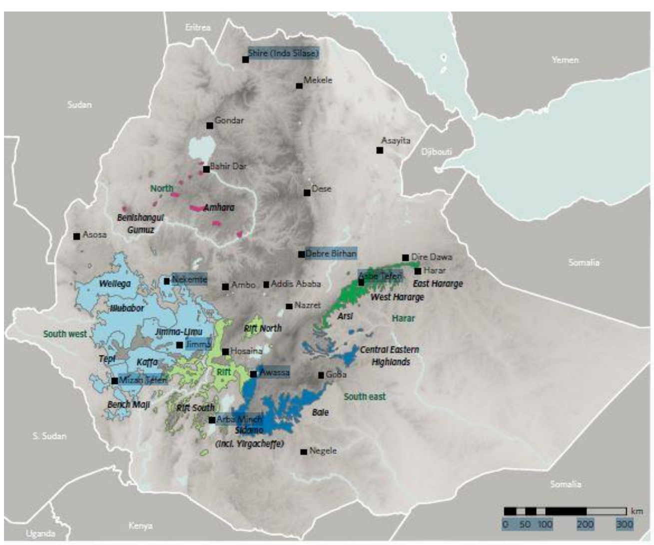


Figure 2. Coffee producing areas in Ethiopia (Source: Williams et al., 2017).

According to Williams, et al., (2017), forest cover is important for coffee because it provides the right conditions for successful cultivation, by reducing daytime air and soil temperatures, increasing humidity and preserving soil moisture. It also has key benefits for agricultural (and natural) ecosystem, including nutrient recycling, soil preservation, watershed preservation, pollination services, temperature buffering, shelter from wind and heavy rainfall, and carbon storage. Ethiopia's coffee forests also provide a home for a diverse assemblage of plants and animals, and are thus important for biodiversity preservation. Data on Ethiopian Coffee (production, area coverage, productivity, etc.) from 2003 to 2016 is shown in Table 3; and trends of Ethiopian Coffee production and Export is shown in Figure 3.

Table 2. Ethiopian Coffee Information, (2003-2016).

Production year	No. of farmers in coffee Production	Average coverage in ha	Production in quintals	Production in quintals/ha
2003/04	2,420,827	232,439	1,261,880	5.43
2004/05	2,587,552	260,201	1,561,707	6.0
2005/06	2,699,477	261,175	1,716,310	6.63
2006/07	2,716,311	295,237.96	2,414,823.85	8.24
2007/08	3,499,219	40,714.07	2,734,001.33	6.77
2008/09	3,223,355	391,296	2,602,392	6.65
2009/10	2,959,093	395,003.48	2,654,693	6.72
2010/11	3,854,931	498,617.85	3,705,694.44	7.43
2011/12	4,042,234	515,882.46	3,768,231.72	7.3
2012/13	4,217,961	528,751.11	2,755,298.73	5,21
2013/14	4,546,785	538,466.80	3,920,062.22	7.28
2014/15	4,723,483	561,761.82	4,199,800.00	7.48
2015/16	5,270,777	653,909.00	4,145,960,00	6.34
2016/17	5,270,777	700,474.69	4,690,910.12	6.7

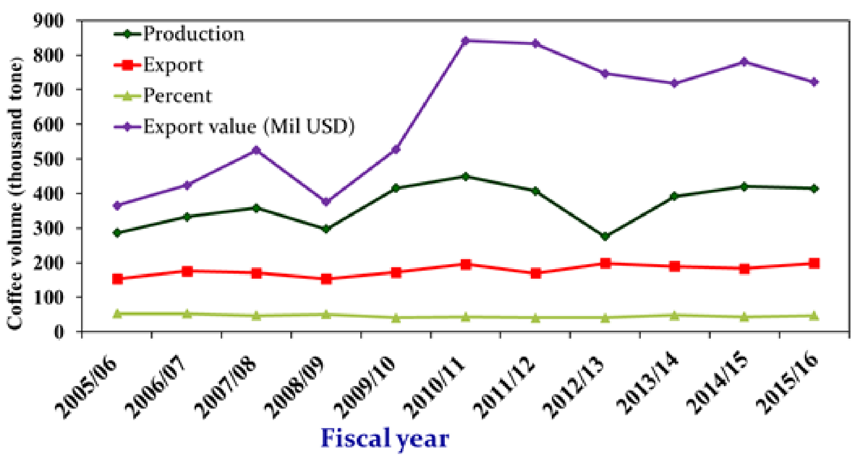


Figure 3. Trends of Ethiopian coffee production and export (Source: ICO, 205/6-2015/16).

Non-timber forest products (NTFPs) play important role in Ethiopian national economy and rural livelihoods. A number of NTFPs have been traded in national and international markets (e.g. forest coffee and honey). A study conducted in southwest Ethiopia focusing on NTFPs (Chilalo and Wiersum, 2011) provided information on the economic importance in the context of this Forest Sector (Table 4).

Table 3. Livelihood activities derived from NTFPs and annual income, ETB/year (Source: Chilalo and Wiersum, 2011)

Activities[1]	**No. of households**	**Percentage**	**Mean revenues (ETB[2]/ household/ year)**
Farming and forest coffee plus honey production	6	4	3,614
Forest coffee production	32	22	2,700
Farming and forest coffee production	5	4	2,700
Honey production	7	5	2,224
Farming combined with production of forest coffee, honey, spices and bamboo	10	7	1,489
Farming and honey production	15	10	1,444
Farming	70	48	1,317

(1) The categories of activities indicate the respondents' opinions with respect to their major occupation. The categorization does not preclude households being engaged in minor additional activities.
(2) ETB = Ethiopian Birr, in the year of research the exchange was approximately US$1 = 8.5 ETB

Ethiopia's vast dry land areas generally known as woodlands harbour a number of plant species of economic importance. These include species in the family Leguminosae including the genus *Acacia* and in the Family Burseraceae including the genera *Boswellia* and *Commiphora*, which provide important gums and incense such as gum arabic, frankincense and myrrh. These products are used in various applications from local use to industrial scale with multi-billion-dollar industries. Ethiopia is among the major producer countries of these products. Gum and resin producing species grow on an area of between 2,855,000 and 4,355,000 hectares. In Ethiopia, there is a distinction between aromatic gums/resins and non-aromatic gums/resins as shown in Table 5 and the export of these is shown in Table 6.

Table 4. Commercial gums and resins of Ethiopia (Source: Kassa and Lemenih, 2011)

Category	**Common name**	**Botanical name**
Aromatic gums/resins	Frankincense/Gum olibanum	*Boswellia papyrifera, B. neglecta, B. rivae, B. microphylla, B. ogadensis*
	True myrrh	*Commiphora myrrha*
	Opoponax	*Commiphora guidotti*
	Hagar	*Commiphora erythraea*, *C. africana*, others
Non-aromatic gums/ resins (gum arabic)	True arabic gum	*Acacia senegal*
	Gum talha	*Acacia seyal*

Table 5. Gums and resins export of Ethiopia from 2003 to 2014 (Source: NGPME, 2014).

Year of production	National export of gums and resins		Year of production	National export of gums and resins	
	Quantity (tons)	Value (in 1000 USD)		Quantity (tons)	Value (in 1000 USD)
2003	1,544	2,200	2010	4,374	12,686
2004	3,109	4,369	2011	4,417	12,750
2005	3,791	4,960	2012	3,504	11,758
2006	3,529	5,363	2013	3,145	10,825
2007	3,976	5,650	2014	3,442	12,151
2008	4,612	6,918	**Averages**	**3,584**	**8,275**
2009	3,563	9,675			

A summary of the contribution of forests to national income in Ethiopia was documented in UNEP (2016). In this document, forest provisioning goods and service contributed about 96.6 billion ETB to national income in 2012-13 (USD 14.8 billion; 11.41% of GDP) of which the most important product being fuel wood (39.1 billion ETB; USD5.9 billion).

Ethiopia has a huge potential to use hydropower as a source of clean energy (Table 7). According to Ethiopia Power System Expansion Master Plan Study Volume 3, Ethiopia’s power is currently generated almost entirely from hydropower. It is also expected that the country’s electricity demand will be met by scaling up renewable generation capacity. The plan is to increase the capacity to approximately 24,092 MW by 2030 and further diversify the energy mix to reduce dependence on hydropower (in recognition of the vulnerability of hydropower to rainfall variability). This will enable Ethiopia to meet future domestic peak demand (estimated at 14,213 MW by 2030) and export additional electricity (maximum demand estimated at 3,655 MW by 2030) to provide a critical source of economic value of forest provisioning services (UNEP, 2016).

Table 6. List of Hydro power plants in Ethiopia (Source: Ethiopian Electric Power. Retrieved 14 September 2017:

ICS Power plant	Coordi-nates	River	Drainage Basin	Installed capacity (MW_e)	Capacity factor (2016/17)	Total reservoir size [km^3]	Dam height [m] run-of-river	Irrigation area [km^2]	Operational since	Status	Notes
Aba Samuel	8.788°N 38.706°E	Akaki	Afar Triangle	6.6	0.25	0.035	22	no	1932		Rehabilitation 1970 to 2016
Koka (Awash I)	8.468°N 39.156°E	Awash	Afar Triangle	43	0.23	1.9	47	no	1960		
Awash II+III	8.393°N 39.352°E	Awash	Afar Triangle	64	0.21	river	run-of-river	no	1966 1971		
Fincha	9.561°N 37.413°E	Fincha	Abbay	134	0.63	0.65	20	no	1973		
Fincha Amerti Neshe (FAN)	9.789°N 37.269°E	Amerti / Neshe	Abbay	95	0.13	0.19	38	127	2011		
Gilgel Gibe I	7.831°N 37.322°E	Gilgel Gibe	Turkana Basin	184	0.43	0.92	40	no	2004		Cascade with Gilgel Gibe II
Gilgel Gibe II	7.757°N 37.562°E	Gilgel Gibe / Omo	Turkana Basin	420	0.41	diversion weir	46.5	no	2010		Cascade with Gilgel Gibe I
Gilgel Gibe III	6.844°N 37.301°E	Omo	Turkana Basin	1,870	0.30	14.7	243	no	2016		Cascade with Koysha
Koysha	6.584°N 36.565°E	Omo	Turkana Basin	(2,160)	(0.34)	6	179	no		Under constructi on	Cascade with Gilgel Gibe III
Melka Wakena	7.225°N 39.462°E	Shebelle	Shebelle	153	0.30	0.75	42	no	1989		
Tana Beles	11.82°N 36.92°E	Beles	Nile	460	0.61	9.1	floodgates	1,400	2010		
Tekeze	13.348° N 38.742°E	Tekeze	Nile	300	0.26	9.3	188	no	2010		
Tis Abay I+II	11.486°	Blue Nile	Nile	84.4	0.015	river	run-of-	no	1953		

	N 37.587°E						river		2001		
GERD (Hidase)	11.214° N 35.089°E	Abbay	Abbay	(6,450)	(0.28)	74	155	no		Under construction, 65% complete (4/2018)	*de facto cascade* with Roseires Dam
Genale Dawa III	5.51°N 39.718°E	Ganale	Jubba	254	0	2.6	110	no	2017	Operational, but out of use for social reasons	cascade with Genale Dawa VI
Genale Dawa VI	5.68°N 40.93°E	Ganale	Jubba	(257)	(0.67)	0.18	39	270		Project implementation	Cascade with Genale Dawa III Public-Private Partnership
Geba I+II	8.211°N 36.073°E	Gebba	Abbay	(385)	(0.52)	1.4	46 70	4,800		Project implementation	
Total 13,320 MWe; Total operational 4,068 MWe											

Despite the significant recent effort to generate energy from hydropower, most households still rely on traditional fuels for their domestic energy needs; biomass is currently the largest fuel source to meet energy needs and continues to account for 72% of total final energy consumption by 2030. Domestic energy requirements are mostly met from wood, animal dung and agricultural residues. It was estimated that biomass energy accounted for 89% of the total national energy consumption in 2010; about 81% of the estimated 16 million households use firewood and 11.5% use leaves and dung cakes for cooking (Geissler et al., 2013).

3.2.1.3 Non-material contributions

Non-material contributions are "nature's impacts on subjective or psychological aspects underpinning people's quality of life, both individually and collectively. The entities that provide these intangible contributions may be physically consumed in the process in what would be considered a material contribution (e.g. animals in ritual fishing) or not (individual trees or ecosystems as a source of inspiration)" (Diaz et al., 2018).

Ethiopian forests, beside their material benefit, provide non-material contributions in a variety of ways. One of the examples, in this regard, comes from the Basketo landscape in Southern Nations Nationalities and Peoples region. The sacred forests of this area (*tsoose*), which represent remnants of the original vegetation of the area, serve different functions: they are ritual sites where the local thanksgiving ceremony (*kaasha*) is conducted as a manifestation to the desire to maintain connectedness among components of the larger community (cosmos); they maintain important elements (species) of the original forest vegetation; they may have a seedbank role since economically important crops like *kororima* (*Aframomum corrorima*) grow spontaneously; and they are breeding sites of birds and other small animals which may serve important ecological functions such as pollination, seed dispersal and pest control (Woldeyes et al., 2016; Woldeyes and Shigeta, 2020).

3.3 Status, Trend and future dynamics of Forest and Woodland ecosystem

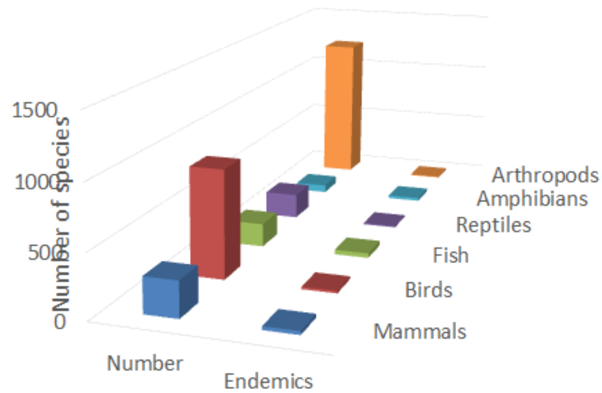
3.3.1 Status of forest and woodland ecosystem and associated species

The forest and woodland ecosystem represents the major and diverse terrestrial ecosystem of Ethiopia. This ecosystem is part of the two of the world's 36 biodiversity hotspots and houses the only global wild Arabica coffee populations. The estimated forest and woodland cover of Ethiopia was close to 300,000 km^2, which was about 27 % of the total land area of the country (Bekele and Berhanu, 2001). According to MEFCC (2018), however, forest and woodland covers estimated to be about 17.35 million ha (15.7% of the country area). The difference in the proportion of area covered by forest and wood land system (between the years 2001 and 2018) demonstrates a continuous change of this ecosystem due to land use pressure.

The forest and woodland ecosystem of Ethiopia makes the largest part of the major Protected Area Systems of the country such as National Parks, Wildlife Reserves, Sanctuaries and Controlled Hunting Areas. Furthermore, the 58 National Forest Priority Areas (NFPAs) were designated inside this ecosystem. The forest and woodland ecosystem of Ethiopia is under serious threats due to deforestation and forest degradation, overexploitation, overgrazing and invasive species. Poverty, population growth, lack of alternative livelihoods, inadequate policy support, inappropriate investment and inadequacy of law enforcement are the drivers for loss of forest and woodland ecosystem (IBC, 2009). During the last century, Ethiopia's forest and woodland declined both in size and quality.

3.3.2 Status of species diversity of forest and woodland ecosystem

Ethiopia is one of the top 25 biodiversity rich countries of the World (WCMC, 1994). The vascular flora of Ethiopia is known to be 6027 species, of which about 10% are endemic (Kelbessa & Demissew, 2014) and many of these species are found in forest and woodland ecosystem (Brenan, 1978; Thulin, 1983; Gebre-Egziabher, 1991). With regard to faunal diversity, arthropods are the most species rich group whereas birds stand next to them (Figure 4). What is important to note here is that arthropods, reptiles and amphibians are the least studied groups. Therefore, the overall number of species and endemic species of Ethiopian fauna may be significantly higher than reported by IBC (2009). Overall, the forest and woodlands of Ethiopia contain the highest biodiversity and have a considerable economic and ecological importance to the nation.



	Number	Endemics
Mammals	284	29
Birds	861	18
Fish	188	37
Reptiles	201	10
Amphibians	63	25
Arthropods	1225	7

■ Mammals ■ Birds ■ Fish ■ Reptiles ■ Amphibians ■ Arthropods

Figure 4. Fauna diversity and endemism in Ethiopia.

The species diversity of the forest and woodland ecosystem vary within and among the vegetation types. Even though a complete inventory of both flora and fauna diversity of forest and woodland ecosystem is lacking, most of them are recognized as important centers of diversity. The estimated number of woody species, mammals and bird species that are found in each ecosystem type is presented in Table 8.

Table 7. Number of woody plants, mammals and bird species of Forest and Woodland ecosystem of Ethiopia (Source: EWNHS, 1996; Woldermariam, 2003; Senbeta, 2006; Friis et al., 2010; Rodrigues et al., 2018, 2019)

Number of Species	Vegetation types of forest and woodland ecosystem					Total for forest and woodland ecosystem
	ACB	CTW	DAF	MAF	TRF	
Woody species	542	199	460	135	101	1000
Mammal species	>100	>50	20	26	33	284
Bird species	>300	>154	56	131	120	>781
Total	>900	>403	506	292	254	-

3.3.3 Status of protected areas

The International Union for Conservation of Nature (IUCN) defined protected areas as areas especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means. So, the concept of protected area encompasses community conservation areas, national parks, controlled hunting areas, sanctuaries, wildlife reserves, biosphere reserves, forest priority areas, and lakes. Hence, protected areas are vital for the conservation of biodiversity. They are integral part of sustainable development enabling the protection of wider landscapes and watersheds as source of important ecosystem services and climate change adaptation and mitigation. They act as refuges for species and ecological processes that cannot survive in intensely managed landscapes. Often, they provide other essential benefits for local communities as well as the national economy at large.

Since early 1960s, Ethiopia has designated many protected areas that include 22 National parks, 5 biosphere reserves, 2 sanctuaries, 2 reserve areas, 3 community conservation areas, many controlled hunting areas and 58 National Forest Priority Areas of which about 37 have been identified as protected forests (MEFCC, 2018). These protected areas cover about 14% of the total area of the country. As indicated above, the majority of are located in forest and woodland ecosystem of the country (Tables 9 & 10).

Despite the designation of various protected areas in Ethiopia, the efforts made so far to conserve and manage this ecosystem has never been satisfactory. These protected areas have been facing a range of threats such as illegal grazing by domestic animal, increased human population growth, expansion of invasive alien species, encroachment of human settlement, human-wildlife conflict, lack of alternative livelihood activities for local community residing adjacent to protected areas, land use pressure and others (Wale et al., 2017). Sustainable and effective protected area management calls for a move away from business as usual towards a greater diversity and decentralized system. The cause of the whole problem is the human factor. Any remedy or palliative must be based on gaining the cooperation of the local community at large in and around the protected areas.

Table 8. Protected Areas of Ethiopia, with their area coverage and ecosystem types (Source: MEFCC 2018).

Name of Protected Area	Key animal/plant species	Major vegetation type	Year established	Area (km2)
National Parks, Sanctuaries, Biosphere Reserves				
Awash National Park	Beisa Oryx, Lesser Kudu, Waterbuck,	ACB	1958	756
Simein Mountains National Park	Walia Ibex, Ethiopian Wolf, Gelada Baboon	DAF, CTW	1959	412
Alitash National Park	Elephant	CTW	1997	2,666
Bahir Dar Blue Nile river	-	Mixed	2008	4,729
Borena Sayint National Park	-	DAF	2001	4,325
Bale Mountains National Park	Nyala, Minelik's Bushbuck, Ethiopian Wolf	MAF/DAF	1962	2,200
Abijata-Shalla Lakes National Park	Pelican, Flamingoes	ACB	1963	887
Omo National Park	Common Eland, Buffalo, Elephant	CTW	1959	3,566
Nechsar National Park	Zebra, Greater and LesserKudu	ACB	1966	514
Mago National Park	Buffalo, Zebra, Hippopotamus	CTW	1974	1,942
Chebera Churchura National Park	Elephant, Lion	MAF, CTW,TRF	1997	1,190
Maze National Park	Swayne's hartebeest,Oribi	CTW	1997	202
Yangudi-rassa National Park	Wild Ass, Soemmoring's Gazelle	ACB	1969	4,731
Gambela National Park	Nile Lechwe, Buffalo, Elephant	CTW, TRF	1966	5,061
Geraile National Park	Beisa Oryx, Grant's Gazelle	ACB	1998	3,558
Dati Wolel National Park	-	-	1998	1,035
Borena National Park	-	ACB	1978	3,730
Gibe Sheleko National Park	-	CTW	2001	248
Loka Abaya National Park	-	ACB	2001	500
Kafeta Shiraro National Park	Elephant, Roan Antelope	CTW	1999	5,000
Arsi Mountains National Park	-	ACB	1986	931
Gibe Valley National Park	-	CTW	-	-
Yayu Coffee Forest Biosphere Reserve	Arabica coffee	MAF, TRF	2010	1,670.21
Kafa Biosphere Reserve	Arabica coffee	MAF	2010	5,406.31
Sheka Forest Biosphere Reserve		MAF, TRF	2015	2,387.50

Majang Biosphere Reserve	Arabica coffee	MAF, TRF,	2017	2,254.90
Babile elephant sanctuary	Elephant	ACB	1962	6,987
Senkele sanctuary	Swayne's hartebeest	ACB	1964	54
Tama reserve	-	-	-	1,665
Chelbi reserve	-	-	-	4,212
Controlled Hunting Areas				
Abasheba Demero	-	-	1994	210
Areba-Gugu	-	-	1995	321
Dindin	-	-	-	280
Besemena-Odobulu	-	-	1993	350
Munessa-Kukie	-	-	1993	111
Shedem Berbere Hanto	-	-	1988	170
Hanto	-	-	1991	190
Bilen Hertalie	-	-	-	1,090
Chifera	-	-	1998	510
Telalak-Dewe	-	-	-	457
Murullie	-	-	-	690
Wilshet-Sala	-	-	2000	350
Sororo-Torgam	-	-	2000	78
Haro Abadiko	-	-	2000	248
Urgan Bula	-	-	2000	78
Hurfa Soma	-	-	2000	215
Adaba-Dodola	-	-	2000	736
Open Hunting Areas				
Gara Gumbi	-	-	-	140
Gara Miti	-	-	-	240
Alluto	-	-	-	89
Sinana	-	-	-	15
Jibat	-	-	-	97
Debre Libanos	-	-	-	31
Gelila Dura	-	-	-	140
Community Conservation Areas				
Simien Gibe	-	-	2001	49
Garameba	-	-	2001	25
Guassa	-	-	-	-
Total				**79,729.70**

Table 9. National forest priority areas and their major ecosystem types of Ethiopia (Source: EFAP, 1994).

No.	Name of National Forest Priority Area	Total (ha)	Major vegetation type
1	Abelti-Gibe	10,000	CTW
2	Abobo-Gog	218,000	CTW, TRF
3	Aloshe-Batu-Adaba-Dodola	40,000	DAF
4	Anferara-Wadera	106,600	DAF
5	Arba Gugu	21,400	DAF
6	Babya Fola	74,300	MAF
7	Belete-Gera	148,500	MAF
8	Bonga	161,400	MAF
9	Bore-Anferara	217,300	DAF
10	Bulki-Malakoza	11,000	DAF
11	Butajira	15,000	DAF
12	Butuji-Melka-Jebdu	45,200	DAF
13	Chato-Sengi-Dengeb	44,860	DAF
14	Chilimo-Gaje	26,000	DAF
15	CilaloGalema	22,000	DAF
16	Denkoro	5,300	DAF
17	Desa	20,000	DAF
18	DindinArbagugu	66,800	DAF
19	GaraMulata	7,000	DAF
20	GebreDima	16,5000	DAF
21	Gedo	10,000	DAF
22	Gergeda	137,400	MAF
23	Gidame	17,000	MAF
24	Gidola-Gamba	30,000	MAF
25	Gidole-Gamba	16,000	MAF
26	Godere	160,000	TRF
27	Goro-Bele	100,000	MAF
28	Guangua-Kaihtas	56,500	DAF
29	Gumburda-Grakaso	26,000	DAF
30	GuraFerda	140,000	CTW
31	Harena-Kokosa	182,000	MAF
32	Jalo-Muktar-Metakesha-A	21,300	DAF
33	Jaro-Gursum	52,300	DAF
34	Jibat-Mute-Jegefo	38,500	DAF
35	Jurgo-Wato	19,900	MAF
36	Komto-Waja-Tsege	9,100	MAF
37	Konchi	13,000	DAF
38	Kubayu	78,400	DAF
39	Linche-Dali-Gewe	50,000	DAF
40	Logo	59,000	DAF
41	Megada	20,800	DAF
42	Mena-Angetu	190,000	MAF
43	Menagesha-Suba	9,800	DAF
44	Messenigo	325,000	DAF

45	MunesaShashemene	98,00	DAF
46	Negele	17,800	DAF
47	Sekela Mariam	10,000	DAF
48	Sele-Anderacha	225,000	MAF
49	Sibo-Tale Kobo	100,000	MAF
50	SigmoGeba	280,000	MAF
51	TiroBoterBecho	85,800	MAF
52	Wangus	415,000	DAF
53	Wof-Washa	8,900	DAF
54	Yabelo-Arero	49,900	DAF
55	Yayu	150,000	MAF
56	Yegof-Erike	18,000	DAF
57	Yeki	122,000	MAF
58	Yerer-Diregebrecha-Zukala	9,600	DAF
	Total	**4,777,860**	

3.3.4 Threats

Forest and woodland ecosystem has long been threatened by a variety of land use pressures in Ethiopia. Deforestation and forest degradation are still the major threats to the natural ecosystems. The key driving forces behind deforestation have been the expansion of agricultural land, unsustainable exploitation of forest resources, logging, non-forestry investment and establishment of new settlements in the forests and woodlands (Table 11). In addition, forest fire, invasive species, and insect pest outbreak are putting immense pressure on this ecosystem. These and other related human activities are still widely prevailing and threatening the very existence of forest and woodland ecosystem in the country. Many of these forests and woodlands are under further fragmentation as they are close to the agricultural frontiers. Today, more than ever before, human activities and global climate change are causing forest and woodland ecosystem even more prone to damage.

Table 10. Some of the threats of the forest and woodland ecosystem of Ethiopia ((Source: Berhanu et al., 2018; MEFCC, 2018)

Vegetation type	Threats
Dry Evergreen Afromontane Forest and Grassland Complex (DAF)	The most extensively inhabited vegetation zone in Ethiopia, where crop cultivation and grazing are widespread; forests have significantly diminished.
Moist Evergreen Afromontane Forest (MAF)	Since the 1970s, its rich timber resources have been heavily exploited; there have been extensive settlements from drought prone areas of the country; and many other commercial activities have attracted huge human influx; currently, it is under severe threat from over logging as

	well as conversion into tea and other commercial plantations.
Intermediate evergreen Afromontane Forest (IAF)	Settlement, agriculture, grazing and fire are the most important threats of IAF.
Combretum–Terminalia Woodland and Wooded Grassland (CTW)	Human influence is growing with settlements; mechanized crop cultivation (particularly sesame) and overgrazing are becoming threats to the vegetation.
Acacia-Commiphora Woodland and Bushland (ACB)	Traditionally occupied by pastoralists and agro-pastoralists, but the woodlands in the Rift Valley are being affected by crop land expansion, over grazing, drought and unsustainable fuel wood harvest and charcoal making.
Transitional Rainforest (TRF)	Inhabited by indigenous people that employ low input and output shifting cultivation practices, including root crops, until recently; in recent years the vegetation system has been selectively logged and also deforested to give way to other land use; some parts of this forest is being threatened due to settlement of refugees and large-scale farming and mining.

3.4 Trends in forest and woodland ecosystem

3.4.1 Protected area trends

The protected areas are Ethiopia's principal strategy to conserve its biodiversity. However, the protected areas in the country are de facto open access resources areas. For example, in Bale Mountains National Park, only "small patch of woodland" is protected which is surrounded by the park headquarters; while the remaining (99%) area of the park is an open access resource for grazing livestock or expanding agriculture (UNDP, 2017). Equally, many of the national parks such as Abijata-Shala Lakes National Park (characterized by ACB), Awash National characterized by ACB) and Gambella National Park (characterized by CTW), and many of the forest priority areas are heavily open to the elements of land use pressure and associated threats. This situation, in turn, resulted in deterioration of faunal resources. For example, Elephant populations in woodlands of Ethiopia have continued to decline, with a loss of 90% since the 1980s, with extirpation from at least 6 of the 16 areas in which elephants were found in the early 1990s. Currently an estimated 1,850 elephants still occur in the country in up to 10 populations, of which five are partially transboundary (UNDP, 2017).

3.4.2 Environmental health trends

Healthy ecosystems deliver life-sustaining services for free, and in many cases on a scale so large and complex that humanity would find it practically impossible to substitute for them

(Holdren and Ehrlich, 1974; Costanza et al., 1997; Melillo and Sala, 2002). With respect to complexity, we often do not know which species are necessary for the services to work, what numbers they must be present in, and whether there are “keystone” species for ecosystem services. Disruption of these natural services can have catastrophic effects (Cardinale et al., 2012). For example, if natural pest control services ceased or populations of bees and other pollinators crashed, there could be major crop failures**.** If the carbon cycle were badly disrupted, rapid climate change could threaten whole societies or life supporting systems.

In Ethiopia, there is limited information available in terms of the link between the assessed ecosystems and environmental health trends. Hence, because of lack of firsthand information on the environmental health trends of forest and woodland ecosystem of Ethiopia, this section presents proxy risk that the assessed ecosystems may cause negative impacts (e.g., disease) to human welfare and animals. It features the ecosystem where humans and animals live in coherence with nature in a balanced way for human prosperity but sensitive to extrinsic influences. It is the association in which each party benefits from the existence of the other; while parasitic cohabitation proves harmful for one of the living beings concerned. For example, the pathogens occur under certain conditions and harm human, animal or plant health. Even though these pathogens are harmless in a healthy natural environment, these pathogens can be deadly as changes may favour them when ecology or climate changes. Apparently, these organisms may cause harmful effects such as human illnesses like malaria, influenza or rabies and others in Ethiopia (Wilcox and Colwell, 2005; Wilcox and Ellis, 2006). In the same way, plants suffer from other infections rather caused by parasitic agents that appear under certain climatic conditions (high heat, too much humidity or high density). In the same way, fungal diseases caused by fungi whose development is linked to disturbances of aeration of living beings in sites exposed to their aggressions (mildews) and other pathogens of legumes or arboriculture (Patz et al., 2000).

Land use change and expansion of human populations into forested areas can result in exposure of immunologically native human and domestic animal populations to pathogens occurring naturally in wildlife (CHGE, 2002; Colfer et al., 2006; Wilcox and Ellis, 2006; Uneke, 2008). Forest clearing and alteration can produce an increase in the abundance or dispersal of pathogens by influencing host and vector abundance and distribution; and can also lead to alteration of ecohydrological functions such as infiltration, peak discharge and runoff which facilitate the survival and transport of water-borne pathogens in watersheds and catchments basins. Malaria is another major killer and factor in the burden of disease in and near forested areas, particularly in Africa (Uneke, 2008). The causal links between deforestation and incidence of malaria are difficult to distinguish. Some logging processes can lead to standing water and increases in mosquito breeding sites. The enormous variability and adaptability of mosquitoes contributes significantly to the difficulty in distinguishing causal factors and in developing effective health maintenance strategies.

Several reports (Patz et al., 2000; Sharp et al., 2001; Patz et al., 2004; Wilcox and Colwell, 2005; WHO, 2005) have indicated that the disease emergence process typically appears to be associated with changes in environment or natural ecosystem. Degradation of environments promote disease emergence in a number of ways. Habitat degradation and climate change alter predator-prey relationships favoring rodents and arthropods (like insects and ticks) which are vectors of human diseases (Wilcox and Colwell, 2005). Emerging viral diseases pose significant threats to human and wildlife populations (Patz et al., 2000; Patz et al., 2004; Wilcox and Colwell 2005; Colfer et al. 2006). Vector-borne diseases are particularly likely to be implicated in vegetated areas. These ailments have varying relationships with deforestation, but in most cases deforestation appears to increase the disease load of local people. Wildlife suffers from the intervention of humans that invade the remote territories of these animals introducing livestock-borne pathogens. Wild animals unimmunized against these agents contract the diseases (e.g. rabies, foot-and-mouth disease, rinderpest, avian influenza) and develop epizootics that eliminate a large proportion of their population (Patzet al., 2004; WHO, 2005; WHO, 2013). The role of birds and insects in the dissemination of pathogens is crucial and with consequent impacts on biodiversity Ethiopia and even at global scale. Though the role of bees in the pollination of plants for the welfare of man and nature is sufficiently understood, these workers of nature are threatened by man who introduces into hives dangerous diseases such as varroosis which harm the bee industry (WHO, 2013). The loss of a species has no equivalent value in nature, and reversing this unfortunate incident remains in the realm of the impossible. If not addressed well, this will affect either the vulnerable human populations or their food stocks or impact the rich biodiversity of the country hindering the food security of the population (FAO, 2015).

3.4.3 The impacts of biodiversity change on the contributions of forest and woodland ecosystem to people

The biodiversity on Earth is continually declining in most biomes of the world and considerably reducing nature's capacity to contribute to people's welfare. The contribution of nature to people is mostly documented through different aspects of biodiversity uses that deliver ecosystem services, which are attached to humans for their well-being. The association between biodiversity and ecosystem services can be traced from individual species or a group of species to ecological processes and ecosystem functions (Diaz et al., 2007; Maes et al., 2016). Some species make unique contributions to ecosystem functioning and, therefore, their loss could cause serious consequences for ecological processes that underpin nature’s contribution to human well-being (Walker, 1992; Schwartz et al., 2000; Cardinale et al., 2012). Greater redundancy represents greater insurance that an ecosystem will continue to provide both higher and more predictable levels of services (Yachi and Loreau, 1999). Central to this is that biodiversity is the key to supporting resilient, productive and healthy functioning ecosystems and therefore underpins the provision of ecosystems services (MEA, 2005).

Deteriorations in the status of biodiversity will indisputably lead to adverse impacts on environment and human well-being. For example, the livelihoods of the majority of the Ethiopian people directly or indirectly depend on forests and woodlands of the country, *inter alia*, as a source of energy, timber for construction, medicine, food (both produced and gathered from the wild) and income generation. If the forest and woodlands threats are unabated, ecosystem services such as regulating the hydrological cycle, soil erosion control, role as carbon sink, environmental amelioration, provision of habitat for varieties of life, clean water and fresh air provision, crop pollination, nutrient recycling, ritual and cultural practices and aesthetic values would be certainly at risk. For example, *Coffea arabica* wild gene pool is found only in the Ethiopian Moist Evergreen Afromontane forest and transitional Rainforest and hence the loss and degradation of this forest and woodland ecosystem that harbor this gene pool will be of grave implications not only for Ethiopia but also for the global community at large.

In Ethiopia, there have been attempts at various levels and scales by governmental and non-governmental actors to promote the sustainable management of environmental resources and minimize biodiversity loss in different ecosystems. The formulation of environment-related policies and strategies has made admirable efforts in terms of policy and strategy responses to address environmental degradation (Asfaw, 2001). One of the most important umbrella policies is the Environmental Policy of Ethiopia. This policy addresses a wide variety of sectoral and cross-sectoral environmental concerns in a comprehensive manner. The major aim of the policy is to ensure sustainable use and management of natural, human made and cultural resources and the environment (EPA, 1997). However, unsustainable use of environmental resources due to gaps in governance has continued to threaten the livelihood of the very same people who rely on these resources for their existence. Most of the key drivers affecting nature's contribution to humans are those associated with the use of nature by humans through ecosystem services. Habitat loss and fragmentation exert major impacts both on constituent species and ecological functions. The rate of change of habitats is expected to increase up to ten times due to global warming (Sherbinin, 2002). Habitat losses caused by extensive use of land and water for agriculture, the draining of wetlands, the clearing of forests for agriculture and other purposes, and the pollution of air, soil and water through unwise use of chemical compounds such as herbicides and insecticides are going to affect biodiversity greatly (IBCR, 2001). Unsustainable use of resources will also lead to identical consequences. For example, humans use grazing land for meat production but overgrazing is a serious threat to the continuous supply of the services (Anderson and Hoffman, 2007; Anderson et al., 2013). Similarly, overharvesting, overfishing and excessive water extraction are recognized to be drivers hampering nature's contributions to people. The benefits of nature can only be achieved if the use of resources is sustainable through good governance across all scales. Since forests and woodlands that account for less than 20% of Ethiopia's land area are immensely important for maintaining ecological balance, appropriate conservation measures need to be taken for ensuring the sustainability of the forest and woodland resources and the biodiversity therein (Hauff, 2002). The major hindrance to operate proactively, in this regard, is the gap in properly understanding the importance of biodiversity and ecosystem services by the Ethiopian public at all levels. This calls for making a continuous effort to raise awareness and make the issue of biodiversity conservation an integral part of the development agenda.

3.5 Direct and indirect drivers of change in forest and woodland ecosystem

3.5.1 Direct drivers of change

Direct drivers are underlying causes of change that result from nature and human decisions and actions. Some examples of direct drivers are habitat degradation and fragmentation, dam construction, intensive agriculture, firewood collection, free livestock grazing, climate change, biological invasion, land use/cover changes, infrastructure construction, mining, landslide, subsidence and flood. Many human interventions in ecosystems generate abrupt and large scale changes that trigger loss of biodiversity and make it more difficult for ecosystems to recover from the negative impacts associated with these human interventions.

Although change in biodiversity could happen due to natural causes, anthropogenic drivers dominate current change. Multiple drivers such as habitat loss and fragmentation, changes in biogeochemical cycles and pollution, climate change, overexploitation and invasive species are increasingly threatening biodiversity, ecosystem services, and their benefits to society. The following are the main direct drivers that brought about change in forest and woodland ecosystem in Ethiopia.

Habitat loss and degradation: Habitat loss and degradation are the ultimate threats to biodiversity in the tropics (Haddad et al., 2015). The Millennium Ecosystem Assessment concluded that as the extensive growth of agriculture is the primary driver of habitat loss in all human-dominated landscapes, it is also the primary threat to biodiversity worldwide (Millennium Ecosystem Assessment, 2005). Historically, habitat conversion is a severe threat to Dry Evergreen Afromontane Forests and Evergreen Scrubs. However, recent deforestation is taking place in Moist Evergreen Afromontane Forest and *Acacia-Commiphora* Woodland and Bushland. This is caused by deforestation for wood products (especially fuel wood), fire, agricultural expansion and overgrazing (EBI, 2014). Because the Dry Evergreen Afromontane forests are generally inhabited by majority of the Ethiopian population and represent a zone of extensive mixed agriculture, the forest is under severe pressure of destruction, mainly because of anthropogenic impacts. Such habitat distraction and fragmentation by human habitation of large populations has led to a significant land use change. Another threat to Dry and Moist Evergreen Afromontane Forest and Grassland Complex is the conversion of high forest sites to commercial plantations which causes ecological impacts and loss of biodiversity. The plantations on Arsi highlands where *Eucalyptus* is key wood product for timber, electric and telecom poles, firewood and the Munessa forest of central Ethiopia are good examples in this regard. Because of such forest degradation, some tree species are becoming locally endangered. For example, *Hagenia abyssinica*, *Podocarpus falcatus*, *Cordia africana* and *Juniperus procera* are highly threatened tree species in Ethiopia (TGE, 1994).

The Afromontane Forest and grassland complex of the country is also threatened by habitat degradation and fragmentation because of anthropogenic pressure. There are several remnant patches of Dry Evergreen Afromontane Forest and Grassland Complex in different parts of the country. The Arero forest in Borana Zone is one example, where there are well-grown trees of *Juniperus procera, Podocarpus falcatus, Prunus africana, Teclea nobilis, Croton macrostachyus, Olea capensis*, *Acacia* spp. and *Ficus* spp. Some other examples include, Asebot forest of West Harerge Zone, Mankubsa-Welensu forest of Guji Zone, Anferara forests around Negele-Borana, Denkoro forest of South Wollo Zone, Yegof forest of South Wello Zone, Hugumburda and Grat-Kahsu forests of southern Zone of Tigray, Chilimo forest of western Shewa Zone, Adaba-Dodola forest in West Arsi, Dinsho, Goba and Berbere forest in Bale Zone, Jelo-Muktar forest in west Hararge Zone, Gara Muleta forest in East Hararghe zone, Wof Washa forest in North Shewa Zone, and Menagesha-Suba forest in Oromia Special Zone surrounding Addis Ababa Administration.

Habitat fragmentation has been increasing in different ecosystems of Ethiopia. For instance, habitat fragmentation indices have showed variability in Bale eco-region with an increasing number of patches in forest and woodland classes since 1986 (Mezgebu and Workneh, 2017). Similarly, the habitat fragmentation in Lowland Forest areas of Ethiopia like Wooded Grassland of the western Gambela region, which was recognized as part of Ethiopian biodiversity hotspots is among the most threatened habitats in the country. The deforestation and fragmentation through the rapid expansion of farmland following settlers, investors and state farms, excessive cutting of trees for firewood and construction and forest fire has devastated heavily the forests and woodlands (Senbeta, 2011; Awoke et al., 2018). This implies that virtually all these unique habitats and associated biodiversity are facing significant threats due to both natural and anthropogenic factors.

In 2010, the Gambela National Regional State had 1.28Mha of tree cover, extending over 42% of its land area. In 2019, it lost 1.22kha of tree cover, equivalent to 417kt of CO_2 emissions (Globl Forest Watch, 2020). Although the country has forest policy and strategies, implementation is noticeably weak due to lack of strong political will and functioning institutions for forest conservation. In most cases, policies give emphasis to the production of crops at the expense of forestland. In this regard, there is a big interest by the government to expand agricultural investment (e.g. rubber plantation, palm oil plantation and biodiesel) into south west forest lands of Ethiopia including the Lowland Semi-Evergreen Forest in recent years. The riparian forests along the river valley and lake outskirt lacustrine forests are significantly fragmented in the name of investment for cotton and vegetables in Abaya and Chamo lake basin (Mezgebe and Raju, 2011). Since habitat loss and fragmentation are the primary threats to biodiversity in the tropics (Haddad et al., 2015), the situation is well reflected in Ethiopia.

Dam construction: Dams constructed for drinking, irrigation and hydroelectric power generation purposes have impact on forest and woodland ecosystem and services both at upstream and downstream portions. Currently, there are about 29 dams and reservoirs recognized by the Ministry of Water, Irrigation and Electricity (Wikipedia, 2019). The construction and development of these water bodies and reservoirs brought about deforestation and forest degradation implying land use and land cover change. This change devastates the provision of biodiversity and ecosystem services that constitute the foundation for survival of the community which resides around such places. The forest resources at the upstream portion would ultimately be submerged and a shift from forest to aquatic ecosystem would completely cause land cover changes. On the other hand, the downstream riparian forests that had benefited from flooding and sedimentation will no longer access the opportunity. Hence, such changes could cause gradual effect on forest and woodland ecosystem.

A complete land use/cover change has already been witnessed on significant part of riparian forests in Ethiopia. For instance, on the basis of land cover assessment in Gibe III, a total of 20,000ha of land is covered by the reservoir submerging an estimated 17,158ha of *Combretum-Terminalia* Woodland and Wooded Grassland and 1,839 ha of Riverine Forest (Gibe III EIA, 2009). In addition, the Ethiopian Renaissance Dam is expected to cover 1883km^2 of land upon complete filling (Abtew and Dessu, 2019). Similar land use/cover changes had either been the case or would occur in dam reservoirs including Gibe I, Koga, Megech, Kesem, Tekeze, Rib, Tendaho, Melkaawokena, Arjo Dedesa, Koysha and Gidabo.

Forest Fire: The other anthropogenic factor that could be taken as a direct driver of change on forest and woodland ecosystem is forest fire. Ethiopian farmers have been using fire as a farming tool for a long time. Fire could be set when farmers start preparing their land. Most of such fires are attended, managed and controlled by the community members. It is considered by farmers as the cheapest and most common tool used for a variety of production activities.

Historically, evidences indicate that high forests of Ethiopia remain victims of war, conflict and forest fires (Lemessa, 2011). Orders of setting forest fire from Tigray to Gondar and Wollo by Yodit/Gudit (849-897); and burning of forests stretching from eastern lowland to central highlands by Gragn Mohamed (1527-1542) had destroyed the forest to free hiding grounds. This has devastated huge forest and woodland resource of the country (Gebre Markos, 1998). There are also fires set irresponsibly in National Parks and protected areas (Table 12). The Bale Mountains National Park, Nech Sar National Park, and Simen Mountains National park have frequently suffered from such catastrophes.

Table 11. Forest fires in Bale Zone and West Arsi Zone in 2008 (Source: Belayneh, et al., 2013)

No	Woreda	Vegetation type	Burnt area (ha)	Total (ha)
1	Goba	Ericaceous vegetation	5,974	6,979
		Bamboo	1,000	
		Hagenia forest	5	
2	Dinsho	Ericaceous Vegetation	2,710	2,710
3	Dalo Mana	Woodland	1,200	1,200
4	Adaba	Ericaceous Vegetation	1,005	1,010
		Juniperus forest	5	
5	Goro	Forest/ Woodland	533	533
6	Harenna Buluk	Harena forest	48	48
7	Gura Dhamole	Forest	293	293
8	Agarfa	Forest	27	27
9	MadaWelabu	Forest	21	21
10	Berbere	Forest	4.25	4.25
Total				**12825**

Fire destroyed 343 ha area of the Simen Mountains National Park area in 2019 (Fortune Megazine, 2019). The recurrent and extensive fire incidence in Bale Mountains National park has damaged 38,150 ha during the period 1999-2008. Similar frequent fire incidences were observed in Nechsar National Park on regular basis because of conflict of interest among nearby pastoral communities.

Combretum-Terminalia Woodland management involves fire, particularly by cattle herders and pastoralists. However, in most cases CTW are exposed to annual burning that is badly affecting not only delicate seedlings but also mature trees. The accidental escaping of fire from domestic users in a fire prone area in Benshangul Gumuz Regional State is a common practice (Gole, 2015). Fire has been noted to be a potent threat to the meager forest resources of the country. The forest fires, which occurred during 1998 and 2000 in Bale, Borana, East Harerge, North Omo zones and other places destroyed an estimated 155,966 ha of forestland (Senbeta and Teketay, 2003). In addition, the 2008 forest fire at Asebot forest alone damaged over 12,700ha of the remnant Dry evergreen Afromontane Forest and Grassland Complex.

Agricultural expansion: different kinds of agricultural practice have contributed to forest and woodland ecosystem loss. Small scale and large scale agricultural schemes (both private and state owned) have been established in Gambella, Benshangul-Gumuz, Afar and some other regions in dense forests and *Combretum- Terminalia* Woodland and Wooded Grasslands (MoFEC, 2015) areas.

In Ethiopia, the major direct driver of deforestation is recognized to be the expansion of traditional smallholder agriculture in forest areas (FAO, 2017). About 80% of new agricultural land was created by converting forests, woodlands and shrub lands in the years between 2000 to 2008 (FCPF, 2011). The ever increasing clearance of forest and woodland ecosystems for rain fed agriculture is a common tradition that enhances the vulnerability of the ecosystems. Expansion of small scale and commercial agriculture such as sugarcane farms, tea plantations, cotton and bio-fuel plantations are the major development activities taking place in *Acacia-Commiphora* Woodland and Bushland, *Combertum-Terminallia* Woodlands and Wooded grasslands, Moist Afromontane Forest and Transitional Rain Forest. This implies that forests and woodlands are shrinking both in size and species diversity (EBI, 2014). The CTW forests in western and northwestern Ethiopia are also destroyed due to commercial agricultural investment for rice, cotton and sesame production and plantations like rubber, palm oil and biodiesel. The CTWs located in the western part of the region bordering Sudan have been degraded and could further be deteriorated as a consequence of overuse and agricultural encroachment. Most woodland areas are currently unmanaged. Where rainfall and soils are suitable, woodlands are increasingly replaced by sesame production in Gambella and Benshangul Gumuz regions (Pistorius, Carodenuto and Wathum, 2017).

The country's ambitious Growth and Transformation Plan, that envisaged a food secure and a middle-income country by 2025, targets agricultural transformation at the center of its strategies. Large-scale agricultural investment of around 1.06 million ha of land has been allocated in Ethiopia for commercial agriculture in recent decades. The land has been allocated from different regional states: SNNPR 348,009 ha (34%), Somali 26,000 (2%); Oromia 22,300 (2%); Gambella 272,112 (26%), Tigray 51,544 (5%), Afar 54,000 (5%), Amhara 121,370 (11%); and Benishangul-Gumuz 160,630 (15%) (Keeley et al., 2014). These lowland areas were covered with high value forest and woodland ecosystem and in some of the cases include some portions of National Parks. Trees were generally cut and burnt during land clearance. Under the pretext of establishing modern farms, some investors have cleared forests and sold the extract as firewood, charcoal and timber for construction without making any investments. Following this, the land was cultivated for one or two seasons, used as collateral to borrow money from banks and then eventually abandoned quitting any production activity. This has become a very serious threat to the forest biodiversity mainly in primary forest areas of the south, southwest and western parts of the country (FFE, 2011). Similar situations have been witnessed on adjoining areas of Lake Ziway, Abaya and Chamo where investors are allowed to establish flower farms and other agribusinesses inside proposed buffer zones in which forests and woodlands are cleared in the same fashion.

Afforestation and Reforestation: Ethiopia has made a strong voluntary commitment in the context of the Bonn Challenge (Pistorius, Carodenuto and Wathum, 2017). The country seeks to implement Forest Landscape Restoration on 15 million ha from the global initiative to restore 150 million ha forest by 2020. In the context of rural Ethiopia, forest establishment and restoration provide a promising approach to reverse the widespread land degradation, which is exacerbated by climate change and food insecurity (Pistorius, Carodenuto and Wathum, 2017).

The government of Ethiopia launched nationwide ecological restoration programs in 2010 to restore degraded ecosystems and mitigate human pressures on natural ecosystems. It was meant towards improving the ecosystem services they provide, reversing biodiversity losses and increasing agricultural productivity (MOFED, 2010). The ecological restoration program mainly focused on the construction of soil and water conservation structures such as terraces and bunds on the hill slope and cultivated lands, gully treatments and stabilization, as well as establishing exclosures on communal grazing lands. During the period 2010-2015, for example, more than 15 million people have contributed unpaid labour equivalent of US$ 750million each year (Seyoum, 2016). Soil and water conservation measures have been introduced in more than 3,000 watersheds and more than 12 million hectares of land have been rehabilitated through implementing physical and biological conservation measures, including exclosures (Lemenih and Kasssa, 2014; Seyoum, 2016). According to Seyoum (2016), tremendous achievements have been registered in less than 10 years. Ten million hectares have been improved through enclosures; 15 million hectares have been treated with conservation measures; and at least 30 million people have benefited from the nationwide ecological restoration programs. The environment has also been restored with biodiversity and the living landscape has been developed.

The total land suitable for afforestation and reforestation activities account for almost 5.3 million hectares (MFECC, 2015). The afforestation and reforestation potential is clearly concentrated in a few regions: Amhara, Tigray and Oromia. The large areas in Somali, Afar and Gambella are mostly excluded due to high climatic risk for afforestation and reforestation actions without additional investment on irrigation systems. The spatial distribution of sparse forest areas with the suitable characteristics for rehabilitation shows that half of the rehabilitation potential is found in the DAF. Most of the forest rehabilitation potential is found in Benishangul-Gumuz, Oromia, Amhara and Southern Nations, Nationalities, and People's Regions, which have also been affected by forest Degradation over the past 10-15 years (Figure 5).

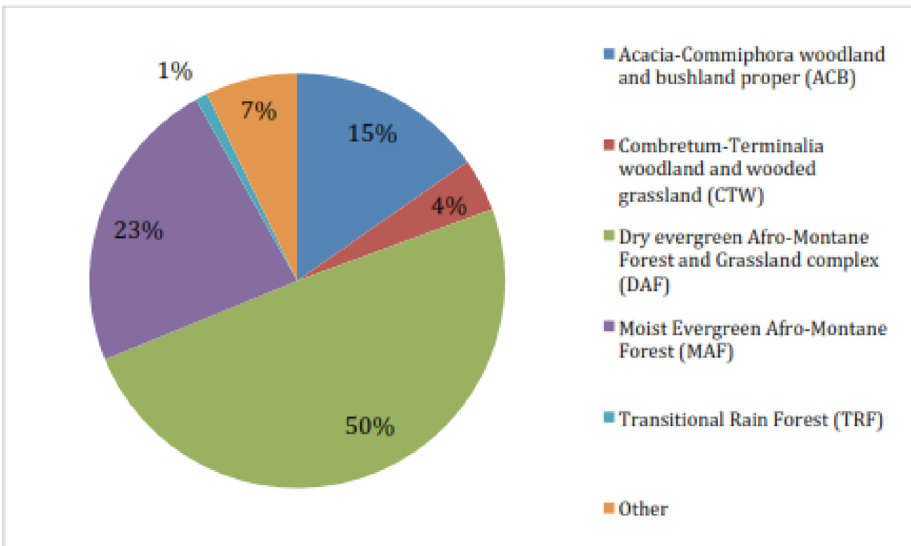


Figure 5. Potential rehabilitation share by degraded forest types in Ethiopia (Source: MFE 2015)

Plantation forests: Plantations are types of managed forest in which the trees are planted of the same age and species, and are intended to maximize the production of wood fiber. It has a positive direct pressure to forest and woodland biodiversity and ecosystem services. Forest plantations are defined by FAO (1993) as forest stands established artificially by afforestation on land where forests previously did not grow, or forest stands established artificially by reforestation on land that had supported forests within the previous 50 years (within living memory) that involves the replacement of the previous trees by new and essentially different trees. Plantation forests of exotic tree species are one form of forests in Ethiopia (Mehari et al, 2016). Ethiopia has a long history of tree planting activities. According to historical records, afforestation started in the early 1400s by the order of King Zera-Yakob (1434-1468). Modern tree planting using introduced tree species (mainly Australian *Eucalyptus*) started in 1895 when Emperor Menelik II (1888-1892) looked into fast growing tree species as solutions for alleviating shortage of firewood and construction wood in the capital city, Addis Ababa (Nawir et al., 2007). During the early 1900s, most of Addis Ababa was reportedly covered by plantation forests.

In the early 20th century most of Addis Ababa was covered and there was about 13,500ha *Eucalyptus* plantations in 1964 (FAO, 1985). In 1991, there were about 162,000ha of plantation forests and about 36,000ha of urban fuel wood plantations managed by the state (MOA, 1991). In 2000, the area of plantation increased to 216,000ha and in 2005 to 419,000 ha. In 2010, the estimate is 972,000ha. Of the total area of plantation forests, 190,400 ha, or 20%, are classified as commercial plantations that produce timber for sawn wood and poles (FAO, 2010).

The importance of the plantation sector in Ethiopia is increasing as the demand for raw materials is rising and the supply from the natural forests is decreasing. The gap between supply and demand is expanding. This has been perceived for many years and led to government-initiated re-greening efforts by the end of the 19th century (Lemenih and Kassa, 2014). Re-greening through area exclosure and afforestation/reforestation are the two main activities done in the country. The area exclosure is employed in a wide range of forest and woodland ecosystem-from Dry Evergreen Afromontane Forest and Moist Evergreen Afromontane Forest and woodlands to the sub-humid Afromontane forests. In 1996, there were only about 143,000ha of exclosure in Ethiopia. However, in Tigray regional state alone the area under area exclosure reached 895,220 ha in 2011 (Yami et al., 2012). Regional states are rapidly increasing areas put under exclosures, and by the end of 2013, exclosures covered 1.54 million ha in Tigray Regional State alone (Gebresilassie, 2013) and 1.55 m ha in Amhara Regional State (ABOA, 2013). Correspondingly, the forest plantation area has increased from an estimated 190,000 ha in 1990 to 972,000 ha in 2011 (Bekele, 2011). Of this area, 190,000 ha are classified as commercial plantations and the remaining 80% are non-industrial plantations (Table 13). Ethiopia started large scale industrial plantations with the primary purpose of supplying industrial round wood for the production of sawn wood, wood-based panels and wood pulp in the early 1970s with support from the Swedish government (FAO, 2010).

Table 12. Area under Plantation Forests (ha) in Four Major Regional States of Ethiopia (Source: Bekele, 2011)

Regional State	Industrial plantations	Non-industrial small-scale private plantations	Peri-urban energy plantations	Total
Oromia	78,800	27,800	26,700	133,300
Amhara	44,600	639,400	-	684,000
SNNP	27,300	64,000	-	91,300
Tigray	39,700	23,700	-	63,400
Total	190,400	754,900	26,700	972,000

Firewood: An estimated 2.4 billion people rely on wood worldwide as their main source of energy for cooking and sterilizing water (FAO and UNHCR, 2018). As stated in Teka (2006), the largest share of energy source is biomass, covering 94%. This includes fuel wood, charcoal, branches, leaves and twigs. In addition, the demand for construction wood has been increasing and extraction from the natural forests has increased similarly. As a consequence, the *Acacia-Commiphora* woodlands are shrinking because of the widespread collection of firewood and charcoal making.

In Afromontane regions of the country, severe increase in fuel wood scarcity puts extra pressure on the remaining natural forest. National parks that are supposed to protect and conserve native plant and animal species are in peril because of the challenges such as collection of fire wood. The national parks like Simen Mountains and Nechsar national park are greatly affected by deforestation caused by extraction of timber and other forest parts for fire wood by the nearby communities.

Charcoal production is the main economic activity and important energy source in developing countries in general and in Ethiopia in particular (Chanie and Tesfaye, 2015). On the other hand, its production is causing a threat in the conservation and management of national parks in Ethiopia (Tefera and Beyene, 2014; Zerga, 2015; Chanie and Tesfaye, 2015; Berihun, et al., 2016).

Mining: As worldwide demand for minerals and metals rises, mineral resources will be further exploited and this can contribute to forest degradation and deforestation (Rademaekers et al., 2010). Developing countries and emerging markets will see greatest supply and demand expansion (Price Waterhouse Coopers, 2012). The excavation activities for road and other infrastructure for selected materials have devastating effects on forest and woodland biodiversity resources. The landslide and subsidence because of such practices is prominent in many areas. The gold mining project at Shakiso and the traditional gold mining practices of Qafta Sheraro, Sheka, Benshangul, Abay Gorge and Wollega are seriously affecting the areas.

Artisanal gold mining leads to land cover and land use change in developing countries (Schueler et al., 2011). The traditional Artesian gold mining threatens the severely depleted status of vegetation resources across the tropical countries (Alvarez-Berríos and Aide, 2015). In this regard, enormous clearance of vegetation resulted in the loss of biodiversity and genetic resources (Calle et al., 2013). For instance, in Tigray where artesian gold miners established new gold mining sites, they aggressively cleared woody and herb species. Studies on artesian mining (Hailemariam et al., 2017) showed that random removal of seedlings, saplings, and trees for gold mining interrupted the continuous replacement of the species in the gold mining area.

In modern mining, degradation of forest and woodland took place in a series of processes of mining. In the exploration phase, surveying, drilling, trenching and blasting exploration devastate the environment. Camp development and road constructions cause a serious habitat loss, fragmentation and increased colonization of invasive species due to road development. Species loss due to site preparation, vegetation removal, stripping of soils, mine infrastructure development (power lines, roads, etc.), construction of plants, offices, and creation of waste rock piles is significant. Mining operations and construction of infrastructure also attracts a lot of labor force working on such developmental projects demanding more natural resources from the surrounding environment. Such temporary increase in local population raises the need for shelter, fuel wood, construction wood, as well as food. All these lead to habitat destruction. Generally, habitat destruction, leading to the loss of biodiversity through the removal of vegetation (deforestation), is said to be one of the most adverse impacts of mining. This is because in many countries like the Philippines, more than half (56%) of all exploration areas and mining leases overlap with areas of high ecological vulnerability. And, six percent of mining leases overlap with protected areas (Miranda et al., 2003). Though not studied and exactly stated, mining areas in Ethiopia are mentioned to overlap with forest covered areas.

Invasive species and bush encroachment: any species that successfully invades ecosystems, where it is previously unknown causing biological change, ecological or economical harm in that ecosystem is known as invasive alien species (Levine et al., 2003). Invasive alien species (IAS) that originate from outside the specific ecosystem are a major cause for local species extinction (Norton, 2009).

IAS is a global problem, where exotic species competes for resources and habitats, altering the physical environment in a way that sometimes causes competitive exclusion of native species with great economic and ecological consequences. In Ethiopia, there are about 35 invasive alien species (e.g. *Opuntia ficus-indica, Prosopis juliflora*, *Argemone mexicana, Lantana camara*, *Eichornia crassipes*) have been identified so far and are posing negative impacts on native species (IBC; 2014; Mulualem and Tesfahunegny, 2016). In most of the Ethiopian national parks, there are visible impacts due to IAS especially in Omo National Park (*Opuntia ficus-indica*), Awash National Park and Babile Elephant Sanctuary (*Prosopis juliflora, Lantana camara*, *Parthenium hysterophorus*), and Yangudi-Rasa and NechSar National Parks (*Prosopis juliflora*); where the grassland has been replaced by encroaching plants, prominently by *Dichrostachys cinerea*, *Acacia mellifera*, *A. nilotica, A. oerfota,* and *A. seyal* and expansion of herbaceous plants, most commonly the species of the family Malvaceae which include *Abutilon anglosomaliae, A. bidentatum and A. figarianu* (Young, 2012; Fetene, Hikler and Yeshitla et al., 2016).

IAS cause changes in the composition and function of ecosystems, affecting biodiversity, ecosystem services, and human welfare. IAS have become a major component of global change and pose a serious threat to local and global biodiversity (Vila and Ibanez, 2011). The expansion of IAS such as *Prosopis juliflora* in Afar and Somali regions has contributed to the loss of species diversity and habitat degradation of *Acacia-commiphora* woodland and bushland areas (EBI, 2014). For instance, endemic plant species such as *Acacia prasinata*, *Boswellia ogadensis*, *Euphorbia doloensis*, *E. ogadensis* and *Indigofera kelleri* are threatened significantly (Shiferaw et al. 2018). The habitats which harbor threatened plant species also harbor many globally threatened and vulnerable mammal and bird species. Because of disruption of ecosystem integrity in the area, these threatened wild animals are further endangered.

The most notorious alien invasive species in the *Acacia-Commiphora* woodlands and bushlands of Ethiopia is *Prosopis juliflora*. Studies detected that over 700,000 ha of land had been taken over by *P. juliflora*, out of which more than 70% is located in the Afar region (Admasu, 2008; Ryan, 2011). In recent decades, bush encroachment and invasion are emerging as one of the severe challenges affecting the *Acacia-Commiphora* woodland and bushland ecosystem. Both bush encroachment and invasion by alien species are causing reduction in native biodiversity as well as altering several ecosystem processes mostly in eastern and southern Ethiopia. The most affected areas in the country are woodlands and thickets in Afar and Borana plateau.

Infrastructure development: Roads, high tension electric power transmission lines, airports, railways and educational and health facilities established for public services devastate forest and woodland ecosystem. The high tension power transmission lines from all stations to the central grid and its distribution to all regions and international lines to Djibouti, Sudan and Kenya has devastated diverse ecosystem types. For example, in Ethio-Kenya electric transmission line, a total of 2841 ha is required for the transmission line right-of-way and Substation. Out of this, 97.65ha was cleared for construction activities of the towers. The Dry Evergreen Afromontane forests and grassland complex, *Acacia-Commiphora* woodland and wooded grasslands, *Combretum-Terminalia* woodlands and wetlands are among the affected ecosystems by the project (ESIA, 2011). Though compensations are given for damages by contracting companies, it is unlikely that the money compensated was used to restore the devastatation of these areas.

In many of the cases the facilities that provide public services like schools, health centers, industrial parks and airports are established by clearing forest and woodland ecosystem. For instance the construction of Arbaminch airport on Arbaminch ground water forest near Lake Abaya has devastated a lot of hectares of forest. The construction of roads to new landscapes could also devastate forest and woodland ecosystem, causing habitat fragmentation.

Urbanization: The rapid expansion of cities and towns and the establishment of new villages have resulted in devegetation of forest and woodland ecosystem. Establishments like Hotels and Lodges on escarpments near parks and lake shores have impact on pre-existing vegetation cover. Such establishments are found in cities and towns like Arbaminch, Bahir Dar, Hawassa, Gondar and Debark. These tourist destinations help to improve local business activities benefiting community members on one hand and provide comfort to tourists on the other. However, such structures are built at the expense of forest and woodland ecosystem. Hence, legal grounds that guarantee compensatory, rehabilitation and restoration activities are expected. The establishment and expansion of cities and towns has subsequent problems that the populations living in and around these centers demand wood for fire and construction works.

Free livestock grazing: This is a common practice in almost all Ethiopian ecosystems including the Afroalpine and Sub-afroalpine habitats. Biodiversity loss occurs primarily through habitat degradation and destruction, land-use changes, and physical modification of landscapes in pastoral communities. The DAF is inhabited mainly by agro-pastoral populations. DAF often host the largest population of livestock per head. Major pastoral areas where free grazing is taking place extend from the north-eastern and eastern lowlands (Afar and Somali) to the southern and south-western lowlands (Borana and South Omo). Number of cattle keeping pastoral/agro-pastoral households is approximated 3.1 million (FAO and NZGGRC, 2017). There are more than 56 million heads of cattle in Ethiopia, providing over 3.8 billion liters of milk (FAO and NZGGRC, 2017) and roughly one million tons of beef per year (Shapiro et al., 2015). The current environmental impact of cattle systems is by far larger than all other livestock species combined. In many densely inhabited areas of Ethiopia, the original forest vegetation now exists only in protected patches around churches, while in the lowlands, much of the woodlands have been removed for better grazing and charcoal production. Extensive and intensive livestock production systems affect biodiversity differently. In extensive systems, a larger number of animal breeds grazing differently devastate the environment significantly by increasing the pressure to encroach more on natural habitats. An increasing livestock population and overgrazing in the pastoral and agro-pastoral areas is the main driver of forest degradation (especially degradation of forest and woodland ecosystem). Use of fire in the management of such grazing lands (to control bushes and reinvigorate growth of forage grasses) is also an important driver of forest degradation.

Livestock density is more than three times greater than the carrying capacity of montane grassland areas (Woldu, 1988). These are areas used for the traditional mixed farming and are densely inhabited by people. They are, therefore, highly disturbed. In CTW ecosystem, overgrazing has resulted in deterioration of the woodlands and wooded grasslands. Unique plants such as *Vitellaria paradoxa, Oxytenanthera abyssinica* and *Boswellia papyrifera* are under threat (EBI, 2014). In some parts of Tigray and Amhara regions, *Combretum-Terminalia* broad-leaved deciduous forests are largely used as grazing sites for livestock, which are increasing due to feed shortage, expansion of crop cultivation and increasing cattle population in the highlands.

Climate change: As a function of human activity, climate change is one of the direct pressures that have impacts on forest and woodland biodiversity and ecosystem services. It is defined as "any change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere greenhouse gases over comparable time periods" (Bustamante et al., 2018). Bellard et al. (2012) summarizes the functional components of biodiversity that are affected by various components of climate change and illustrates that biodiversity is affected by climate change at all levels of organization - from genetic to biome. For example, at a biome scale, there could be an increase in catastrophic events such as flooding or forest fires. At an ecosystem scale, the composition, structure, and function of the ecosystem could be affected. At a community scale, inter-specific relationships could be disrupted due to mis-matches between the timing of events. At a species level, species distribution and range sizes may be affected as climatic conditions change. In terms of populations, recruitment, age structures and sex ratios could all become altered due to changing climates.

According to Ethiopia's NAPA (2007), the major impacts of climate change on forests include the expansion of tropical dry forests and the disappearance of lower montane wet forests, and the expansion of desertification. One of the specific impacts of climate change is the increased fire risk: drier conditions will increase the risk of fire, making forest fires more frequent and intense, resulting in degradation. Further impacts of climate change include land-use change; increase in invasive species such as *Prosopis juliflora* and *Acacia drepanolobium* in areas like Afar and Somali regions, where they have already started to cause considerable socio-cultural damage; and changes in forest-dependent livelihoods due to changes in forest extent. Furthermore, the changing climate will impact species with a narrow ecological range (e.g. highland bamboo, alpine species), which are likely to be threatened. The climate change and variability has impacted the *Accia-Commiphora* woodland and wooded grassland thereby affecting the livelihood of pastoral communities like Nyangatom. The unpredictable seasonal variations of drought and flooding occurring on recurrent basis are impacts of climate change in such areas.

Landslide and subsidence: Landslides have resulted in large numbers of casualties and huge economic losses in the hilly and mountainous areas of the Ethiopian highlands. The forest and woodlands in such unstable areas get thrown away or sink down. This incidence is mainly rainfall driven. The geology of the area and its steepness determines the magnitude and coverage of the landside. For instance a study conducted in Tigray, Adishu area has identified thirteen major landslides with clear downthrown head scarps and down spread toes (Amare et al., 2018). In Dessie and its environs, a total of 22 specific active landslide sites were identified (Ayenew and Barbieri, 2005). Landslides are also reported in all hilly areas of the Gilgel Gibe catchment (Abebe et al., 2010). In addition the Gamo, Gofa and Sidama hilly landscapes are frequently subjected to such incidences with much causality and devastation of forest, woodland and agricultural lands.

Flood: Flood is also a naturally driven direct driver that affects forest and woodland biodiversity and ecosystem services. The lowland areas of the country in Omo, Somali, Afar, Gambella, Tigray and Oromia regions have suffered from such catastrophe. According to OCHA (2018), flash flood incidences have affected hundreds of thousands of people in Afar (Awsi), Oromia (Arsi, East Shewa, East and West Hararge zones) and Somali (7 zones) regions. Areas affected by recurring floods have been advocating for enhanced flood early warning, mitigation and preparedness mechanisms. In Somali region, more than 27,000 flood-affected households (165,000 persons) needed urgent food, water, and health services (OCHA, 2018). Overflow of Genale and Wabi Shebelle rivers and related tributaries due to heavy rains in the Somali region and the highlands of Oromia have affected more than 83 kebeles in 19 woredas (districts) of Afder, Fafan, Liben, Nogob, Siti, Shebele and Warder Zones. The forest and woodland biodiversity resources are affected by being washed away or submerged in water body.

3.5.2 Indirect drivers of change

Indirect drivers are the underlying causes of change that are generated outside the forest and woodland ecosystem. They are indirect drivers because they do not affect the forest and woodland biodiversity directly but affect the provision of ecosystem services. The influence of such drivers could be positive or negative. Indirect drivers are complex interplays of many social, economic, political, cultural and technological processes. These indirect drivers strengthen direct drivers. Some of the indirect drivers of change include: population and demographic trends, governance systems, institutions, economic development, technological development and welfare, social conflict and weak law enforcement.

Population and demographic trends: the existing population boom is an important variable in influencing ecosystem condition. Estimates show that natural population growth in Ethiopia is at an average annual rate of 2.6% (CSA, 2007). Higher population implies i increased demand for forest and woodland products, grazing and farming areas, which are becoming the most serious forces of degradation (Lemenih and Kasssa, 2014). Self-initiated and government sponsored settlement programs have been conducted in *Accacia-Commiphora* woodlands and bushlands. Successive governments used settlement in the *Combertum-Terminalia* woodland wooded grassland areas as a strategy for reducing food insecurity of vulnerable households in the degraded highland areas. Between 2000 and 2004 alone, about 440,000 household heads or 2.2 million people have been formally settled in four regional states of Ethiopia namely, Amhara, Oromia, SNNPR and Tigray. Considering the wood demand for construction and fuel as well as land for crop cultivation, moving such number of people has led to clearance of an estimated 1.7 million ha during the same period (Lemenih and Kasssa, 2014). New settlements and areas under crops could hamper seasonal mobility of the people indigenous to the area, and this may instigate conflicts between the two groups. The population explosion could also lead to increased number of unemployment forcing a segment of the society to depend on the forest and woodland ecosystem as a means of livelihood. The massive increase in demand for fuel wood for cooking caused by sudden influxes of refugees and other displaced people is usually the main driver of forest and woodland degradation and deforestation in displacement settings (FAO and UNHCR, 2018).

Displacement and migration: of the estimated 65 million forcibly displaced people worldwide, 80% are forest dependent, relying at least in part on forest products for energy, shelter, fodder, and nutrition and cash income. home to Africa's second largest refugee population after Uganda, Ethiopia hosts more than 900,000 people in 26 camps who have fled conflict, drought and persecution in neighboring countries such as South Sudan, Sudan, Somalia and Eritrea (UNHCR, 2019). Natural vegetation covers particularly the forest, woodland and grassland is dwindling in alarming rate in the past three decades. The settlers use the woodland product for firewood, charcoal, construction and preparing their farming tools (Awoke et al., 2018). One refugee from

South Sudan, Maymuna explained about the dense forest selected for refugee camping saying that "This area used to be a dense forest, until the government cleared it a year ago when we arrived. They built shelter for us" (Amare, 2018). The refugee camps in Gambella, Somali, May Ayni of Tigray and Afar Berhale and Benshangul-Gumuz were established in the same fashion at the expense of the lowland forest and woodlands. Among these, *Combretum-Terminalia* woodland and wooded grasslands occur mainly in the northwestern, western and southwestern parts of the country; specifically in Tigray, Amhara, Benishangul Gumuz, Gambella, Oromia and SNNPR are subjected to devastation because of camping problems. Recent decades have witnessed an unprecedented scale of immigration from highlands to the CTW through resettlement programs, which continue to cause large scale deforestation and degradation of the "woodlands" into croplands. Besides, the ever seen (more than three million) recent internal displacements in different regions of the country have aggravated the situation making natural resources vulnerable to devastation and consumption.

Generally, the other form of demographic trend contributing to resource degradation is increased migration to forest lands. Rural poverty, highly unequal distribution of agricultural land, lack of employment opportunities, and government policies which opened up forest areas is among the major underlying factors motivating movements to forest lands. Because migrants convert forest covered land s and woodlands for agriculture and continuously cultivate these lands, soil fertility declines after only a few years of use.

Economic development: countries' economic development may have positive or negative pressure to change. It is a fact that every developmental activity is done at the expense of the environment. Limited employment and low incomes, along with demographic pressure, contribute to deforestation because people searching for a living have to choose whether to migrate or to turn to agricultural activities on the only land available, the remaining forest resource. This increases the number of landless farmers in the country's mountainous areas who are blamed as the main culprits for the destruction of the forest resources. On the other hand, people with better economic status aspire for well managed and conserved biodiversity resource. Hence, the better the economic development, the better the conservation of forest and woodland biodiversity and ecosystem services in environmentally planned way. Here, the problem is to reach this better economic status, a compromise between natural resource and economic development could be sought.

Governance system: Government policy and commitment to the conservation and sustainable utilization of forest and woodland ecosystem is fundamental for the conservation of forest and woodland biodiversity and ecosystem services. The presence of a conducive policy and legislative instruments as well as strategic plans to address the conservation of these natural resource safeguards the resource base in many ways. The National Biodiversity Strategy and Action Plan and other relevant policy documents are instrumental for smooth governance of the forest and woodland biodiversity and ecosystem services. The process of forest governance change in Ethiopia is not autonomous; rather, it is embedded in a more general process of political economy in the country (Negassa, 2014). The main objective of the forest legislation during the Emperior's period (1960s) was not so much to promote resource conservation but rather to enlarge the sources of state revenue (Dessalegn, 2001). This shows that the forest resource management paradigm during that time was more of a protectionist nature because the forests were preserved and protected for their economic value mainly as a source of fuel wood and construction material. In addition, little attempt was made for new plantation. In 1980, the military government regime (*Derg*) proclaimed a new law called forest and wildlife conservation and development proclamation No. 192/1980 by accusing the previous government of its improper and unplanned exploitation of the country's forest resources and stated that the forest cover was depleted because of the selfish interest of the aristocracy and the nobility (Sisay, 2008). The forest management system during the *Derg* period had again a protectionist and utilitarian nature. Forests were protected mainly for their economic value (Eshetu, 2014). Post 1991, following the establishment of a new government (i.e. EPRDF), a new proclamation came into picture, namely, Forest Conservation, Development and Utilization Proclamation-No. 94/1994. The other great endeavor was the establishment of Ethiopian Forestry Action Program (EFAP), which is a working document that has direct relation with forest development and conservation. The EFAP set forth forestry development as major objective aiming specifically to sustainably increase production of forestry products, to increase agricultural production by reducing land degradation and increasing soil fertility, to conserve forest and woodland ecosystem, and to improve the welfare of rural communities. Generally, governments of Ethiopia, both in the past and at present, tried to implement different interventions to rehabilitate the degraded areas and to maintain the remaining forests, though most of the economic policies rather aggravated and still are aggravating the rate of forest destruction (Eshetu, 2014).

Technological development: Technological development has both positive and negative impacts on forest and woodland biodiversity and ecosystem services. The improved machineries meant for intensive and extensive agricultural expansion could facilitate deforestation. This was observed in Benshangul Gumuz and Gambela regional states and South Omo zone, where mechanized deforestation related to agricultural investment has taken place. On the other hand, technological advancements in biotechnology play significant role to save endangered and threatened species. Replacement of forest products by non-forest material through advanced technology could reduce the burden on forest and woodland ecosystem.

Weak law enforcement: This is one among the prominent challenges that could not be overcome in Ethiopia**.** The regulatory system is inadequate and inefficient resulting in weak enforcement of existing laws. Although the federal and regional forest proclamations (e.g., in Oromia) clearly show applicable legal consequences for forest trespassers and offenders, enforcement of those penalties are not realized due to lack of guidelines and implementation procedures. Absence of institutions and committed work force at different levels are also some of the hindrances to enforce law. For example, although the management plans developed are approved and in place, the Rift Valley Lakes and National Parks management plan including buffer zoning are not enforced.

Social conflicts: Competitions for resource in national parks, protected areas and communal properties are challenges that result in social conflicts among ethnic groups. The conflict in Nech Sar National Park which is associated to illegal encroachment of communities around the park and that seriously threatening the status of the park is a good example in this case. Similar conflicts are also not uncommon around forage and watering points in pastoralist areas between Afar and Somali regions, as well as pastoralists along Ethio-Kenya border.

Culture and religion: Culture and religion play a significant role in conserving forest and woodland ecosystem. The provision services for medicinal and other use values of each plant species has contributed for the survival of the specific vegetation in particular and the ecosystem in general. Sacred natural sites provide ecological libraries for landscape restoration and could be considered as institutional models for biodiversity conservation. It has a positive pressure driving changes in this ecosystem. The core religious values of Ethiopian Orthodox Tewahido Church communities have ensured the protection of church forests (Izabela and Klepeis, 2018). The woodland patches surrounding churches and the dense forest monasteries in different parts of the country could be taken as positive direct pressures of change to maintain woodland and forest biodiversity and ecosystem services.

These "church forests" are biodiversity reserves of critical importance for the future of Ethiopia. Spiritual enclaves that are home to churches, monasteries, and other ecclesial lands actively managed by the Ethiopian Ortodox Tewahido Church clergy, maintain the forest resources in a sustainable way for their subsistence needs (Goodin, 2019). Around 21,000 Dry Afromontane Forest fragments remain in the northern highlands of Ethiopia, ranging in size from 3 to 300 hectare (Goodin, 2019). Moreover, there are more than 35,000 Orthodox church communities (Wassie et al., 2009), with new high-resolution satellite imagery revealing more than 8,000 church forests ranging from less than one hectare to over 100 hectares in Amhara region alone.

Sacred forests often exist as isolated patches of natural forest even after conversion of the surrounding matrix to different forms of land use. Unlike the parts of the country where sacred forests are restricted to church and monasteries, the sacred forests in southern part of the country (Borana, Gamo, Kafa, Sheka, Majang, etc.) are taboo areas governed by traditional institutions. The best places to view these practices are the Gamo highlands. Forests in the Gamo highlands are under a range of different governance regimes. Some forests are considered sacred and protected accordingly by community and religious leaders while others have no sacred status and are generally subjected to a much wider range and intensity of uses by the surrounding communities. The Sodhe bamboo sacred forest is managed and protected through the traditional belief systems by traditional leaders (Gello, 2017). The Shawo *Syzygium* sacred forest and the Negassa sacred forest are among the traditionally managed sacred forests in Gamo highlands.

3.5.3 Drivers interaction in forest and woodland ecosystem

In the Ethiopian context, the direct anthropogenic pressures (habitat degradation and fragmentation, dam construction, agricultural expansion, firewood, free livestock grazing, afforestation and deforestation, climate change, biological invasion, land cover changes, infrastructure construction and mining) are dominant in driving changes when compared with natural causes (wildfire, drought, floods, landslide subsidence). Among the direct anthropogenic drivers of change, agricultural expansion, afforestation and reforestation, biological invasion and fire are significantly affecting the forest and woodland biodiversity and ecosystem services.

There is cause and effect relationship among the pressures driving changes in forest and woodland ecosystem. The indirect drivers that are behind direct drivers include population and demographic trends, displacement and migration, economic development, technological advances and social conflicts. The ultimate effect of these all indirect driven pressures lead to degradation and loss of forest and woodland biodiversity and ecosystem services. For instance, increase in population pressure will call for the need to have more land for agriculture. To access such lands, forest and woodland clearance will follow; this in turn devastates the existing natural resource. Such understanding of causal dependencies between human activities and their various impacts on the ecosystem is a major challenge for science and requires integration of knowledge across different ecosystem components, linking physical, chemical and biological aspects with existing and emerging anthropogenic stressors.

3.6 Knowledge about benefits of forest and woodland ecosystem

3.6.1 People perception of forest and woodland ecosystem

Recent statistics show that Ethiopia has 17.22 million ha of forest resources, i.e. covering 15.5 percent of the country's total area. The country has been largely dependent on goods and services obtained from its forests (FAO, 2017). Ecosystem services are the benefits provided by ecosystems that contribute to making human life possible (Mace et al., 2011). The knowledge about the benefit of forest and woodland biodiversity and ecosystem services is important to conserve the ecosystem as a whole. Human use of natural resources has long history since paleolithic age. People and natural resources are highly interlinked with complex relationships. The wellbeing of people in Ethiopia by and large depends on the wellbeing of the biophysical environment (air, water, land, flora and fauna). This is due to the dependence of the majority of the people on natural resources, and subsistence agriculture (Sida, 2003). The heavy dependence on land, water, biodiversity and climatic resources made the bond very tight and made people vulnerable to the changes, resulting in sufferings of communities that rely on environmental resources. A high proportion of Ethiopian farmers, who were involved in a survey, found to perceive the forest cover as rapidly declining and would be interested in tree planting–especially if a private ownership of woodland and forests could be assured.

The forest and woodland ecosystem provides many services. One of the regulatory functions of this ecosystem is associated with improving water flow, water percolation and water quality improvement issues in diverse watersheds. Its other services are climate change mitigation through carbon sequestration and microclimate regulation. Forest and woodlands are also homes of wildlife and sites of tourist attraction in various landscapes of the nation.

The ecosystem services concept helps describe the benefits which humans receive from nature and natural processes. The ability of trees, woodlands and forests to provide a wide range of ecosystem services is very much dependent on where they are located and how they are managed. Hence, profound understanding of how people perceive, acquire and use ecosystem services can help influence behavioral compliance with management and policy prescriptions.

Understanding the perception of communities about ecosystem services derived from the forest and woodland ecosystem is an important step in defining their role in the multi-scale governance thereby allowing them to contribute their share in sustainable management efforts of forest and woodland ecosystems. The value system of a person or a group is directly relevant to the perception. Characterizing, assessing and valuing ecosystem services can support forest management in a number of ways. These include demonstrating the human and societal goods and services which trees, woodlands and forests provide.

Perception is the process by which people translate sensory impressions into coherent and unified view of the world around them. In our context, people’s perception is the way how people look at ecosystem services. They get every material goods, necessary consumables, traditional medicine and aesthetic and spiritual services from the ecosystem. Many people perceive that these ecosystem services are declining mainly as a result of shifting to cultivation and also due to deforestation for various purposes (Tadesse et al., 2014). The introduction of religions that downgrade the traditional management practices of forest and woodland biodiversity resources and ecosystem services are some of the challenges perceived by people (Gello, 2017).

The successful conservation of forest and woodland ecosystem is dependent upon the attitudes of the local people who are inherently connected with the forests and their active participation in forest management (Tesfaye et al., 2012; Ameha et al., 2014; Siraj et al., 2016). Several studies also noted that previous benefits and values can affect the conservation attitudes of the local people towards forest conservation and management (Tesfaye, 2011; Ameha et al., 2014; Siraj et al., 2016). According to Oskamp (1977), values refer to things that people consider being precious so that they are the most important and central elements in a person's system of attitudes and beliefs. Attitudes are positive or negative responses of people towards a certain activity (Elias, 2004). In Ethiopia, local people are directly dependent on the forest resources to satisfy their livelihoods (Ameha et al., 2014; Siraj et al., 2016). Previous studies suggested that the perception and attitudes of local people towards Forest and Woodland ecosystem are affected by socio-economic variables, such as sex, age, level of education, occupation type, length of local residence, land and livestock ownership, income level, grazing land ownership, and plan to stay in the area in the future (Takahashi and Todo, 2012; Tadesse and Kotler, 2016). Moreover, perception and attitudes of local people towards forest and woodland biodiversity resources are influenced by previous benefits (access to and control over resources) (Tesfaye et al., 2012; Takahashi and Todo, 2012; Tadesse and Kotle, 2016).

Understanding the importance of ecosystem services to people is a significant aspect of ecosystem services assessment (Castro et al., 2013). The delivery of ecosystem services that contribute to the well-being of the people may not guarantee optimal use because different people gain benefits from these services in different ways, according to their access to these resources and what value they place on its judicious management (Hein et al., 2006; Kozak et al., 2011). The concept of ecosystem assessment is being used as a way to inform and support landscape management. The social perception towards ecosystem services is relevant in order to identify not only the most important or relevant services to people, but also the trade-off between ecosystem services (Martín-López et al., 2012; Meijaard et al., 2013).

In a study conducted by Senbeta (2018), local communities identified 16 ecosystem services that include six provisional services (freshwater supply, wild food, timber, fuel wood, medicinal, fiber), four regulating services (soil erosion control, climate regulation, maintenance of soil fertility, water purification), three cultural services (aesthetic, spiritual and hunting) and one supporting service (biodiversity repository). Further, the status and trend of the ecosystem services identified by the discussants mentioned to have been declining over the last 50 years. The conversion of forest and woodland ecosystem to agriculture and settlement was the major threat identified.

3.6.2 Contribution of traditional ecological knowledge to sustainability of forest and woodland services

Forest and woodland biodiversity resources have strong link with indigenous communities. The knowledge, experience and practice that pass from generation to generation brought about improvements in sustainable use of these natural resources. Much of the world's biodiversity resources has been used and managed by indigenous peoples (Takako, 2004). Indigenous peoples and their socio-cultural relationship with biological systems have largely been contributing to sustainable conservation of biodiversity. Ethiopia is rich in local community knowledge in a wide range of fields like sustainable forest management, soil and water conservation, seed selection and preservation, advancement of traditional farm implements, development of appropriate farming systems, and adaptation of effective coping mechanisms withstanding food insecurities through time (Endale, 2016).

Wise access to resources and structured traditional institutions to manage forest and woodland biodiversity is observed in many parts of Ethiopia. In many cases, such practices are governed by locally appointed hereditary leaders. The cultural and spiritual values and services coupled with customary laws reveal a traditional knowledge system. Indigenous people are aware of a large variety of uses of biodiversity including medicinal uses, and their knowledge of habitat preference, life history, and behavior relevant to efficient foraging for such resources is well established (Mekonen, 2017). TEK is receiving global attention since the United Nations Conference on Environment and Development (UNCED, 1992). An account on the nature and functions of sacred and church forests is given below to demonstrate the benefits of TEK and local perception in the conservation of forest resources and maintenance of associated ecosystem services.

Sacred forest: Traditional ecological practices of forest management have been overlooked for long period. However, alarming degradation of these resources has started redirecting the attention to valorize the traditional practice. Many forest patches of cultural and spiritual importance are better protected through traditional ecological knowledge. The Oromo tradition to maintain and use trees as shelter and shed during dry season is a common situation in Guji Oromo and Walesa area (Fufa, 2013). In southern Ethiopia, these sacred forests are generally considered to be small and not to support many species of conservation importance (Dissasa, 2012). However, there are forest pockets that are under traditional community management. Some indigenous conservation practices of forest resources in Southern Ethiopia are traditionally well developed. The sacred forests of Shawo at Dita; the bamboo forest of Sodhe at Daramaalo, that of Doshke and Negassa forests around Chencha and the sacred forests (*tsoose*) of Basketo are good examples (Woldeyes et al., 2016; Gello, 2017; Tezazu and Mezgebe, 2019; Woldeyes and Shigeta, 2020). These forest patches are of diverse fauna and flora with several benefits such as provision of traditional medicine, food and sites for ritual activities. The Sacred forests also contained a higher density of national priority species for conservation, e.g. *Juniperus procera*, *Cordia africana*, *Hagenia abyssinica*, *Prunus africana* (a species recognized as internationally vulnerable), *Vepris dainellii* (an endemic species), and species useful to local people such as *Olea europaea* subsp. *cuspidata*, *Olea capensis* subsp. *macrocarpa,* and *Olea welwitschii* (Gello, 2017). This indicates the importance of these sites for biodiversity conservation and other ecosystem services.

Monasteries and church forests: DAF has disappeared from most of the highlands in northern Ethiopia, except around churches, mosques in zones of Wollo and some inaccessible pockets. Hence, a patch of indigenous old-aged trees in the northern highlands of Ethiopia signifies the presence of a church/monastery in the middle. These church forests are visible from a great distance, with a majestic appearance, usually built on small hills. They are sanctuaries for different organisms, ranging from microbes to large animals, which have almost disappeared in most parts of northern Ethiopia (Wassie, 2002). Church forests are forest and/or woodland plantations enclosed in church by closure of plantation of trees of high canopy as shed to followers. The Christian philosophy traditionally teaches humanity the dominance over nature that all other living things have been created for its use. In some of the most productive tropical parts of the world (e.g., Latin America, Asia, and some parts of Africa), Europeans colonized and cleared the forests to cultivate rubber, cacao, coffee, tea, pepper, sugarcane and cardamom. However, the Ethiopian Orthodox church clergy conserved forests surrounding every church. This is because of the belief that priests protect the human spirit as well as all of God's creatures called "church forests". These small swathes of primary forest (some over 1000 years old) provide important ecosystem services, including freshwater springs, pollinators, honey, medicinal plants, native seed banks, shade, plant materials used for painting murals, firewood, and building materials (Lowman, 2011). This important religious concept has protected the church forests for many generations; while the remaining 95% of northern Ethiopia's landscape has been cleared for agriculture. Currently, these church forests are under some threat of shrinkage as a result of encroaching cattle that feed on the seedlings within, children seeking firewood, and surrounding agricultural practices (Reynolds et al., 2017). Efforts to build stone walls, with strong community and religious support, have become an important solution to the conservation of church forests, and because these walls are sanctioned by the priests, they are a desired landscape attribute for the local people.

3.7 Impacts of policies and institutional arrangement on biodiversity conservation and ecosystem services in Ethiopia

3.7.1 Analysis of policies and legal instrument on biodiversity conservation and ecosystem services

Building on Governance of Forests Initiative (GFI) analytical framework, the impacts of policy and legal instruments on biodiversity conservation and management of forest and woodland ecosystem services were analyzed under two key dimensions:

- **Legal and policy framework**, which focuses on the policies, laws, and regulations that set the overarching social, environmental, and economic objectives for management of forest ecosystem services and biodiversity conservation.
- **Law enforcement**, which refers to efforts to enforce and promote compliance with forest and biodiversity related laws and regulations, including through detection of illegal activities, prosecution of offenders, and application of sanctions.

The GFI framework uses scoring method that assign quantitative values to indictors based on literature analysis in order to concisely summarize assessment results. Based on the evidence extracted from policy, legal and other relevant documents, a score for each indictor was critically assigned. Following the experience of GFI assessment in Brazil, we consistently assigned quantitative values ranging from 1 to 4 denoting: 1= never, 2= sometimes, 3= often, 4= always. After calculating average score or cumulative performance, the quality of each sub-dimension is determined as: 1-1.5= very weak, 1.6-2.5= weak, 2.6-3.5= moderate, 3.6-4 = strong. In assigning the score, the activity specifically focused on critically evaluating how well a specific element of quality has been met compared to the description or diagnostic question stipulated under each indictor. In doing so, the assessment data was double-checked before drawing conclusions about the quality of a specific indicator. Moreover, the detailed guidance provided on WRI manual (see Davis et al., 2013) was carefully employed, in translating assessment data into scores and drawing conclusions about elements of quality and indicators. Accordingly, in-depth literature review was conducted on systematically selected national and international legal and policy documents relevant to forest and biodiversity conservation and institutional arrangements. The literature review focused on synthesizing and collating lessons from key policies, laws, and regulations that define the social, environmental, and economic objectives of forest and woodland ecosystem and sustainable biodiversity conservation. The following policy and legal instruments were consulted.

- Constitution of the Federal Democratic Republic of Ethiopia (Proclamation No. 1/1995)
- Environmental Policy of Ethiopia (1997),
- Forest development, conservation and utilization policy and strategy (2007),
- Forest development, conservation and utilization (Proclamation No. 1065/2018),
- Development, conservation and utilization of wildlife (Proclamation No 541/2007),
- Environmental Impact Assessment (Proclamation No. 299/2002),
- Legislation on Expropriation of Landholdings for Public Purposes and Payment of Compensation (Proclamation No 455/2005),
- The Rural Land Administration and Land Use (Proclamation No. 456/2005),
- Regulations on land Expropriated and payment of Compensation (Reg. No. 135/2007)
- The Rural Development Policy and Strategy (2001),

- Access to Genetic Resources and Community Knowledge, and Community Rights (Proclamation No. 482 /2006),
- National Biodiversity Strategy and Action Plan,
- Growth and Transformation Plan (GTP),
- Ethiopia's Climate Resilient Green Economy Strategy (CRGE),
- Convention on Biological Diversity (CBD), and
- The Convention on International Trade in Endangered Species (CITES).

3.7.1.1 Legal and policy framework

Legal and policy framework dimension analyzes key policies, laws, and regulations that define the social, environmental, and economic objectives of forestry sector and biodiversity conservation. Legal and policy framework is analyzed under three sub-dimensions and 17 indictors (Table 14).

Table 13. Assessment criteria and indictors for the legal and policy framework on forest and biodiversity conservation

Sub-dimensions	Indictor	Description
National objectives for forest management and biodiversity conservation	Consistency	Major forest policies and laws are consistent with broader national development goals
	Coordination	Major forest policies and laws consider linkages with other economic sectors that impact forests
	Sustainable utilization	Major forest policies and laws set clear objectives for the sustainable management and utilization of forest resources
	Conservation	Forest policies and laws set clear objectives for forest protection and conservation
	Economic development	Forest policies and laws set clear objectives for economic development of the forest sector
	Respect of rights	Forest policies and laws set clear objectives for recognizing the rights of local communities
Legal basis for community participation in forest management and biodiversity conservation	Participation requirements	The legal framework requires forest managers to engage local communities in forest management planning and operations
	Participation platforms	The legal framework establishes permanent structures to facilitate community participation in local forest management activities
	Community-based approaches	The legal framework promotes community-based forest management approaches
	Extension programs	The legal framework establishes financial assistance and extension programs to facilitate community-based forest

		management approaches
Legal basis for biodiversity conservation	Forest protection	The legal framework establishes designated areas for forest protection and conservation of biodiversity
	Species protection	The legal framework contains provisions for the protection of endangered, rare, or threatened species of flora and fauna
	Trade controls	The legal framework controls the trade of endangered, rare or threatened forest-dependent species of flora and fauna
	Biodiversity database	The legal framework requires a regularly updated national database of biodiversity and genetic resources
	Forest definitions	The legal framework provides clear definitions that distinguish plantations and forests
	Invasive species control	The legal framework contains clear regulations to control the spread of invasive species
	Penalties	The legal framework defines clear penalties for failing to comply with biodiversity protection measures

As indicated in Table 14, the three dimensions are: (i) National objectives for forest management and biodiversity conservation, which evaluates whether objectives in forest policy and law are consistent with national development goals and strategies; (ii) Legal basis for community participation in forest management and biodiversity conservation, which assess to what extent the legal framework facilitate community participation in forest management and biodiversity conservation; (iii) Legal basis for biodiversity conservation, which evaluates to what extent the legal framework promotes protection and conservation of biodiversity. The cumulative performances of this dimension scored moderate.

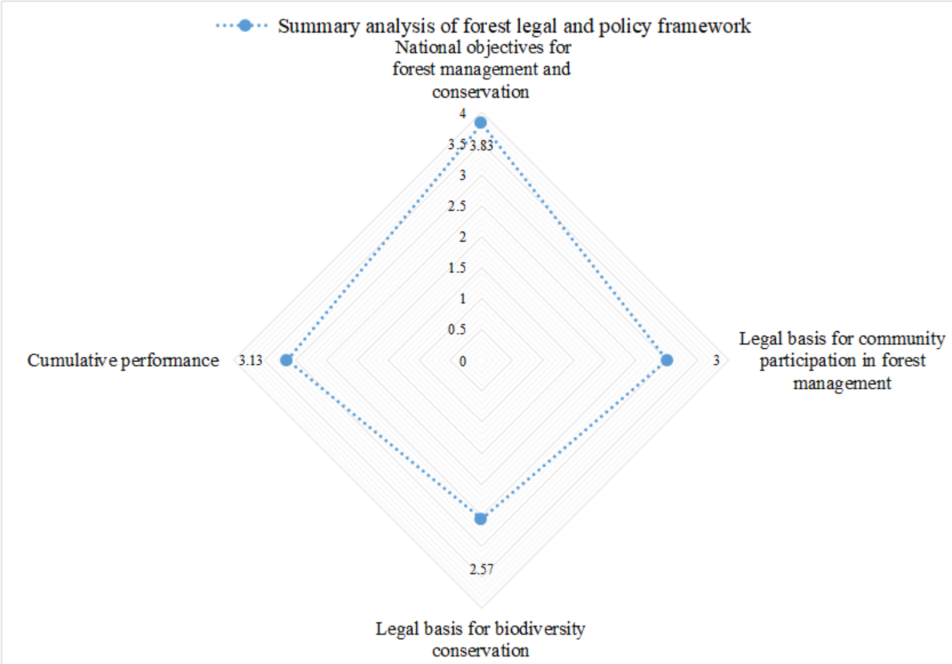


Figure 6. Analysis of legal and policy framework dimension (source: author analysis).

As indicated in Figure 6, the national objective for forest management and biodiversity conservation is evaluated strong. This is mainly because a number of legislations exist that show that objectives in forest policy and law are consistent with national development goals and strategies. For example, the new Forest Conservation and Utilization proclamation No. 1065/2018 is consistent with the national priorities and development plans such as GTP II, CRGE, and National REDD$^+$ strategy. The sub-dimension that concerns on the legal basis for community participation in forest management is evaluated moderate. This is mainly because both the 2007 forest policy and the 2018 forest proclamation require public participation in forest management planning and operations. However, the evaluation is moderate because participation requirements are not sufficiently strong to ensure that community feedback is reflected in management decisions from the early stages of planning. On the other hand, sub-dimension that concerns on the legal basis for biodiversity conservation is evaluated weak mainly because of the gap in terms of establishing a national database of biodiversity and genetic resources, which may be useful for a national biodiversity monitoring system to track species, habitats, ecological communities, and genetic diversity. Although there are rules that stipulate penalties for failure to comply with measures to protect biodiversity, these penalties are not properly tied to the nature and severity of the violation.

3.7.1.2 Forest law enforcement

Forest law enforcement dimension analyzes the efforts to enforce and promote compliance with forest laws and regulations, including the detection of illegal activities, prosecution of offenders, and application of sanctions. It is analyzed under three sub-dimensions and 15 indictors (Table 15).

Table 14. Assessment criteria and indictors for forest and biodiversity related law enforcement

Sub-dimensions	Indictor	Description
Legal basis for forest-related offenses and penalties	Definition of offenses	The legal framework clearly and comprehensively defines all major types of forest infractions
	Definition of penalties	The levels and types of penalties prescribed vary according to the nature and severity of the infraction
	Calculation of penalties	The legal framework prescribes clear methods for assigning penalties and calculating fines for forest related offenses that minimize administrative discretion.
	Updating of penalties	The legal framework allows for regular updating of financial penalties or indexing for inflation.
	Compensatory measures	The legal framework calls for compensatory penalties such as restitution or restoration where appropriate.
Legal basis for forest law enforcement	Institutional mandates	The legal framework establishes clear institutional roles and responsibilities for forest law enforcement
	Clear procedures	The legal framework defines clear procedures for pursuing and documenting forest law enforcement investigations
	Inspection powers	The legal framework grants law enforcement officers authority to conduct inspections and gather evidence
	Enforcement powers	The legal framework grants law enforcement officers authority to arrest suspects
	Performance incentives	The legal framework establishes incentives for forest law enforcement actors to carry out their responsibilities consistent with the law
Application of penalties	Legal expertise	Decision-makers issuing penalties are trained in the legal framework for forest offenses and penalties
	Consistency	Assigned penalties are generally consistent with the law and appropriate given the nature of the offense
	Compliance	Financial penalties are paid in full in a timely manner
	Monitoring of compliance	Compliance with penalties is monitored and further legal action is taken in cases of noncompliance.
	Public disclosure	Information about penalties and their state of compliance is publicly disclosed

As indicated in Table 15, the three sub-dimensions are: (i) Legal basis for forest-related offenses and penalties, which evaluates to what extent the legal framework define a clear system of forest-related offenses and penalties; (ii) Legal basis for forest law enforcement, which assesses to what extent the legal framework define clear powers and procedures for forest law enforcement; (iii) Application of penalties, which evaluates to what extent appropriate penalties applied and enforced in a timely manner. The cumulative performance of this dimension is weak.

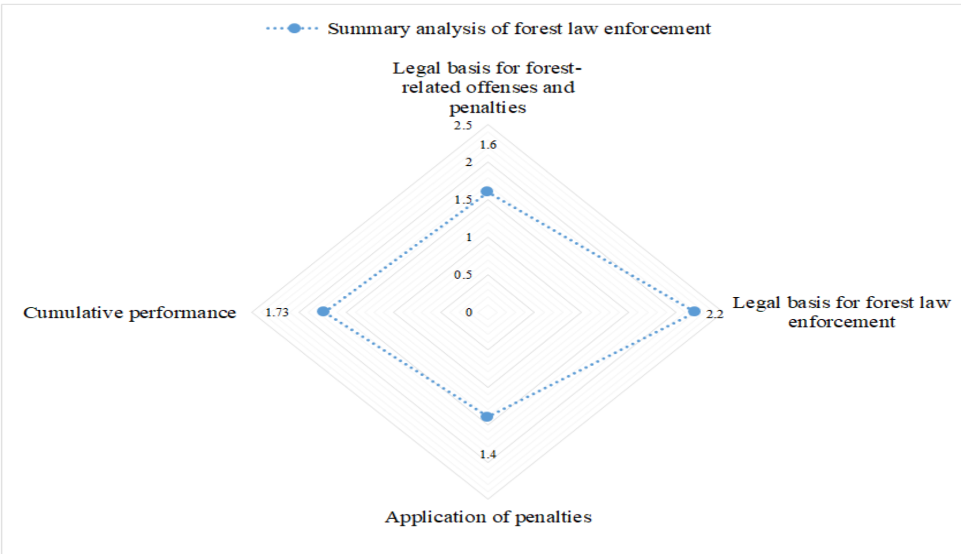


Figure 7. Analysis of forest law enforcement dimension

Two of the sub-dimensions namely legal basis for forest-related offenses and penalties; and legal basis for forest law enforcement scored weak (Figure 7). The third sub-dimension – application of penalties– scored very weak. Some of the key reasons for the weak performance of forest law enforcement dimension are:

- There is lack of clarity in the legal framework to provide how the severity of a penalty for a forest crime is determined. For example, there is limitation in the legal framework in providing parameters or guidance for how fine or jail time is determined in practice, which could minimize the power of officials to reduce fines or waive jail time without justification,
- Although the legal framework defined major types of forest infractions, those definitions are stipulated only at proclamation level and not properly translated into regulations, directives and guidelines. For example, there is lack of directive or guideline that defines

a clear set of procedures or protocols for pursuing and documenting forest law enforcement investigations,

- The legal framework is not clear in defining compensatory measures for forest infractions. For example, the new forest law is not clear on how to pay fines for restoration in cases of illegal harvesting or forest clearing,
- The legal framework does not clearly define the roles and mandate of institutions in a way that create coherence and avoid conflicts or overlaps,
- Very weak monitoring of compliance with penalties issued for forest crimes by relevant institution, and weak follow up in terms of taking further legal action in cases of noncompliance, and
- There is a weak practice of routinely documenting forest crimes and publicly disclosing information about penalties and their state of compliance.

3.7.2 Analysis of forest and biodiversity institutional arrangement

Forestry and biodiversity institutional arrangements have seen remarkable dynamics and continuous change in emphasis over the past half a century in Ethiopia (Table 16). This dynamic trend indicates that biodiversity and forest institutional regimes in Ethiopia have been significantly affected by the prevailing national economic and political orientation in the country.

Table 15. The institutional fluxes of the forestry sector since World War II

Year	Institutional status
1945 – 1950	Forestry Division in the Ministry of Agriculture (MoA)
1951	Forestry became a semi-autonomous department within MoA
1955	Department dissolved and merged with MoA
1971	State Forest Development Agency
1980	Forest and Wildlife Conservation and Development Authority (FAWCDA)
1984	FAWCDA dissolved and became part of MoA
1992	Ministry of Natural Resources Conservation and Environmental Protection (MNRCEP)
1995	MNRCEP dissolved and mandate divided into department under MoA and Environmental Protection Authority
2004	All natural resources conservation issues, including forest and wildlife are organized under Ministry of Agriculture and Rural Development (MoARD)
2008	Forestry as a team was non-existent at federal level and its activities were subsumed under Sustainable Land Use and Watershed Management Case Team in the MoARD
2011	Organized as a Forest Development Case Team under the Natural Resources Conservation and Development Directorate of the MoA
2013	Ministry of Environment and Forest (MEF) established
2015	Ministry of Environment, Forest, and Climate Change
2018	Environment, Forest, and Climate Change Commission

Besides the national political-economic change, the dynamics in global forest and biodiversity related discourses have significantly influenced the institutional arrangement in the country (Figure 8). The institutional arrangements that govern forest and woodland ecosystem in Ethiopia has been shaped by factors such as changes in the broader political economy including agricultural development policy directions, the continuous challenge of deforestation and associated environmental problems and the dynamics in international discourses. With regard to the latter factor, the Ethiopian forestry institutions have substantive responses to global trends and processes, notably the energy crises of the 1970s, the Rio Earth Summit and the international climate change negotiations such as the REDD$^+$ and other green growth initiatives. The period between mid-1970s and mid-1980s was often mentioned as a ‘golden age’ in the history of Ethiopian forestry when the sector received high political attention and institutional profile. It was also the period when Ethiopia designated many protected areas throughout the country that includes national parks, wildlife reserves, national forest priority areas, and community conservation areas.

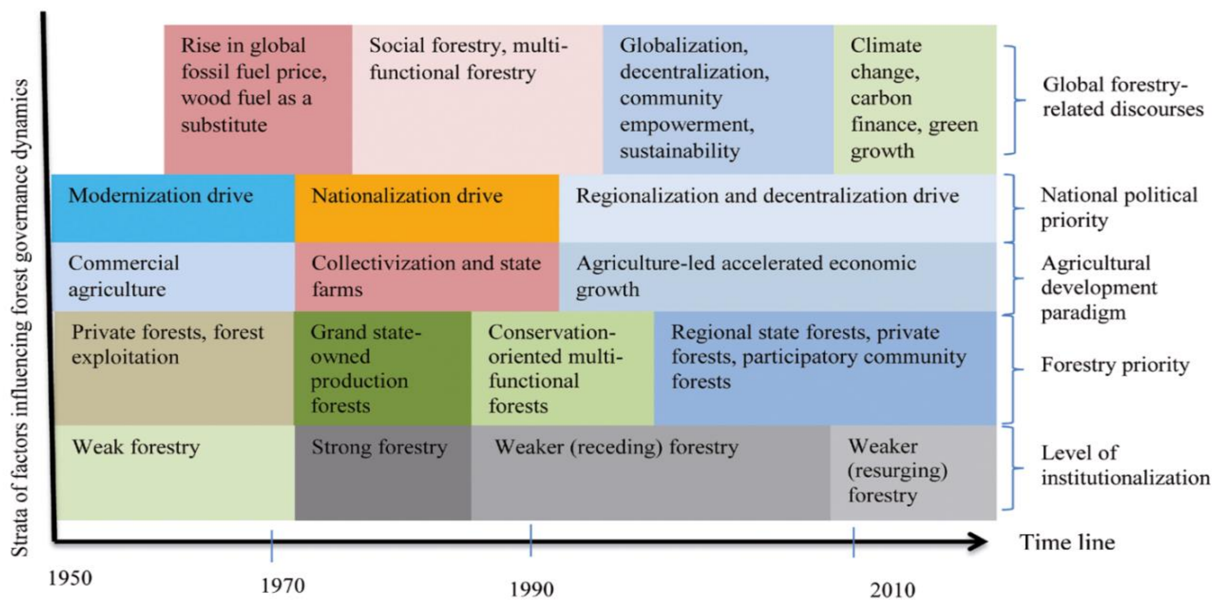


Figure 8. Institutional dynamics and strata of factors influencing institutional arrangements governing forest and woodland ecosystem in Ethiopia (source: Negassa, 2014).

In response to the alarming scale of deforestation and within the framework of social, political, and economic changes, Ethiopia introduced decentralized forest management reform since the early 1990s. This process shared forest management power and duties among subnational units of government. It evolved within the broader political framework characterized by the change from a unitary state to a federal arrangement, involving the transfer of major policy issues from the central state to regional governments. Within this framework, a new forest law was enacted in 1994, specifying the competencies of federal and regional states. The regional states are also mandated by the constitution to formulate and implement their own regional forest laws. Nonetheless, the national government remained mandated to set standards and policy frameworks on affairs concerning environmental and natural resource management. Article 51, sub-article 5 of the 1995 constitution particularly vested the power to enact laws for the utilization and conservation of land and other natural resources, including forestry and biodiversity, to the Federal government.

The emerging carbon financing schemes such as the REDD$^+$ initiative brought renewed attention to the forestry and biodiversity conservation in Ethiopia. The Climate Resilient Green Economy (CRGE) strategy is one of the key governmental strategies envisioned to propel Ethiopia into middle-income-country status by 2025 following low-carbon development pathways (FDRE, 2011). The CRGE strategy was launched at the 17th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Durban, in 2011. The strategy has three overarching goals: fostering economic development and growth, ensuring abatement and avoidance of future emissions and improving resilience to climate change. The forestry sector was selected as one of the four pillars in this transformational policy. Consequently, the forestry sector has shown signs of resurgence after more than two decades of marginalization and subordination. Recognition of the essential role of the Sector was reflected in the establishment of a new Ministry of Environment and Forest and Climate Change (MEFCC) in June 2013. The MEFCC was, therefore, a nodal institution responsible for facilitating the implementation of the CRGE strategy and responsible for all activities of planning, promotion, coordination and development of the environmental, forest and climate change sectors. The MEFCC is reinstituted as Environment, Forest, and Climate Change Commission (EFCCC) in 2018 with similar mandates.

Forestry activities and institutional mandates encompass multiple sectors. This is recognized in Agenda 21 of the UNCED non-legally binding agreement, which emphasizes the need for coordination among sectors in ensuring sustainable forest management, by harmonizing different policies that have an impact on forest conditions. This is mainly because forest-related problems often cannot be dealt only within the forestry sub-sector, and solutions require coordination across the related sectors. The inter-sectoral nature of forestry is also recognized in several studies in Ethiopia where the problems of forest governance lie outside the forest sector, such as in agriculture, energy, industry, settlement programs, infrastructure development, population growth and tenure and property right arrangements (Negassa, 2014). Sectors such as forestry that are based on long-term planning and investment must be built on a stable institutional ground. Without stability, organizations will always remain weak and deprived of institutional memory, a critical tool that helps to inform policies.

In conclusion, the GFI (Governance of Forests Initiative) framework is adopted as analytical tool for examining policies and practices in forest and biodiversity governance (Davis et al., 2013). The GFI framework provides a comprehensive set of indicators that can be used to diagnose and assess the impacts of policies and institutional arrangements on biodiversity conservation and forest ecosystem services. Accordingly, biodiversity conservation and ecosystem service issues at multiple sub-dimensions and indictors level was analyzed. Through this comprehensive analysis it has been identified which legal and policy and law enforcement issues scored weak and very weak that requires serious corrective measures to improve forest governance in Ethiopia (Table 17).

Table 16. Forest legal and policy framework and Forest law enforcement

Dimensions	Score	Key gaps and focus for policy actions
Legal basis for biodiversity conservation	Weak	Establish a national database of biodiversity and genetic resources that should be part of a national biodiversity monitoring system to track species, habitats, ecological communities and genetic diversity
Legal basis for forest-related offenses and penalties	Weak	Forest-related offenses and penalties should be clearly defined in the legal framework and they should be differentiated by the nature and severity of the crime. The financial penalties for forest infractions should be routinely updated and compensatory measures need to be clearly defined in the legal framework
Legal basis for forest law enforcement	Weak	A directive or guideline is needed to clearly define procedures that govern forest law enforcement investigations, frequency of law enforcement monitoring, handling of evidence, and reporting of infractions
Application of penalties	Very weak	Law enforcement agencies including judges and prosecutors need to get formal training on the forest legal framework. Forest related penalties need to be consistent with the rules in the legal framework, and the penalties should be proportional to the crime; concerned institution should monitor the level of compliance and enforcement of penalties

3.8 References

Abebe, B., Dramis, F., Fubelli, G., Umer, M. and Asrat, A., (2010). Landslides in Ethiopian Highlands and the Rift, *Margins Journal of African Earth*, 56 (4-5), 131-138.

ABOA (Amhara Bureau of Agriculture). (2013). 'Forest Development and Utilization in Amhara National Regional State: Issues Requiring Attention'; Presented to a workshop organized by CIFOR Ethiopia Office: Addis Ababa, Ethiopia.

Abtew, W. and Dessu, S.B., (2019). 'The Grand Ethiopian Renaissance Dam on the Blue Nile'. Springer, P. 179.

Admasu, D., (2008). 'Invasive plants and food security: The case of *Prosopis juliflora* in the Afar region of Ethiopia', p. 1–13. FARM-Africa, IUCN.

Álvarez-Berríos, N.L., and Aide, M.T., (2015). 'Global demand for gold is another threat for tropical forests'. *Environmental Research Letters*, 10(1), 014006. DOI: 10.1088/1748-9326/10/1/014006.

Amare, *K.*, Mebrahtu, *G.*, *and* Gebremiceal, *A.*, (2018). Landslide characterization and distribution in northern Ethiopia. *Bull Eng Geol Environ* 77, Pp. 581.

Ameha, A., Larsen, H.O. and Lemenih, M., (2014). 'Participatory forest management in Ethiopia: Learning from pilot projects'. *Environmental Management,* 53, Pp. 838–54.

Anderson, P. M.L, and Hoffman, M.T., (2007). The impacts of sustained heavy grazing on plant diversity and composition in lowland and upland habitats across the Kamiesberg mountain range in the Succulent Karoo, South Africa. *Journal of Arid Environment*, 70, Pp.686-700.

Anderson, P.M.L., Okereke, C., Rudd, A., and Parnell, S., (2013). Regional Assessment of Africa. In T.Elmqvist, M. Fragkias, J. Goodness, B. Güneralp, P.J. Marcotullio, R.I. McDonald, M. Schewenius (Eds.), *Urbanization, biodiversity and ecosystem services: Challenges and opportunities* (pp. 453-459). Dordrecht: Springer.

Asfaw, G., (2001). 'Assessment of the environmental policy of Ethiopia', In Z. Tadesse (Ed.), *Environment and Development in Ethiopia,* Forum for Social Studies. Addis Ababa, Ethiopia, *p.*17–39.

Awoke, Z., Teferi, B., and Mekonen, T., (2018). Impacts of resettlement on Woodland resource utilization in Abobo Woreda, Gambella, Ethiopia. *Journal of Resources Development and Management*, 41, Pp. 67–77.

Ayenew, T. and Barbieri G., (2005). Inventory of landslides and susceptibility mapping in the Dessie area, Northern Ethiopia. Engineering Geology, 77, Pp. 1-15.

Bekele, M. and Berhanu, L., (2001). State of Forest genetic Resources in Ethiopia. Sub-Regional Workshop FAO/IPGRI/ICRAF on the conservation, management, sustainable utilization and enhancement of forest genetic resources in Sahelian and North-Sudanian Africa (Ouagadougou,Burkina Faso, 22-24 September 1998). Forest Genetic Resources Working Papers, Working Paper Forestry Department, FAO, Rome, Italy.

Belayneh, A., Yohannes, T. and Worku, A., (2013). 'Recurrent and extensive forest fire incidence in the Bale Mountains National Park (BMNP), Ethiopia: Extent, Cause and Consequences. *International Journal of Environmental Sciences'*, 2(1), p. 29-39.

Bellard, C., Bertelsmeier , Leadley, C.P, Thuiller, W. and Courchamp, F., (2012). 'Impacts of climate change on the future of biodiversity', *Ecol Lett.*, 15(4), p. 365–377.

Berhanu, A., Demissew, S., Woldu, Z., Friis, I. and van Breugel, P., (2018). 'Intermediate evergreen Afromontane forest (IAF) in northwestern Ethiopia: observations, description and modelling its potential distribution' *Phytocoenologia*, 48(4), Pp. 351–367.

Berihun, A., Yirga, G. and Tesfay, G., (2016). 'Human-Wildlife Conflict in Kafta-Sheraro National Park, Northern Ethiopia' *World Journal of Zoology*, 11(3), p.154-159.

Berisso, T., (1995). Deforestation and Environmental Degradation in Ethiopia: The Case of Jam Jam Province1. *Northeast African Studies*, 2, Pp.139-155.

Bishaw, B., (2009). 'Deforestation and Land Degradation in the Ethiopian Highlands: A Strategy for Physical Recovery', *Ee-JRIF*, 1(1), p.5 -18.

Brenan, J. P. M., (1978). Some aspect of the phytogeography of tropical Africa. *Ann. Miss. Bot. Gard.*, 65(2), Pp. 437-478.

Bustamante, M., Helmer, E. H., Schill, S., Belnap, J., Brown, L.K. et al., (2018). 'Chapter 4: Direct and indirect drivers of change in biodiversity and nature's contributions to people', In IPBES: The IPBES regional assessment report on biodiversity and ecosystem services for the Americas. Rice, J., Seixas, C. S., Zaccagnini, M. E., Bedoya-Gaitan, M., and

Valderrama, N. (eds.). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany, Pp. 295-435.

Calle, Z., Henao-Gallego, N., Giraldo, C., Armbrecht, I., (2013). A comparison of vegetation and ground dwelling ants in abandoned and restored gullies and landslide surfaces in the Western Colombian Andes. *Restoration Ecology*, 8, Pp. 114.

Cardinale, B. et al., (2012). ‘Biodiversity loss and its impact on humanity’, *Nature*, 486, p.59–67.

Castro, J., García-Llorente, M., Martín-López, B., Palomo, I. and Iniesta-Arandia, I., (2013). ‘Multidimensional approaches in ecosystem services assessment’, In: Alcaraz-Segura, D., Di Bella, C.M., Straschnoy, J.V. (Eds.), *Earth Observation of Ecosystem Services*, CRC press, p. 441–468.

Chanie, S. and Tesfaye, D., (2015). Threats to biodiversity conservation and ecotourism activities in Nechsar National Park, Ethiopia. International Journal of Biodiversity and Conservation, 7:2, Pp.130-139.

CHGE (Center for Health and the Global Environment). (2002). ‘Biodiversity: Its Importance to Human Health. Center for Health and the Global Environment, Harvard Medical School.

Chilalo, M. and Wiersum, K., (2011). The role of non-timber forest products for livelihood diversification in Southwest Ethiopia. Ee-JRIF - Agriculture and Forestry issue, 3:1, pp 44-59.

Colfer, C.J.P., Sheil, D., Kaimowitz, D. and Kishi, M., (2006). ‘Forests and human health in the tropics: some important connections’, *Unasylva*, 57, Pp.3-10.

Costanza, R. *et al*. (1997). The value of the world's ecosystem services and natural capital. *Nature*, 297, Pp. 950-953.

Costanza, R., d’Arge, R., de Groot, R., Farberk, S., Grasso, M., Hannon, B., LimburgI, K., Naeem, S., O’Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., and van den Belt M., (1997). The value of the world’s ecosystem services and natural capital. *Nature,* 38, Pp. 253–260.

CSA (Central Statistical Agency). (2007). ‘Statistical Abstracts’, Addis Ababa, Ethiopia.

Darbyshire, I., Lamb, H. and Umer, M., (2003). ‘Forest clearance and regrowth in northern Ethiopia during the last 3000 years’, *The Holocene*, 13, p. 537-546.

Davis, C., Williams, L., Lupberger, S. and Daviet, F., (2013). 'Assessing Forest Governance: The Governance of Forests Initiative Indicator Framework', World Resources Institute (WRI), Washington, Dc 20002, USA. ISBN 978-1-56973-815-3.

Davis, P., Woldemariam, T., Baena, S. and Moat, J., (2012). 'The Impact of Climate Change on Indigenous Arabica Coffee (*Coffea arabica*): Predicting Future Trends and Identifying Priorities', *PLoS ONE*, 7, e47981.

Desissa, D., (2012). 'Fragmented forests in south-west Ethiopia: impacts of land-use change on plant species composition and priorities for future conservation', PhD thesis, United Kingdom.

Dessalegn, R., (2001). 'Environmental change and state policy in Ethiopia: lessons from past experience'. *Forum for social studies monograph Series 2*, Pp. 10-108.

Díaz, S., Lavorel, S., de Bello, F., Quetier, F. Grigulis, K. and Robson, M., (2007). Incorporating plant functional diversity effects in ecosystem service assessments. *Proceedings of the National Academy of Sciences of the United States of America, 104*, 20684-20689.

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T. et al., (2018). *Assessing nature's contributions to people. Science,* **359:** 6373, Pp. 270-272.

EBI (Ethiopian Biodioversity Institute). (2014). 'Ethiopia's Fifth National Report to the Convention on Biological Diversity', Addis Ababa, Ethiopia.

EFAP (Ethiopian Forestry Action Program). (1994). 'Synopsis Report of the Ethiopian Forestry Action Program', Ministry of Natural Resources Development and Environmental Protection, Addis Ababa, Ethiopia.

Endale, T., (2016). The role of indigenous people in the biodiversity conservation in Gamo area of GamoGofa zone, Southern Ethiopia. International Journal of Biodiversity and Conservation, 8:10, Pp. 244-250.

EPA (Environmental Protection Authority). (1997). 'The Conservation Strategy of Ethiopia, Volume II', Federal Policy on the Environment. Addis Ababa.

Eshetu, A.A., (2014). 'Ecotourism as a viable strategy for livelihood diversification and sustainable natural resource management in Ethiopia (from eco-development paradigm point of view)'. *J Environ Sci Water Resour*, 3, Pp. 40–52.

ESIA (Environmental and Social Impact Assessment). (2011). 'Environmental and Social Impact Assessment: Ethiopia- Kenya Power Interconnection Project'. African Development Bank Group. P.48.

EWCA (Ethiopian Wildlife Conservation Authority). (2009). 'The Value of the Ethiopian Protected Area System: Message to Policy Makers'.

EWNHS (Ethiopian Wildlife and Natural History Society). (1996). 'Important Bird Areas of Ethiopia: A first inventory', Samayata Press, Addis Ababa, Ethiopia.

FAO (Food and Agriculture Organisation). (2007). 'The State of Food and Agriculture: Paying Farmers for Environmental Services'. FAO, Rome, P. 240.

FAO. (2010). 'Forest Resource Assessment 2010', Country Report Ethiopia, FAO, Rome.

FAO. (2015). 'Global Forest Resources Assessment 2015: How are the world's forests changing?', Rome.

FAO and UNHCR. (2018). 'Managing forests in displacement settings: guidance on the use of planted and natural forests to supply forest products and build resilience in displaced and host communities', by A. Gianvenuti, A. Guéret and C. Sabogal. Rome, p. 84.

FAO, and NZGGRC. (2017). 'Supporting low emissions development in the Ethiopian dairy cattle sector – reducing enteric methane for food security and livelihoods', Rome. p. 34, http://www.fao.org/3/ai6821e.pdf.

FCPF (Forest Carbon Partnership Facility). (2011). 'Forest Carbon Partnership Facility', Federal Democratic Republic of Ethiopia, Addis Ababa.

Fetene, A., Hilker, T., Yeshitela, K., Prasse, R., Cohen, W., and Yang, Z. (2016). 'Detecting trends in landuse and landcover change of Nechsar National park, Ethiopia'. *Environmental Management*, 57(1), Pp. 137–147.

FRA (Forest Resources Assessment). (2010). 'Global Forest Resources Assessment 2010, country report'. FAO, Rome.

Friis, I., Demissew, S. and van Breugel, P., (2010). 'Atlas of the Potential vegetation of Ethiopia', Addis Ababa University Press.

Fufa, D., (2013). ‘Indigenous Knowledge of Oromo on Conservation of Forests and its Implications to Curriculum Development: the Case of the Guji Oromo’, A Thesis Submitted to the Department of Curriculum and Teachers Professional Development Studies in Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Curriculum Design and Development Addis Ababa University, Addis Ababa, Ethiopia.

G/Egziabher, T., (1991). Diversity of the Ethiopian FloraJ.M.M. Engles, J.G. Hawkes and W. Melaku (Eds.), Plant *Genetic Resources of Ethiopia*, Cambridge University Press, Cambridge. Pp. 75–81.

Gebremarkos, W., (1998). The Forest Resources of Ethiopia; Past and Present, in Walia - Journal of the Ethiopian Wildlife and Natural History Society, 19, Pp. 10 - 28, Addis Ababa.

Gebresilassie, M., (2013). Forest development endeavors in Tigray region: Opportunities, challenges and way forward. In Proceedings of the Workshop Organized by CIFOR Ethiopia Office, Addis Ababa, Ethiopia.

Geissler, S., Hagauer, D., Horst, A., Krause, M., and Sutcliffe, P., (2013). Biomass Energy

Gello, G., (2017). ‘Traditional Ecological Practices of Forest Governance, Repercussion, Biodiversity Conservation and Climate Change Mitigation of *Sodhe* Forest, Deramalo *Woreda*, Gamogofa Zone, SNNPR, South Ethiopia’, MSc Thesis Arba Minch University, Ethiopia.

Gibe III EIA. (2009). ‘GIBE III Hydroelectric Project: Environmental and Social Impact Assessment’. Ethiopian Electric Power Corporation. Addis Ababa, P. 358.

Global Forest Watch. (2020). ‘Tree Cover in Gambela Peoples, Ethiopia’. World Resources Institute. Accessed on 09/09/2021’. http://www.globalforestwatch.org.

Goodin, K.D., (2019). Ethiopian Orthodox Tewahedo Church Forests and Economic Development. The Case of Traditional Ecological Management. McGill University.

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., and Collins, C. D., (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. Science Advances, 1, e1500052.

Hailemariam, M., Mushir, A., Zbelo, T., and Niguse, A., (2017). Impacts of artisanal gold mining systems on soil and woody vegetation in the semi-arid environment of northern Ethiopia. *Journal of Tropical Geography*, 38, Pp. 386–401.

Hauff, V., (2002). Sustainability Analysis: The Key to the Future. In: Deutschland Magazine, February/March, 2002, 2.

Hein, L., van Koppen, K., de Groot, R.S., and van Ierland, E.C., (2006). Spatial scales, stakeholders and the valuation of ecosystem services. *Ecol. Econ*., 57, Pp. 209–228.

Holdren, J. P., and Ehrlich, P. R. (1974). Human population and the global environment. *American Scientist,* 62, Pp. 282-292.

IBC (Institute of Bodiversity Conservation). (2005). 'National Biodiversity Strategy and Action Plan', Institute of Biodiversity Conservation, p. 103.

IBC. (2009). 'Ethiopia's 4th Country Report to the Convention on Biological Diversity (CBD)', November 2009, Addis Ababa, Ethiopia.

IBCR (Institute of Bodiversity Conservation and Research). (2001). 'Twenty Five years of Biodiversity Conservation and Utilization and Future Plan of Action'.

ICO (International Coffee Organization). (2015). '*Historical Data on the Global Coffee Trade',* Website: http://www.ico.org/new_historical.asp?section=Statistics.

Izabela, O., and Klepeis, P., (2018). Ethiopian church forests: a socio-religious conservation model under change, *Journal of Eastern African Studies*, 12:4, Pp. 674- 695.

Kassa, H., Lemenih, M., (2011). 'Opportunities and challenges for sustainable production and marketing of gums and resins in Ethiopia', CIFOR.

Kelbessa, E., Demissew, S., (2014). 'Diversity of vascular plant taxa of the fora of Ethiopia and Eritrea'. *Ethiop J Biol Sci*, 13 (supp.). Pp. 37–45.

Kozak, J., Lant, C., Shaikh, S., Wang, G., (2011). 'The geography of ecosystem service value: the case of the Des Plaines and cache river wetlands', Illinois. Appl. Geogr., 31, Pp. 303–311.

Krieger, D. J., (2001). 'Economic value of Forest Ecosystem Services: a review', The Wilderness So-ciety, Washington, DC.

Lemenih, M., (2009). The current and prospective economic contribution of the forestry sector in Ethiopia. T. Heckett and N. Aklilu (Eds), *Proceeding of a workshop –Ethiopian forestry at crossroads*: The need for a strong institutions. Occasional Report No. 1/2009.

Lemenih, M. and Kasssa, H., (2014). ‘Re-Greening Ethiopia: History, Challenges and Lessons’. *Forests* 5, Pp. 1896-1909.

Levine, M.J., Vilà, M., D'Antonio, M.C., Dukes, S.J., Grigulis, K., Lavorel, S., (2003). ‘Mechanisms underlying the impacts of exotic plant invasions’. Proceedings of the Royal Society B: *Biological Sciences* 270, Pp. 775–781.

Logan, W. E. M., (1946). An introduction to the forests of Central and Southern Ethiopia. *Inst. Paper No*. 24, 58pp.

Lowman, M.D., (2011). Finding sanctuary: Saving the biodiversity of Ethiopia, one church forest at a time. *Explorers Journal*, 88, Pp. 26–31.

Mace, G.M., Bateman, I., Albon, S., Balmford, A., Brown, C., Church, A., Haines-Young, R., Pretty, J.N., Turner, K., Vira, B. and Winn, J., (2011). ‘Chapter 2: Conceptual framework and methodology’, In: *UK National Ecosystem Assessment: Technical Report*. United Nations Environment Programme World Conservation Monitoring Centre, Cambridge.

Maes, J. *et al.*, (2016). ‘An Indicator Framework for Assessing Ecosystem Services in Support of the EU Biodiversity Strategy to 2020’, *Ecosystem Services, 17*, p. 14-23.

Martín-López, B., Iniesta-Arandia, I., García-Llorente, M., Palomo, I., Casado-Arzuaga, I. et al., (2012). ‘Uncovering ecosystem service bundles through social preferences’, *PLoS One* 7, e38970.

MEA (Millennium Ecosystem Assessment). (2005). Ecosystems and Human Well-Being: Biodiversity Synthesis-Millennium Ecosystem Assessment. World Resources Institute, Washington, D.C.

MEFCC (Ministry of Environment, Forest and Climate Change). (2018). National Forest Sector Development Program, Ethiopia: Volume I: Situation Analysis. Addis Ababa, Ethiopia.

Meijaard, E., Abram, N.K., Wells, J.A., Pellier, A.S., Ancrenaz, M., Gaveau, D.L.A., Runting, R.K. and Mengersen, K., (2013). ‘People's perceptions about the importance of forests on Borneo’, *PLoS One* 8, e73008.

Mekonen, S., (2017). Roles of Traditional Ecological Knowledge for Biodiversity Conservation. Journal of Natural Science Research, 7, 15. Pp. 21-27.

Melillo, J. and Sala, O., (2002). 'Ecosystem services. In: Biodiversity: Its Importance to Human Health', Interim Executive Summary. E. Chivian (Ed.), MA: Center for Health and the Global Environment, Harvard Medical School, Pp. 15-20, Boston.

Mezgebe, A.H., and Raju S.A.J., (2011). 'Towards sustainable Utilization of Lake Chamo Biodiversity Resources: Geospatial analysis of lake level Changes, Challenges and Opportunities, Ethiopia'. International Conference on Sustainable Development of Natural Resources in Africa 2011. Accra, Ghana.

Mezgebu, A. and Workneh, G., (2017). 'Changes and drivers of afro-alpine forest ecosystem: future trajectories and management strategies in Bale eco-region, Ethiopia' *EcolProcess*, 6, p. 42.

Minten, B., Tamru, S., Kuma, T. and Nyarko, Y., (2014). 'Structure and Performance of Ethiopia's Coffee Export Sector', Working paper 66. June 2014. Addis Ababa: Ethiopian Development Research Institute (EDRI) and International Food Policy Research Institute (IFPRI). p 30.

Miranda, M., Burris, P., Bingcang, J.F., Shearman, P., Briones, J.O., La Vina, A., and Menard, S., (2003). Mining and critical ecosystems: Mapping the risks. World Resources Institute.

MoFEC (Ministry of Finance and Economic Cooperation). (2015). Brief Note on the (2007 EFY) NAS Estimates, Minstry of Finance and Economic Development, Addis Ababa.

MOFED (Ministry of Finance and Economic Development). (2010). Growth and Transformation Plan of Ethiopia. 2010/2011-2014/15 of the federal democratic republic of Ethiopia.

Mulualem, G. and Tesfahunegny, W., (2016). 'Review of Key Wildlife Threats Factors from Literature and Observation Perspectives: A Way Forward for Sustainable Wildlife Genetic Resource Conservation Practices in Ethiopia', *Journal of Zoology Studies*, 3(5), p 01-12.

NAPA (National Adaptation. Programme of Action). (2007). 'Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia'. The Federal Democratic Republic of Ethiopia, Ministry of Water Resources, National Meteorological Agency, Addis Ababa. P. 96.

Negassa, A., (2014). ‘Forest governance dynamics in Ethiopia: Histories, arrangements and practices’ *PhD thesis*, Wageningen University, NL.

NGPME (Natural Gum Processing and Marketing Enterprise). (2014). ‘Gums and Resins Export of Ethiopia From 2003 To 2014’. Natural Gum Processing and Marketing Enterprise, Addis, Ababa.

Norton, D.A., (2009). ‘Species invasions and the limits to restoration: learning from the New Zealand experience’, *Science*, 325, p. 569–571.

Nyssen, J., Poesen, J., Moeyersons, J., Deckers, J., Haile, M and Lang A., (2004). Human impact on the environment in the Ethiopian and Eritrean highlands—a state of the art. *Earth Sci Rev*, 64, Pp. 273–320.

OCHA (United Nations Office for the Coordination of Humanitarian Affairs). (2018). United Nations Emergency Response Fund (CERF) Annual Report 2017.

Oskamp, (1977). ‘Attitudes and opinions’. Prentice-Hall. P. 466.

Patz, J. A., Graczyk, T.K., Geller, N. and Vittor, A.Y., (2000). ‘Effects of environmental change on emerging parasitic diseases’, *International Journal for Parasitology*, 30, p. 1395–1405.

Patz, J.A., Daszak, P., Tabor, G.M., Aguirre, A.A., Pearl, M., Epstein, J., Wolfe, N.D., Kilpatrick, A.M., Foufopoulos, J., Molyneux, D. and Bradley, D.J., **(**2004). ‘Unhealthy landscapes: policy recommendations on land use change and infectious disease emergence’, *Environmental Health Perspectives*, 112, p. 1092–1098.

Pistorius, T., Carodenuto, S., and Wathum, G., (2017). Implementing Forest Landscape Restoration in Ethiopia, *Forests*, 8: 61; doi: 10.3390/f8030061.

Price Waterhouse Coopers. (2011). Mine 2011 - The game has changed: Review of global trends in the mining industry. http://www.pwc.com/gx/en/mining/publications/2011-mine-emerging-markets-and-trends.jhtml.

Reynolds, T.W., Collins, C.D., Wassie, A., Liang, J., Briggs, W., Lowman, M.D., Shimekach, T., and Adamu, E., (2017). Sacred natural sites as mensurative fragmentation experiments in long-inhabited multifunctional landscapes. Ecography, 40, Pp. 144–157.

Rodrigues, P., Dorresteijn, I., Senbeta, F.and Fischer, J., (2019). Living on the edge: rapid assessment of the mammal community in a coffee forest in southwestern Ethiopia. *African Journal of Ecology*, 57, Pp. 279-285.

Rodrigues, P., Dugo, G.S., Dorresteijn, I., Schultner, J., Hanspach, J., Hylander, K., Senbeta, F.and Fischer, J., (2018). Coffee management and the conservation of forest bird diversity in south-western Ethiopia. *Biological Conservation*, 217, Pp.131-139.

Rojahn, A., (2006). 'Incentive mechanisms for a sustainable use system of the montane rain forest in Ethiopia' Wirtschafts- und Sozialwissenschaftliche Fakultaet der Christian Albrechts Universitaet Kiel, Germany. SPGS Newsletter Issue No. 39: 10 Years of Supporting Com-mercial Tree Planting in Uganda, December 2014.

Ryan, F., (2011). '*US Forest Service Technical Assistance Trip to Ethiopia: Invasive species management',* Report Submitted to USAID.

Schueler, V.T., Kuemmerle, F. and Schroder, H., (2011). 'Impacts of Surface Gold Mining on Land Use Systems in Western Ghana'. *Ambio* 40, Pp. 528-539.

Schwartz, M.W., Bringham, C. A. , Hoeksema, J.D., Lyons, K.G., Mills, M.H., and van Mantgem, P.J., (2000). Linking biodiversity to ecosystem function: implications for conservation ecology. *Oecologia*, 122, Pp. 297-305.

Senbeta, F., (2018). 'Diversity, threats and conservation status of Coffee Forest in Ethiopia'. *Ethiopian Journal of Biological Sciences*, 17(2), Pp. 169-188.

Senbeta, F. and Denich, M., (2006). 'Effects of wild coffee management on species diversity in the Afromontane rainforests of Ethiopia', *Forest Ecol Management,* 232, p.68–74.

Senbeta, F., & Teketay, D., (2003). 'Diversity, community types and population structure of woody plants in Kimphee forest, a unique nature reserve in southern Ethiopia'. *Ethiopian Journal of Biological Sciences,* 2, Pp. 169-187.

Sharp, P.M., Bailes, E., Chaudhuri, R.R., Rodenburg, C.M., Santiago, M.O. and Hahn, B.H., (2001). The origins of acquired immune deficiency syndrome viruses: where and when? Philosophical Transactions of the Royal Society of London, Series B, *Biological Sciences*, 356, Pp. 867–876.

Sherbinin, A., (2002). '*A CIESIN Thematic Guide to Land-Use and Land-Cover Change*' NY: The Trustees of Columbia University.

Shiferaw, W., Demissew, S. and Bekele, T., (2018). 'Ecology of soil seed banks: implications for conservation and restoration of natural vegetation: a review'. *Int J Biodiversity Conservation*, 10(10), Pp. 380–93.

Sida (Swedish Internationa Development Agency). (2003). Strategic Environmental Analysis Ethiopia; background documents country strategy 2003–2007. Swedish Internationa Development Agency, Department for Africa. Artice No. SIDA2142en Takako, 2004. Traditional Ecological Knowledge: From the Sacred Black Box to the Policy of Local Biodiversity Conservation.

Siraj, M., Zhang, K., Xiao, W., Bilal, A., Gemechu, S., Geda, K. and Xiaodan, L., (2016). 'Does Participatory Forest Management Save the Remnant Forest in Ethiopia?' Proceedings of the National Academy of India–Section B: *Biological Sciences*, Pp 15.

Sisay, N., (2008). 'Ethiopian government efforts to increase forest cover: a policy oriented discussion paper'. In Bane, J, Sisay, N., Alemu, M. and Randall, B.P. (edts.). Polices to increase forest resources of Ethiopia, Proceedings of a policy workshop organized by Environmental Economics Policy Forum for Ethiopia (EEPFE) and Ethiopian Development Research Institute (EDRI). Addis Ababa, Ethiopia.
FAO (2017). 'The future of food and agriculture – Trends and challenges'. Rome.

Strategy Ethiopia.
https://rise.esmap.org/data/files/library/ethiopia/Documents/Clean%20Cooking/Ethiopia_Biomass%20energy%20strategy%20Ethiopia.pdf

Tadesse, G., Zavaleta, E. and Shennan, C., (2014). Effects of land-use changes on woody species distribution and above-ground carbon storage of forest-coffee systems. *Agriculture, Ecosystems and Environment*, 197, 21-30.

Tadesse, S.A. and Kotler, B.P., (2016). 'Attitudes of local people towards the Mountain Nyla (*Tragelaphus buxtoni*) in Munessa, Ethiopia'. LAP LAMBERT Academic Publishing, P. 192.

Takahashi, R. and Todo, Y., (2012). 'Impact of Community-Based Forest Management on Forest Protection: Evidence from an Aid-Funded Project in Ethiopia'. *Environmental Management,* 50, Pp. 396–404.

Takako, (2004). Traditional Ecological Knowledge: From the Sacred Black Box to the Policy of Local Biodiversity Conservation.

Tefera, A., (2015). 'Ethiopia: Coffee Annual Report' *GAIN Report* (number ET1514–26/5/2015). USDA Foreign Agricultural Service. Pp 6.

Tefera, A. and Tefera, T., (2014). GAIN Report (number ET1402–13/5/2014). USDA Foreign Agricultural Service. Pp. 11.

Teferra, F. and Beyene, F., (2014). 'Indigenous claims and conflicts in managing the Abijata-Shalla Lakes National Park, Ethiopia', *International Journal of Biodiversity Science, Ecosystem Services, and Management*, 10(3), p. 216-227.

Teka, M., (2006). 'Energy Policy of Ethiopia'. Ministry of Mines and Energy, Geothermal Energy Conference, Addis Ababa.

Tesfaye, K., (2006). Genetic diversity of wild Coffea arabica populations in Ethiopia as a contribution to conservation and use planning. *Ecology and Development Series 44*, Center for Development Research (ZEF), University of Bonn.

Tesfaye, Y., Roos, A., Campbell, B.J. and Bohlin, F., (2012). 'Factors associated with the performance of user groups in a participatory forest management around Dodola Forest in the Bale Mountains, southern Ethiopia'. *Journal of Development Studies*, 48(11), Pp. 1665–82.

Tesfaye, Y., Roos, A., Campbell, B.M. and Bohlin, F., (2011). 'Livelihood strategies and the role of forest income in participatory-managed forests of Dodola area in the Bale Highlands, southern Ethiopia'. *Forest Policy and Economics*, 13, Pp. 258–65.

Tezazu, S. and Mezgebe, A.H., (2019). 'Woody Species Composition Analysis of Shawo Sacred Forest, Ethiopia'. *Int.J.Appl.Sci.Biotechnol.*, 7(1), Pp. 12-21.

TGE (Transitional Government of Ethiopia). (1994). ‘Proclamation no. 94/1994: A Proclamation to Provide for the Conservation, Development and Utilization of Forests’. Negarit Gazeta of the Transitional Government of Ethiopia. Addis Ababa.

Thulin, M., (1983). Leguminosae of Ethiopia. *Opera Botanica*, 68, Pp.1–223.

UNCED (United Nations Conference on Environment and. Development). (1992). Report of the *United Nations Conference* on *Environment* and. *Development*. Rio de Janeiro, 3-14 June *1992*. Volume I. Resolutions Adopted by the *Conference*.

UNDP (United Nations Development Programme). (2017). Enhanced Management and Enforcement of Ethiopia’s Protected Area Estate Project. United Nations Development Programme, Addis Ababa, Ethiopia.

Uneke, C., (2008). ‘Deforestation and Malaria in sub-Saharan Africa: an overview’, *The Internet Journal of Tropical Medicine*, 6(1), p. 1-12.

UNEP (United Nations Environment Programme). (2016). The contribution of forests to national income in Ethiopia and linkages with REDD+. United Nations Environment Programme: Nairobi.

UNHCR (United Nations High Commissioner for Refugees). (2019). ‘Global Report 2019’. The UN Refugee Agency, P. 125.

Vila, M., and Ibanez, I., (2011). Plant invasions in the landscape. *Landscape ecology*, 26:4, Pp. 461-472.

Von Breitenbach, F., (1963). ‘The Indigenous trees of Ethiopia’, Addis Ababa: Ethiopian Forestry Association.

Wale, M., Kassie, A., Mulualem, G., Tesfahunegny, W., and Assefa, A., (2017). Wildlife Threats and Their Relative Severity of Eastern Ethiopia Protected Areas. *Ecology and Evolutionary Biology*, 2, Pp. 59-67.

Walker, B.H., (1992). ‘Biodiversity and ecological redundancy’, *Conservation Biology*, 6, p.18-23.

Wassie, A., (2002). ‘Opportunities, constraints and prospects of the Ethiopian Orthodox Tewahido Church in conserving forest resources: the case of churches in South Gonder, Northern Ethiopia'. M.Sc. Thesis, Swedish University of Agricultural Sciences, Skinnskatteberg, Sweden.

WCMC (World Conservation Monitoring Centre). (1994). Biodiversity Data Source book.World Conservation Monitoring Centre, World Conservation Press, Cambridge, UK.

WHO (World Health Organisation). (2005). Preventing chronic disease: a vital investment. Geneva, Switzerland.

WHO. (2013). WHO traditional medicine strategy: 2014-2023.

Wikipedia. (2019). Dams and reservoirs in Ethiopia. http://www.wikipedia.org/wiki/DamsandreservoirsinEthiopia#Listofdamsandreservoirs accessed on April 20 2019.

Wilcox, B. A. and Ellis, B., (2006). 'Forests and emerging infectious diseases of humans' *Unasylva,* 57(224), p.11-18.

Wilcox, B.A. and Colwell, R.R., (2005). 'Emerging and reemerging infectious diseases: biocomplexity as an interdisciplinary paradigm', *EcoHealth*, 2(4), p.244–257.

Williams, J., Baena, S., Moat, J., Wilkinson, T., (2017). 'Coffee Farming and Climate Change in Ethiopia: Impacts, Forecasts, Resilience and Opportunities, Summary Report 2017'. Royal Botanic Gardens and Environment and Coffee Forest Forum, P. 40.

Woldermariam, T., (2003). Vegetation of the Yayu forest in SW Ethiopia: impacts of human use and implications for in situ conservation of wild *Coffeaarabica* L. populations. Doctoral Dissertation, Center for Development Research, University of Bonn.

Woldeyes F. and Shigeta. M., (2020). Local Worldview Linked Resource Perception and Conservation Behavior: An Evidence from Basketo and Kafa (Southwestern Ethiopia). *African study monographs*. Supplementary issue (2020), 59, pp. 83-103.

Woldeyes, F., Asfaw, Z., Demissew, S. and Roussel, B., (2016). Homegardens (Aal-oos-gad) of the Basket People of Southwestern Ethiopia: Sustainable agro-ecosystems characterizing a traditional landscape. *Ethnobotany Research and Applications,* 14, pp. 549-563.

Woldu, Z., (1988). Variation in grassland vegetation on the central plateau of Shewa, Ethiopia. Ph.D. Thesis, Uppsala, Sweden.

Yachi, S. and Loreau, M., (1999). Biodiversity and ecosystem productivity in a fluctuating environment: The insurance hypothesis. *Proc. Natl. Acad. Sci. U.S.A.*96, Pp. 1463–1468.

Yami, M., Mekuria, W., and Hauser, M., (2012). The effectiveness of village bylaws in sustainable management of community-managed exclosures in Northern Ethiopia. *Sustain. Sci*. 8, pp. 73–86.

Young, J., (2012). Ethiopian Protected Areas A ‘snapshot’. A reference guide for future strategic Planning and Project Funding. Addis Ababa, Ethiopia.

Zerga, B., (2015). ‘Awash National Park: Its Degradation Status and Protection Measure. *Palgo Journal of Agriculture*, 2(3), p. 57-66.

4. Aquatic and Wetland Ecosystem

Contributors

Corresponding Lead Author: Debissa Lemessa (PhD)

Lead Author: Tena Alamirew (PhD)

Contributing Authors: Argaw Ambelu (Professor)

Ayele Hegena (PhD)

Bikila Warkineh (PhD)

Editor: Seyoum Mengistu (Professor)

External Peer Reviewer: Ayalew Wondie (PhD)

Table of Contents

List of Tables

List of Figures

Executive summary

Ethiopia is endowed with substantial sources of aquatic and wetland ecosystem. The total water body (i.e., rivers and lakes) in the country is estimated at 7444 km^2 (0.07%). Though the wetland resources of the Country are not fully documented, there are 12 major wetlands that occupy an estimated area of 18,587 km2 (1.5 %) of the country. The country is endowed with 11 major fresh water lakes, and nine saline and alkaline lakes {4.1.3}. A growing number of man-made reservoirs (Gibe III, Tekeze, GERD, etc.), the GERD covers 1874 km^2 at the full capacity, are also improving the surface water storage potential (well established) {4.1.3, 4.2}. However, these reservoirs may alter the seasonal flooding, and cause loss of downstream wetlands (inclusive).

Aquatic and wetlands ecosystem provides to humans and the environment. The regulating services provided by wetlands include: enormous benefits air quality regulation; climate regulation; control of flood water; waste treatment and pollution prevention (established but incomplete) {4.2.2}. Wetlands provide habitat for pollinators which provide an important ecosystem service to ensure food security. However, the study of pollinator diversity in wetlands is lacking. Empirical data of pollinators in aquatic and wetland ecosystem and their contribution to the national economy is not yet investigated (unresolved) {4.2.4}. Aquatic and wetlands ecosystem is biodiversity hotspots in Ethiopia encompassing at least 10% of the Ethiopian floral diversity, providing habitat for at least 25% avifaunal diversity and hosting several other mega faunas {4.2.4}.

Aquatic and wetlands ecosystem provide key cultural and relational values and they enhance quality of life in Ethiopia (established but incomplete). Wetlands provide land and water for agricultural production and hence contribute to food security. This ecosystem also provide cultural and recreation services to people in Ethiopia and thus plays key roles in cultural manifestation of various ethnic groups, providing affirmation of beliefs, identity and justice (inconclusive) {4.2.1, 4.2.3}.

The wetlands in Ethiopia are degrading at rapid rate due to the over exploitation of the resources by human activities (established but incomplete). Causes of rapid aquatic and wetlands ecosystem degradation include: excessive water abstraction; drainage agriculture;

overgrazing and deforestation. Moreover, aggradation of river channels; mining activities; introduction of exotic species; urbanization and pollution; overexploitation of resources and climate change are the major causes of wetland degradation in Ethiopia (established but incomplete) {4.3.2, 4.4.2}. Moreover, seismic events in some part of the country are leading to expansion of lakes, which is threatening livelihood due to flooding (inconclusive) {4.3.2, 4.4.2}.

The biodiversity in aquatic and wetlands ecosystem is rapidly declining (inconclusive). Due to a rapid degradation of wetlands in Ethiopia, numerous wildlife and floral diversity are expected to decline. In addition, the traditional wetland knowledge systems and their contribution toward conservation and wise use of the resources are declining (unresolved) and hence this knowledge management needs explorations {4.3.2, 4.5.1}**.**

The factors responsible for the loss (drying of lakes and shrinking of wetlands) and degradation (pollution, invasive plants) can be grouped as indirect and direct drivers. These major drivers this regard, are rapid population growth (human and livestock), inadequately managed urban expansion and wetland encroachment international trade and agricultural investment and absence of a compressive national policy that recognizes the values and benefits of wetlands and aquatic resources ((well established). Climate change is expected to exacerbate all the direct and indirect pressures {4.4.1, 4.4.2}.

As the result of growing socio-economic demands, wetlands are converted to agricultural land (e.g. in lower Omo and Awash)(well established) {4.2.4, 4.3.2}, over abstraction leads to the demise of water bodies (e.g. Lake Haramaya) (well established) {4.3.2, 4.4.2}, silt up of lakes and water bodies, pollution kills aquatic animals and renders water unsafe for human and other uses (e.g. Lake Hawassa and Zeway) {4.2.4, .4.4.2}, the proliferation of invasive alien species, e.g., water hyacinth (well established) {4.3.2, 4.4.2 }.

Low community awareness is one of the key challenges in wetland conservation. The low awareness may lead to the degradation of wetlands in different parts of the country (established but incomplete). However, the level of awareness of different institutions is not well understood (established but incomplete) {4.5.1}.

Exemplary indigenous and local practices, such as the Konso community, the Irreechaa festivity areas and the Orthodox Church forests give opportunities to expand wetland and

aquatic resources conservation (well established). Moreover, the local community conservation practices in Biosphere Reserves in different parts of the country are some of the examples in watershed management practices {4.2.3, 4.2.4, 4.5.1}.

During the last three decades, considerable progress has been made toward developing the wetland policy and laws in Ethiopia (well established). During these times, wetland policy and laws are under developments to foster sustainable aquatic and wetlands and their ecosystem management. At different scales, the legislative development and organizational reforms have played role in reducing environmental challenges although their impacts to reverse damages are weak. In many instances, the laws that have been in place lack systems in realizing effective implementation due to fragmented institutional bounded mandates and lack of coordinated efforts among different sectors. The policy and legal instruments are patchy to conserve wetlands and further interventions in policy reform and implementation are needed to address wetlands challenges in Ethiopia {4.6}.

Key findings

- A water body in Ethiopia is estimated at 7,444 km2 (i.e., 0.07 % of the land area of the country). These include the 11 major freshwater lakes and nine major saline/alkaline lakes. Natural wetlands cover 1.5–2 % of the landmass of the country. Moreover, a there are growing number of man-made reservoirs (Gibe III, Tekeze, GERD, etc.). In a full supply, GERD is estimated to inundate 1874 km^2 at full capacity which is any new ecosystem to be added.
- Aquatic and wetland ecosystem is biodiversity hotspot in Ethiopia encompassing at least 10% of the Ethiopian floral diversity, providing habitat for at least 25% of avifaunal diversity, and hosting several other mega faunas.
- Aquatic and wetlands resources in Ethiopia, as is the case in the world, provide regulating services such as air quality regulation; climate moderation; control of floods, waste treatment and pollution prevention.
- Although wetlands are known to provide habitat for pollinators, the study of pollinator diversity in wetlands is lacking. Empirical data on pollinators in wetlands and their contribution to the national economy is not yet investigated.
- Aquatic and wetland habitats provide key cultural and relational values and they enhance the quality of life in Ethiopia.
- They provide cultural, mental and emotional services and values to the people of Ethiopia and thus play key roles in the cultural manifestation of various ethnic groups, providing affirmation of beliefs, identity and justice.
- Wetlands, besides serving as kidneys for many lakes and reservoirs, provide numerous ecosystem benefits to nature and humanity. However, the economic and biodiversity potential of wetlands and their contribution to sustainable development have not been well recognized.
- Ethiopia is rapidly losing its wetlands due to degradation caused by unsustainable human activities like excessive water abstraction; habitat changes due to agricultural practices; drainage agriculture; rapid land-use changes; overgrazing and deforestation, exotic species, etc., resulting in severe water scarcity (e.g. Harar and Zeway towns Water Supply system), increased vulnerability to drought and flood, loss of livelihoods (e.g. fishery in Koka, Zeway and Hawassa).

- The biodiversity of Aquatic and Wetland ecosystem is rapidly changing and deteriorating. Numerous wildlife and floral diversities are expected to decline.
- In addition, the traditional wetland knowledge systems and their contribution toward conservation and wise use of its resources are declining and the management of biodiversity needs careful study.
- Growing socio-economic demand due to population increase (2.46%), rapid urbanization (4.63%), increased food and energy per capita consumption, international trade (agricultural investment), absence of coherent policy and regulatory mechanism are the major indirect drivers of aquatic resources and wetlands degradation in Ethiopia.
- The direct drivers responsible for wetland and aquatic resource degradation in the country are over-abstraction (of water as in Lake Haramaya and Abijata, or fish in many lakes), pollution (e.g. Hawasaa and Zeway lakes and Awash river), alien or opportunistic plants invasion (e.g. water hyacinth in Lake Tana), overgrazing and dominance of opportunistic non-palatable plants (e.g. Cheffa wetlands).
- There is growing awareness of the threats to aquatic and wetland resources. Sector organizations such as MoWIE are in the process of drafting regulations and explicitly delineating wetlands and buffer zones in the draft policy document.
- A low level of community awareness of wetland conservation is one of the significant findings reported by different researchers. Insufficient awareness by itself is a significant obstacle to the various efforts of wetland conservation.
- Capitalizing on indigenous knowledge about the different conservation measures such as pollution, regulating and supporting practices such as buffering, application of controlled grazing, and watershed management, is found to be vital to the sustainable use of aquatic resources.
- Exemplary indigenous practices, such as the Konso community, Ethiopian Orthodox Church forest conservation practices, and the Irreechaa festivity areas, give opportunities to expand wetland and aquatic resource conservation.
- Best practices of conservation exist in the Kaffa biosphere reserve and different parts of the country through watershed management practices.
- At different scales, the legislative development and organizational reforms have played their role in reducing environmental challenges although their impacts to reverse damages

are contested. In many instances, the laws that have been introduced lack the tools that facilitate their effective implementation including mandates.

- Although it is now in the process of developing standalone wetland legislation and accession to the Ramsar Convention, Ethiopia is yet to have a compressive policy that addresses issues of wetlands and buffer zones.
- Issues of wetlands are addressed along with other policy and regulatory instruments.
- Further interventions to reform or develop and implement are important to address wetlands challenges in Ethiopia.
- The policy and legal instruments implementations, compliance and enforcement are patchy, irregular, incomplete, and ineffective to protect or conserve wetlands as other environmental issues.

4.1. Introduction

Ethiopia is located in the Northeast of the horn of Africa between the geographical coordinates of 3°-14.8° north latitude, 33°-48° east longitude bordering Eritrea by about 1033 km, Djibouti (343 km), Somalia (1,640 km), Kenya (867 km), South Sudan (1299 km), and the Sudan (744 km). The total area of Ethiopia is 1.13 million km² of which 7,444 km² is water body (this is before GERD (1,874 km²) the construction of which is expected to be completed in 2022/23).

Ethiopia has complex topographic formations dominated by rugged mountains, flat-topped plateaus, deep gorges, valleys, river and lakes. About 45% of the country is highland area with altitude greater than 1500 m a.m. while 55% of the total area is lowland (<1500 m a.m.). There are high diversity of terrains with wide variations in climate, soils, natural vegetation and settlement patterns. Erosion, volcanic eruptions and tectonic movements over the ages have contributed to the nation's diverse topography. The highest altitude is at Ras Dashed (4533 m a.m.) and the lowest altitude is at Danakil depression (120 m basil.) in Afar region.

According to the Census undertaken in 2007, the population of the Country was 73.9 million which showed an increment of 39.6 %within 13 years from 53.1 million in 1994 (CSA, 2008). The population growth rate is in Ethiopia ranges between the higher growth rates of the top ten countries in the world. The 2018 World Bank estimate of the population is at 109.5 million and forecasted the same to grow to over 210 million by 2060.

Ethiopia lies near the equator where maximum heat from the sun is received. But the climate varies greatly. Its nearness to the equator is counterbalanced by the topographic-induced variations. It is cold on the plateau and hot in the lowlands. Over the highland areas of Ethiopia, climate is healthy and cool. However, in places below 1,200 m, the conditions are tropical. The Somali Region and the Danakil Depression in the Afar Region have a hot, sunny and dry climate producing fully desert or semi-desert conditions. The terrain in the lower southwest (e.g. Gambella) is hot and swampy.

There are broadly three traditional agroclimatic zones; the '*Qola*' or hot lowlands (below approximately 1,500 meters), *Woina Dega* (1,500-2,400 m a.s.l.), and *Dega* (above 2400 m a.s.l.). Mean annual temperatures range from 10-16°C at *Dega*, 16-29°C at *Woina D*ega and 29-33°C at *Qola*. In general, the highlands receive higher rainfall than the lowlands. The weather is usually sunny and dry, but the short (*Belg*) rains occur from February to April and the large (*Meher*) rains from mid-June to mid-September. Ethiopia has four major seasons: Summer which is traditionally called *Kiremt* (June–August); autumn (*Tibi)* (September–November); winter (Bega) (December–February) and spring (Belg) (March–May). However, the coldest month is not always in 'Bega' and the hottest month is not always in 'Kiremet'. The average seasonal temperatures are: Summer Low of 10°C & high of 39°C; Autumn Low of 12°C and high of 35°C; Winter Low of 10°C & high of 31°C; and Spring Low of 13.3°C & high of 32°C. Annual rainfall is more than 2,700 mm in the southwestern highlands, and then gradually decreases towards the north to less than 200 mm, northeast to less than 100 mm, and southeast to less than 200 mm.

Owing to the high contrasts of physiographic and climatic features, Ethiopia has diverse ecosystems. There are 10 major ecosystems, and 18 major and 49 minor agro-ecological zones that are inhabited by a great diversity of animal, plant and microbial genetic resources. Evidence suggests that there are 1408 known species of fauna and 6,603 species of flora, of which 15.1% are considered endemic. With this, Ethiopia is known to be one of the biodiversity hotspots of the world.

4.1.1. Rainfall

The sole source of water in Ethiopia is endogenous rainfall. The spatially averaged mean annual rainfall of the country is 848 mm/year or 936.4 BCM/yr. The spatial (Figure 1) and temporal variability, however, limits the resource availability for supporting the overly subsistence rainfed agricultural economy of the country. Annual rainfall tends to be generally high (> 2000 mm/year) in the northwest, west and southwest while it declines to 200 mm/year in the northeast and southeast. Moreover, the inter-annual rainfall variability, exacerbated by climate change is high, particularly in semi-arid and arid agro-ecological zones which account to over 61% of the landmass and where bimodal rainfall regimes are prevalent.

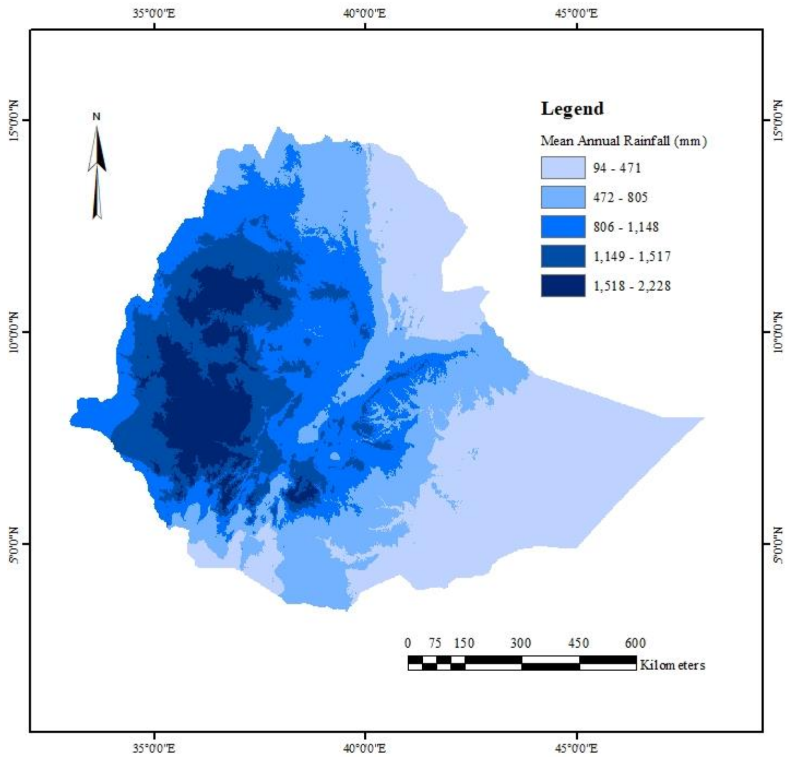


Figure 1. Figure 1. Rainfall distribution and pattern of Ethiopia generated from CHRIPS 1981–2017 data by Water and Land Resource (source: WLRC, 2019)

4.1.2. Surface water

The total annual renewable water has been estimated at 122 BCM. Kebede (2013) estimated the annual renewable groundwater potential to be 20 BCM though the estimates cannot be accurate. From this, 18 BCM of the groundwater is considered an overlap between surface-water and groundwater. The surface water is divided into four major drainage systems and 12 drainage basins (Figure 2). The four drainage systems are:

- The basins draining towards the Mediterranean Sea that include Abbay, Baro-Akobo, Tekeze and Mereb basins that cover 32.15% of the country's landmass and contribute about 70% of the total internal renewable flow,
- The basins draining towards the Indian ocean formed by Wabi Shebele and Genale Dawa rivers that cover 32.37% of the Country and 7.58% of the annual flow,
- The rivers forming closed internal drainage- the Awash, Omo-Gibe, Central Rift Valley lakes and Danakil basins and cover 22.33% of the country and contribute to about 25.52% of annual surface flow. This consists of a group of independent endorreic basins

extending from Danakil/Afar Depression in the north to the Lake Turkana in the south, and

- The Northeast Coast (including the Aysha, Danakil, and Ogaden) which are considered as 'dry basins' account 13.18% of the landmass and contribute to 0.69 % of the annual flow.

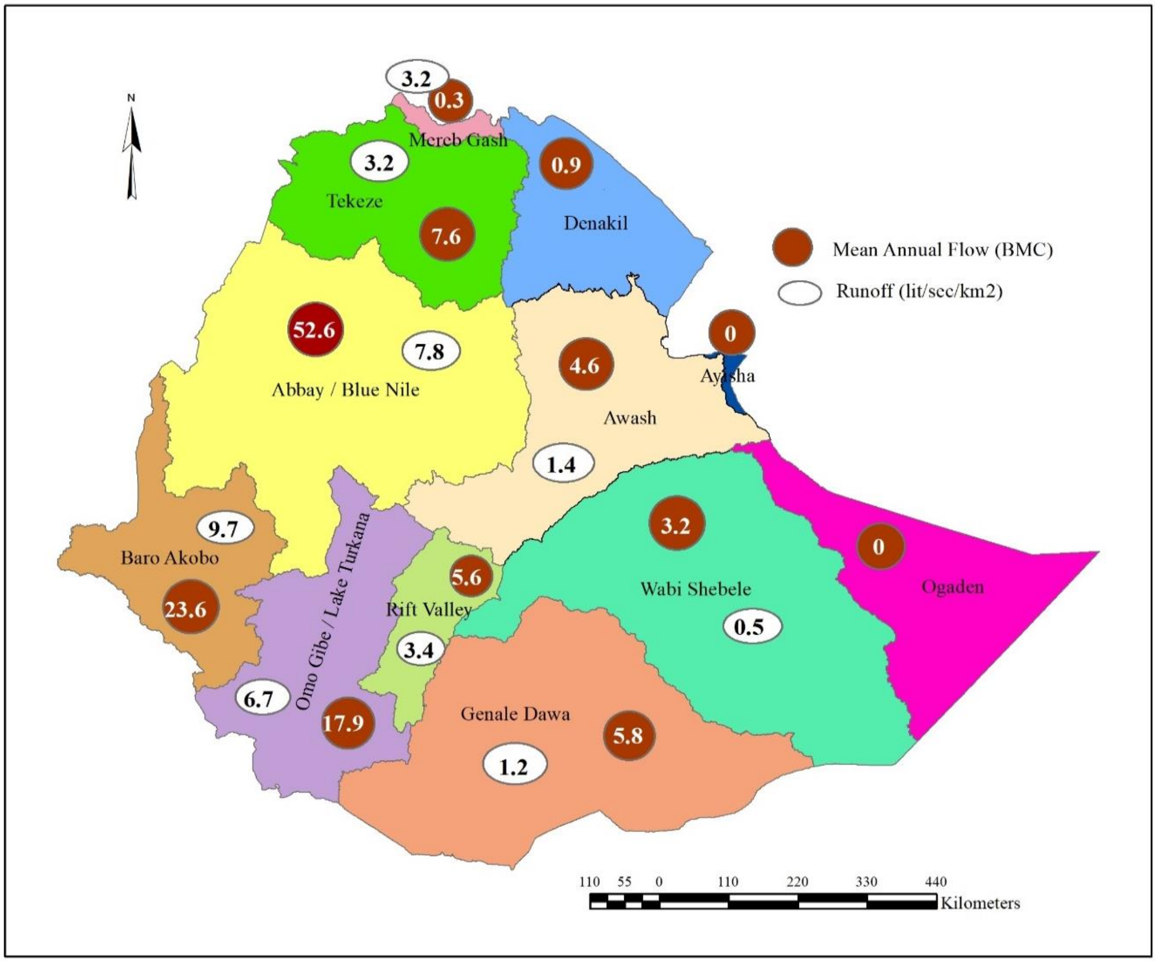


Figure 2. The 12 drainage basins of Ethiopia with corresponding mean surface water and drainage coefficient. The values in white circle are the drainage coefficients (l/s/km2), while values in the red circle are the renewable annual surface water potential

Most of the Ethiopian uplands have slopes to the northwest and nearly all the large rivers flow in that direction to the Nile, comprising some 85% of its water. Those rivers are Tekeze River in the north, Abbay in the center, and Sobat in the south and about four-fifths of the entire drainage is discharged through these three arteries. Another large river is the southward flowing Omo river, with 14% of the entire drainage, the largest river outside the above-mentioned three main arteries discharging to the west, and by far the main feeder of the endorheic Lake Turkana Basin. The rest is carried off by the Awash river which runs out in the saline lacustrine district along the border with Djibouti; by the Shebelle and Jubba rivers, which flow southeast through Somalia, though the Shebelle most often fails to reach the Indian Ocean.

4.1.3. Natural and Manmade Lakes

Ethiopia is endowed with numerous lakes with a total surface area of over 7000 km^2. The major lakes include eleven freshwater lakes, nine saline or alkaline lakes (Table 1). Many of these are crater lakes. Seven of the twelve major natural lakes are found in the Rift Valley. Lake Tana, with an area of 3156 km^2, is the largest of all the lakes in the country with an exploitable water volume of 8.90 BCM. The total exploitable amount of water from the lakes has been estimated to be 12.85 BCM. Most lakes, except Abaya, Chamo, Langano, Tana, and Zeway are terminal lakes. Abijata and Shala lakes are alkaline and have concentrations of chemicals used in the production of soda ash.

Table 1 . Location, and morphometric characteristics some Ethiopian Lakes (Source: GIRDC, 2018, EFCC, 2017, and Awlachew et al., 2007)

Lake Name	Longitude	Latitude	Type	Maximum depth (m)	Average depth (m)	Surface area (km^2)	Total Water volume (BCM)
1. Tana	37.5000	12.0000	Freshwater	14.00	9.00	3156.00	32.40
2. Abaya	37.8833	6.4333	Freshwater	24.50	7.00	1140.00	9.81
3. Langano	38.7166	7.6000	Freshwater	46.00	20.00	230.00	3.80
4. Chamo	37.5500	5.8333	Freshwater	14.20	10.23	317.00	3.24
5. Hawassa	38.4879	7.0401	Freshwater	23.22	12.00	100.00	1.36
6. Zeway	38.8333	8.0000	Freshwater	9.00	3.00	440.00	1.10
7. Hayq	39.7166	11.3333	Freshwater	81.77	32.65	23.34	1.01
8. Afambo	41.6833	11.4166	Freshwater			17.60	
9. Gemeri	41.6667	11.5333	Freshwater			72.00	
10. Haramaya	42.0045	9.4049	Freshwater				
11. Zengena	36.9666	10.9138	Freshwater	166.00		0.25	
12. Shala	38.5333	7.4833	Alkaline	266.00	86.00	370.00	37.00
13. Abijata	38.6000	7.6166	Alkaline	14.00	8.00	180.00	1.00
14. Besaka	39.8666	8.8666	Alkaline	–	8.40	48.50	0.28
15. Ashenge	39.5000	12.5805	Freshwater	25.50	14.00	140.00	0.25
16. Abbe	41.7833	11.1666	Salt lake	37.00	8.60	320.00	
17. Afrera/Afdera	40.9166	13.2833	Salt lake	160.00		12.50	
18. Chew Bahir	36.9500	4.7166	Salt lake	7.50	–	1125.0	
19. . Karum	40.4166	14.0166	Salt lake				
20. Turkana	36.1166	3.5833	Salt lake				
21. Bario	41.6258	11.3753	unknown				
22. Kadabassa	40.4914	10.2030	unknown				
Total							**91.246**

For the purpose of hydropower generation, municipal and irrigation water use, dams are constructed across the country by the government. Some of these dams are diversions, but many form water bodies which are identified as reservoirs. Table 2 lists the major reservoirs and their characteristics. Although the construction of water harvesting micro-dams and water harvesting ponds have been in progress since 2000, adequate information have not been systematically collected and organized information on the status of these water bodies.

Table 2. Major reservoirs and their characteristics (Source: GIRDC, 2018)

Dam	Completion year	Latitude	Longitude	River	Dam height (m)	Reservoir size (km^3)
1. Aba Samuel	1932	8.788	38.706	Akaki	22	0.035
2. Alwero	1995	7.860	34.493	Alwero	-	0.075
3. Amerti	2011	9.789	37.269	Fincha	38	0.040
4. Angereb	1986	12.613	37.486	G/Angereb	34	0.005
5. Chomen lake	1973	9.561	37.413	Fincha	20	0.650
6. Dire	1999	9.148	38.934	Dire	46	0.019
7. Fincha	1973	9.558	37.366	Fincha	25	Na
8. Gafarsa	1955	8.787	38.706	Little Akaki	17	0.007
9. Genale III	2017	4.267	42.017	Genale	110	2.600
10. Gilgel Gibe I	2004	7.929	37.391	Gilgel Gibe	40	0.920
11. Gilgel Gibe III	2015	6.844	37.301	Gilgel Gibe	243	14.700
12. Kessem	2015	9.150	39.883	Kessem	90	0.500
13. Koga	2008	12.167	36.633	Koga	20	0.083
14. Koka	1960	8.468	39.159	Awash	47	1.900
15. Legadadi	1967	9.066	38.957	Sendafa	40	0.044
16. Melka Wakena	1989	7.176	39.431	Shebelle	40	0.750
17. Midimar	1996	14.204	38.911	Wari	33	0.010
18. Neshe	2011	9.789	37.269	Fincha	38	0.150
19. Ribb	2017	12.031	38.008	Ribb	74	0.234
20. Tekeze	2010	13.300	38.710	Tekeze	185	9.300
21. Tendaho	2014	11.690	40.955	Awash	53	1.900
Total existing						33.098
GERD	Incomplete	11.214	35.089	Abay	155	74.000
With GERD						107.098

4.2. Aquatic and wetland resources contribution to people and quality of life

According to EFAP (Ethiopian Forestry Action Program, 1989), Ethiopia, with its different geological formations and climatic conditions is endowed with considerable water resources. The aquatic and wetland ecosystem includes twelve river basins, eight major lakes, many swamps, floodplains and man-made reservoirs and about 122 BCM of water runs off annually from the above sources (Leykun, 2003; Finlayson et al., 1999).

According to EPA (2003), the Ethiopian wetlands render social, economic and ecological benefits. Aquatic and wetland ecosystem provides include provisioning, regulating, supporting and cultural services (MEA, 2005; Wondie, 2018). Specifically, these benefits include the provision of food, water, household materials, dry season grazing for livestock, regulation of hydrological systems, flood control, pollutant chemical control, filtration of water flow and sediment trapping, reeds for thatching, crafts or floor covering, provision of medicinal plants, fish resources, permanent source of water for irrigation, recreation and tourist areas, phytoplankton and zooplankton organisms as useful sources of food for fish and macro-invertebrates, cultural and ethical values, etc. In these regards, Moges (2016) and Wondie (2018) have identified wide range of ecosystem services in aquatic and wetland habitats of Lake Tana in Northwest and Boye in southwest of Ethiopia as indicated in Table 3 and 4.

Table 3. Ecosystem services provided by wetlands of Lake Tana

Ecosystem Service	Shesher	Megech	Chimba	Ras Abay	Avaji	Gudo Bahir	Wonjeta	Kurt Bahir	Legdiya
Provisioning services									
Crops (rice, maize, Teff)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Vegetables (Potatoes, onions,)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fruits (Ficus spp., Syzygies spp, Mimosas spp.)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Chat	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sand (Peat)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Livestock	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fish	✓	✓	✓	✓	✓	✓	✓	✓	✓
Wetland products (e.g. papyrus)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Honey	✓	✓	✓	✓	✓	✓	✓	✓	✓
Water for domestic use (drinking, bathing, washing)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Water for irrigation	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fuel wood	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fodder and grazing services	✓	✓	✓	✓	✓	✓	✓	✓	✓
Craft materials (for mattress, basket, etc.)	✓	✓	✓	✓	✓	✓	✓	✓	✓

Seedling raising	✓	✓	✓	✓	✓	✓	✓	✓	✓
Medicinal plants	✓	✓	✓	✓	✓	✓	✓	✓	✓
Regulating Services									
Microclimate regulation (carbon sequestration)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Runoff and erosion regulation	✓	✓	✓	✓	✓	✓	✓	✓	✓
Water regulation (flow and storage)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Water purification (pollution control)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Flood control	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sediment retention	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cultural services									
Recreational services	✓	✓	✓	✓	✓	✓	✓	✓	✓
Spiritual services	✓	✓	✓	✓	✓	✓	✓	✓	✓
Educational and research services	✓	✓	✓	✓	✓	✓	✓	✓	✓
Supporting services	✓	✓	✓	✓	✓	✓	✓	✓	✓
Biodiversity conservation	✓	✓	✓	✓	✓	✓	✓	✓	✓
Soil formation (accumulation of organic matter)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Nutrient cycling	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pollination	✓	✓	✓	✓	✓	✓	✓	✓	✓

Studies conducted by Moges (2016) also pointed out that most wetlands in southwestern Ethiopia are overexploited. He studied wetlands of Boye, Agar, Haro, Merowe, Bunchier, and Dude wetlands located in the vicinity of towns and rural ones. These wetlands are supporting the local community, specifically the poor in many ways (Figures 3).

Figure 3. Local fishing practices by communities around Lake Tana (Source: Wondie, 2018)

In general, Moges (2016) has listed most of the services provided by some of the wetlands of Jimma zone (Table 3.10). He reported that the highest ecosystem provision is water source service for human and animal consumption by the majority of the communities (over 70% of the households), whereas the least (3%) ecosystem service obtained is the use of wetlands as fish source (Figure 4).

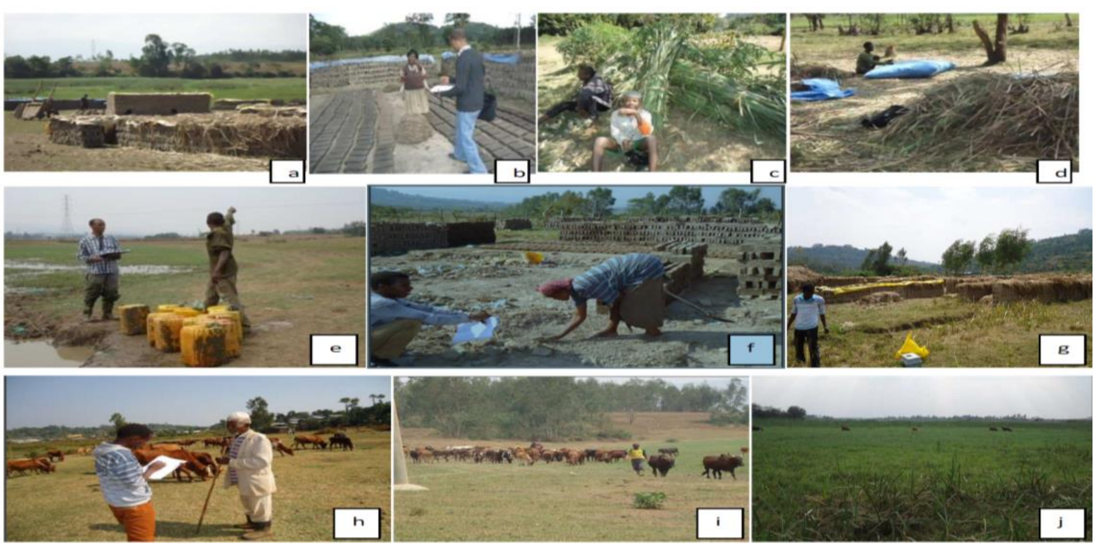


Figure 4. Different socioeconomic services obtained from wetlands of Jima zone. .

Brick productions, grass harvesting, mattress-making in peripheries of Boye (a-d), Haro (f) and Merowe (g) wetlands, water extraction from Haro for brick-molding (e), and grazing at Agar (h) and Haro (i) and Boye (j) wetlands during interview for data collection (Moges, 2016).

Table 4. Major ecosystem services identified in selected wetlands of southwestern Ethiopia.

Ecosystem services	Boye	Agar	Merowe	Haro	Bunchier	Dude
Provision of services						
Crops (maize, Teff)		✓	✓	✓		
Vegetables (potatoes, onions)			✓	✓		
Fruits (Ficus sp., Phoenix reclinata)	✓	✓	✓		✓	✓
Fish	✓	✓				
Honey	✓		✓		✓	✓
Drinking water for animals	✓		✓	✓	✓	✓
Water for domestic use (bathing, washing, cleaning)	✓	✓	✓	✓	✓	✓
Drinking water for humans	✓	✓	✓	✓	✓	✓
Water for irrigation	✓	✓	✓	✓	✓	✓
Firewood		✓	✓	✓	✓	✓
Plant, water and clay extraction for brick-making	✓		✓	✓		
Fodder and grazing services	✓	✓	✓	✓	✓	✓
Craft materials (for mattress, etc.)	✓	✓	✓	✓		
Seedling raising	✓			✓		
Sand	✓			✓		
Medicinal plants	✓	✓		✓	✓	✓
Regulation services						
Microclimate regulation	✓	✓	✓	✓	✓	✓
Runoff and erosion regulations	✓	✓	✓	✓	✓	✓
Water flow regulation	✓	✓	✓	✓	✓	✓
Water purification	✓	✓	✓	✓	✓	✓
Sediment retention	✓	✓	✓	✓	✓	✓
Carbon sequestration	✓	✓	✓	✓	✓	✓
Pollination	✓	✓	✓	✓	✓	✓
Disease control	✓	✓	✓	✓	✓	✓
Cultural services						
Wedding	✓					
Recreational services	✓	✓				
Spiritual services	✓	✓	✓	✓	✓	✓
Educational and research services	✓	✓	✓	✓	✓	✓
Biota conservation (*nursery and refugium*)	✓	✓	✓	✓	✓	✓

An economic valuation study conducted at the three wetlands of Eastern Ethiopia, namely, Adele, Teneke, and Haramaya, revealed that the annual ecosystem service rendered by the wetlands is 34956 Ethiopian Birr (Semu and Workie, 2019). Major services identified and evaluated in these wetlands were water abstraction for domestic use, cattle watering, and irrigation. It was noted that most of the households utilizing the wetlands had no awareness of conservation and protection from pollution. It was unfortunate to read that communities living around those wetlands were not willing for conservation.

Wetlands and water bodies are highly celebrated among Ethiopian society. In Oromo culture, rivers and lakes are considered as sacred places where local traditions dictate people pay tribute before river crossing. Annual celebration of "*Irreechaa*" (recently registered as UNESCO intangible cultural heritage), is now-a-days attracting millions of Oromos and visitors annually to Bishoftu Lake where an annual thanksgiving takes place. Even though studies lack that provide the historical significance of water bodies and wetlands for spiritual wellbeing of Ethiopian societies, wetland resources such as several *Carex* species are used all over the country in coffee ceremonies, annual celebrations and for religious celebrations. This aspect of aquatic and wetlands ecosystem contributions to quality of life needs further investigations as most studies are generic in a sense that they do not provide quantitative and even qualitative data substantiating these services. (e.g., plant succession), biodiversity, and plant-animal interactions. For more advanced students, particularly those at the high school and college levels, and professionals seeking to learn more about wetlands, they serve as excellent research sites.

4.2.1. Provisioning services

Aquatic and Wetland is among the most productive ecosystem in the world, comparable to rain forests and coral reefs.

As described by Davies & Day (1998) wetlands provide enormous ecosystem services and goods as listed below.

- Food (crop-rice, fish, game, vegetables, fruit),
- Water (drinking, irrigation, cleaning),
- Raw materials (fiber, clay for pottery, timber, fuel wood, fodder, fertilizer),
- Genetic resources (crop-improvement and medicinal purposes),
- Therapeutic resources (biochemical products, models and test-organisms), and
- Ornamental resources (artisan work, decorative plants, pet animals, fashion).

A recent review by Feto (2019) showed that wetlands are the most productive habitats which supply wide diversity of natural products directly consumed or marketed for income generation. Depending upon the type of wetland, many products can be harvested from wetlands, and are often the most direct economic benefits. According to this study the list of the products includes sedge, fuel and construction wood, medicinal plants, edible plant, craft materials, ornamental plants, fish and potable water. Sedge harvested from wetlands are used for various purposes such as roof thatching (dwelling house, pest watching tukul, granary (grain storage), livestock shelter, beehive covering, as raw material for crafting (raincoat, matt, broom, basket, boat, carpet etc.), ceremonial (floor covering during festivals), for mulching in nursery, compost making and fodder (Afework et al., 2000). These are very important material contribution of aquatic and wetlands ecosystem that require proper quantification and detailed studies.

Agriculture often needs flat topography, fertile soil and reliable supply of water, which means that wetlands are often potentially valuable agricultural resources (McCartney et al, 2005). Consequently, in many parts of Ethiopia where valley bottom swamps and seasonal flood plains are found, agriculture is the main economic activity among the local population. Indigenous farming has been developed especially during the dry season after the water recedes, e.g. "*bonnie"* agriculture in western zones of Oromia and "*Bahir shesh"* on the shores of Lake Tana, Amhara Regional State. Wetland agriculture is the key component of food security strategies of the local communities (Bognetteau et al., 2003). The concept of food security is built on three pillars; i.e. availability, access and use. Therefore, food security according to FAO (2003) is defined as a situation that exists when all people at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life. According to the review by Feto (2019) currently wetland cultivation in the area increased to the extent of complete cultivation of all the available wetlands in some localities. For instance, in Illu-Abba-Bora Zone, the percentage of the available wetlands under agriculture increased by more than double (from 27.7% in 2003 to 65.6% in 2006).

Wetlands provide direct benefit for community groups who depend on livestock production for their livelihood by providing feed and fodder for the animals. For instance, Borkena and Cheffa wetlands support thousands of pastoralists from nearby Afar, Amhara and Oromia Highlands who move to the wetlands with their livestock during dry seasons in search of pasture and water. Wetlands provide play considerable roles in the livestock production sector by providing pasture and fodder (Legesse, 2008). Aquatic and wetland ecosystem is a source of water for humans and livestock, agriculture and other economic activities and thus are very important in food security of Ethiopia.

Ethiopian fresh water lakes are an important source of fish which sustain thousands of fishermen and also provide domestic protein source (Tesfaye and Wolff, 2014). Wetlands provide an important breeding, nursery and feeding grounds for several fish species. Particularly, wetlands are a major source of fish and fisheries contributing to the local economy especially in the Rift Valley areas of Oromia and SNNPR and around Lake Tana in the Amhara Region (Lemlem, 2003).

4.2.2 Regulating services

Wetlands provide multiple ecosystem services such as storing and regulating water flows and water quality, providing unique habitats to flora and fauna, and regulating micro-climatic conditions (Davies & Day, 1998; Teferi et al., 2010). Some of these regulating services provided by wetlands are described below:

- Air quality regulation (dust, chemicals, nutrients, agrochemicals, metals, etc.),
- Waste treatment (wetlands serve as water purification reactor to the incoming wastewater discharges, e.g., Avaji and Boye in Bahir Dar city and Jimma town, respectively),
- water purification/pollution control/-Pollution prevention (as a sink for metals, nutrients, agrochemicals, etc. e.g., Boye wetland prevents the contamination of Gilgel Gibe river and the dam from pollution),
- Climate regulation (carbon sequestration, the influence of vegetation on rainfall, temperature balancing, etc.),
- Moderation of extreme events (storm protection and flood prevention),
- Control of water flows (help to maintain natural drainage, irrigation and drought prevention)-Water flow/storage regulation,
- Erosion prevention (retention of soil and sediment),
- Maintenance of soil fertility (soil formation, peat accumulation, decomposition of dead

- Provision of health services (water source, medicinal plant source, recreational services, source of micronutrient, etc.).
- plants and animals, etc.), and

Microbes, plants and fauna are part of the cycles for water, nitrogen and sulfur in wetlands. Wetlands store carbon within the plant communities and soil instead of releasing it to the atmosphere as carbon dioxide. Thus, wetlands help to moderate global climate conditions. As the plant material continues to break down into smaller and smaller particles, it becomes increasingly enriched (nutritious) due to bacterial, fungal and protozoan activity.

The diversity of habitats in a watershed or larger landscape unit is also important for other ecological functions associated with wetlands. One such function, biogeochemical cycling, involves the biological, physical, and chemical transformations of various nutrients within the biota, soils, water, and air. Wetlands are very important in this regard, particularly related to nitrogen, sulfur, and phosphorous. A good example of this is an anaerobic (non-oxygenated) and chemically reduced wetland soils and the muddy sediments of aquatic habitats like estuaries, lakes, and streams, which support microbes that function in nitrogen and sulfur cycling. Upon death and decay, nitrogen and sulfur in plant and animal biomass is released through mineralization. Much of these chemical nutrients are eventually transformed into gaseous forms and released into the atmosphere, where it becomes available again for certain plants and the associated nitrogen-fixing bacteria in the soil. This is literally a major defense for mud, since it is the anaerobic and chemically reducing conditions in the substrate, in conjunction with various microbes that ensure the gaseous release of the nitrogen and sulfur. On the other hand, phosphorous does not have a gaseous form, but vascular plants in wetlands transform inorganic forms of phosphorus (that might otherwise be shunted into undesirable algal blooms) into organic forms in their biomass as they grow. Thus, wetlands provide the conditions needed for the removal of both nitrogen and phosphorus from surface water. Scientists also point out that atmospheric maintenance is an additional wetland function. Wetlands store carbon within their live and preserve (peat) plant biomass instead of releasing it to the atmosphere as carbon dioxide, a greenhouse gas affecting global climates. Therefore, wetlands moderate global climatic conditions. Even though, studies focusing on this role of wetlands is lacking in Ethiopia, wetlands are important for maintaining habitat diversity, climate regulation and maintenance of air quality.

The role of wetlands in pollution control is a well established ecosystem service. Wetlands have been referred to as a “living machine” (MacDoland, 1994) and one of nature’s most effective ways of cleansing polluted water. Wetlands are the “Kidneys of the planet” because of the natural filtration processes that occur as water passes through. All wetlands, fresh-water or salt have many distinguishing features, the most notable of which are the presence of standing water, unique wetland soils and plants adapted to or tolerant of saturated soils. In the Ethiopian context, marsh areas, swamplands, flood plains, natural and artificial ponds, volcanic creator lakes and upland bogs are treated collectively as wetlands (EIBC, 2007; Abebe and Geheb, 2004). According to Luise et al. (1999), wetlands provide numerous functions. Wetland functions are the inherent processes occurring in wetlands; wetland values are the attributes of wetland that the society perceives as beneficial). Under appropriate circumstances wetlands can provide water quality improvement (William, 1997), cycling of nutrients, habitat for fish and wildlife, flood storage and the resynchronization of storm rainfall and surface runoff (Ramsar Convention Secretariat, 1997), and passive recreation such as bird watching and photography, active recreation (such as hunting, education and research) and aesthetics as well as landscape enhancement (Tanner and Sukias, 2003).

Wetlands are naturally engineered environments that can be used to treat waste discharges from the point and non-point sources that improve water quality, whether it relates to wastewater, groundwater, industrial waste streams. Many cities and towns in Ethiopia have no waste treatment plants; the municipal and factory effluents are directly discharged into wetlands in the vicinity. Though this act is unacceptable by all standards of measures, wetlands still sink the different pollutants coming into them. Many wetlands in Ethiopia such as Lake Tana, Lake Zeway, Boye wetland in Jimma, etc. are receiving wastewater discharges from nearby towns where the downstream segment is getting less affected.

Boye wetland receives wastewater discharges from Jimma town and the surrounding watershed. The study on Awetu watershed indicated that heavy organic load is being retained in Boye wetland and the downstream BOD is found to be less than the upstream due to its purification mechanisms (Figure 5).

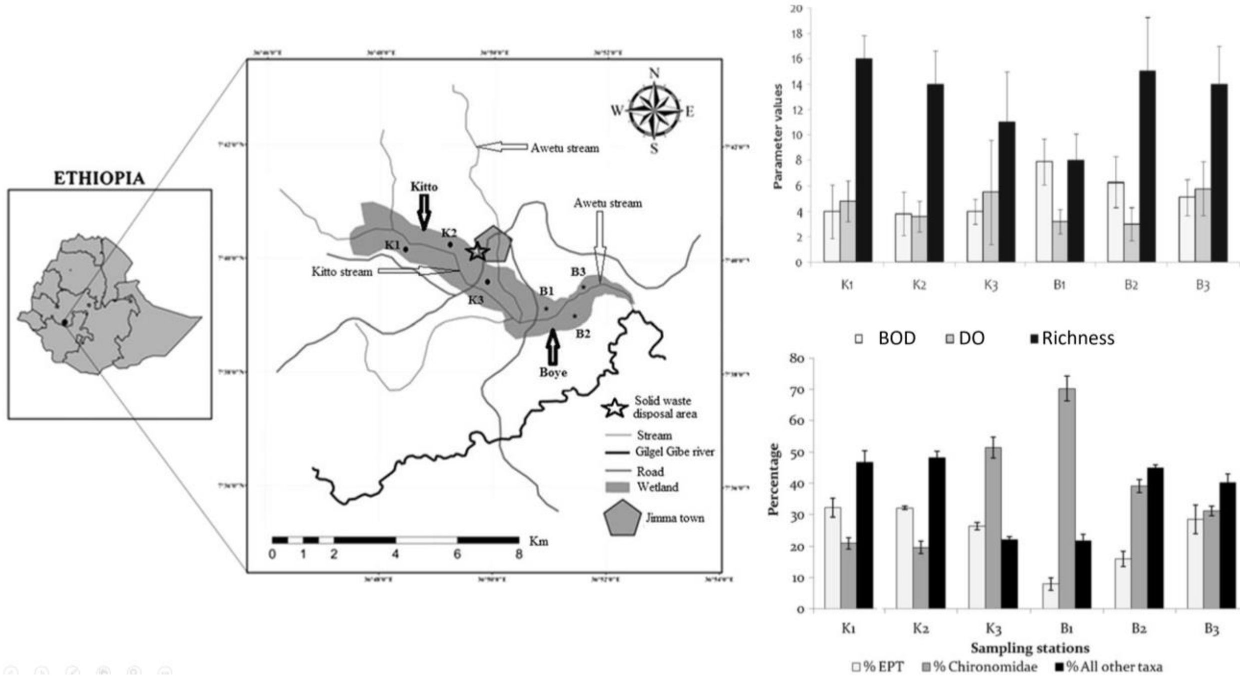


Figure 5.Organic load and species richness of the wetlands following receiving wastewater discharge from Jimma town (Source: Ambelu et al., 2013).

Studies indicate that Boye (Figure 6) wetland retains about 100 kg of TSS/ha/day and 12 kg of nutrients/ha/day from the surrounding point and non-point sources (De Troyer et al., 2016). Similar reports were also found from the wetland study of eastern Ethiopia. Wetlands of Adele, Teneke and Haramaya had organic pollution revealed by the elevated BOD concentrations (Semu & Workie, 2019). Wetlands function based on the natural principle, which is a very efficient and cost-effective method of water quality purification. Aquatic and wetland ecosystem have many advantages over conventional treatment systems. Some of the benefits are increased local biodiversity, creation of green space within urban areas, and flood control. Wise use of wetlands as a waste treatment technology is also robust and can be easily adapted to solve even the most challenging water pollution problems. Sustainability and resiliency are essential components of future water and environmental conservations, where wetland systems can play an important role. However, the current uncontrolled activities are affecting wetlands' efficiency of harboring biodiversity due to unbalanced waste inputs. In previous times, Boye and the surrounding wetlands were having hippopotamus, but currently, they have shifted to the Gilgel

Gibe I reservoir where open water is found (Ambelu, personal communication). Wetlands located to substantial pollution sources, such as Boye wetland, are heavily polluted. According to Prati Index, most wetland sites in the middle of Jimma town and downstream places have an elevated pollution status (De Troyer et al., 2016).

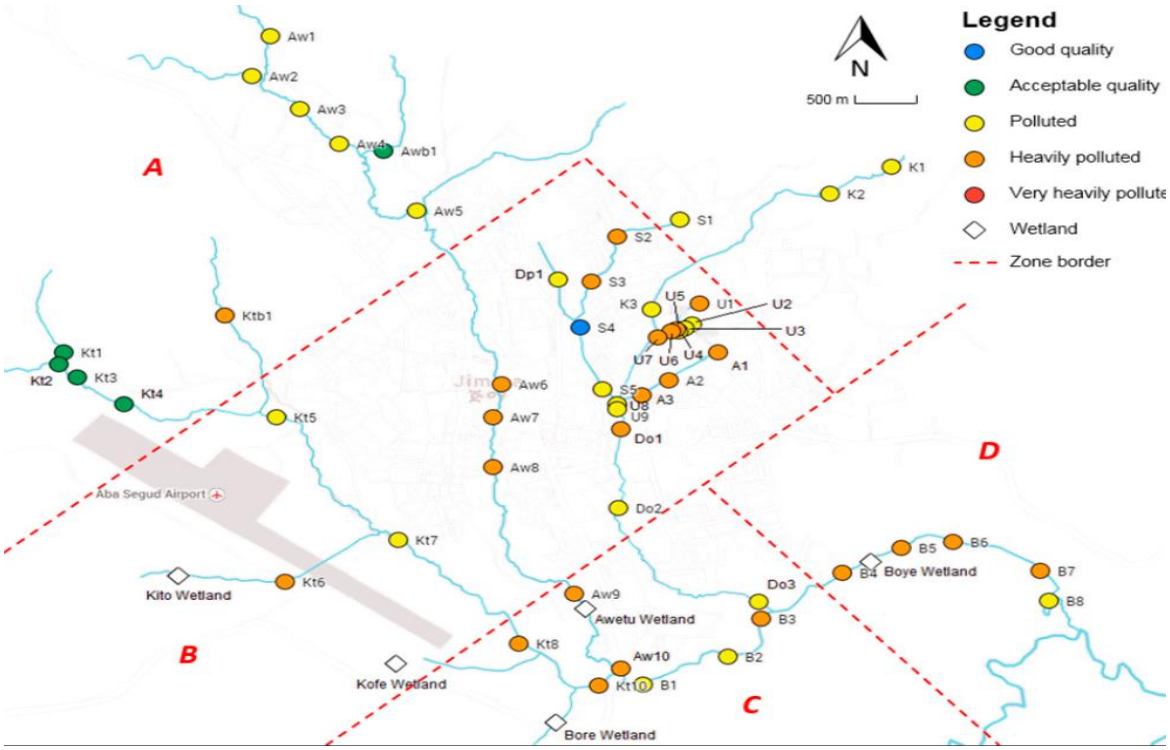


Figure 6. Water quality status of streams in Jimma town based on oxygen Prati index (Source: De Troyer et al., 2016)

Hydrophytic vegetation of wetlands has paramount importance in terms of flood control. Without wetlands, especially in mountainous nations such as Ethiopia, flood control is seemingly impossible. Wetlands function as natural sponges that trap and slowly release surface water, rain, snowmelt, groundwater and flood waters. Trees, root mats and other wetland vegetation also slow the speed of flood flowing waters and distributes them more slowly over the floodplain. Wetlands within and downstream of urban areas counteract the surface water runoff from pavement and buildings and reduce erosion. The water holding capacity of wetlands helps control floods and prevents water logging of crops. Preserving and restoring wetlands together with other water retention can often provide the level of flood control otherwise provided by expensive dredge operations and levees. Floodplains as flood abatement features (Awash River);

reservoirs regulate flows and prevent flooding by releasing excess water through spillways such as Koka and Legedadi.

Wetlands improve water quality in nearby rivers and streams, and thus have considerable value as filters for future drinking water. When water enters a wetland, it slows down and moves around wetland plants. Much of the suspended sediment drops out and settles to the wetland floor. Plant roots and microorganisms on plant stems and in the soil absorb excess nutrients in the water from fertilizers, manure, leaking septic tanks and municipal sewage. While a certain level of nutrients is necessary in water bodies, excess nutrients can cause algal growth that is harmful to fish and other aquatic life. A wetland's natural filtration process can remove excess nutrients before water leaves a wetland, making it healthier for drinking, swimming and supporting plants and animals. Because natural wetlands are so effective at removing pollutants from water that flows through them, engineers and scientists construct systems that replicate some of the functions of natural wetlands. These constructed treatment wetlands use natural processes involving wetland vegetation, soils and their associated microbial life to improve water quality. They are often less expensive to build than traditional wastewater and storm water treatment options, have low operating and maintenance expenses and can handle fluctuating water levels. However, there are scanty examples of the effective uses of wetlands for water quality improvements in Ethiopia.

4.2.3. Cultural services

Aquatic and wetlands ecosystem provides numerous cultural benefits to humans. In Ethiopia, even though few studies abound on the extent among different regions and ethno-linguistic and cultural diversities, this ecosystem provides important cultural, religious, recreational and aesthetic values to the society. A notable example includes the "*Irreechaa*" ceremony that is celebrated by the Oromo people and the Epiphany of the Ethiopian Orthodox church.

Many scientists agree that all human health ultimately depends on ecosystem services that are derived from biodiversity resources. The inter-linkages between biodiversity, ecosystem services, and human health are inherently complex and maintaining the balance is vital to ensure biodiversity-human wellbeing win-win conservation. Wetlands are rich in biodiversity and the contribution to human health is immense, for example, the provision of medicinal plants, among others. In this aspect, the Lake Tana islands, namely, Dek, which harbor various medicinal plants, are good examples (Teklehaymanot, 2009). Many plants around Lake Tana are known for their natural healing properties and the provision of traditional medicine. More than 67 plant species are used as natural remedies by the local communities for generations exercised to treat a wide range of illnesses such as coughs, swellings, and weight loss. Tana's treasure chest of natural medicine has yet to be fully explored.

These days, microbial resistance is increasing, and making biodiversity reserves the best alternative to overcome such challenges. Ethiopia has biosphere reserves which are rich in biodiversity and conserving these sites has paramount importance to improve health. In this regard, The Strategic Plan for Biodiversity 2011-2020 with 20 global targets of the Aichi Biodiversity Targets are formulated to guide national and international efforts to conserve biodiversity. While all the Targets have potential linkages to health and wellbeing, Aichi Target 14 focuses explicitly on ecosystem services that contribute to health, livelihoods, and wellbeing (Secretariat of the Convention on Biological Diversity, 2018). Some less polluted wetlands are sanctuaries of rare animals, such as the hippopotamus (Figure 7).

Moges (2016) pointed out that about 34% of the households use a variety of wetland plant species as traditional medicine. Commonly used medicinal plants harvested from wetlands are *Commelina latifolia*, *Ageratum conyzoides*, *Persicaria decipiens*, *Ludwigia abyssinica*, *Colocasia esculenta*, *Vernonia* spp., *Oenanthe palustris*, *Croton macrostachyus*, and *Lindernia rotunda*.

Figure 7. Hippopotamus in relatively less polluted Boye Wetland in 1999 (Photo credit: Ambelu).

Wetlands provide many recreational, educational, and research opportunities. The recreational benefits associated with wetlands, of course, also serve to educate. Wetlands are studied in conjunction with environmental programs at adult continuing education facilities and at environmental centers. Furthermore, many school systems at the lower, middle, and high school levels use these valuable ecosystems as outdoor laboratories for environmentally related courses, since they serve as excellent study sites to learn about vegetative structure (e.g., the density and cover of the vegetation) and ecological functions (e.g., nutrient cycling), natural ecological processes. Moreover, Aquatic and Wetland ecosystem provides the society with gateways for emotional exploration and thus enhance self-reflection.

The agrarian developing countries are heavily reliant on natural resources for sustenance, export commodities and income from fish, timber and minerals, as well as tourism. At the local level, a large proportion of the rural poor also depend on ecosystem services for survival. Out of the 1.2 billion people living in extreme poverty around the world, approximately 900 million live in rural areas, where biodiversity and ecosystem services contribute to food security and nutrition, providing the raw materials that underpin health systems (WI, 2005). This dependence arises from several reasons, among which are shown below.

- The poor are dependent on agriculture (often subsistence agriculture), and have limited access to alternative sources of income from modern technologies,
- The rural poor are more likely to inhabit marginal areas where lands are less productive, and
- The wetland agricultural products significantly contribute to the income of the poor households.

A study conducted by Wondie (2018) indicates that the socio-economic activities of the local people are highly affecting the Tana wetlands (Table 9). Most wetlands around Lake Tana are affected by agricultural activities, cattle grazing, vegetation clearance specifically papyrus, waste discharges from Bahir Dar city, fishing, and irrigation activities. Gilgel Gibe I reservoir is also providing similar socioeconomic services to the local communities, though it is highly affected by agricultural expansion to the wetland areas, siltation, overfishing, and recreational activities. Deforestation, tillage and water abstraction, waste discharge and sand dredging are some of the major socioeconomic services provided by wetlands of the Gilegel Gibe River (Ambelu, 2009).

4.2.4. Supporting services

High diversities of microbe, plant, insect, amphibian, reptile, bird, fish and mammal species inhabit in wetlands. In wetlands, complex trophic interaction is taking place among these organisms. For example, invertebrates and small fish are the food sources for larger predatory fish, amphibians, reptiles, birds, and mammals including humans. Numerous species of birds and mammals rely on wetlands for food, water, and shelter, especially while migrating and breeding. Therefore, similar to other ecosystems, aquatic and wetland ecosystem provides multiple supporting services including soil formation, pollination and habitats for biodiversity.

Soil formation

Wetland soils are unique in that these soils possess physical, chemical, and morphological properties which are different from upland soils. The accumulation or convergence of water in certain parts of the landscape alters the development, form, and chemical properties of the soils creating a special class of soils known as *hydric soils*. The hydric soils in turn alter the movement of water in the wetlands. Wetlands occur where hydrologic conditions are driven by climate, topography, geology, and soils cause surface saturation to form hydric soils and competitively favour hydrophytic flora. Topographic features determine the processes of the formation and characteristics of soils by affecting water movement and the soil and the local hydrologic budgets. Moreover, topographic position is particularly and important factor in controlling surface and subsurface water flow and accumulation. Although several topographic features are complex and irregular, there exist distinct patterns of hillside slope elements that occur in most geomorphic settings.

The hydrology, soils, and watershed processes of wetlands all interact with vegetation and animals over time to create the dynamic physical process upon which wetlands are based. With respect to many ecosystem processes, the physical factors defining a wetland environment at any particular time are often treated as independent variables, but in fact none of these variables are independent of the others. For example, the hydro pattern of a wetland (the time series of water levels) is often considered a master variable that affects the soils, biogeochemistry, and biology of a wetland, but the hydro pattern is in turn affected by the physical properties of the soil underlying the wetland. Any explanation of the physical factors defining the wetland prototype is therefore circular, and the order of presentation is somewhat arbitrary.

In the soils of the wetlands biogeochemical processes take place in the zone where plants, animals, and microorganisms interact with the hydrologic cycle and other elemental cycles. Particularly, soil contains both mineral and organic materials as well as the adjacent water-filled and air-filled pore spaces. The physical and chemical properties of a soil may influence the processes that lead to wetland formation and function. The biogeochemical processes in seasonally saturated soils can lead to the accumulation of organic matter and transformations of iron-based minerals, which may influence nutrient cycling, soil acidity, and soil color. The soil physical properties including soil texture, soil structure, bulk density, porosity, and pore size distribution directly affect hydraulic conductivity, water storage, and water availability.

Pollination

Pollinators are key factors determining agricultural productivity and play an important role in maintaining biological diversity by pollen grains from stamen to the stigma in flowering plants. The degradation of wetlands causes the loss of habitats and food sources for pollinators and in turn these negatively affect the service that the pollinators provide in maintaining ecosystem function and agricultural production. It has been suggested that the decline in pollinating birds and mammals is primarily due to unsustainable agriculture, invasive species, and hunting. Similarly, the declining of pollinators has been attributed to the fragmentation, degradation and loss of habitat, pesticide use, and invasive species (UNEP, 2008). In Ethiopia, the study of pollinators and their roles in wetlands is lacking and the empirical data regarding the contributions of pollinators to the national economy is not yet available.

Biodiversity and habitat

Wetlands are hotspots of biodiversity and known to be among the most productive systems. Even though previous studies have focused on floristic diversity and vegetation composition of wetlands, information on the overall diversities of all life forms are lacking. According to Rebecca (2006), wetlands provide a habitat for many species of plants, animals and other organisms that depend on the reliable sources of water and nutrients in the wetland to survive, and cannot live elsewhere. These are wetland dependent organisms and are at risk if a wetland is threatened. Many animals, especially birds, use wetlands as a source of food, water and shelter but do not rely entirely on wetlands as their habitat. Many plant species grow well in wetlands due to the ample water and nutrients they provide, but are not obligate wetland plants as they are found in other habitats too (Woldu and Yeshitela, 2003). The overall species diversity of a wetland can be higher than the surrounding habitats due to the high productivity of wetlands and the fact that many have quite complex niche structure providing a variety of microhabitats for different species, which form a continuum of different microhabitats from a dry terrestrial to an aquatic environment. All together, in wetlands there are high functional diversities that make up the environment (Woldu, 2000).

Regarding diversity of plants in aquatic and wetland ecosystem, Alemu (2018) has reported on the abundance of riparian vegetation in the Gilgel Gibe Watershed and identified about 108 riparian vascular plant species (Table 5).

A recent synthesis showed that 549 plant species are found in wetlands and wetland related environments in Ethiopia (Kahsay et al., 2022, Tesfaye and Warikneh, 2022) (Figure 8). These 549 plant species are classified into 282 genera and 83 families and this is including ferns. Among the families, Poaceae is the dominant family with 96 species followed by Asteraceae and

Fabaceae each with 55 and 40, respectively (Figure8-11). Out of five hundred forty-nine floral diversity twenty-seven are ferns represented with eight families and twelve genera. Most of those species are located around southwestern, western, northwestern and Rift Valley lakes and its surrounding of Ethiopia and a careful survey of the whole country may add more wetland plant species.

Table 5. List of vascular riparian vegetation species from Gilgel Gibe Watershed (Source: Alemu, 2018)

Adiantum spp	*Hyparrhenia cymbaria* (L.) Stapf
Acanthus polystachiusDelile	*Hypericum quartinianum* A. Rich.
Acacia spp	*Impatiens hochstetteri* Warb.
Ageratum houstonianum Mill.	*Indigofera* sp.
Albizia gummifera (J.F Gmel.) C.A.Sm.	*Lablab purpureus* (L.) Sweet
Allophylus abyssinicus (Hochst.) Radlk.	*Lagenaria abyssinica* (Hook.f.) C.Jeffrey
Apodytes dimidiata E. Mey. ex Arn.	*Laggera crispata* (Vahl) Hepper &J.R.I.Wood
Asparagus africanus Lam.	*Lippia adoensis* Hochst.
Bersama abyssinica Fresen.	*Ludwigia abyssinica* A. Rich.
Bidens macroptera. (Sch. Bip. ex Chiov.) Mesfin	*Maesa lanceolata* Forssk
Bidens pilosa L.	*Manilkara butugi* Chiov.
Brucea antidysenterica J.F. Mill	*Maytenus arbutifolia* (Hochst. Ex A. Rich.) R. Wilczek
Brugmansia suaveolens (Humb. & Bonpl. ex Willd.) Bercht. & J. Presl	*Millettia ferruginea* (Hochst.) Baker
Calpurnia aurea (Aiton) Benth	*Mimusops kummel Bruce ex* A.DC.
Canarina abyssinica Engl.	*Myrsine africana L.*
Canthium oligocarpum Hiern	*Ocimum gratissimum* L.
Carissa edulis (Forssk.) Vahl	*Ocimum lamiifolium* Hochst. Ex Benth.
Cassipourea malosana (Baker) Alston	*Olea welwitschii* (Knobl.) Gilg & Schellenb.
Clausena anisate (Willd.) Hook.f. ex Benth.	*Oncoba spinosa* Forssk.
Clematis hirsuta Guill. &Perr.	*Penniseturn macroururn* Trin.
Clerodendrum myricoides (Hochst.) R.Br.exVatke	*Penniseturn polystachio*n (L.) Schult.
Clutia abyssinica Jaub. &Spach	*Penniseturn thunbergii*Kunth
Cordia africana Lam	*Persicaria senegalensis* (Meisn.) Soják
Coffea arabica L	*Phoenix reclinata* Jacq.
Commelina benghalensis L.	*Phytolacca dodecandra* L'Her.
Combretum paniculatum Vent.	*Phyllanthus ovalifolius* Forssk.
Conyza bonariensis (L.) Cronquist	*Piper capense* Lf.
Croton macrostachyus Hochst. Ex Delile	*Pittosporum viridiflorum* Sims
Cynodon dactylon (L.) Pers.	*Plectranthus alpinus* (Vatke) Ryding
Cyperus papyrus L.	*Plectranthus punctatus* (L f.) L'Her
Cyperus sesquiflorus (Torr.) Mattf & Kük.	*Podocarpus falcatus* (Thunb.) Endl.
Cyperus spp	*Pterolobium stellatum* (Forssk.) Brenan
Dalbergia lactea Vatke	*Pycnostachys abyssinica* Fresen.
Datura stramonium L.	*Pycnostachys eminii* Gürke

Dioscorea schimperiana Hochst. ex Kunth	*Rhamnus prinoides* L'Hér.
Ehretia cymosa Thonn.	*Ricinus communis* L.
Ekebergia capensis Sparrm.	*Erythrococca trichogyne* (Müell. Arg.) Prain
Entada abyssinica A. Rich.	*Rubus spp*
Eucalyptus grandis W.Hill	*Rumex nepalensis* Spreng.
Euclea racemosa L.	*Rytigynia neglecta* (Hiern) Robyns
Ficus sur Forssk.	*Salix mucronata Thunb.*
Ficus thonningii Blume	*Sapium ellipticum* (Hochst.) Pax
Ficus vasta Forssk.	*Senna didymobotrya* (Fresen.) H.S. Irwin & Bameby
Galinsoga parviflora Cav	*Senna petersiana* (Bolle) Lock
Galiniera saxifraga (Hochst.) Bridson	*Sesbania sesban* (L.) Merr.
Gouania longispicata Engl.	*Setaria megaphylla* (Steud.) T. Durand &Schinz
Grewia ferruginea Hochst. ex A. Rich.	*Sida rhombifolia* L.
Guizotia scabra (Vis.) Chiov.	*Solanum anguivi* Lam.
Hibiscus berberidifolius A.Rich.	*Syzygium sp* (Willd.) DC.
Hibiscus macranthus Hochst. exA. Rich	*Teclea nobilis* Del.
Hygrophila schulli (Hamilt.) MR. & S.M Almeida	*Trichilia dregeana* Sond.
	Vernonia amygdalina Delile

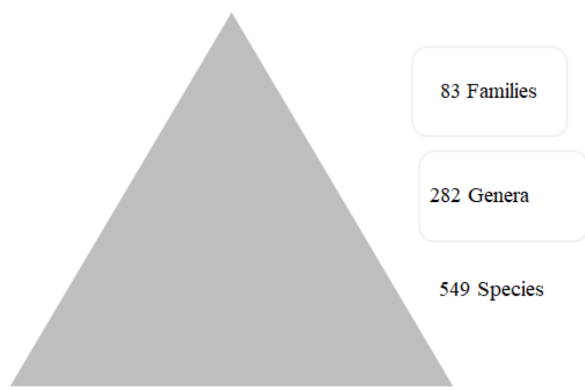


Figure 8. Number of wetland species and their categories under their respective genera and families

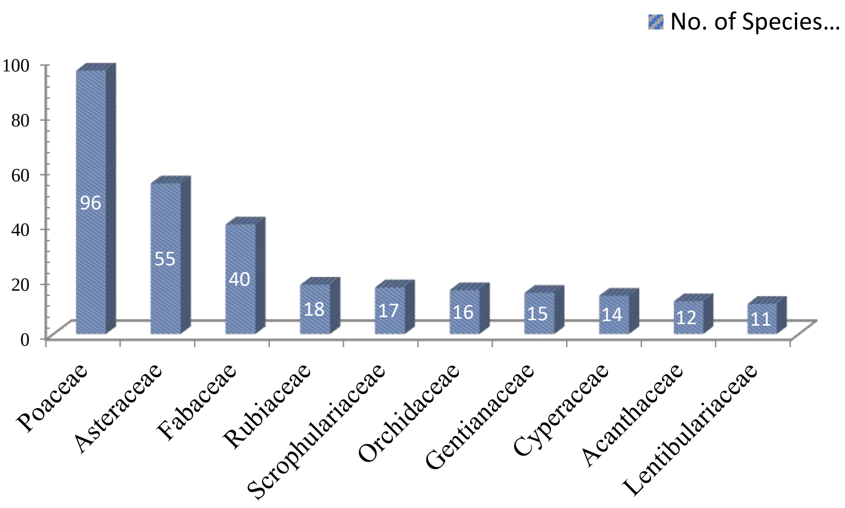


Figure 9. Dominant wetland plant families from flora of Ethiopia (Source: Tesfaye and Warikneh, 2022))

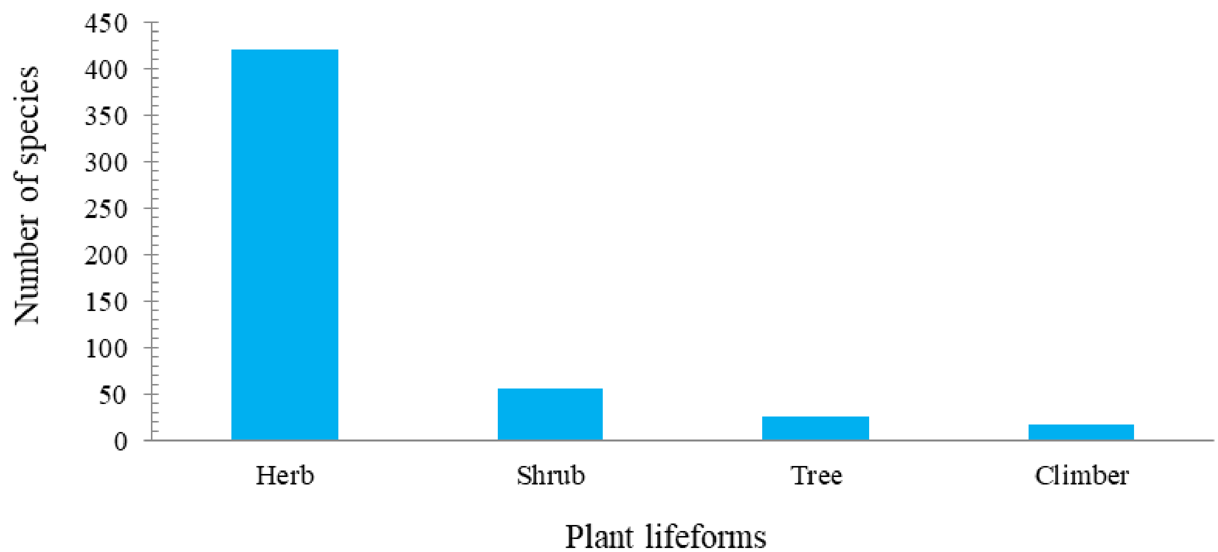


Figure 10. Classification of wetland flora based on their growth habits (Source: Tesfaye and Warikneh, 2022)

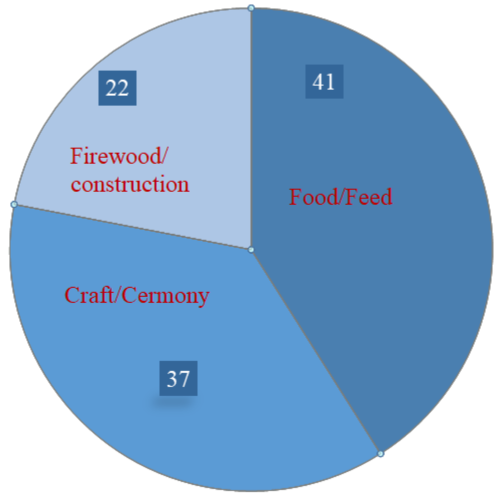


Figure 11. Classification of wetland flora based on their uses

The total wetland flora of Ethiopia is estimated at 549 species including ferns and these accounts for 9 % of the total floral diversity of the country, of which 31 (6%) are endemic species (Table 6). This indicates that wetlands could have an important role in conservation of plant biodiversity including endemic flora. The distribution and population status of these endemic wetland flora need to be investigated.

Table 6. List of endemic wetland flora of Ethiopia (Source: Tesfaye and Warikneh, 2022))

No.	Species Name	Family Name	Habit
1.	*Agrostis mannii*	Poaceae	Herb
2.	*Alopecurus baptarrhenius*	Poaceae	Herb
3.	*Callitriche favargeri*	Callitrichaceae	Herb
4.	*Chiliocephalum schimperi*	Asteraceae	Herb
5.	*Cleome gynandra L.*	Capparidaceae	Herb
6.	*Crotalaria polhillii*	Fabaceae	Herb
7.	*Habenaria aethiopica*	Orchidaceae	Herb
8.	*Haplocarpha hastate*	Asteraceae	Herb
9.	*Helichrysum elepbantinum var. formosissimum*	Asteraceae	Shrub
10.	*Hypoestes forskaolii*	Acanthaceae	Herb
11.	*Impatients rothii*	Balsaminaceae	Herb
12.	*Kniphofia hildebrandtii*	Asphodelaceae	Herb
13.	*Kniphofia insignis*	Asphodelaceae	Herb
14.	*Kniphofia isoetifolia*	Asphodelaceae	Herb
15.	*Kohautia platyphylla*	Rubiaceae	Herb
16.	*Pennisetum humile*	Poaceae	Herb
17.	*Pennisetum uliginosum*	Poaceae	Herb

18.	*Peucedanum mattirolii*	Apiaceae	Herb
19.	*Phyllanthus mooneyi*	Euphorbiaceae	Herb
20.	*Poa chorkensis*	Poaceae	Herb
21.	*Polysphaeria aethiopica*	Rubiaceae	Shrub
22.	*Ranunculus simensis*	Ranunculaceae	Herb
23.	*Senecio steudelii*	Asteraceae	Herb
24.	*Senecio ochrocarpus*	Asteraceae	Herb
25.	*Smithia abyssinica*	Fabaceae	Herb
26.	*Swertia pumila*	Gentianacea	Herb
27.	*Thesium matteii*	Santalaceae	Herb
28.	*Thunbergia ruspolli*	Acanthaceae	Herb
29.	*Trifolium calocephalum*	Fabaceae	Herb
30.	*Urtica simensis*	Urticaceae	Herb
31.	*Vernonia filigera*	Asteraceae	Shrub

Similarly, Ethiopian wetlands harbor diversity of birds. There are more than 860 bird species in the country, among which about 25% are wetland dependent **(**EWNHS, 1996). A detailed study by Bird Life International identified important wetland areas for the breeding and survival of birds and noted that many Ethiopian wetlands provide significant provisioning and supporting services for threatened and vulnerable bird species in Ethiopia (EWNHS, 1996). Similarly, diversity of other life forms in wetlands can be estimated to be high thus making wetlands vital for biodiversity conservation. The rift valley lakes and wetlands serve as stop-over sites for migratory bird species including some endangered ones. Thousands of lesser flamingos are reported to be found in Lake Abijata in periods between 1990 and 1994 (Siraj, 2004). According to Afework (2005) there are more than 40 wetlands which are identified as important bird areas in Ethiopia supporting high diversity of species including endemic birds.

For instance, the farming activities and waste dumping around Jimma town are threatening the Qofe and Boye wetlands and the species they harbor. Qofe and Boye wetlands are highly affected by these activities and few unique bird species are currently unavailable (Figure 12) These wetlands were known to house some unique aquatic birds of which Wattled ibis and Rouget's rail are endemic species to Ethiopia (Mereta, 2013).

Figure 12. Some wetland birds in the Jima zone (Source: Mereta, 2013)

Ethiopia is has a significant diversity of fish, though the contribution this resource to the national economy GDP remains meager. Some studies indicate that Ethiopian waters hold about 180 fish species, some freshwater shrimps and crabs, commercially important microalgae and diverse vegetation are yet underutilized but all together are potentially of great economic and socio-cultural importance. Fisheries provide economic support directly and indirectly to about half a million people and serve as source of affordable protein for many households (Tesfaye and Wolff, 2014).

Like the other group of plants and animals, a diversity of vertebrates other than stated above and invertebrates are found in Ethiopian aquatic and wetland ecosystem. A finding of a recent study commissioned by the Ethiopian Panel on Climate Change (2015,)however, showed that with an increase in salinity-alkalinity, the diversity of phytoplankton were limited to a few tolerant species. This has been reported from several case studies in Abijata and Chitu (Gebre Mariam and Taylor, 1997; Wood and Talling, 1988; Kebede and Willen, 1998). These studies do not show the estimate of phytoplankton diversity in Ethiopia's wetlands and water bodies. The same study indicated that the diversity and composition of zooplankton is also a reflection of the severity of salinity-alkalinity in lakes; the impact of predation by fishes and climatic conditions (Nilssen, 1984; Green and Mengistu, 1991; Fernando, 1994; Lemma, 2001). In the tropics, including the Ethiopian rift valley lakes, where water temperature is always high, fish predation activity on zooplankton is high throughout the year and thus leading to diminishing biodiversity of zooplankton. When macro zooplanktons (e.g. *D. Barbata*) are removed by fish, grazing pressure of zooplankton on phytoplankton becomes low. The elimination of macro zooplankton results in increase of phytoplankton biomass and diversity, which is assisted by nutrient inputs from extensive uncontrolled fertilizer use in the watersheds (Elhigzi et al., 1995; Tudorancea and Taylor, 2002; Lemma, 2001).

Ethiopian Panel on Climate Change (2015) has report the following issues worth considering:

- Cladocerans are generally absent in saline lakes (Shala, Abijata and Chitu) (Green and Mengistu 1991),
- Rotifers are generally abundant in the Ethiopian rift valley lakes as a response to year-round predation by fishes on macro zooplankton (Lemma, 2007). They exhibit a marked deduction in species in salinity over 2 g/l (Shala, Abijata and Chitu) (Green and Mengistu, 1991) Cladocerans Bosmina, Ceriodaphnia, Diaphanosoma and Moina (Green and Mengistu, 1991 and Lemma current observations) Lovenula africana (synonymous with Paradiaptomus africanus) (Tudorancea and Taylor, 2002; Lemma, 2008), and
- Small-bodied cyclopoids such as Africocyclops, Thermocyclops, Eucyclops and Paracyclops are common in freshwater lakes (Defaye, 1988).

Woldesenbet (2019) has identified about 34 macro-invertebrate families and 39 diatom species from both less impacted and profoundly impacted sites in Lake Zeway (Tables 7 and 8).

Table 7. List of macro invertebrate taxa (family) identified from Lake Zeway (Source: Woldesenbet, 2019).

Macro invertebrates			
Aeshnidae	Dreissenidae	Naucoridae	Pleuroceridae
Baetidae	Gerridae	Nepidae	Polymitarcyidae
Belostomatidae	Hirudinidae	Notonectidae	Sphaeriidae
Caenidae	Hydrachnidae	Notoridae	Tabanidae
Chironomidae	Hydrophilidae	Oligochaetes	Tetragnathidae
Cicadellidae	Hydropsychidae	Philopotamidae	Unionidae
Coenagrionidae	Libellulidae	Physidae	Veliidae
Corbiculidae	Lymnaeidae	Pisauridae	
Corixidae	Mesoveliidae	Planorbidae	

Table 8. List of diatom species identified in Lake Zeway (source: Woldesenbet, 2019)

Diatom Species	**Diatom Species**
Achnanthidium sp.	*Gomphonema parvulum*
Afrocymbella beccarii	*Hantzschia amphioxys*
Anomoeoneis sphaerophora	*Navicula subrhynchocephala*
Aulacoseira ambigua	*Navicula zanoni*
Aulacoseira granulata	*Nitzschia acicularis*
Aulacoseira granulata	*Nitzschia amphibia*
Aulacoseira muzzanensis	*Nitzschia clausii*
Caloneis aequatorialis	*Nitzschia intermedia*
Craticula ambigua	*Pinnularia grunowii*
Cyclotella meneghiniana	*Pinnularia subgibba*
Cyclotella ocellata	*Pinnularia viridiformis*
Cymbella kappii	*Pleurosigma salinarum*
Diploneis ovalis	*Rhopalodia operculata*
Encyonema volkii	*Sellaphora pupula*
Encyonopsis microcephala	*Stephanodiscus* sp.
Gomphonema aequatoriale	*Surirella angusta*
Gomphonema affine	*Thalassiosira baltica*
Gomphonema augur	*Tryblionella calida*
Gomphonema gracile	*Ulnaria ulna*

Similarly, Wondimagegn (2019) identified 46 macro invertebrate families (Table 9) and 105 diatom species (Table 10) from different sites of Lake Hawassa during 2016-2017.

Table 9. List of macro invertebrates found in Lake Hawassa (Source: Wondimagegn, 2019)

	Macro invertebrates	
Aeshnidae	Naucoridae	Notonectidae
Argulidae	Nepidae	Physidae
Baetidae	Noteridae	Pisauridae
Belostomatidae	Gerridae	Piscicolidae
Caenidae	Glossiphoniidae	Planorbidae
Chironomidae	Gomphidae	Pleuroceridae
Cicadellidae	Hydracarina	Polymitarcyidae
Coenagrionidae(Larva)	Hydrophilidae	Psychodidae
Cordulegastridae	Hydrophilidae(larvae)	Pyralidae
Corixidae	Labiduridae	Scirtidae
Corydalidae	Libellulidae	Sericostomatidae
Culicidae	Liptoceridae	Tabanidae
Curculionidae	Lumbericulidae	Tetragnathidae
Dytiscidae	Mesoveliidae	Veliidae
Dytiscidae larvae	Naididae	
Gelastocoridae	Noteridae larvae	

Table 10. List of diatom species identified from Lake Hawassa (Source: Wondimagegn, 2019)

Name of Diatom Species	**Name of Diatom Species**	**Name of Diatom Species**
Achnanthidium exiguum	*Epithemia hyndmanii*	*Nitzschia frustulum*
Achnanthes impexa	*Epithemia sorex*	*Nitzschia gracilis*
Achnanthidium minutissimum	*Eunotia bilunaris*	*Nitzschia kuetzingioides*
Afrocymbella reichardtii	*Eunotia formica*	*Nitzschia latens*
Amphora libyca	*Eunotia incisa*	*Nitzschia palea*
Amphora ovalis	*Eunotia monodon*	*Nitzschia palea*
Amphora veneta	*Fragilaria capucina*	*Nitzschia terrestris*
Anomoeneis sphaerophora	*Fragilaria tenera*	*Nitzschia vermicularis*
Aulacoseira muzzanensis	*Gomphonema angustum*	*Pinnularia acrosphaeria*
Aulacoseira ambigua	*Gomphonema augur*	*Pinnularia gibba*
Aulacoseira granulate	*Gomphonema gracile*	*Pinnularia viridis*
Aulacoseira granulate	*Gomphonema intricatum*	*Placoneis gastrum*
Caloneis bacillum	*Gomphonema olivaceum*	*Psammothidium levanderi*
Cocconeis placentula	*Gomphonema parvulum*	*Pseudostaurosira elliptica*
Cocconeis placentula	*Gomphonema pumilum*	*Rhoicosphenia abbreviate*
Craticula ambigua	*Gomphonema vibrio*	*Rhopalodia gibba*
Craticula buderi	*Halamphora montana*	*Rhopalodia gibberula*
Craticula cuspidata	*Lemnicola hungarica*	*Rhopalodia musculus*
Cyclostephanos dubius	*Mastogloia braunii*	*Rhopalodia rupestris*
Cyclotella krammeri	*Mastogloia elliptica*	*Sellaphora pupula*
Cyclotella meneghiniana	*Mastogloia smith*	*Stauroneis sphoenicenteron*
Cyclotella ocellata	*Mastogloia smithii*	*Staurosira abrevistriata*
Cymbella cistula	*Navicula capitoradiata*	*Staurosira construens*
Cymbella kappii	*Navicula decussis*	*Staurosirella pinnata*
Cymbella leptoceros	*Navicula phyllepta*	*Stephanodiscus minutulus*
Cymbella neocistula	*Navicula radiosa*	*Surirella engleri*
Cymbella turgidula	*Navicula reichardtiana*	*Surirella linearis*
Diploneis smithii	*Navicula tenella*	*Surirella ovalis*
Encyonema caespitosum	*Nitzschia af. Closterium*	*Tabularia fasciculate*
Encyonema muelleri	*Nitzschia amphibia*	*Thalassiosira faurii*
Encyonema silesiacum	*Nitzschia clausii*	*Thalassiosira rudolfi*
Encyonopsis microcephala	*Nitzschia denticula*	*Tryblionella apiculata*
Epithemia adnata	*Nitzschia desertorum*	*Tryblionella umbilicata*
Epithemia argus var. *alpestris*	*Nitzschia draveillensis*	*Ulnaria acus*
Epithemia frickei	*Nitzschia etoshensis*	*Ulnaria contracta*

The composition of these macro-invertebrate and diatom communities is an indication of the ecological status (in terms of pollution) of the aquatic system in relation to the human pressure on it (Woldesenbet, 2019; Wondimagegn, 2019*)*.

The Ethiopian Panel on Climate Change (2015) showed that there are at least 27 amphibian species which are endemic to Ethiopia, but their total diversity is yet to be known. The crocodiles in the crocodile farm on the shores of Lake Abaya and Nile monitor (*Varanus niloticus*) are common in the rift lakes of Ethiopia and elsewhere in other lakes and rivers of Ethiopia. Other wetland reptiles particularly those that are endemic to highland areas as Bale mountains include *Chamaleo balebicornutus* (Bale mountains two-horned chameleon), *C. harennae* (Bale mountains heather chameleon), *Lamprophis erlangeri* (Ethiopian house snake) and *Bitis parviocula* (Ethiopian mountain adder). Among the mammals of wetlands, hippopotamus is very common in Ethiopian wetlands. Several other mammals visit wetlands by the day or make their living in grasslands or shrubs along the water systems.

Unlike many other parts of the country, southwestern Ethiopia has relatively pristine wetlands, such as in the Yayo and Kafa Biosphere reserves. In Kafa Biosphere Reserve remarkable biodiversity were recorded, though the aquatic inventory is very limited. The Reserve is inhabited by lots of fauna and flora. Species recordings in this ecosystem have documented around 244 species of plants, 300 species of birds and 300 species of mammals. Along with the forests, aquatic habitats are the significant suppliers of ecosystem services to the local population as source of water, food, animal feed, building materials and income. Most biodiversity found in this natural reserve is mainly dependent on the wetland ecosystem found in Kafa Biosphere Reserve (NABU, 2014). In general, Ethiopian Aquatic and Wetland ecosystem is area of high endemicity and high biodiversity.

Environmental justice and equity dimension of aquatic and wetlands ecosystem

Environmental justice is defined as the “fair treatment and meaningful involvement of all people with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies”. Moreover, it is defined as the ‘distribution of environmental risks and benefits; fair and meaningful participation in environmental decision-making recognition of community ways of life, local knowledge, and cultural differences, and the capability of communities and individual to function and flourish in society. In view of these definitions, wetland degradation has a differential impact on the poor and vulnerable groups.

Wetlands and related aquatic resources degradation due to habitat alteration such as dam construction (e.g. the Omo wetlands) and river course diversions (e.g. the Tana Beles hydropower project), pollution due to agricultural, industrial, and municipal wastes (e.g. Hawassa, and Zeway lakes, and Awash River), overexploitation [e.g. Haramaya, Abijata, and Cheleleka Lakes (Wolka et al., 2015), invasive species (e.g. water hyacinth in Lake Tana, *Parthenium* in Chefa wetlands) affects dis-proportionately the poor. For instance, when aquatic resources are polluted (e.g. Hawassa and Zeway) the livelihood of those artesian fishermen and women whose livelihood depends on capture and processing and selling of the fish are most affected. Wetlands are open access commercial grazing lands (e.g. Dawa Chefa (Tessema et al., 2013), Fogera and others). When these wetlands are overtaken by invasive species, the carrying capacity declines and along with it the livelihood declines and vulnerability of pastoral communities increases (Negussie et al., 2019).

In most cases, wetlands are public resources. Wetlands as public goods are commonly subject to public control to protect environmental justice (Getches, 1990). Wetlands as public resource - they are managed by the 'public trust doctrine' (PTD). The doctrine gives recognition to special public right over wetlands (Olson, 2014). In Ethiopia, all-natural resources, including wetlands, are public property; the ownership is vested upon the state and the people of Ethiopia. (FDRE Constitution, 1995). Wetlands are not a private or ordinary common right they confer. Accordingly, the Federal Government is empowered to regulate the use of water resources across the country. Under public ownership of wetlands, public property rights are imposed against resources users (Cole, 2002). This duty affects how wetlands are exploited. Permit is commonly used to regulate the behaviors of users.

When the rights over wetlands access and uses are transferred to private or corporate through permit systems, the primary victims are the local communities whose livelihood depends on the wetlands (provisioning, support, cultural, and regulation) services. Draining wetlands for crop production, whether it is small or large, is accompanied in land tenure shift [e.g. Gambella (Degife et al., 2017), Omo (Kamski, 2016), Dawa Cheffa wetlands (IBC, 2009)].

Though there are no specific mentions of 'Environmental Justice' in many of environmental policy and legal instruments in Ethiopia, they impose regulated access and use of water bodies.

Ethiopia formulated a number of policies, legal instruments and guidelines (cf. Section 3. 6) that require the inclusion of environmental and social impact assessment (ESIA) report be submitted. The ESIA report is expected to incorporate the potential environmental and social impacts of a proposed project, evaluating alternatives and designing appropriate mitigation, management and monitoring measures. Such proactive measures may manage environmental injustice that affects local people disproportionately. The major challenge might be the implementation and enforcements of regulatory tools in place. The observation in some lakes suggests that wetland access and use are denied to local people once the areas are transferred to private or corporate ownership. Yet, Ethiopia has not developed environmental law that defines buffer zones that enable local communities to access wetlands.

Although every major development intervention is required to submit comprehensive assessment report, the capacity of the regulatory institutions at all levels to assess comprehensiveness of the assessment has made the whole exercise a mere formality.

Relational values of aquatic and wetland ecosystem

Understanding how people relate to their environment is very important. Recreational, spiritual, cultural, educational and other values that are loosely clustered under cultural services are derived from the attributes of wetlands. For example, recreational value might be attached to the presence of rare species, from the fact that wetlands add to the landscape beauty, or their potential for angling. Spiritual value might be gained from the landscape beauty. Religious and cultural values might be gained from the provision of a place for conducting ceremonies. Educational and scientific value might be gained from the presence of unimpacted environments which provide an opportunity for understanding natural biological processes. In all of these cases, the estimation of current value does not require any quantitative biophysical information on the wetland. However, estimation of a change in these values due to a change in wetland condition would require estimates of changes in the parameters that affect these values. As is the case for provisioning services, these changes have seldom been quantified on the basis of statistically accurate predictive relationships. The current tendency is for the estimation of change in the relevant parameters on the basis of expert opinion, and more recently, for the construction of response curves which are more explicit in the assumptions made.

In conclusion, aquatic and wetlands ecosystem is important features in the landscape that provide numerous beneficial services for people and for fish and wildlife. Some of these services, or functions, include protecting and improving water quality, providing fish and wildlife habitats, storing floodwaters and maintaining surface water flow during dry periods. These valuable functions are the result of the unique natural characteristics of wetlands. Wetlands provide many societal benefits: food and habitat for fish and wildlife, including threatened and endangered species; water quality improvement; flood storage; shoreline erosion control; economically beneficial natural products for human use; and opportunities for recreation, education, and research. Moreover, wetlands provide valuable non-material ecosystem services to the Ethiopian society. They are sites of cultural celebration; they provide various resources for public health and prevention of natural hazards including climate mitigation.

4.3 Current status and future trends of aquatic and wetland ecosystem

4.3.1. Definitions

As defined by the Ramsar Convention on Wetlands (Ramsar Convention Secretariat, 2016) under Article 1.1, wetlands are “areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters.” Ethiopia has diverse wetlands across the country, from the lowlands of Afar to the highlands of Bale Mountains, several crater lakes in central highlands of the country and flood plains of Baro and Akobo Rivers in Gambella. The major types of wetlands in Ethiopia include swamps, marshy wetlands, flood plains, natural and human-made lakes, peaty wetlands and swamp forest wetlands (Abunie, 2003). In addition, there are large number of valley-bottom wetlands especially in the highland parts of the country, but are often neglected due to their small sizes. These wetland types are highly degraded, drained and used for small scale irrigation but also as a grazing land in dry season. These are often seepage wetlands and they are in many cases sole source of drinking water for the local communities.

Wetlands are threatened environments at global scale (Maltby, 1986). Wetlands provide many ecosystem services but throughout the world are exposed to a range of direct and indirect pressures. While technologically advanced nations properly document and address key issues affecting wetlands, at other locations such as in much of Africa and in Ethiopia in particular, lack of data, resources and methods are hindering thorough assessment. Proximity to resource availability such as water, food and fuel has been increasingly becoming a determining factor for human settlements, with early examples including the Indus delta (Meynell and Qureshi, 1993), Nile delta (Maltby, 2009) and Mekong delta (Duc, 1993).

Ethiopia is often categorized as a ‘water tower’ of Africa (BBC News, 2004, accessed on Feb. 2, 2015) mainly because of its 14 major rivers that crisscross the country but on the other hand also a dry country. Ethiopia is an origin for the world’s longest river, the Nile (about 85 % of the Nile annual outflow originating from highlands of Ethiopia), and the highlands of Ethiopia receiving an annual rainfall of above 1000 mm, it is no wonder that the country is named water tower of Africa. Ethiopia can also be categorized as a dry land country since the vast majority of the country’s lowlands receive much less annual rainfall or no rain at all. This variability of incident rainfall patterns and wide differences in wetness across the country makes Ethiopia extremely vulnerable to climatic change and climatic variability. The highlands of Ethiopia, especially mountains, are origin of all perennial rivers.

With a rapid population growth in developing countries and consequently increasing consumptive demand, wetlands are rapidly reaching a tipping point. One of the challenges in Ethiopia is provision of water with sufficient amount and optimum quality for human consumption and livestock production, in addition to the dependency of Ethiopia’s agriculture on seasonal rainfall, which is becoming more and more erratic. It is, therefore, imperative that the country utilizes all its natural resources wisely and sustainably. Wetlands in Ethiopia is highly degraded despite their valuable ecosystem services and provisions (Hailu, 2007). Also, globally wetlands are highly degraded, which according to Millennium Ecosystem Assessment (MEA) (2005), “degradation and loss of wetlands (both inland and coastal) is continuing more rapidly than for any other ecosystems”.

In general, the total wetland cover of the country is not exactly known (Hailu, 2007). Up to date, there is no comprehensive inventory of all wetlands in the country and studies on wetland hydrology, ecology, and biogeochemistry are sporadic. Yet, there are people who tried to estimate the total wetland cover of the country. For instance, Hillman (1993) identified 73 major wetlands in Ethiopia and he estimated that these wetlands cover about 13, 699 km^2, which is about 1.4% of the total landmass cover of the country. FAO in 1984 (Cited in Asmamaw, 2020), based on aerial photographs and early Landsat data put the estimate at about 0.74% of the total landmass of Ethiopia for permanent water bodies and wetlands and about 2% when shallow lakes, small wetlands, peat lands, swamp forests and seasonal wetlands are included. Therefore, based on the current estimate about 2% of Ethiopia's landmass could be considered wetland. However, Ethiopia has numerous restorable croplands and rangelands which could increase the wetland area of the country.

4.3.2. Current Status and Future Trends

Table 11 shows some wetlands and water bodies in Ethiopia with their degradation status. The agriculture productivity of the country relies on provisioning service of these vital ecosystems.

Table 11. Some selected water bodies and wetlands in Ethiopia where data are available (+ = slightly degraded; ++ = moderately degraded, requires intervention and +++ = extremely degraded and in need of restoration. Empty cells indicate that the extent of ecosystem services is unknown in these lakes (Source: EWNHS, 2017).

	Wetlands	Area (km^2)	Recharge	Major uses	Degradation status
1	Zeway	434	Katar, Meki, streams	Fishery, livestock, recreation, local climate stabilization, irrigation, water abstraction	++ tributary rivers degradation, land degradation and sedimentation
2	Shala	400	Furfer, Dijo Angeilu	Mineral production, recreation, local climate stabilization	+
3	Langano	230	Teyi, small streams	Fishery, livestock, recreation, local climate	+
4	Abijata	205	Bulbula, Hora Kelo	Recreation, mining, livestock	+++ Mineral mining, drying up of Bulbula river
5	Abaya	1160	Blaten,Gelana and others	Fishery, irrigation	+
6	Beseka	30	Ground water	Recreation, scientific study	
7	Chitu	0.8	Ground water		+
8	Chukala	1.0	Precipitation	Recreation	+
9	Hora Arsedi	1.1	Precipitation	Recreation, Irrecha, Fish	+++

10	Bishoftu	1.5	Precipitation	Recreation	+
11	Hora Oda/Arenguade	1.1	Precipitation	Recreation	+
12	Wonchi	8.9	Precipitation	Recreation	++ Sedimentation Land degradation
13	Dendi	15.0	Precipitation	Recreation	+
14	Bishoftu Guda	18.0	Precipitation	Recreation	+
15	Hora Kilole		Precipitation	Irrigation and Fish	+++
16	Cheleleka		Precipitation	Agriculture, grazing	Lost or beyond restoration
17	Fincha'a	345	Fincha'a, Amerti	Hydro-power, fishery, Irrigation, recreation, local climate stabilization	+
18	Koka	236	Awash, Mojo	Hydro-power, fishery, irrigation, recreation	+++
19	Melka Wakena	81.6	Wabe	Hydro-power, fishery	
20	Lake Ashenge	14,000 ha		water, fish, vegetation	+
21	Tekeze dam		Tekeze	Provision of fish, water and hydroelectric power Regulatory services in moderating climate change in this arid environment	+++
22	Geba catchment	5137 km^2	Feeds into Tekeze	Potable water	+++
23	Mereb River	5,893 km^2		No data	+

In addition to these water bodies there are numerous rivers, streams and other wetland types including dams, reservoirs, flooded areas, floodplains, swamps, marshes, salt marshes, irrigation fields, plantations, seasonal pans, and ponds in Ethiopia. Major rivers such as Muger, Didessa and its tributaries, Dabus, Genale and Gibe rivers provide essential water resources for the Oromia region and other regional states in Ethiopia. For instance, the Didessa River has vital supportive ecosystem services. It contributes 25% of the flow of the Abbay River and most of its catchment is relatively pristine. Although human encroachment is increasing in the sub-basin, still the ecological condition of the Didessa River basin can be said to be good to moderate. The Mugher River serves as source of potable and irrigation water, and supports livelihood of a large segment of the farming population along the riparian. The river has significant contribution to the flow of the Blue Nile in its middle course.

Wetlands and water bodies (aquatic habitats) lie along an environmental gradient of moisture. From practical management, utilization and conservation point of views, it is important to consider them under same system. The Ramsar convention definition of wetlands encompasses a wide variety of inland habitats such as marshes, peatlands, floodplains, rivers and lakes, and coastal areas such as saltmarshes, mangroves, intertidal mudflats and seagrass beds, and also coral reefs and other marine areas no deeper than six meters at low tide. In addition, human-made wetlands including dams, reservoirs, rice paddies and wastewater treatment ponds and lagoons are all categorized as wetlands. (RCS, 2013, 2016). It is important though to recognize Ethiopia is not signatory to the Convention and there is a strong argument for inclusion of other wetland types unique to Ethiopia, such as the valley bottom and mountain seepage wetlands.

According to the Assessment of Wetlands for National Restoration Potential in Ethiopia (2017), the following key factors are the main drivers aquatic and wetland ecosystem degradation in Ethiopia.

Overexploitation

Excessive water abstraction: any excessive withdrawal of water either directly from the wetlands or from feeder rivers and other water bodies associated with the wetlands reduces their size and ultimately leads to their disappearance. Lake Haramaya is a typical example for this case. Excessive withdrawal of water for various purposes is now becoming a serious problem all along the rift valley lakes starting from Lake Afdera in the north to Lake Turkana in the south. This is mainly the case in the Zeway-Shala basin (Ayenew, 2012). The effect of water diversion from feeder rivers is better reflected in the larger lakes than in the wetlands. However, as the lakes start to recede the associated wetlands will start to shrink. The flood plains are also seriously affected by abstraction of water from rivers for irrigation purposes. Obviously, the flood plains are recharged by overflow of water from the adjoining rivers. The above consequences are aggravated by habitat loss and fragmentation, water diversion structures, impoundments and sedimentation of storage reservoirs.

Overgrazing: is a serious problem in all wetlands of Ethiopia due to high livestock population density in excess of the carrying capacity of the grazing lands. Grazing livestock can degrade wetlands that they use as a food and water source. Compaction of soils by livestock trampling is a common consequence in overcrowded wetlands by livestock which can also cause eutrophication from urea and manure. Overgrazing of riparian areas by livestock reduces streamside vegetation, preventing runoff filtration, increasing stream temperatures, and eliminating food and cover for fish and wildlife. Stream bank destabilization and erosion then cause downstream sedimentation. Sedimentation reduces stream and lake capacity, resulting in decreased water supply, irrigation water, flood control, hydropower production, water quality, and impairment of aquatic life and wetland habitat.

Overexploitation of resources: this includes the overexploitation of fish resources from the water bodies and macrophytes from the nearby shores. In many of the freshwater bodies of Ethiopia especially in highland lakes such as Lakes Tana and Hayq and rift valley lakes such as Lakes Zeway, Hawassa, Langano and Chamo, from where the majority of the fish catch is coming, there are overexploitations of the fishery resources (EWNHS, 2017). This is mainly caused by increased number of fishermen that created pressures beyond the sustainable production level of the lakes. The fishermen operating in these lakes are not all registered and the fishing gears they are using are not regulated. Some of the fishing gears are so destructive that smaller fingerlings below the size are caught and some are wasted. Fishing during the breeding seasons of the fishes is not prohibited in some regions; even though it is legally prohibited in some, enforcement of the legislation has become a daunting task and could not be implemented.

Increased demand for agricultural land associated with population growth continues to be a significant cause of wetland loss in some parts of the world. Infrastructure development and river flow regulation constitute another major cause of wetland degradation and loss, as well as the invasion of non-native species and pollution. Transformation of Lake Haramaya into grazing field, conversion of Boye pond into marshland, water hyacinth invasion in Lake Tana are very clear examples that demonstrate ecosystem mismanagement is affecting the aquatic systems of Ethiopia.

The previous finding indicated that Haramaya and Hora-Kilole were exposed to contrasting human interventions (Lemma, 2003). From Lake Haramaya water was abstracted mercilessly, while water is added to Lake Hora-Kilole through the diversion of water of a nearby river by agricultural experts by constructing a weir. As a result, Lake Haramaya continually shrunk and disappeared due to uncontrolled water withdrawal for irrigation and municipal uses, whereas Lake Hora-Kilole increased in volume. Such uncontrolled contrasting anthropogenic intervention has caused ecological changes as observed from measurements of various limnological parameters.

Similarly, Lake Cheleleka is diminishing due to overexploitation, expansion of horticulture, silt accumulation from the surrounding farmland, grazing field, and due to forest clearance. This fact is not different from the current status of Lake Zeway. Study participants indicated that high levels of human activities, especially water abstraction and water pollution, were the leading causes of lake degradation. Absence of sustainable utilization and protection of the lake has aggravated the problem. Coordinated activities among all lake stakeholders in the participation and decision-making process could be vital to restore or at least minimize degradation (Desta et. al, 2015).

Habitat alteration

Habitat changes due to agricultural expansion: Historically, agriculture has been the major factor in causing loss and degradation of freshwater and estuarine wetlands through construction of drainage, ditches, forest roads, dams, dikes/dykes, levees, aerial application of damaging pesticides (herbicides, fungicides, insecticides, fumigants); and ground water withdrawals. These activities can alter a wetland's hydrology, water quality, and species composition. Excessive amounts of fertilizers and animal waste reaching wetlands in runoff from agricultural operations, including confined animal facilities, can cause eutrophication. The debate about the future of wetlands tends to divide between those seeking to develop these areas for agricultural production (crop producers and livestock husbandry) and those who believe that wetlands must be preserved as much as possible in a state to maintain their ecological contributions to the ecological system.

Drainage agriculture: wetlands have been drained and used for agriculture. Wetlands play significant roles in attenuating floods and acting as temporary storages during the wet season. This situation helps in reducing peak flows in the major rivers during the rainy season and also contributes to the base flow during the dry season by releasing what is stored during the wet season. This capacity of several wetlands is diminished due to drainage agriculture. The wet season flows are increasing from time to time while the dry season flow has been reduced significantly over the past years. Drainage of valley bottom and mountain seepage wetlands for farming and animal husbandry are common in western and northern parts of Ethiopia.

Land use changes: shortage of farm land has forced many farmers to use land near lake shores. The land use pattern in the watershed of Lake Zeway and Lake Tana are dominated by agricultural practices has led to degradations. Seasonal wetlands such as the shallow Lake Cheleleka have disappeared as residential land due to urban incursion and land grab continued by speculators.

Watershed perturbation*:* clearance of forests and the resultant erosions from surrounding catchments would seriously affect the biological and physico-chemical processes in water bodies. In Ethiopia, there is rapid land use land cover change especially the conversion of natural forests to cultivated land and grazing lands hold the widest part. Food and agricultural organization of the United Nations (FAO, 2005) illustrated that, in the year between 1990–2000 the total natural forest cover of the country has decreased by 9% with the estimated rate of 40,000 ha per year while plantation has been increased only by 1%.

Fertilizers from agricultural fields surrounding water bodies cause excessive load of nutrients and eutrophication. In turn, eutrophication is the main cause of fish deaths due to the depletion of oxygen and generation of toxic gases like H_2S and CH_4 and such rampant impacts have been observed in Lakes Chamo, Babogaya, Bishoftu Guda, and Hashenge. Due to soil erosion siltation has been critical problems in lakes, reservoirs and rivers. For example, Lake Haramaya was turned into a grazing land and farmland, Moreover, Hawassa and Koka reservoirs are affected by siltation as a result of degradation of the wetlands. The worst scenarios are observed in Lakes Abaya and Chamo. Lake Tana is severely affected by agriculture and water hyacinth, which is an invasive alien species, .

Deforestation: is the main cause of land degradation. It is estimated that about1900 million tons of soil are being eroded annually in the highlands. This is equivalent to an average of 35 tons from every hectare in the highlands. However, most losses are from croplands, totaling an estimated 22% of the land area of the highlands and the remaining 20% is from overgrazed grasslands and little from waste and other lands. Most of this being deposited as sediment on grass and forest land, but the part that is carried into rivers is lost carried away from the highlands every year (EWNHS, 2017).

Aggradation of river channels: is another problem resulting from sedimentation. For example, the stretches of the Awash in the lower valley lost their natural capacity to carry floods of even much less than peak flows. Consequently, flooding in these areas has now become a yearly phenomenon.

Mining activities: sand mining is the process of removal of sand and gravel from in and around wetlands, usually rivers and flood plains. As the demand for sand increases in industry and construction, the issue has become cumbersome. The erosion caused by dredging can incise beds, erode banks, reduce the number of sandbars and islands, and undermine bridges and other structures all of which have potential to impact aquatic biota. *Soda ash mining* has been taking place in Lake Abijata and abstraction from feeder rivers; the lake is on the verge of complete dry-up (EWNHS, 2018).

Invasive alien species: as a result of disturbance and habitat degradation, wetlands can be invaded by aggressive, highly-tolerant, non-native vegetation, such as water hyacinth *(Eichhornia crassipes)*, and salvinia *(Salvinia molesta*), or can be dominated by a monoculture of cattails *(Typha* spp.*)* or common reed *(Phragmites* spp.*).* Water hyacinth and similar species can rapidly fill a wetland and are a threat to water quality in some areas. The invasion by water hyacinth *(Eichhornia crassipes)* is very much noted in Lake Tana from the highland lakes, Koka reservoir in the rift valley and lake Tatta in Gambella. It appears that currently it is spreading to other water bodies including Lake Zeway and Abaya in the rift valley. Non-native species may be introduced on purpose. For example, water hyacinth has been noted for its ability to sequester nutrients and is used for wastewater purification. Carps are exotic fish species that degrade wetlands. Carps, introduced for various purposes, severely increased the turbidity of water bodies. These species have been introduced, for example, into Lakes Zeway and Langano as well as Koka reservoir and are causing loses of endemic fish diversity (EWNHS, 2018).

Urbanization and pollution: Cities and towns are expanding in Ethiopia and these expansions create pressure on the surrounding environment. It is not uncommon that most of these are established around water bodies and wetlands. The importance of water for urban construction and dwellers is indispensable. They are not only source of water, but also provide many economic, social and environmental services. Obviously, most of these cities and towns are with no proper sewerage systems and many of the households and industries release their wastes into the surrounding water bodies (Desta et al., 2015).

Climate change: climate change and recurrent droughts are threats to wetlands of Ethiopia. Nitrous oxides, sulfurous oxides, heavy metals, volatilized pesticides, hydrocarbons, radionuclides, and other organics and inorganics are released into the atmosphere by industrial and agricultural activities, and from vehicles. These compounds can enter wetlands through wet and dry atmospheric deposition and can adversely affect aquatic organisms and the terrestrial organisms that feed on them. There is also an increase in temperature due to climate change which is generally affecting aquatic and wetland, and other ecosystems. Such phenomena adversely affect hydrological cycles, which in turn affect the biodiversity resources and various services of wetlands. Obviously, in times of recurrent drought and dry times, the pressures that would be exerted on wetlands are huge since they are the only major sources of water, fodder, and crop production, and contribute to saving lives of humans, livestock and wild biodiversity.

Seismic events: the Ethiopian rift experiences frequent tectonic activity manifested as earthquakes and rarely also by volcanism. New ground cracks are being created and these cracks result in the disappearance and /or reduction of the sizes of wetlands as evidenced in the Main Ethiopian Rift. The case of Beseka Lake in the Awash valley is a good example to show the effects of seismic activities on the nature of wetlands.

Lack of coherent policies and institutional arrangement is one of the key factors causing degradation of wetlands. In Ethiopia, wetland related concepts are incorporated in different policies and strategies (e.g. Ethiopian Water Resources, Agriculture and Environmental policies). The Conservation Strategy of Ethiopia, which forms the basis for the Environmental Policy of the country, has also mentioned wetland-related issues. Unlike the National Environmental Strategy, the Gambella Region's Conservation Strategy contains a separate section devoted to wetlands. However, Ethiopia generally lacks a specified policy to wetlands. There appear to be strategy documents that favour irrigation agriculture through drainage at the expense of wetlands. These documents encourage draining and conversion of wetlands into other forms of land use particularly for improving agricultural yield. The Environmental Policy in its general aim of protecting the environment highlights only the importance of wetlands for water resources management. For instance, agriculturalists consider the moist fertile soil as the potential for growing grain; fishery managers find a support base for producing fish; hydrologists calculate capacities to provide water for industry, agriculture, and domestic use; while public health specialists, in contrary, assume that wetlands as breeding sites of mosquitoes that for transmit malaria disease.

Investment in wetland management is rarely integrated. Instead, wetlands are invariably viewed by each user as single-product system, precluding other values, while single-purpose returns fall far short of expectations. The absence of a stand-alone policy and an institution duly empowered to issue and implement wetland laws and coordinate management activities is the underlying cause for the deterioration of the wetlands of Ethiopia.

Wetland management in Ethiopia also suffers from capacity limitations such as lack of skilled manpower, finance and technology. Wetland focused training programs are very scarce in higher learning institutions of the country. Programs are not implemented to fill this gap nationally. As a result, there is a shortage of wetland specialists. There is also awareness problem from grassroots up to decision maker levels. The scarcity of wetland focused institutions and weak relation of the country to wetland affiliated global institutions such as the Ramsar Secretariat has hampered its capacity building opportunities. Unsustainable land management systems contribute to further degradation of natural resources including wetlands, as the farmers try to draw short term benefits, although destructive, rather than thinking of long-term returns because of insecurity in ownership. As a result, there is intensive cultivation by draining the wetlands, especially with limited knowledge about wetland management.

Wetland degradation is a serious problem in Ethiopia and this does relate to biodiversity loss and species extinction. It is known that reduction of the area of wetland in a landscape often reduces biodiversity because many organisms depend on the wetlands and riparian zones with which they are frequently associated. Wetland loss is assumed to be the main reason for threatening and declining biodiversity in wetlands. Blem and Blem (1975) showed the importance of river bottomlands to wildlife relative to adjacent uplands in Illinois. Ohmart and Anderson (1986) have shown that an availability of large riparian areas, which include wetlands, is the primary factor that explains the number of birds that breed at high elevations in central Arizona. Weller

(1988) views wetlands as islands in a terrestrial sea, and suggests that bird diversity follows the rules of island biogeography (more species with larger island area), as shown for prairie potholes. Similarly, Leibowitz et al. (1992) conclude that many waterfowl species are sensitive to reductions in area, patch size, wetland density, and proximity to other wetlands. It is assumed that 25% of Ethiopian birds are associated with wetlands. They cite work that supports the need for many small wetlands as well as for large ones. Harris (1988) also points out that data on waterfowl, which provide some of the best long-term records of species that depend on wetlands, show steady declines (mallard down 35 % from 1955 to 1985, pintail down 50%). Fish, which are good surrogates for aquatic biodiversity (Moyle and Yoshiyama, 1994), are sensitive to alteration of habitat, including wetlands. In the United States, 41 fish species have become extinct in the past century (Minckley and Douglas, 1991), and an estimated 28 % of freshwater fish species in North America are seriously reduced in abundance or distribution. In addition, studies (Hickman, 1994) are beginning to document the extensive increase in biodiversity that occurs when wetlands are created or restored in a disturbed landscape. Factors other than reduction of area can cause a decline in biodiversity. For example, Moyle and Sato (1991) found that habitat heterogeneity is closely related to species diversity of fish communities, presumably because a more variable habitat provides a wider range of biological niches.

A large number of both invertebrates and vertebrates show some association with wetlands, but species vary widely in the nature of this association. Some taxa, including certain species of aquatic invertebrates and amphibians, may be confined to wetlands or dependent upon them for specific stages of the life cycle. Waterfowl and mammals also have a range of dependencies on wetlands for food and habitat. For individual species, the suitability of a particular wetland for habitat or for food may be critically dependent on the duration and time of year at which the wetland is inundated or saturated with water. In particular, species that require the presence of water for extended intervals will obviously not be able to live in a wetland that is inundated or saturated for a couple of weeks per year, but might be well suited to wetlands that show constant inundation. Even though studies are scanty, similar trend is assumed to have occurred in Ethiopia as well.

Despite some studies on the traditional knowledge systems in aquatic and wetland ecosystem, there has not been any organized large-scale systematic investigation at large scale and across culture in Ethiopia. An often-cited study is from Illu-Abba-Bora and West Wollega region where studies focused on local community-based institutions that coordinate the management of natural resources and their link with socio-ecological resilience, adaptation and sustainability within rural livelihood systems (Dixon and Wood, 2007). This study showed that the resilience and sustainability of local institutions is influenced by their relationship with external actors and institutions, particularly in facilitating, supporting or hindering local institutional arrangements. This study drew upon their findings of participatory fieldwork undertaken in eight wetland-using communities of Illu-Abba-Bora and Western Wellega zones in Oromia Region and argued that although local institutions do play a key role in coordinating wetland management and sustaining the benefits from wetlands, the sustainability and resilience of the institutions themselves is threatened by a range of factors (Dixon et al., 2009). Despite their grassroots nature, their effectiveness is influenced by their reliance on local government backstopping that appears to have diminished in recent years, as well as a perceived lack of local government support for collective action over individual rights. But the local institutions are in the revival in Ethiopia with several cultural activities undertaken in wetland areas that have created opportunities to strengthen local knowledge institutions.

In conclusion, the wetland and aquatic ecosystem in Ethiopia is under pressures emanating from land degradation and unsustainable development competing with wetlands and water bodies. Even though similar trend is observed in the globe, being a dry country, Ethiopia needs to pay attention to this fragile ecosystem. The biodiversity, the ecosystem function and the associated services have been disrupted. The traditional knowledge systems long associated with sustainable management and wise uses of wetlands have diminished over the last few decades. Hence, unless precautionary measures were taken with priority, the continuing loss and degradation of wetland and aquatic ecosystem could pose a serious threat to nature and human wellbeing.

4.4. Drivers of the degradation of aquatic and wetland ecosystem

4.4.1. Indirect drivers

Drivers of change refer to all those external factors that affect nature, anthropogenic assets, nature's contributions to people and a good quality of life. They include institutions and governance systems and other indirect and direct natural and anthropogenic drivers (Pinto et al,. 2013). As such, drivers are usually considered to be economic and social goals of those involved in the industry, as well as economic and social policies of governments. Under Ethiopian condition, the major indirect drivers of aquatic and wetland ecosystem degradation and biodiversity loss include high population growth exceeding the potential that the economy can support unplanned urban sprawl and land grab, livestock population increase in open access communal grazing lands, international agricultural trade (investment) and climate change.

4.4.1.1. Population Growth

According to CNRS (2012), the area of the globe covered by wetlands (swamps, marshes, lakes, etc.) has dropped by about 6 % in 15 years. This decline is particularly severe in tropical and subtropical regions, and in areas that have experienced the largest increases in population in recent decades. Prigent et al. (2012) also noted that this is consistent with an expected higher anthropogenic effect in these areas: human population growth and the expansion of economic activities are collectively placing great demands on local hydrology, including draining of marshes and wetlands for constructions and water withdrawals for agriculture and human needs. The population of Ethiopia has increased over the last four decades: 42.6, 53.5, 73.8 and 91 million in 1984, 1994, 2007 and 2013, respectively (CSA, 2013). Population growth rate of Ethiopia is among the fastest in the world which is estimated at 2.43 % per annum. The national population of Ethiopia was reported 73.7 million in 1997 (CSA, 1997) and UNDESA (2017) estimated over 105 million- the largest in Africa next to Nigeria growing at a rate of 2.43 % (Figure 13). About 60 % of the population is under the age of 25 years, and with this rate of growth and demographic profile, the population is projected to double by 2063.

The GOE promulgated its first ever explicit, comprehensive and multispectral population policy in 1993. The policy aimed at harmonizing population growth rate with that of the economy and the capacity of the country for sustainable socio-economic development. This policy might have had some contributions to the modest decrease in population growth rate. However, Ethiopia has changed in many forms since 1993, and new national perspective is required to ensure that population growth is managed (Hailemariam, 2016).

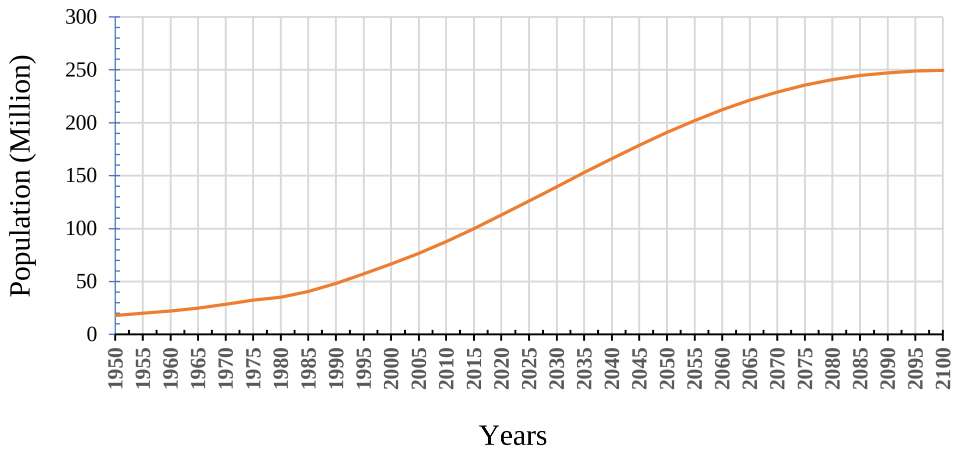


Figure 13. Trend and projected total population and population growth rates of Ethiopia (Source: UNDESA, 2017)

4.4.1.2. Wetland Policy, Tenure and Governance

The governance of wetland and aquatic resources reflects the range of political, social, economic and administrative system that is in place to manage and protect wetland and aquatic resources (Verhoeven & Setter, 2010). As outlined in Section 3.6, Ethiopia has a number of policies, strategies, and regulations addressing the broad ranges of environment and biodiversity protection, water resource management, and forest and land use. Many policies and proclamations recognize wetland's contribution to society, environment and biodiversity. Nevertheless, till this date, the country does not have a standalone wetland policy and strategy, and there are no wetlands demarcated and gazetted for protection. Ethiopia is not also a signatory of the Ramsar Convention despite the presence of extensive wetlands of national and international importance particularly for migratory birds and wildlife.

There are, however, recent developments in formulating legislative instruments to manage wetlands. The first of these is the establishment of river basin organizations as custodians of water resources. The Abbay, Awash, and Rift Valley Lakes Basin offices have been established to serve as custodians of their respective basins. The Environment and Forestry and Climate Change Commission (EFCCC) has drafted wetland protection regulation which awaits the approval of the parliament. Rift Valley Lake Basins Development Offices have drafted Buffer Zone protection act and submitted it to the Ministry of Water, Irrigation and Electricity (MoWIE). UNESCO has designated Lake Tana Biosphere Reserve for the conservation of the biological and cultural diversity around the lake while promoting sustainable economic and social development has been initiated as of 2015 (http://www.laketana-biosphere.com). Yet, this large but shallow lake remains threatened due to siltation, invasion by water hyacinth and ecosystem degradation in the operation and management of the hydropower dams.

In summary although the development of regulatory instruments is too late to save a number of Aquatic and Wetland resources and other threatened ecosystems could be saved if the proclamations are promulgated, and mandates and responsibilities are clarified. Ethiopia needs to make an inventory of vulnerable wetlands that have important functions and services including biodiversity conservation, develop a clear policy and law, ensure that laws and regulations will be enforced at all levels. Communal grazing wetlands also need to have a sustainable utilization arrangement.

4.4.1.3. Economic Growth and Human Development

Human development expressed in terms of improved income and welfare is related to increase in *per capita* water supply requirement and waste generation both liquid and solid wastes, and the consumption of more food with more water footprint. As an example, under GTP II (2015-2020), the minimum targets of per capita water supply service levels were at 100 l/c/day for category-1 towns/cities, 80 l/c/day for category-2 towns/cities, 60 l/c/day for category-3 towns/cities, 50 l/c/day for category-4 towns/cities, up to the premises and 40 l/c/day for category-5 towns/cities within a distance of 250 m with piped system for 75% of the urban population (NPC, 2016).

In major towns like Addis Ababa, residential and business constructions tend to be high-rise multistory apartments. Such structures require more water to convey liquid wastes; hence the per capita water requirement and corresponding waste generation will also be much higher.

4.4.1.4. International Trade

In an effort to meet the growing food demand and the scarcity of foreign currency, Ethiopia is putting up large area of land for large scale agricultural development for foreign direct investment (FDI). To this effect, land has been leased for international investors in low-lying wetlands or forest areas. This will transform the landscape with changes in the ecosystems and the impacts require a systematic investigation with the support of the national and regional government and the local communities.

4.4.2. Direct drivers

Proximate causes (pressures) are the human activities or immediate actions that directly cause loss and degradation of aquatic and wetland ecosystem. In this regard, the major direct drivers include wetland conversion to farmlands, overgrazing, deforestation, soil erosion, invasive species, pollution, over abstraction, and mining.

4.4.2.1. Climate Change

Global climate change due to the rise of the concentration of greenhouse gases such as CO_2, CH_4 and N_2O in the atmosphere is expected to become an important driver of the loss and change in the wetlands (Serdeczny et al., 2016). Anthropogenic caused climate change leading to increased surface temperature and an increase in extreme weather events is both direct and indirect driver of wetland and aquatic resources degradation. Global mean temperature is estimated to increase by 6°C due to the global warming at the end of this century and together with precipitation change may steepen regional aridity gradients (Fay et al., 2016; Prigent et al., 2012).

Global warming increases the evaporation of water into the atmosphere and changes the patterns of major airstreams and ocean currents such as *El Niño and La Niña*. This in turn alters the distribution of precipitation, though some regions experience greater rainfall and flooding while others become more prone to droughts (Rosenzweig et al., 2007).

The major consequences that can be predicted from climate change for wetlands are perturbations in hydrological systems, which can cause intense droughts or inundations. More frequent and longer periods of drought reduce the amount of run-off into rivers, streams and lakes; also the water table drops, so there is less groundwater to supply springs and shallow wells (Moomaw et al., 2018). Both lentic and lotic aquatic resources have been identified as among the ecosystems most vulnerable to climate change worldwide by changing temperatures and pattern of flow variability (Bates et al., 2008; Sala et al., 2000).

On the other hand, wetlands play roles as a source of and sink for greenhouse gases; influence local and regional temperature, precipitation, and other climatic processes, and lakes as sentinels of climate change (Adriana et al., 2008). According to MEA (2005), of all ecosystems, freshwater aquatic habitats appear to have the highest proportion of species at risk of extinction by climate change (Hayal et al., 2012; Lettenmaier et al., 2008; Wrona et al., 2006).

Ethiopia is highly vulnerable to the impacts of climate change owing to various factors (Conway & Schipper, 2011; Hayal et al., 2012). The mean annual temperature has increased by 1.3°C between the years 1960 and 2006 (CRGE, 2011; EPCC, 2015). This is estimated to be an average rate of 0.28°C increase in temperature per decade (Simane et al., 2016). The country is experiencing an increase in frequency and intensity of extreme events like floods, droughts and heat waves, and an intensification of natural variability (Stephen et al., 2017). The country has a limited ability to cope with the negative impacts of climate variability. More frequent and longer periods of drought reduce the amount of run-off into rivers, streams and lakes; also the water table drops, even if there is less groundwater to supply springs and shallow wells. Furthermore, the hydrology, productivity, and ecosystem services from aquatic resources and wetlands depend on very much on their water balance (Erwin, 2009; Fay et al., 2016). Hence, any alteration in the hydrological balance is expected to have an adverse impact on wetland and aquatic resources.

4.4.2.2 Wetland conversion to crop land

In Ethiopia, conversion to cropland has been the major factor for wetland loss and degradation. With increasing population and consequent decline of *per capita* premiere cultivable land, farmers with the support of extension agents endeavor to drain wetlands and convert them into agricultural lands including the promotion of recession farming. For a government whose primary development goals is food security and poverty reduction, the consequences of wetland loss or degradation has been found to be secondary. From another perspective, wetlands are considered suitable for large scale mechanized commercial agricultural investment. For instance, effort to promote rice production in Fogera flood plain near Lake Tana resulted in the conversion of the wetland into cropland (Worku, 2014).

The area of Dawa Chefa wetland in the Awash River Basin in Amhara Regional State, Oromia zone, was 7.4 % in 1984 while it shrank to 2.6 % in 2013 (Hussien et al., 2018). This wetland has always been the dry season grazing land for both highland and pastoral (lowland) communities. There is always a conflict on this shrinking wetland between the two communities.

Although detail systematic inventory of wetland conversion has not been made, there are various initiatives including the major rivers, such as Baro-Akobo, Wabi-Shebele, Omo-Ghibie, and Tekeze, which encourage local communities to practice flood protection and convert wetlands to cultivable lands (Nederveen, 2012; Jos and Setter, 2012).

Table 12. Dawa Chefa wetland land use land cover change between 1984 and 2013 (Source: Argaw2018).

LU/LC Class	1984		1993		2000		2013	
	Area in hectare	Area %	Area in hectare	Area %	Area in hectare	Area %	Area in hectare	Area %
Wetland	18603.63	7.4	16052.31	6.41	12,713.04	5.1	6396.57	2.6
Urban	1084.86	0.4	1753.29	0.7	2966.94	1.2	3573.18	1.4
Bush Land	83800.53	33.5	83381.13	33.33	68422.68	27.2	82287.36	32.9
Forest	83697.84	33.5	75772.62	30.29	60225.21	24.1	27347.31	10.9
Grass	29012.67	11.6	29146.5	11.65	38134.08	15.2	59998.68	24
Farmland	33975.72	13.6	44069.4	17.62	68841.18	27.4	70572.15	28.2

4.4.2.3 Livestock population increase

Ethiopia has the largest livestock population in Africa which is estimated at 56.7 million cattle including 12.65 million milking cows under lowland pastoral and highland crop-livestock mixed farming systems (Shapiro et al. 2015; 2017). The trend in livestock population is expected to increase due to growing demand for livestock products associated with increase in population, urbanization, expanding *per capita* income (Table 12).

Wetlands are primarily used in all agro-ecologies as open access communal dry season grazing areas with not well-defined land tenure. Moreover, the conversion of steep slopes and marginally productive lands which otherwise would have been used as grazing areas pushes cattle to congregate all year round in the wetlands giving little time for the wetland to recover during the rainy season. This resulted in overgrazing (Figure 14 and 15), primary productivity decline, invasion of non-palatable plant species and biodiversity degradation (EWNHS and WI, 2018).

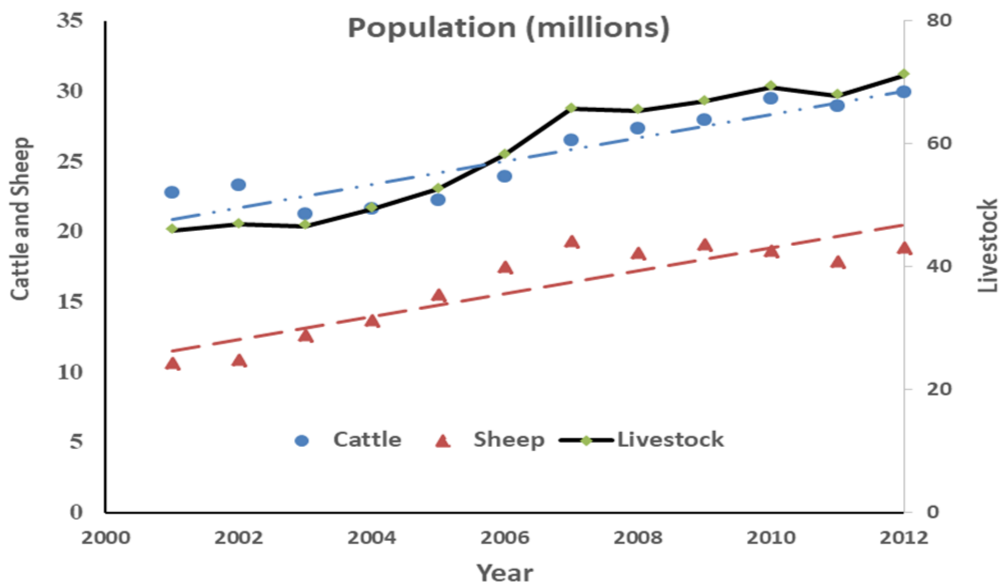


Figure 14. The numbers of cattle and sheep in Ethiopia during 2000-2012 (Source: IWMI, 2016)

Table 13. Change in livestock population and grazing land between 2007 and 2013

Year	Livestock population (TLU)	Grazing land (ha)	Livestock stocking rate (TLU/ha)
2007	50,514,720	59,958,344	0.84
2013	55,509,430	13,288,994	4.18
Change (2013-2007)	4,994,710	(-46,669,350)	3.34
Percentage Change (2013-2007)	9.9	(-77.84)	398

Figure 15. Livestock on overgrazed grazing land (Source: Tena, 2017).

4.4.2.4. Overgrazing

Several wetlands go through a wet/dry cycle that is essential to maintain their productivity and functions. In dry months, wetland drawdown provides optimal conditions for a diverse range of forage species, and cattle can graze continuously, leading to pasture degradation. Overgrazing results in decline of palatable perennial species and dominance of non-palatable invasive species.

According to EWNHS and WI (2018), compaction of soil by livestock trampling is a common consequence in overcrowded wetlands. Urea and manure can result in high nutrient inputs. Overgrazing of riparian areas by livestock reduces streamside vegetation, prevents runoff filtration, increases stream temperatures, and eliminates food and cover for fish and wildlife. Stream bank destabilization and erosion then cause downstream sedimentation. Sedimentation reduces stream and lake capacity, resulting in decreased water supply, irrigation water, flood control, hydropower production, water quality, and impairment of aquatic life.

Livestock rearing in Ethiopia remains to be based on open access grazing system. In the past, wetlands along river courses and flood plains used to be dry season grazing lands, but cattle would move to drier upland during the wet season leaving the wetlands to recover. As declining of farmland holdings and farmland productivity continued, marginal lands which otherwise would have been used for wet season grazing area are converted to croplands. This forces livestock to remain in wetlands all year-round resulting in overgrazing (Argaw, 2014)

4.4.2.5. Deforestation

The ecological linkages between water, wetlands and forests represent the intricate interdependence of the ecosystems and our resources (Blumenfeld et al., 2009). Forests play a pivotal role in the hydrological cycle by affecting rates of transpiration and evaporation, and influencing how water is routed and stored in a watershed and this consequently affect the preservation of wetlands, which act as natural reservoirs and rich in biodiversity and the ecological services (e.g. food, sanitation, and energy).

In Ethiopia, there is rapid land use/land cover change, especially the conversion of natural forests to cultivated land. FAO illustrated that in the year between 1990–2000, the total natural forest cover of the country has decreased by 9% with the estimated rate of 40,000 ha per year while plantations have increased only by 1% (FAO, 2016). Clearance of forests and the resultant erosion from surrounding catchments would seriously affect the biological and physico-chemical situations in water bodies including wetlands. Deforestation, besides exposing hill slopes to erosion, increases the risk of flood and reduces base flow.

4.4.2.6 Soil erosion

The loss of soil from agricultural lands not only affects agricultural productivity but also causes siltation of lakes, reservoirs, and aquatic and wetland associated aquatic ecosystem degradation and biodiversity loss (e.g. Lake Haramaya). The 2007 State of the Environment report shows that soil erosion by water is the dominant degradation process in Ethiopia, and occurs particularly on croplands, with annual soil loss rates on average of 42 tons/ha/year for croplands, and as high as 300 tons/ha/year in extreme cases. A recent study in Ethiopia using USPED model by the Economics of Land Degradation (ELD) Initiative (Hurni et al., 2015) reported that the present annual net erosion is 940 million tons/year, or 18 tons/ha/year.

Fertilizers from agricultural fields surrounding water bodies may cause, through erosion, excess loadings of nutrients that could cause eutrophication in the water body. In turn, eutrophication is the main cause of fish kills and deaths of other aquatic organisms by causing depletion of oxygen and generation of toxic gases. Fish kills, caused by the above problems, have been observed in Lakes Chamo, Hayq, Babogaya and Ashenge in Ethiopia in the past years. Due to unwise utilization of land, deforestation and overgrazing of watershed, soil erosion is increasing from time to time and causes siltation of lakes, reservoirs and rivers. Lake Hawassa and Koka Reservoir are live examples affected by siltation problems, which emanates from degradation of the wetlands (EWNHS and WI, 2018).

Table 14. Landscape transformation and rate of erosion estimates in 2007 and 2015 (Source: Ethiopian Mapping Agency; Landsat (2007 ETM+) and Computed based on Hurni (1986) and Hurni et al. (2015)

Land use	2007			2015			Net soil loss	
	Rate of soil loss (t/ha/yr)	Area (ha)	Soil loss (t/yr)	Rate of soil loss (t/ha/yr)	Area (ha)	Soil loss (t/yr.)	Tons	**%**
Annual cropland	42.0	15401065	646,844,730	20.2	21,372,910	431,732,782	-215,111,948	-33
Perennial crops	8.0	1998612	15,988,896	4.0	4,390,664	17,562,656	1,573,760	10
Grazing land	5.0	59958344	299,791,720	5.0	13,288,994	66,444,970	-233,346,750	-78
Currently unproductive	70.0	4467485	312,723,950	20.2	12,457,975	251,651,095	-61,072,855	-20

land								
Currently uncultivated land	5.0	21984726	109,923,630	5.0	1,400,565	7,002,825	-102,920,805	-94
Forest	1.0	4232354	4,232,354	5.0	16,156,166	80,780,830	76,548,476	1,809
Wood land and shrub land	5.0	9522796	47,613,980	5.0	48,498,108	242,490,540	194,876,560	409
Total	**19.6**	**117565382**	**1,437,119,260**	**9.8**	**117,565,382**	**1,097,665,698**	**-339,453,562**	**-24**

4.4.2.7 Invasive alien species

A species is considered an "invasive alien species" when it spreads beyond its natural area of distribution. There are growing list of alien and native invasive species that threaten ecosystem diversity. As a result of disturbance and habitat degradation, wetlands can be invaded by aggressive, highly-tolerant, alien (non-native) floral species, such as water hyacinth (Eichhornia crassipes), and salvinia (Salvinia molesta), or can be dominated by a monoculture of cattails (Typha spp.) or common reed (Phragmites spp.). Water hyacinth and similar species can rapidly colonize a wetland and are a threat to water quality in some areas. The invasion of water hyacinth has been in Lake Tana from the highland lakes, Koka reservoir in the rift valley (Figure 16) and Lake Tata in Gambella. It appears that, currently, it is spreading to other water bodies including Lake Zeway in the rift valley. (EWNHS and WI, 2018). Prosopis juliflora is a recent biodiversity disaster taking over the dry season grazing wetlands of Afar pastoralists (Shiferaw et al., 2019).

Figure 16. Koka Reservoir/dam water hyacinth invasion (Photo Credit: Tena, 2017)

4.4.2.8 Urbanization

Although Ethiopia is an agrarian country where 81% of the population residing in the countryside engaged dominantly in subsistence agriculture, rapid urban expansion has been taking place at the rate of 4.5 % (Stephen et al., 2017). However, several of the urban sprawls are not guided by informed municipal planning.

As it is often the case, settlements including large cities and towns started around water sources. For instance, Hawassa, Bahir Dar, Bishoftu, Zeway and Arbaminch, were established near water sources. Others with no standing water sources are also established following river courses. Through time, settlement demand for water exceeds what the system can supply. One such example is Addis Ababa City which was established centering Akaki river and its tributaries in mind. The City’s water demand is now estimated at 0.8 million cubic meters per day exceeding what the system can supply making water as one of the major limiting factors for the sustainable development of the city.

Urbanization indirectly affects wetlands in different ways. Wetlands are generally considered as wastelands and tend to be owned communally with no or loose tenure rights. Hence, local governments are not overly motivated to enforce urban sprawl by draining surrounding wetlands. In many towns and settlements, wetlands are used as solid and liquid waste disposal sites with no or minimum treatment. Although wetlands are known to have the capacity to remove contaminants from contaminated water sources by binding metals to iron and aluminum ions via adsorption to clay surfaces or through carbonates precipitating as inorganic compounds, but, there is a limit to how much a particular aquatic and wetland ecosystem can safely remove these pollutants.

Lake Hawassa has had a lot to contribute for the development of Hawassa town. With growing population and absence of any functional waste disposal system, solid waste, and municipal waste including that of the hospital and university is discharged with little or no treatment. The lake is now losing its grace; the fish in the lake is suspected of being contaminated due to pollution (Yirgu, 2011). Further, municipal authorities often find it easy and less costly to transfer wetlands for industrial expansion with little community resentment. The Cheleleka wetland, which is dubbed as the kidney of Lake Hawassa, is encroached for settlement, industry zones, agriculture etc. in all directions (Belete, 2017).

4.4.2.9 Pollution

The sources of pollution in aquatic and wetland ecosystem range from point sources (e.g. urban and industrial) to non-point (diffuse) sources from farms and settlements. As most cities and towns are established around water bodies and wetlands, they have substantial impact on the loss and degradation of wetlands. Most of these cities and towns are with no proper sewerage systems and many of the households and industries release their wastes into the surrounding water bodies. Degradation is due to changes in water quality, quantity, and flow rates; increases in pollutant inputs; and changes in species composition as a result of introduction of non-native species and disturbances. The major pollutants associated with urbanization are sediment, nutrients, oxygen-demanding substances, heavy metals, hydrocarbons, bacteria, and viruses.

Mosquito control efforts in urbanized and resort communities has resulted in wetlands loss and degradation through drainage, channelization, and use of toxic pesticides. Urban and sub-urban agriculture using irrigation ditching can increase contamination of wetlands receiving irrigation drainage water, particularly where soil is alkaline or contains selenium or other heavy metals. Agricultural pesticides enter wetlands through runoff and atmospheric deposition and accumulate in fish and in other aquatic organisms (Johnston, 1991).

The majority of industries in Ethiopia are located along the banks of rivers and streams from where they draw water for their processes. Most of the high-water consuming industries in Ethiopia discharge wastewaters directly into the streams and water courses without any kind of treatment whatsoever (Figure 17). Added to this, so far there is no strict restriction on industrial plants discharging wastewater into the rivers and water courses. On the other hand, few industries in the city of Addis Ababa, which are equipped with treatment facilities, divert waste water into the storm water drainage system or the water course. The reason could be either for technical reasons related to the waste water treatment plant operation or for practical reasons since there are no regulations and effective control regarding industrial and domestic discharges by concerned bodies.

Figure 17. Lake Hawassa used for untreated solid and liquid waste disposal site (photo credit: Alamirew, 2018)

4.4.2.10 Over-abstraction and flow alteration

Wetlands in Ethiopia are currently being lost or altered by over utilization and unregulated management. Over abstraction has been responsible for the demise of Lake Haramaya. The aquatic and wetland ecosystem and biodiversity was lost due to the dry-up of lake Harar and Haramaya and the community in the area has been facing acute scarcity of water (Figure 3.18).

Excessive water abstraction for irrigation along with the decline in the storage capacity of Lake Zeway is responsible for decline in the inflow into Lake Abijata. Further, water is diverted to evaporation pans to extract soda ash (anhydrous sodium carbonate) for the sulphate production. The extent of shrinking is shown in Figure 3.19. The surface area of the lake in 1973 was 205 km^2 and it decreased to 93 km^2 in 2005. Correspondingly, the available food for migratory bird species also declines.

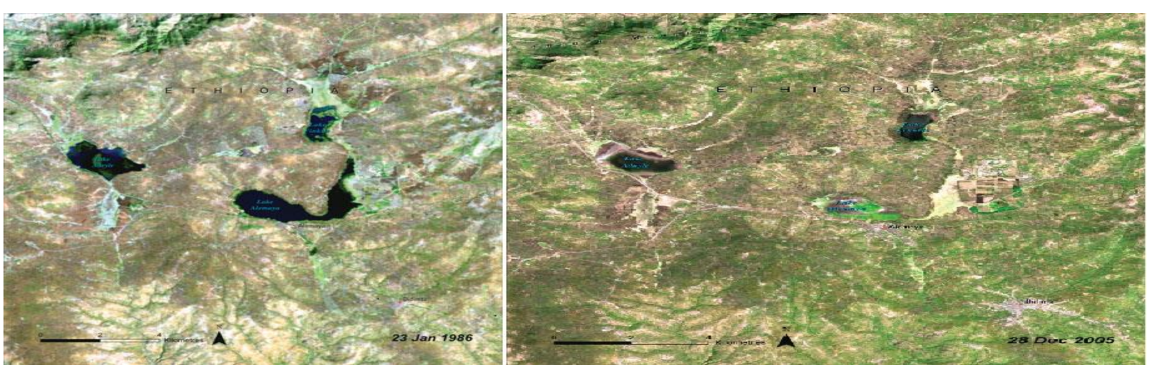


Figure 18. State of Lake Haramaya between 1986 and 2006

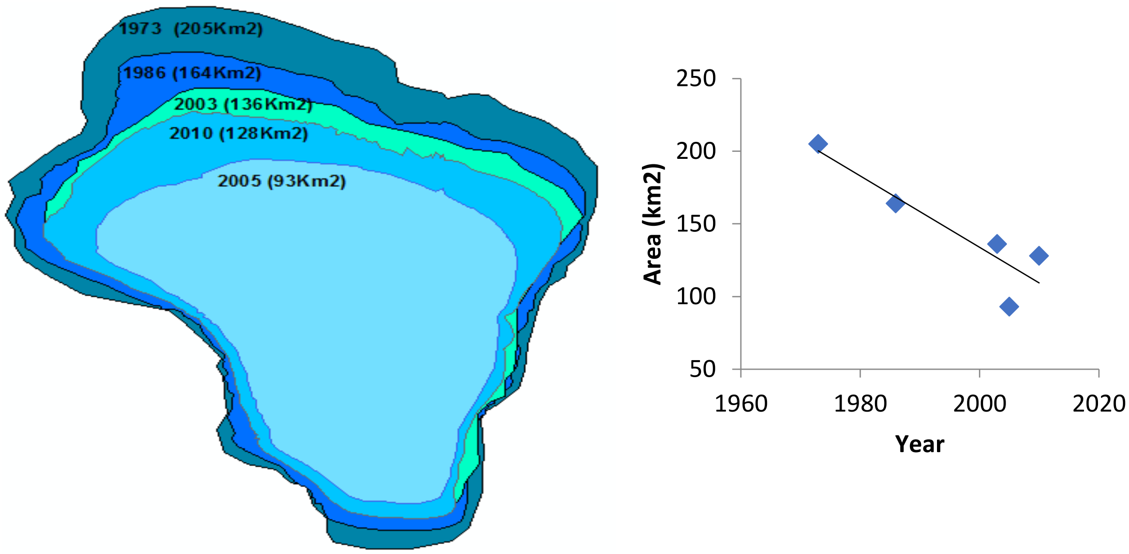


Figure 19. Trend in spatial extent of Lake Abijata (generated from Google map data)

4.4.2.11 Mining Activities

Mining industry may have an impact on wetlands and associated aquatic resources in different ways. Mining operations can degrade wetlands through hydrologic alterations, high metal concentrations, and/or decreased pH. Sand mining is the process of removal of sand and gravel from inside and around usually rivers and flood plains and thus it destroys the breeding habitats of fish species. Soda ash mining in Lake Abijata, salt mining in Afar (particularly from Lake Afdera) is responsible for shrinking of water bodies. Phosphate mining in Lake Asal, which requires lots of fresh waters from the upland springs, will affect the water table and hydrology of the lowland wetlands.

4.5 Level of awareness and aquatic and wetland ecosystem management

Evidence is lacking about the level of awareness on the importance of wetland management. In several aspects government policies often fail to recognize the importance of local management practices particularly in areas where high agricultural production is envisaged in wetlands (Dixon & Wood, 2007). Despite the supply of different ecosystem services to the society, Ethiopian wetlands are not well managed and maintained. Previous studies indicate that there was wetland management in western Ethiopia; for example, in Illu-Abba-Bora Zone of southwestern Ethiopia there was considerable conservation of the wetland resources (Dixon, 2005).

In many parts of Ethiopia, a wetland is considered an abandoned land. As a result, draining of the water column, or dumping of wastes are the common practices in Aquatic and Wetland ecosystem. Several earlier studies indicated that low awareness on the significance of wetland conservation and absence of sense of ownership have caused degradation and deterioration of wetland ecosystem (Berhanu, 2012; Moges, 2016; Semu and Workie, 2019).

4.5.1 Local communities aquatic and wetland ecosystem management practices

Studies show that there are cultural (religious and non-religious) practices of wetland conservation in different parts of the country. For example, there are ritual practices nearby water bodies by the Ethiopian Orthodox Church which promotes wetland conservation (Abbott, 2018). Ethiopian Epiphany (T*imket*) is celebrated by orthodox followers once in a year near a river, spring, lake, marshland or where surface water is available and there are believes that some springs are holy (*Tsebel*) and heal people from their illness and such practice contributes to aquatic and wetland ecosystem conservation (Orlowska and Klepeis, 2018). Moreover, 'Irreechaa' which is a cultural festivity celebrated by the Oromo communities near water bodies twice in a year (Mekuria, n.d.) and other rituals practiced near wetlands contribute to the conservation of this ecosystem.

The spectacular traditional watershed management practices include terracing and buffer stripping. In this regard, during the previous times, most of the farming communities in Ethiopia (e.g. in Gojjam) do not plow the land to the edge of the river or water body for two primary responses: (1) to avoid degradation of the river bank as it will quickly collapse if riparian vegetation is cleared-off and plowed to the edge and (2) to use the buffers as a hayfield or spare grazing land for the oxen used for tillage and to collect biomass fuel (Ambelu, 2009). This has tremendous importance in protecting the aquatic habitats and maintains the diversity of biota.

The remarkable cultural landscape of Konso is known for the indigenous knowledge of stone terracing of the highlands. Such practices substantially contribute to the protection of aquatic habitats in the watershed (MoA, 2016). It is believed that in many parts of Ethiopia, indigenous biodiversity conservation practices exist, but only a few are documented. Gandile et al. (2017) reported the indigenous practices for biodiversity conservation in the Gamo Gofa Zone. Communities in the zone understand well about the importance of biodiversity conservation for the livelihood, protection of humans and livestock. These communities conserve moringa, *farinosa*, *bamboo*, and other shrubs for different purposes.

A recent study in Dinki Watershed, Northern Shoa of Amhara region (Asmamaw et al., 2020) indicated that the majority of the communities have local knowledge and are used in their daily activities and have the adaptive capacity in managing land and water resource degradation. These practices suggest that different actors need to capitalize on indigenous knowledge of the community to conserve wetland resources which will lead us to sustainable development. It is, therefore, vital to promote these cultural practices for the conservation of aquatic and wetland ecosystem.

Various reports (e.g. Farm Africa n.d.) indicated that watershed management practices in Tigray and Oromia regions were found to be helpful for the restoration of indigenous species, increase of groundwater table, and to minimize siltation in aquatic habitats (Figure 20). Such success was attained within 20 years of interventions employing area closure, afforestation, and check-dam, and micro-dam constructions. These interventions were implemented together with beekeeping activities at various levels of the landscape in Tigray (Tamene et al. 2014).

.Figure 20. Watershed management practices in Karaba (Oromia) and Abraha-Atsbeha, Tigray (IWMI, 2016)

The ecohydrological initiative by the Ministry of Water, Irrigation, and Electricity of Ethiopia has also shown a promising result of wetland conservation. The ecohydrological approach of wetland conservation is aimed at the creation of public awareness, minimize pollution, maximize ecosystem service, preservation of biological diversity, and water resources. This time, ecohydrological demonstration sites are being developed around Bahar Dar (Ribb watershed located in Lake Tana Sub-basin), and Asela (Burkitu Reservoir). It has a demonstration site where restoration of the water system and biodiversity was successful. They are working on awareness creation, community mobilization for watershed management and apply new techniques of contaminant retention mechanisms (Figure 21).

Figure 21. Watershed management through the Application of biodegradable geotextile for the rehabilitation of degraded land in Lake Tana catchment (Source: Zerihun, 2016)

4.5.2 Policies and institutional arrangements for aquatic and wetland ecosystem management

The Convention on Wetlands is the only international legal treaty that primary focus on wetlands, signed in 1971 in the Iranian city of Ramsar and known as the Ramsar Convention. It came into force in 1975. The Convention uses a broad definition of wetlands as ‘areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres’ (Ramsar Convention, 1971).

The wise use of wetlands and their habitats are vital for improving human livelihoods and the biodiversity conservation. Wetlands provide a wide range of ecosystem services that place them at the heart of the sustainable development. Wetlands are home to 40% of the world's species, including freshwater fish which is the main source of protein for nearly one billion people and accounts for at least 15% of animal protein in the diets of a further two billion people (Bellew 2018). Wetlands, however, are the most rapidly declining across the world. In some countries, humans often equate wetlands with wasteland, a place to be drained, filled in, burnt off and re-purposed to other uses (Davidson et al., 1991; Suman, 2019; Gebresllassie et al., 2014; Gashaw and Mehari, 2014). Scientific studies show that 64% of the world's wetlands have disappeared since 1900 (Ramsar Convention, 2018). The recent World Wetland Outlook informs there is three times faster decline~~s~~ of wetlands observed within the last three decades when compared with forest resources. It was known that measured against 1700, an estimated 87% have been already lost in places where data exists (Ramsar Convention, (2018).

It is estimated that wetlands cover approximately 1.5-2 % of Ethiopia's landmass (EPA-Ethiopian Environmental Authority, 2004). Although there are some studies, there is no well documented study informing on the wetland resources and their status (Seid, 2017, Ethiopia is facing diverse wetland degradation challenges. In Ethiopia wetlands are widely neglected resources and usually connoted as '*Tef Meret*' which is meant to mean wasteland. As a result of this perception, wetlands are seen as dispensable resources that can be filled, drained or polluted. Wetland degradation is continuing in Ethiopia due to population pressure and over exploitation of wetland resources; poor watershed management; weak local institutions setup and capacity for management; limited or no coordination of national institutions for the sustainable management of wetlands; poor knowledge and lack of awareness about wetlands and other related factors (Giweta and Worku, 2018). Amongst others, lack of proper policy, law and organizational arrangements to enhance coordinated management of the wetlands are key factors contributing to unsustainable utilization of wetland in the country (Giweta and Worku, 2018). Often, wetland wise use is affected by policies that have been developed by governments at different scales. Ability to define root causes and measures including strategies to reverse the challenges affect their impacts. Environmental law is founded upon fair, clear, and implementable laws (UNDP, 2006). Sustainable Wetland governance also requires coherent policies that manage cross-cutting issues and promote coordination of actions amongst stakeholders. A further aspect of the effectiveness of wetland strategies, policies and laws also depends on introducing tools to ensure compliance which can include both coercive and non-coercive measures (Ramsar Convention, 2018).

Policy is not an end by itself. The policy instrument requires effective strategies and laws, including strong institutions with adequate human and financial resources supported by active citizen participation. The engagement of government at federal, regional, zonal, river basin, district and local levels should, based on the nature of the problem, be strengthened in both vertical and horizontal scales and go beyond administrative boundaries (Rahmato, 1999).

To achieve wise use and conserve healthy wetlands, amongst others, it is important to strengthen legal and policy arrangements (Ramsar Convention, 2018). In this paper, the effect of the adoption of the 1995 Ethiopian Constitution and the wetland laws that have been adopted at national and local levels are described. Further, the impacts of accession to the Ramsar convention, a convention that promotes the concept of wise use, will be considered.

Since the adoption of the 1995 Ethiopian Constitution, many wetland policies, strategies and laws have been progressively developed at the national and local levels. Many of the regional states (local level governments) have formulated one or more general environmental laws designed to protect and conserve wetlands. Such instrument development has helped the country to slow or reverse some wetland degradation. However, the progress made towards protecting and conserving wetlands remains weak. The policy and decision-makers in diverse sectors of the country often underestimate the value of wetlands. The root causes for such failure may be a growing implementation failure including considerable failure of compliance and enforcements.

As there is no legally accepted definition of wetlands in Ethiopia the definition given by the Ramsar Convention could be relevant to adapt to Ethiopian context. According to the Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat, “wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters” (Ramsar Convention, 1971, 2013, 2016, 2018). Progressively, the definition of wetlands has become well comprehensive to include inland and human made wetlands. At present, many of the Ethiopian policy, legal and strategic documents do not directly deal with wetlands. However, conservation, management and wise utilization of natural resources, including water bodies have been addressed by many policy and legal instruments.

A policy or law or strategy may not be formulated without specific or general problems that it aims to control or prevent. Smart wetland policy and law or strategy strengthens wise use of wetlands. The effectiveness of a wetland policy and law may be measured by the extent of its impact to ensure the wise use of the resources. A widely used definition of 'wise use', within the context of wetlands at the international level, is provided in the Ramsar Convention, which defines the wise use of wetlands as "… their sustainable utilization for the benefit of mankind in a way compatible with the maintenance of the natural properties of the ecosystem". The notion of 'wise use' captures the need to protect and conserve the integrity of wetlands while acknowledging the importance of wetlands in providing a livelihood to human communities and their activities. The idea attempts to bring a balanced consideration of wetlands management as a useful principle, steering clear from excluding human communities from interacting with wetlands in their daily life.

To manage wetland challenges and enhance wise utilization, introducing proper policy and law is essential (Garay and Sadoff, 2007). Most water and wetland problems are capable of being solved or at least controlled (UNDP, 2006). Many of the wetland and water crises arise from the inappropriate policy and legal instruments (Gleick, 1998). With inefficient policy and legal instruments, it may not be possible to manage sustainable wetland challenges effectively (Falkenmark et al., 2007).

In order for the wetland law to be effective, it needs to reflect three important features (Anabo, 2016). Firstly, it should be consistent with fundamental rights. Secondly, it should be inclusively developed and equitably implemented. Thirdly, wetland related laws should be enforced and measures taken to ensure compliance.

A further factor which enhances the effectiveness of laws and policies is having a strong competent authority that oversees environmental issues and helps regional and local authorities to comply with their duties to protect the environment. One key challenge in Ethiopia is that environmental protection duties are fragmented as they are discharged by many different federal and regional organizations despite the Environment, Forest and Climate Change Commission being mandated as the sole authority and regulator of environmental matters. Such institutional proliferation, accompanied by a lack of coordination leads to fragmentation and inefficient legal enforcement. Such fragmented engagement exposes wetlands to the risk of not being managed properly. To add to the fragmentation problem in Ethiopia, some entities engaged in environmental concerns have mixed roles that are both developmental and also deal with environmental protection. This means that these organizations lack impartiality and undermine environmental protections in favour of development goals.

4.6 Policy and laws governing Wetlands management in Ethiopia

Ethiopia does not have a standalone wetland policy or law. However, it does not mean that there is no policy or legal instrument designed to manage wetlands. Several, general policies, strategies, programmes and laws provide rules on how to manage wetlands within varying contexts. For example, the Ethiopian Constitution, Ethiopian Water Resources Policy and laws, agriculture and environmental policies consider wetland as important natural capital. These instruments will be discussed in detail in the upcoming sections.

4.6.1 FDRE Constitution

Since the 1970s, many countries have enshrined a constitutional right to a healthy environment. Ethiopia has been one of these countries that have given recognition to environmental protection through its constitution. This is an important factor for the sustainable management and protection of wetlands. Within the Ethiopian legal system, the constitution is the supreme law that provides a general legal framework that guides overall government function including policy and legal development. All policy and other subordinate laws, practices and decisions must follow the rights that have been set out by the constitution. Articl 9(1) of the constitution states that any 'law, customary practice, and decision made by state organ or public officials inconsistent with the constitution are null and void'. That makes the constitution a core policy instrument of the land. Under the constitution, property is divided into private and public property. The Ethiopian constitution defines private property as:

as any tangible or intangible product which has value and is produced by the labour, creativity, enterprise or capital of an individual citizen, associations which enjoy juridical personality under the law, or in appropriate circumstances, by communities specifically empowered by law to own property in common.

This ownership right includes natural resources including wetlands (FRDE Constitution No.1/1995 Article 40(3)). The ownership of private property, whether tangible or intangible, may be separated from land ownership. Under the constitution, Article 40(3) states, "the right to ownership of rural and urban land, as well as of natural resources is exclusively vested in the State and in the people of Ethiopia". Article 40(3) of the Constitution goes on to say, "Land is a common property of the people of Ethiopia and shall not be subject to sale or to other means of exchange". The state and the people of Ethiopia together own the land and the natural resources. While the constitution does not make a direct reference to wetlands, this does not mean wetlands are an open access natural resources. Since wetlands are part and parcel of natural resources, it would be appropriate to consider them under the Constitutional provisions that deal with natural resources and the environment. Accordingly, natural wetlands are not owned by the private owners.

Under the right to development, Article 43 of the constitution further recognizes sustainable development, which embraces economic and social development as well as environmental sustainability. The constitution establishes principles that recognize social, economic and environmental issues. Article 43(1) states 'the People of Ethiopia as a whole, and each Nation, Nationality and People in Ethiopia in particular have the right to improved living standards and the right to sustainable development'.

Article 43(3) also further pledges that 'all international agreements and relations concluded, established or conducted by the State shall protect and ensure Ethiopia's right to sustainable development.' The constitution further highlights 'the basic aim of development activities shall be to enhance the capacity of citizens for development and to meet their basic needs.' [The FDRE Constitution, No.1/1995, Article 43(4)] Under Article 44(1) the constitution recognizes environmental rights, 'all persons have the right to a clean and healthy environment'. It also imposes obligation that the 'Government shall endeavour to ensure that all Ethiopians live in a clean and healthy environment.' For this effect, the FDRE constitution, No.1/1995, Article 92(2) states 'the design and implementation of programmes and projects of development shall not damage or destroy the environment'. Environmental protection, however, is not left to the government alone. It is the duty of both the government and the citizens of Ethiopia. Public and stakeholder participation is one of the most crucial tools for the involvement of citizens in the protection and conservation of the environment. In terms of participation at the planning and implementation levels, Article 92(3) of the constitution states that 'people have the right to full consultation and to the expression of their views in the planning and implementations of environmental policies and projects that affect them directly'. Participation enables people to realize their rights to clean environment, clean water, meeting basic needs and discharging their obligations. Participation is also a key tool to hold the government accountable for any failures to discharge its constitutional obligations.

A small number of African countries recognize the right to clean water as a constitutional right. Ethiopia is one of these countries. In Ethiopia, the right to clean water is enshrined in the 1995 Ethiopian Constitution. Article 90(1) the constitution states that ‘to the extent the country’s resources permit, policies shall aim to provide all Ethiopians access to public health and education, clean water, housing, food and social security’. None of the previous Ethiopian constitutions explicitly recognized this right. It was more than twenty years ago from the year when Ethiopia has given recognition to the right to clean water, and imposed obligation both on government and its citizens to protect the environment. Its inclusion within the constitution signifies government’s political commitment that imposes legal obligations on the government to develop access to clean water. The recognition of the right to access clean water under the constitution should make the issue of water as one public concern, and provide a legal foundation for its protection. It also requires the state to formulate policies, laws and implementation plans that will facilitate conservation of natural resources including wetlands to ensure sustainable access to clean water. The effective implementation of the right to access clean water also depends on the will and capacity of the government and other stakeholders to sustainable conservation of wetlands.

Under the heading Environmental Rights, Article 44 (1) of the FDRE Constitution, No.1/1995, states that all persons have the right to a clean and healthy environment. The right includes the right to an environment that is not harmful to their health or wellbeing; and right to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that prevent pollution and ecological degradation, promote conservation, and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development. The design and implementation of programs and projects of development shall not damage or destroy the environment. It goes without saying that all of these rights must be protected so as to ensure the right to live in a clean and healthy environment.

4.6.2 The 1997 Ethiopian Environmental Policy

The 1997 Environmental Policy of Ethiopia was enacted with the overall objective to improve and enhance the health and quality of life of all Ethiopians and to promote sustainable social and economic development. This goal is to be achieved through the sound management and use of natural, human made and cultural resources and the environment as a whole. This overall policy goal clearly reflects that the Ethiopian Government has the intention and commitment to respect the constitutionally guaranteed right to sustainable development and environmental right. According to the policy goal, these rights are better fulfilled through sound management and use of natural and other resources. Wetlands**,** as part of the country's natural resources are considered by the Environmental Policy of Ethiopia as a means to achieve sustainable development and improved livelihood of all Ethiopians, provided they are managed and utilized wisely.

The Environmental Policy specifically deals with water resources in section 3.4 and engages the issue of wetlands. Section 3.4 (b) recognizes that natural ecosystems, particularly wetlands and upstream forests, are fundamental in regulating water quality and quantity and to integrate their rehabilitation and protection into the conservation, development and management of water resources. Similarly, section 3.4 (d) promotes the protection of the interface between water bodies and land (e.g. lake shores, river banks and wetlands) and section 3.4 (g) requires that all major water conservation, development and management projects be subjected to an EIA process and requires that the costs and benefits of protecting watershed forests, wetlands and other relevant key ecosystem components be included in the economic analysis of such water projects. As can be seen from these specific policy elements, wetlands are fundamental habitats for the regulation of the quality and quantity of water resources.

4.6.3 Water policy

The 1999 Water Policy underscores that water resources management policy will enhance the development of the country's water resources to ensure an optimum contribution towards accelerated socioeconomic growth. The overall goal of the Policy is to enhance and promote national efforts towards the efficient, equitable and optimum utilization of Ethiopia's valuable water resources on a sustainable basis. In terms of this policy, the wise management and utilization of wetlands is to be achieved through various approaches and strategies. These strategies include incorporating environmental conservation and protection requirements as integral parts of water resources management; encouraging ESIA to be a major criterion in all water resources projects; ensuring watershed management practices constitute an integral part of the overall management of water resources; creating appropriate mechanisms to protect the water resources of the country from pollution and depletion so as to maintain their sustainable development and utilization; conserving water resources through the integration of appropriate measures in the main water use categories. From these policy tools it can be seen that water resources must be sustainably used for the socioeconomic development of the country and the wellbeing of its people. Although the policy did not mention anything about wetland in its contents and main body,, it defined them in the glossary section in exactly the same way as the Ramsar Convention. The policy underlines the importance of following an integrated water resources management approach for the development and protection of the country's water resources.

4.6.4 The Ethiopian Water Sector Strategy

In 2001, the Ethiopian Water Sector Strategy was introduced as a strategy that reflects how to translate the National Water Resources Management Policy into action. The National Water Sector Strategy aims at providing a road map in terms of ways and means to attain the water policy objectives with due recognition to the principles around which these objectives have been developed. The strategy under subsection 4.1.1 underlines the aim to reclaim existing wetlands, and prevent the formation of the new ones by using appropriate mechanisms; undertake the inventory of existing wetlands; develop preventive mechanisms to avoid formation of water-logged areas; develop guidelines as to how to reclaim wetlands, and enforce these guidelines and carry out appropriate drainage works on all wetlands (Ethiopian Water Policy, 1999, Section 2.1.1).

The direction of the Strategy is not compatible with the wise use of water resources of the country. The sub-section of the strategic document that deals with wetlands does not go hand in hand with the principles of the policy and other laws of the country. It lacks synergy with environmental policies in place. The strategy entirely undermines the ecological and economic importance of wetlands. It identifies wetlands as with no useful ecological services to society and environment, and it treats them as a source of disease and a threat to public health. It seems the strategy has been developed against the purposes and policy objectives of the FDRE Constitution and the international environmental agreements that Ethiopia has ratified. As this is the water sector strategy, it is even confusing why the strategic document embarked upon the elimination of such ecologically beneficial resources for environmental, social and economic sustainability**.**

4.6.5 Wetland Related Development Programmes

To implement the aims and objectives in the policies and laws, Ethiopia has established different programmes focusing on community-based participatory watershed management to rehabilitate degraded land and watersheds (Ethiopian Water Policy 1999, Section 2.1.1). The community–based watershed management programmes in Ethiopia include managing environmental resources to enable transitions (MERET) to more sustainable livelihoods and the productive safety net programme (PSNP). Tongul and Hobson (2013) conducted a case study on 'interventions and impacts' of the pilots' community-based watershed management which suggests that the catchment areas of watersheds were being rehabilitated; upstream catchments increased recharge while the lower catchments and rain-fed agriculture production were transformed into micro-irrigation.

Subsequently, the Water Sector Development Program of 2002-2016 of the Government of Ethiopia which was formulated for the periods of 5 years cycles consisted of three phases: 2002-2006, 2007 - 2011 and 2012-2016. The program has been prepared in support of the fundamental principles and objectives endorsed and issued by the Ethiopian Government in its Water Resources Management Policy and Water Sector Strategy. The program was made with the view to achieving the MDGs/SDGs. The program in Chapter 11, where it deals with the "Potential Social and Environmental Impacts" highlights that the Government recognizes that the Water Sector Development Program (WSDP) has positive and negative environmental and social impacts. As a result of this, the Government committed itself to take measures so that the positive impacts are enhanced and the negative impacts diminished or avoided through ESIA. The program specifically mentions the negative impacts which could be caused to wetlands as a result of activities such as hydropower and irrigation projects. It calls for the need to have EIA for some specific projects.

4.6.6 The Rural Development Policies and Strategies

Within the same year when national water strategy was formulated, the Rural Development Policies and Strategies document was introduced with a view to bring about accelerated economic growth to the country and ensuring food security. The document underlines the importance of conserving and wisely utilizing the country's natural resources for sustainable development. As natural resources, wetlands might have been considered that this policy and strategy document have considered the conservation and wise utilization of water resources, including wetlands.

4.6.7 The Water Resources Management Proclamation No. 197/2000

Ethiopia has Water Resources Management Proclamation identified by No. 197/2000. The purpose of the proclamation as is given in Article 3 is to ensure that the water resources of the country are protected and utilized for the highest social and economic benefits of the people of Ethiopia, to follow up and supervise that they are duly conserved, to ensure that harmful effects of water are prevented, and that the management of water resources is carried out properly. Water resource is defined by the proclamation as surface or ground water, with the exclusion of mineral and geothermal deposits. This definition obviously includes wetlands in the meaning of water resources of the Country.

4.6.8 The FDRE Environmental Pollution Control Proclamation No. 300/2002

The Environmental Pollution Control Proclamation introduces comprehensive rules regulating the point source pollution. The legislation requires that standards need to be formulated to regulate point source pollutant discharges in the environment. Subsequently, the Regulation called on the prevention of industrial pollution regulation which was enacted to give detailed rules in relation to industrial pollution. The Regulation incorporates rules to regulate point source pollution as provided in the environmental pollution control proclamation. The Regulation requires industries to minimize the generation of pollutants by limiting them to the relevant environmental standard and to dispose of waste and other pollutants in an environmentally friendly way.

4.6.9 Ethiopian Water Resources Regulation No. 115/2005

To implement this Proclamation i.e. the FDRE Environmental Pollution Control Proclamation No. 300/2002, Regulation No. 115/2005 was issued. The Regulation, even if it does not specifically mention wetlands, provides for actions and measures to be taken, by the supervising body, which under the Regulation is the Ministry of Water Resources (now Ministry of Water, Irrigation and Electricity) for the purpose of protecting water bodies (which include wetlands). As part of the regulatory framework, a permit is introduced to manage water use. Users may get permits temporarily or permanently and revoked if water is depleted or the usage of the water resources causes a negative impact on the environment as per the provisions of EIA Proclamation No. 299/2002. Despite the regulated utilization of water resources, implementation does not seem strong to reverse the wetlands challenges.

In March 2006, Action Professionals' Association for the People (APAP) has brought a legal action against the FDRE Environmental Protection Authority in the Federal First Instance Court of Ethiopia. The claim was against the immense pollutant discharges from point and diffuse sources to the water body of the Awash River (FDRE, the Federal First Instance Court, Court File Case No. 64902). This case was the first ever legal dispute in Ethiopia that was brought against a governmental regulator for its failure to protect the water resources. The case was supported by scientific study and expert witnesses. After investigating the case, the court rendered a decision in favour of the defendant, and similar decisions were rendered by the Federal High and Supreme Courts at the appellate levels (FDRE, the Federal High Court, Court Case File No. 64902, Federal High Court, Court Case File No. 51052 and the Federal Supreme Court, Court Case File No. 3977). The central statement of the courts' decisions was that the defendant, the Environmental Authority, was not responsible for the failure to act.

The material facts of the claim implied that unregulated and untreated effluent discharges were affecting the tributaries of the Awash River, which caused damage to the river's water resources, to people and to biodiversity. The plaintiff argued that the defendant should take administrative and legislative measures to stop the continuing water pollution and clean up the streams. It also requested the court to introduce inspectors that would conduct a follow-up of the implementation process and measures decided to rectify the on-going pollution problem. The outcome of the case absolves the defendant, while stressing two main issues that it considered meant that it should not be held accountable for the environmental damage. The first claim indicated substantive law problems. In particular, the defendant argued that the majority of the industries polluting the Awash River tributaries were pre-existing. These industries were exempted from the pollution control legislation as they were privileged by the exemption provision.

4.6.10 The River Basin Councils and Authorities Proclamation No. 534/2007

The River Basin Councils and Authorities Proclamation No. 534/2007 defines "Water Resources" by including wetlands as availability, both in quantity and quality of surface and ground water in a river basin including aquatic and wetlands ecosystem. In its Article 4, the Proclamation states the objectives of establishing the Councils and Authorities. The overall objectives of river basin High Councils and Authorities is promoting and monitoring the integrated water resources management process in the river basins falling under their jurisdictions with a view to using of the basins' water resources for the socioeconomic welfare of the people in an equitable and participatory manner, and without compromising the sustainability of the aquatic habitats. Similarly, the Rural Land Administration and Land Use Proclamation No. 456/2005 under its Article 13 (10) states that the biodiversity in rural wetland shall be conserved and utilized as necessary, in accordance with a suitable land use strategy. From regional laws, the Oromia Rural Land Administration and Use Proclamation (No. 130/2007) in its Article 18 (10) states that biodiversity in rural wetlands shall be conserved and utilized in accordance with a suitable land use strategy as necessary. Its Article 20 is devoted to wetland management. It provides that rural land users must refrain from performing activities that cause damage to the wetlands and springs. It provides that wetland shall be used for agricultural purposes, with the consent of the community and technical support of professionals.

The Southern Nations, Nationalities and Peoples Regional State Rural Land Administration and Use Proclamation No. 110/2007 in its Article 13 (10) provides that the biodiversity in rural wetland shall be conserved and utilized as necessary, in accordance with a suitable land use strategy. Details shall be determined by a regulation. The SNNPRS Rural Land Administration and Use Regulation No. 66/2007, although issued to implement the Proclamation, does not give detailed rules on wetlands. In its Article 13 (2), the regulation provides that wetlands, based on a study and with community participation, shall be protected from sedimentation and loss of biodiversity. Details shall be determined by directives. However, no directive is yet developed to implement the regulation regarding wetlands.

The Benishangul Gumz Regional State developed its Rural Land Administration and Use Proclamation No. 85 /2010, which imposes obligation on land users to protect spring areas and wetlands from damage which are caused by improper farming. In its Article 24 (6) & (7), the proclamation provides that water bodies' development activities enabling the protection of wetlands shall be carried out by the government and participation of the community. It strictly prohibits the use of wetlands in the manner damaging their sustainability. The Proclamation under its Article 13 (4) provides a rule on the obligation of communal land users in that they are obliged to protect natural vegetation cover, wildlife, wetlands and other natural resources on the communal lands.

4.6.11 Policies and laws under development

Ethiopia has drafted further policies and laws that would contribute directly or indirectly sustainable management of wetlands in the country. National Wetland Proclamation was drafted by the active participation of diverse stakeholders including Wetland International. Now the draft has been commented by the General Attorney office. Once the comments incorporated in, it would be submitted to the prime Minster office, the Council Ministers to evaluate and decide on its adoption. The National Wetland Proclamation accommodates rules designed to protect or conserve wetlands from unsustainable human interventions. In Ethiopia, one major challenges to wetland or any other natural resources unsustainable exploitation is, lack land use policy that provides a framework for optimal land development. To tackle, misuse and mismanagement of wetlands from unsustainable land use or development, since 2018, Ethiopia has formulated land use policy, and the instrument is under consideration for its adoption. Its adoption would try to reverse so many wetlands degradation and pollutions' problems. Wetlands provide many ecosystem services. Many of such resource's costs are not internalized to show environmental price signals in the goods and services. Environmental costs widely disregarded upon determining products or services of their costs. To avoid such wrongful practices, since 2019 Ethiopia is under development of Payment for Ecosystem Services legislation which is widely regarded as innovative legal framework that would be used as tool to internalize environmental costs and mobilize funds that would be used to conserve aquatic and wetlands, and other ecosystems. The legislation designs to establish ecofund that devotes to centrally administer ecosystem services payments and then mobilize to conserve, protect or rehabilitate aquatic and wetland, and other ecosystems. Environmental Policy under amendment also considers ecosystem sustainability at the centre–that would require aquatic and wetlands, and other ecosystems sustainability beyond conservation-oriented wetlands managements in some defined contexts.

The Environmental Policy specifically deals with water resources in section 3.4 and engages the issue of wetlands. Section 3.4 (b) recognizes that natural ecosystems, particularly wetlands and upstream forests, are fundamental in regulating water quality and quantity and to integrate their rehabilitation and protection into the conservation, development and management of water resources. Similarly, section 3.4 (d) promotes the protection of the interface between water bodies and land (e.g. lake shores, river banks and wetlands) and section 3.4 (g) requires that all major water conservation, development and management projects be subjected to an EIA process and requires that the costs and benefits of protecting watershed forests, Aquatic and Wetlands and other relevant key ecosystems would be included in the economic analysis of such water projects. As can be seen from these specific policy elements, wetlands are fundamental habitats for the regulation of the quality and quantity of water resources.

4.6.12 International Agreements

Ethiopia is a party to many multilateral environmental agreements that are directly or indirectly related to wetland conservation and wise use. Amongst others, Ethiopia is a party to the Convention on Biological Diversity, the Convention on Migratory Species (and its African-Eurasian Migratory Water bird Agreement), and the Convention on International Trade in Endangered Species of Wild Fauna and Flora, and the World Heritage Convention. The Country is committed to implement the UN SDGs Goals which covers 17 Sustainable Development Goals (SDGs) and 169 associated targets. The SDG 14 encourages the protection of coastal and marine areas while the SDG 15 calls for conservation and sustainable use of inland freshwater habitats and their services. The SDG 6 specifically focuses on water and sanitation with a target relating to trends in water-related ecosystems. The Aichi Biodiversity Targets which are part of the Strategic Plan for Biodiversity 2011-2020, for the Convention on Biological Diversity under its Targets 5 and 11 seek to halt ecosystem loss, aims to at least halve, and ideally eliminate, loss of natural habitats by 2020, aims to conserve at least 17% of terrestrial and inland water, and 10% of coastal and marine areas by 2020 in “effectively and equitably managed, ecological representative and well-connected systems of protected areas and other effective area-based conservation measures”. Similarly, Targets 6, 7 and 10 focus on conservation of coral reefs and sustainable use of aquatic species and on management of aquaculture. In December 2015, 196 governments including Ethiopia have adapted the Paris Agreement taking ambitious actions to combat climate change and improve mitigation and adaptation. The Paris Agreement on climate change calls on contracting parties to address climate change challenges including nature-based solutions as a key component. Amongst others, wetlands play a critical role in both adaptation through resilience building and mitigation through carbon storage and sequestration.

The Ramsar Convention on Wetlands is the only multilateral environmental agreement with a primary focus on wetlands, signed in 1971 and came into force in 1975. To date 170 countries have joined as Contracting Parties. Ethiopia is not yet acceded the Ramsar Convention and has missed the opportunities for managing wetlands through cooperation and partnerships including benefits emanating from the Convention as means of implementations.

The main objectives of the Convention are the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world. The Convention under its Article 5 establishes that the Contracting Parties shall consult with each other about implementing obligations arising from the Convention especially in the case of a wetland extending over the territories of more than one Contracting Party or where a water system is shared by Contracting Parties. They shall at the same time endeavour to coordinate and support the present and future policies and regulations concerning the conservation of wetlands and their flora and fauna. This collaborative arrangement gives opportunities contracting parties to work together in the conservation of shared wetlands. In addition to contracting parties' cooperation, Ramsar does have 19 regional initiatives which support cooperation and capacity-building on wetland-related issues across the globe.

In general, the Convention accommodates three primary obligations: conserving and using wisely all wetlands, designating and conserving at least one wetland of international importance and cooperating across national boundaries on transboundary wetlands, shared wetland. As wetlands provide diverse ecosystem services, sustainable wetlands conservation plays a key role in delivering the Sustainable Development Goals, Aichi Biodiversity Targets, and the Paris Agreement on Climate Change through carbon sequestration and supporting resilience building and other related commitments under environmental and non-environmental treaties.

The Ramsar Convention considers the ecological character of wetlands: the combination of the ecosystem components, processes and benefits/ services that characterize a wetland at a given point in time (Ramsar Convention, 2005). It calls the contracting parties for maintaining the ecological character of all wetlands, and reporting any adverse human-induced changes in a Ramsar Site to the Secretariat including taking necessary actions to restore these sites to their former state. The 'Wise use' of the wetlands is at the centre of the Convention that applies to all wetlands. This notion is defined as the maintenance of a wetland's ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development (Ramsar Convention, 2005). As many of wetlands' pressures are transcending beyond administrative boundaries, the Convention calls for international cooperation in wetland management (The Ramsar Convention Secretariat, 2010b). At present, there are a lot of cooperation and partnerships arrangements across the globe to manage sustainable wetlands (Ramsar Convention, 2018).

4.7 References

Abbott, A., (2018). Biodiversity thrives in Ethiopia's church forests. *Nature*, Current Issues. https://www.nature.com/immersive/d41586-019-00275-x/index.html.

Abebe, Y. D. and Geheb, K. (eds)., (2004). Wetlands of Ethiopia. *Proceedings of a seminar on the resources and status of Ethiopia's wetlands*, International Union for Conservation of Nature and Natural Resources (IUCN), vi + 116pp.

Abunie, L., (2003). The distribution and status of Ethiopian wetlands: an overview. In: Yilma Abebe, D. and Geheb, K. (eds.). Wetlands of Ethiopia, Proceedings of a Seminar on the Resources and Status of Ethiopia's Wetlands, IUCN 2003.

Adriana, R., O'Reillyb, C. M., Zagaresec, H., Bainesd, S. B., Hessene, D. O., Kellerf, W., Winderl, A. M., (2008). Lakes as sentinels of climate change. Limnol Oceanogr, 54(6): 2283–2297.

Afework, H., (2005). Ethiopian Wetlands Distribution, Benefits and Threats. Proceedings of the second awareness creation workshop on Wetlands in the Amhara region, Addis Ababa Ethiopia, pp. 9-16.

Afework, H., Dixon, A. B. & Wood, A. P., (2000). Nature, extent and trends in wetland drainage and use in Illubabor Zone, Southwest Ethiopia. Ethiopian Wetlands Research Programme and the University of Huddersfield, pp.117-129.

Alemu, T., (2018). Riparian Vegetation Status and Development of Plant-Based Monitoring Tool for Ecological Assessment of Highland Streams in Southwestern Ethiopia. Jimma University.

Ambelu, A., (2009). Biological monitoring based on macroinvertebrates for decision support of water management in Ethiopia, Department of Applied Ecology and Environmental Biology, Ghent University Public defense, 2 July 2009.

Ambelu, A., (2019). Field observations of the wetlands and aquatic systems around Jimma City.Jimma University, Ethiopia.

Ambelu, A., Mekonen, S., G/Silassie, A., Malu, A. & Karunamoorthi, K., (2013). Physicochemical and Biological Characteristics of Two Ethiopian Wetlands. Wetlands, 33(4), 691–698. https://doi.org/10.1007/s13157-013-0424-y.

Anabo, Ayele (2016). The Quest for Salient Features of Effective Water Resources Management Systems: Assessing the English and the Ethiopian Water Policies and Laws, PhD thesis, accessed on 11th July 2019, https://kar.kent.ac.uk.

Argaw, K. H., (2014). Assessment of Spatio-Temporal Changes of Wetlands using GIS and RS Techniques in Dawa Chefa Area in the Northern Central Ethiopian Highlands. Thesis. Mekelle University (MU).

Asmamaw, M., Mereta, S. T., & Ambelu, A., (2020). The role of local knowledge in enhancing the resilience of Dinki watershed social-ecological system, central highlands of Ethiopia. PLOS ONE, 15(9), e0238460. https://doi.org/10.1371/journal.pone.0238460.

Atkins, J. P., Burdon, D., Elliott, M., & Gregory, A. J., (2012). Management of the marine environment: Integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. Marine Pollution Bulletin. Marine Pollut, 62: 215–226.

Awulachew B S, Yilma AD, Loulseged M, Loiskandl W, Ayana M, Alamirew T., (2007). Water Resources and Irrigation Development in Ethiopia. Retrieved from Colombo, Sri Lanka.

Ayele, A., (2016). The Quest for Salient Features of Effective Water Resources Management Systems: Assessing the English and the Ethiopian Water Policies and Laws, PhD thesis, accessed on 11th July 2019, https://kar.kent.ac.uk.

Ayenew, T., (2012). Current status and threats to selected Ethiopian wetlands. In: Sue Edwards (ed.). Ethiopian Environment review No. 2; Forum for Environment, Addis Ababa, Ethiopia.

Barry, S., Gebru, G., Desta, S., Negassa, A., Nigussie, K., Aboset, G., & Mechale, A. H., (2017). Ethiopia Livestock Sector Analysis. Ministry of Livestock and Fisheries, Addis Ababa.

Bates, Bryson & Zbigniew, Kundzewicz & Wu, Shaohong & Palutikof, Jean. (2008). Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat.

BBC (British Broadcasting Corportation) News. (2004). BBC NEWS/Programmes/This World/Ethiopia fact file. Accessed on Feb. 2, 2015.

Belete, M.D., (2018). Ecohydrology to harmonize industrialization and ecological safety in urban environment: Case of Hawassa Lake, industries and Cheleleka wetland. Ecohydrology & Hydrobiology. Volume 18, Issue 2, April 2018, Pages 192-200.

Bell, S., (2012). DPSIR = A Problem Structuring Method? An exploration from the "Imagine" approach. European Journal of Operational Research, 222: 350-360.

Bellew, H., (2018). 5 RSPB wetland reserves working wonders for people and wildlife, Published on Friday 2 February 2018, Accessed on 10 July 2019.

Benishangul Gumz Regional State. (2010). Rural Land Administration and Use Proclamation No. 85 /2010, Article 22(1)(e).

Berhanu, G., (2012). Valuation of Choke Mountain Range Wetland Ecosystem, East Gojjam, Amhara Region, Ethiopia: Application of Choice Experiment Valuation Method, MSc Thesis, Addis Ababa University.

Blem, C. R. and Blem, L. B., (1975). Density, biomass, and energetics of the bird and mammal populations of an Illinois deciduous forest. Illinois Acad. Sci. Trans. 68:156-184.

Blumenfeld, S., Lu, C., Christophersen, T. and Coates, D., (2009). Water, Wetlands and Forests. A Review of Ecological, Economic and Policy Linkages. Secretariat of the Convention on Biological Diversity and Secretariat of the Ramsar Convention on Wetlands, Montreal and Gland. CBD (Convention on Biological Diversity) Technical Series No. 47.

Bognetteau, E., Wood P., Afework H., and Legesse T., (2003). Wetlands and food security in South-West Ethiopia: An economic, ecological and institutional analysis for sustainability. EWNRA, Addis Ababa, Ethiopia.

CNRS (Délégation Paris Michel-Ange). (2012). Population pressure impacts on world wetlands. ScienceDaily. Retrieved June 5, 2019 from www.sciencedaily.com/releases/2012/05/120511122101.htm.

Cole, D., (2002). Pollution & property: comparing ownership institutions for environmental protection, Cambridge University press.

Conway, D., & Schipper, E.L.F., (2011). Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia. Global Environmental Change. 21:227–37.

CSA (Central Statistical Authority). (1998). The 1994 Population and Housing Census of Ethiopia: Results at Country Level, Volume I: Statistical Report. Addis Ababa.

CSA. (2008) Summary and statistical report of the 2007 population and housing census. CSA (Central Statistical Agency of Ethiopia), Addis Ababa.

CSA. (2013). Population projection for Ethiopia. – 2007-2037.Central Statistical Agency, Addis Ababa.

Davidson, N. C., Laffoley, Dd'A,, Doody, J. P., Way, L. S., Gordon, J., Key, R. Drake, C. M., Pienkowski, M. W., Mitchell, R. M. and Duff, K. L., (1991). Nature conservation and estuaries in Great Britain. Nature Conservancy Council: Peterborough, UK.

Davies, B., & Day, H., (1998). Vanishing Waters. University of Capetown. Capetown, South Africa.

De Troyer, N., Mereta, S., Goethals, P., & Boets, P., (2016). Water Quality Assessment of Streams and Wetlands in a Fast Growing East African City. Water, 8(4), 123. https://doi.org/10.3390/w8040123.

Defaye, D., (1988). Contribution à la connaissance des crustacés Copépodes d'Ethiopie. Hydrobiologia, 164: 103-147.

Degife, A. W. & Mauser, W., (2017). Socio-economic and Environmental Impacts of Large-Scale Agricultural Investment in Gambella Region, Ethiopia. In: Azeb W. Degife, & Wolfram Mauser (eds) Socio-economic and Environmental Impacts of Large-Scale Agricultural Investment. Journal of US-China Public Administration, 14, No. 4, 183-197. April 2017.

Degife, A. W., F. Z., & Wolfram, M., (2018). Assessing land use and land cover changes and agricultural farmland expansions in Gambella Region, Ethiopia, using Landsat 5 and Sentinel 2a multispectral data. EHeliyon, 4, https://doi.org/10.1016/j.heliyon.2018.e00919.

Desta, H., Lemma, B., Albert, G., & Stellmacher, T., (2015). Degradation of Lake Ziway, Ethiopia: A study of the environmental perceptions of school students. Lakes & Reservoirs: Research & Management, 20(4), 243–255. https://doi.org/10.1111/lre.12111.

Dixon A. B., Hailu, A., Semu, T. & Taffa, L., (2009). Local responses to marginalization: human–wildlife conflict in Ethiopia's wetlands. Geography, 94, 38–47.

Dixon, A. B., & Wood, A. P., (2007). Local Institutions for Wetland Management in Ethiopia: Sustainability and State Intervention. In: B. van Koppen, M. Giordano, & J. Butterworth (eds) Community-based Water Law and Water Resource Management Reform in Developing Countries. pp. 130-145. London, UK: CAB International.

Dixon, A. B., (2005). Wetland sustainability and the evolution of indigenous knowledge in Ethiopia. The Geographical Journal, 171(4), 306–323. https://doi.org/10.1111/j.1475-4959.2005.00172.x.

Duc, L.D., (1993). Rehabilitation of the Melaleuca floodplain forests in the Mekong Delta, Vietnam. In: T.J. Davis (ed.) Towards wise use of wetlands. Gland, Switzerland: Ramsar Convention Bureau, Wise Use Project.

EBI (Ethiopian Biodiversity Institute). (2014). Ethiopia's Fifth National Report to the Convention on Biological Diversity. Addis Ababa, Ethiopia.

EFAP (Ethiopian Forestry Action Programme). (1989). The Challenges for Development. Addis Ababa, Ethiopia. Vol. II.

EFCCC (Environment, Forestry and Climate Change Commission). (2017). State and Outlook of the Environment, Addis Ababa, Ethiopia.

Elhigzi, F. A. R.; Haider, S. A., & Larsson, P., (1995). Interactions between Nile tilapia (*Oreochromis niloticus*) and cladocerans in ponds (Khartoum, Sudan). Hydrobiologia, 307: 263-272.

EPA (Ethiopian Environmental Protection Authority. (2011). Climate Resilient Green Economy Strategy, Addis Ababa, Ethiopia. 188p.

EPA. (2003). Guidelines and Standards for Environmental Pollution Control in Nigeria. 238 pp., Environmental Protection Authority, Addis Ababa.

EPCC (Ethiopian Panel on Climate Change). (2015). First Assessment Report, Working Group II Biodiversity and Ecosystems, Published by the Ethiopian Academy of Sciences.

Erwin, K. L., (2009). Wetlands and global climate change: the role of wetland restoration in a changing world. Wetlands Ecol Manage, 17:71–84. doi:10.1007/s11273-008-9119-1.

EWNHS (Ethiopian Wildlife and Natural History Society). (1996). Important Bird Areas of Ethiopia: A First Inventory. Semayata Press, Addis Ababa, Ethiopia.

EWNHS and WI, (2018). A First Directory of Ethiopian Wetlands: Descriptions, Ecosystem Services, Causes of Degradation & Recommendations for Restoration and Sustainability. Addis Ababa, Ethiopia: Ethiopian Wildlife and Natural History Society and Wetlands International.

EWNHS. (2017). Assessment of Wetlands for National Restoration Potential in Ethiopia. Report submitted to the Ethiopian Wildlife and Natural History Society (EWNHS), Addis Abeba.

Falkenmark, M., Berntell, A., Jagreskog, A., Lundgvist, J., Matz, M. and Tropp, H., (2007). On the verge of a new water scarcity: a call for good governance and human ingenuity. SIWI Policy Brief, 3.

FAO (Food and Agriculture Organization). (2002). The State of Food Insecurity in the World 2001. Rome.

FAO. (2003). Fishery country profile, Ethiopia. www.fao.org.

FAO. (2008). Scoping agriculture–wetland interactions: Towards a sustainable multiple-response strategy. FAO Water Reports 33, Food and Agriculture Organization, Rome, Italy. http://www.fao.org/fileadmin/user_upload/faowater/docs/WaterReports33.pdf.

FAO. (2016). Forestry Contribution to National Economy and Trade in Ethiopia, Kenya and Uganda. By Kilawe, E. and Habimana, D. Addis Ababa, Ethiopia.

Farm Africa. (n.d.). Integrated Watershed Management: Sustainable Agriculture for Improved Food Security in Tigray, Ethiopia. Retrieved November 19, 2019, from https://www.farmafrica.org/downloads/resources/farm-africafood-security-in-tigrayintegrated-watershed-management-(1-of-1).pdf.

Fay, P. A., Guntenspergen, G. R., Olker, J. H., & Johnson., A. W., (2016). Climate change impacts on freshwater wetland hydrology and vegetation cover cycling along a regional aridity gradient. Ecosphere, 7(10):e01504. 10.1002/ ecs2.1504.

FDRE (2002). Environmental Pollution Control Proclamation NO. 300/2002, Environmental Protection Authority, Addis Ababa, Ethiopia

FDRE (Federal Democratic Republic of Ethiopia), The Federal First Instance Court, Court File Case NO. 64902, Addis Ababa, Ethiopia

FDRE (Federal Democratic Republic of Ethiopia). (1995). The Constitution of the Federal Democratic Republic of Ethiopia, NO.1/1995.

FDRE. (1999). Ethiopian Water Policy, 1999, section 2.1.1

FDRE. (1999). Ethiopian Water Policy, 1999, section 2.1.1. Misntry of Water Resources, Addis Ababa.

FDRE. (2008). Prevention of Industrial Pollution, Council of Minsters Regulation, NO. 159/200, Addis Ababa, Ethiopia.

Fernando, C. H., (1994). Zooplankton, fish and fisheries in tropical freshwaters. Hydrobiologia, 272: 105–123.

Feto, H., (2019). A Review on the Importance, Distribution and Threat of Ethiopian Wetlands. Journal of Natural Sciences Resear. ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online) DOI: 10.7176/JNSR Vol.9, No.6.

Finlayson C.M., Davidson, N.C., Spiers, A.G., Stevenson, N.J., (1999). Global wetland Gandile, A.U., Mengistu, S.T. and Nake, F.M., (2017). Biodiversity conservation using the indigenous knowledge system: The priority agenda in the case of Zeyse, Zergula and Ganta communities in Gamo Gofa Zone (Southern Ethiopia). International Journal of Biodiversity and Conservation. Vol. 9(6): 167-182.

Garay, D. and Sadoff, C., (2007). ‘Sink or swim? Water security for growth and development’. Water Policy, 555-556.

Gardner, R., Barchiesi, S., Beltrame, C., Finlayson, C., Galewski, T., Harrison, I., Rosenqvist, A. A., (2015). State of the World’s Wetlands and their Services to People: A compilation of World’s Wetlands and their Services to People: A compilation of recent analysies. Ramsar Briefing Note No. 7. Gland, Switzerland: Ramsar Convention Secretariat.

Gashaw, T. and Wolff, (2014). The state of inland fisheries in Ethiopia: a synopsis with updated estimates of potential yield. Ecohydrology & Hydrobiology, 14 (3), pp. 200-219.

Gebremariam, Z. and Taylor, W. D., (1997). Bacteria-chlorophyll relationships in Ethiopian lakes of varying salinity: Are soda lakes different? Journal of Plankton Research, 19 (5): 647-654.

Gebresllassie, H., Gashaw, T., and Mehari, A., (2014). Wetland Degradation in Ethiopia: Causes, Consequences and Remedies, Journal of Environment and Earth Science, 4(11).

Getches, D. H., (1990). Water Law, West Nutshell Series, West Publishing Co.

GIRDC (Generation Integrated Rural Development Consultant). (2018). Assessment of National Water used and demand forecast (Draft Report), Addis Ababa, Ethiopia.

Giweta, M. & Worku, Y., (2018). Reversing the Degradation of Ethiopian Wetlands: Is it Unachievable Phrase or a Call to Effective Action? Int J Environ Sci Nat Res., 14(5), September 28, 2018, PP. 1-4.

Gleick, P., (1998). Water in Crisis: Paths to Sustainable Water Use. Ecological Applications, 8(3) 571.

Green, J. & Mengistou, S. (1991). Specific diversity and community structure of Rotifera in a salinity series of Ethiopian inland waters. Hydrobiologia, 209 (1991): 95-106.

Hailemariam, A., (2016). Implementation of the Population Policy of Ethiopia: Achievements and Challenges. Population Horizons, 13(1): 1–14.

Hailu, A., (2007). Potential Wetland Resources of Ethiopia: Use and Threats. In: Abebe Ameha Mengistu (ed.), Proceedings of the Public Meetings on Harnessing the Water Resources of Ethiopia for Sustainable Development in the New Ethiopian Millennium Forum for

Environment. In partnership with Global Water Partnership Eastern Africa (Ethiopia Country Water Partnership, ECWP), WaterAidEthio, Wetlands and Natural Resources Association (EWNRA).

Harris, L. D., (1988). The nature of cumulative impacts on biotic diversity of wetland vertebrates. Environ. Mgmt. 12:675-693.

Hayal, D., Brook L, & Fetene, A., (2012). Aspects of climate change and its associated impacts on wetland ecosystem functions - A review. J Am Sci 8(10):582-596.

Hickman, S., (1994). Improvement of habitat quality for nesting and migrating birds at the Des Plaines River Wetlands Demonstration Project. Ecol. Eng. 3:485-494.

Hillman, J. C. (ed.), (1993). Ethiopia. Compendium of Wildlife Conservation Information. NYZS – The Wildlife Society International, New York Zoological Park, Bronx, NY and Ethiopian Wildlife Conservation Organization, Addis Ababa, 2 Vols. 786pp.

Hurni, H., (1986) Guidelines for Development Agents on Soil Conservation in Ethiopia. Community Forest and Soil Conservation Development Department, Switzerland.

Hurni, K., Zeleke G., Kassie M., Tegegne B., Kassawmar T., Teferi E., Moges A., Tadesse D., (2015). Economics of Land Degradation (ELD) in Ethiopia Case Study. Soil Degradation.

Hussien Kassaye, Biadgilgn Demissie and Hailemariam Meaza, (2018). Spatiotemporal wetland changes and their threats in North Central Ethiopian Highlands. Journal of Tropical Geography, 39(4). doi:10.1111/sjtg.12242.

IBC (Institute of Biodiversity Conservation). (2009). Ethiopia's 4th Country Report to the Convention on Biological Diversity.n Addis Ababa, Ethiopia.

IBC. (2007). Ecosystems of Ethiopia. www.gov.et.

IWMI (International Water Management Institute). (2016). An Assessment of Integrated Watershed Management in Ethiopia, IWMI Working Paper 170.

Johnston, C. A., (1991). Sediment and nutrient retention by freshwater wetlands: Effects on surface water quality. Critical Reviews in Environmental Control, 21:491-565.

Jos T. A. Verhoeven, Setter, T. L., (2012). Agricultural use of wetlands: opportunities and limitations, Annals of Botany, Volume 105, Issue 1, January 2010, Pages 155–163, https://doi.org/10.1093/aob/mcp172.

Kahsay A, Lemmens P, Triest L, De Meester L, Kibret M, Verleyen E, Adgo E, Wondie A and Stiers, I., (2022) Plankton Diversity in Tropical Wetlands Under Different Hydrological Conditions (Lake Tana, Ethiopia). Front. Environ. Sci. 10:816892. doi: 10.3389/fenvs.2022.816892

Kamieniecki, S., & Kraft, M. E., (2013). The Oxford Handbook of U.S. Environmental Policy. Oxford: Oxford University Press.

Kamski, B., (2016). The Kuraz Sugar Development Project (KSDP) in Ethiopia: between 'sweet visions' and mounting challenges. Journal of Eastern African Studies 10(3):568-580. DOI: 10.1080/17531055.2016.1267602.

Kebede, E. and Willen, E., (1998). Phytoplankton in a salinity-alkalinity series of lakes in the Ethiopian Rift Valley. Algological Studies, 89: 63-96.

Kebede, S. (2013). Groundwater in Ethiopia. Springer Hydrogeology.

Kevern Cochrane and Cassandra De Young (2009). Climate change implications for fisheries and aquaculture Overview of current scientific knowledge. Food and Agricuture Organisation(FAO) Rome.

Legesse, T., (2008). The Roles of Wetlands in Food Security and Poverty Reduction in Ethiopia. Ethiopian Wetlands and Natural Resources Association, pp. 28-36.

Leibowitz, S. C., Abbruzzese, B., Adamus, P. R., Hughes, L. E., & Irish. J., (1992). A synoptic approach to cumulative impact assessment: A proposed methodology. EPA/600/R-92/167.

Lemlem, S., (2003). Biodiversity potentials and threats to the southern Rift Valley lakes of Ethiopia. In: Abebe and K. Geheb (eds.). Wetlands of Ethiopia, proceedings of a seminar on the resources and status of Ethiopia's wetlands. IUCN, pp. 31-34.

Lemlem, S., (2003). Biodiversity potentials and threats to the southern Rift Valley lakes of Ethiopia. In: Abebe and K. Geheb (eds.). Wetlands of Ethiopia, proceedings of a seminar on the resources and status of Ethiopia's wetlands. IUCN, pp. 31-34.

Lemma, B., (2003). Ecological changes in two Ethiopian lakes caused by contrasting human intervention. Limnologica, 33(1), 44–53. https://doi.org/10.1016/S0075-9511(03)80006-3.

Lemma, B., (2008). Introduction to Lake Ecology, Aquaculture and Fisheries in Ethiopia. HaramayaUniversity, Haramaya, Addis Ababa University Printing Press, Addis Ababa, Ethiopia, pp: 416.

Lemma, B., Bendorf, J. and Koschel, R., (2001). Fish predation pressure on and interactions between Cladocerans: observations using enclosures in three temperate lakes (Germany) and one tropical lake (Ethiopia). Limnologica, 31: 209–220.

Lettenmaier, D.; Major, D.; Poff, L.; Running, S., (2008). Water resources. In: Backlund, P.; Janetos, A.; Shimel, D.; Walsh, M.; eds. The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. Synthesis and Assessment Product 4.3. Washington, DC: U.S. Climate Change Science Program, Subcommittee on Global Change Research: 121–150.

Leykun, A., (2003). The Distribution and Status of Ethiopian Wetlands: An Overview: IUCN, pp.12-17.

Luise, D., Robert, E., Lamonte, G., Barry, I., Jeffrey, L., Timonthy, B., Glenn, R., Melanie, S., Charles, T. and Harold, W., (1999). The Handbook of Constructed Wetlands. A Guide to Creating Wetlands for Agricultural Wastewater, Domestic Wastewater, Coal Mine Drainage and Storm Water in the Mid-Atlantic Region. General Considerations. Vol. 1.

MacDonald, L., (1994). Water Pollution Solution: Build a Marsh. J. American Forests. 100(7/8), pp. 26-30.

Maltby, E., (1986). Waterlogged wealth, London: Earthscan.

Maltby, E., (2009). The changing wetland paradigm. In: E. Maltby, and T. Barker (eds.). The wetland handbook. Oxford: Wiley-Blackwell.

McCartney, M. P.; Masiyandima, M. and Houghton-Carr, H. A., (2005). Working wetlands: Classifying wetland potential for agriculture. Colombo, Sri Lanka: International Water Management Institute (IWMI), pp. 31-38.

MEA (Millennium Ecosystem Assessment). (2005). Ecosystem and Human Well-being: Wetlands and Water - Synthesis. World Resources Institute, Washington, DC.

Mekuria, B., (n.d.). Oromia's Irreecha Festival – A Revival of an Ancient African Culture – An Attempt to Understand and Explain [Http://www.waaqeffannaa.com/irreechaa/oromias-irreecha-festival-a-revival-of-an-ancient-african-culture-an-attempt-to-understand-and-explain/]. WAAQEFFENNA.

Mereta, S. T., (2013). Water quality and ecological assessment of natural wetlands in Southwest Ethiopia. PhD thesis, Ghent University, Gent, Belgium.

Meynell, P-J. and Qureshi, M. T., (1993). Water Resources management in the indus river delta. Pakistan. Parks Intern. J Prot Area Magment, 5 (2) 15-23.

Minckley, W. L., and Douglas, M. E., (1991). Discovery and extinction of western fishes: A blink of the eye in geologic time. In: W. L. Minckley and J. E. Deacon (eds.). Battle Against Extinction: Native fish management in the American West. Tucson: Univ. Arizona Press. Pp. 7-17.

MoA (Minitry of Agriculture). (2016). Guidlines for Development Agent on Soil and WaterConservation in Ethiopia. Ministry of Agriculture. https://boris.unibe.ch/80013/1/Guidelines_Soil_and_Water_Conservation_in_Ethiopia_2016.pdf.

Moges, A., (2016). The Ecosystem Services and Ecological State of Wetlands in Jimma Highlands of Ethiopia for the Development of Plant Based Monitoring Tool. PhD Dissertation, Jimma University.

Moomaw, W. R., Chmura, G. L., Davies, G. T., Finlayson, C. M., Middleton, B. A., Natali, S. M., Sutton-Grier, A. E., (2018). Wetlands in a Changing Climate: Science, Policy and Management. Wetlands, 38:183–205.

Moyle, P. B., and Sato. G. M., (1991). On the design of preserves to protect native fishes. In: W. L. Minckley and J. E. Deacon (eds.). Battle against Extinction: Native fish management in the American West, Tucson. Univ. of Arizona Press. Pp. 155-169.

Moyle, P. B., and Yoshiyama. R. M., (1994). Protection of aquatic biodiversity in California. Fisheries 19:6-18.

NABU (Nature and Biodiversity Union). (2014). Conservation and sustainable use of the last wild coffee forests of Ethiopia. Retrieved May 18, 2019, from https://en.nabu.de/projects/ethiopia/kafa/biodiversity /index.html.

Nederveen, S. C., (2012). Flood Recession Farming: An Overview and Case Study from the Upper Awash Catchment, Ethiopia. Master thesis, Hydrology, code 450122, 39 ECTS. Vrije Universiteit Amsterdam.

Negussie, W., Wu, W., Alemayehu, A., & E., Y., (2019). Assessing dynamics in the value of ecosystem services in response to land cover/land use changes in Ethiopia, East African Rift System. Applied Ecology and Environmental Research, 17(3): 7147-7173.

Nilssen, J. P., (1984). Tropical lakes - functional ecology and future development: the need for a process-oriented approach. Hydrobiologia, 113: 231-242.

NPC (National Planning Commission). (2016). Addis Ababa Growth and Transformation Plan II (GTP II) (2015/16-2019/20): Volume I: Main Text. Addis Ababa, Ethiopia.

Ohmart, R. D., and Anderson, B. W., (1986). Riparian habitat. In: A. Y. Cooperrider, R. J. Boyd, and H. R. Stuart (eds.). Inventory and Monitoring of Wildlife Habitat. Denver. BLM.

Ohmart, R. D., and Anderson, B. W., (1986). Riparian habitat. In: A. Y. Cooperrider, R. J. Boyd, and H. R. Stuart (eds.). Inventory and Monitoring of Wildlife Habitat. Denver. BLM.

Olson, J., (2014). All board: Navigating the course for universal adoption of the public trust doctrine, Vermont Journal of Environmental Law.

Orlowska, I., & Klepeis, P. (2018). Ethiopian church forests: a socio-religious conservation model under change. Journal of Eastern African Studies, 12(4), 674–695. https://doi.org/10.1080/17531055.2018.1519659.

Pinto, R., de Jonge, V., Neto, J., Domingos, T., Marques, J., & Patrício, J., (2013). Towards a DPSIR driven integration of ecological value, water uses and ecosystem services for estuarine systems. Ocean & Coastal Management, 72: 64-79.

Prigent, C., Papa, F., Aires, F., Jimenez, C., Rossow, W. B., & Matthews, A. E., (2012). Changes in land surface water dynamics since the 1990s and relation to population pressure. Geophysical Research Letters, 39, L08403,. doi:10.1029/2012GL051276, 2012.

Rahmato, D., (1999), Water resources development in Ethiopia: issues of sustainable and participation. Forum for Social Studies, Addis Ababa.

RCS (Ramsar Convention Secretariat). (2018). Global Wetland Outlook: State of the World's Wetlands and their Services to People. Gland, Switzerland: Ramsar Convention Secretariat.

RCS. (2005). Resolution IX.1 Annex A: A conceptual framework for the wise use of wetlands and the maintenance of their ecological character. Nineth Meeting of the Conference of the Parties to the Convention on Wetlands (Ramsar, Iran, 1971), Kam.

RCS. (2013). The Ramsar Convention Manual. (6th Edition). Ramsar Convention Secretariat (RCS), Gland, Switzerland. 109pp.

RCS. (2016). An Introduction to the Convention on Wetlands (previously The Ramsar Convention Manual). Ramsar Convention Secretariat, Gland, Switzerland.

RCS. (1971). Convention on Wetlands of International Importance especially as Waterfowl Habitat. Ramsar, Iran.

RCS. (1997).The Ramsarconvention manual: a guide to the convention on wetlands. Gland, Switzerland.

Rebecca, U. C., (2006). Plant communities of a wetland in western Ethiopia. Master of Science Thesis. Evolution and Biodiversity Department of Biology, University of Oslo, Norway.

Rosenzweig, C., Casassa, G., Karoly, D., Imeson, A. L., Liu, C., Menzel, A., Rawlins, S., Root, Seguin, T. L. (2007). Assessment of observed changes and responses in natural and managed systems. Climate Change, 2007: Impacts, Adaptation and Vulerabilty in Afrca, Cambrdge Press.

Sala, O. E., Chapin, F. S., Armesto, J. J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L. F., Jackson, R. B., Kinzig, A., Leemans, R., Lodge, D. M., Mooney, H. A., Oesterheld, M., Poff, N. L., Sykes, M. T., Walker, B. H., Walker, M., & Wall, D. H., (2000). Global Biodiversity Scenarios for the Year 2100. Science, 287(5459), 1770–1774. http://www.jstor.org/stable/3074591

SCBD (Secretariat of the Convention on Biological Diversity). (2018). 2018 UN Biodiversity Conference. Accessed from: https://sdg.iisd.org/events/2018-un-biodiversity-conference/.

Schlosberg, D., (2009). Defining Environmental Justice: Theories, Movements, and Nature. Oxford University Press.

Seid, G., (2017). The Status of Wetland Ecosystems in Ethiopia and Required Actions for Conservation, Journal of Resources Development and Management, 32 , p94.

Semu, A. A., & Workie, T. M., (2019). Ecological assessment and economic valuation of three wetlands in Eastern Hararghe, Oromia Regional State, Ethiopia. African Journal of Environmental Science and Technology, 13(10), 410–416. https://doi.org/10.5897/AJEST2018.250.

Serdeczny, O., Adams, S., Baarsch, F., Coumou, D., Robinson, A., Hare, W., Schaeffer, N., Perrette, M., (2016). Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions. Reg Environ Change, DOI 10.1007/s10113-015-0910-2.

Shapiro, B., et al., (2017). Ethiopia livestock sector analysis. International Livestock Research Institute (ILRI) Project Report. Nairobi, Kenya.

Shapiro, B., Gebru, G., Desta, S., Negassa, A., Nigussie, K., Aboset, G. & Mechal, H., (2015). A. Ethiopia livestock master plan. ILRI Project Report. Nairobi, Kenya: International Livestock Research Institute (ILRI). Nairobi, Kenya.

Shiferaw H., Bewket W., Alamirew T., Zeleke G., and Teketay, D., (2019). Implications of land use/land cover dynamics and Prosopis invasion on ecosystem service values in Afar Region, Ethiopia. Science of the Total Environment, vol: 675 pp: 354-366.

Simane, B., Beyene, H., Deressa, W., Kumie, A., Berhane., K., and Samet, J., (2016). Review of Climate Change and Health in Ethiopia: Status and Gap Analysis. Ethiop J Health Dev., 30(1 Spec Iss): 28–41.

Siraj, B., (2004). Wetlands of Oromia: Their conservation and contribution to food security and poverty reduction. Proceedings of the National Consultative workshop on the Ramsar Convention and Ethiopia, March 18-19, 2004, Addis Ababa Ethiopia. pp. 12-16.

Stephen, D., Abate, A., Bekhechi, M., Köhlin, G., Medhin, H., Mekonnen, A. . Wikman., A. A., (2017). Ethiopia Country Environmental Analysis (CEA): Realizing Green Transformation. Ministry of Environment, Forestry, Climate Change.

Suman, D. O., (2019). Mangrove Management in Coastal Wetlands, Accessed on https://www.sciencedirect.com/topics/earth-and-planetary-sciences/wasteland ,

Tamene, L., Mekonnen, K., Woldearegay, K., & Adie, A., (2014). Report of an integrated watershed management and water harvesting training workshop and experience sharing visit in the Ethiopian Highlands. Retrieved from: International Livestock Research Institute. https://cgspace.cgiar.org/bitstream/handle/10568/67034/AR_Ethiopia_iwrm_april2014.pdf?sequence=1&isAllowed=y

Tanner, C. C. and Sukias, J.P.S., (2003). Linking pond and wetland treatment: Performance of domestic and farm systems in New Zealand. Wat. Sci. Tech., 48(2), 335–343.

Teferi, E., Uhlenbrook, S., Bewket, W., Wenninger, J. & Simane, B., (2010). The use of remote sensing to quantify wetland loss in the Choke Mountain range, Upper Blue Nile Basin, Ethiopia. Hydrology and Earth System Sciences Discussions, 7, 6243–6284.

Teklehaymanot, T., (2009). Ethnobotanical study of knowledge and medicinal plants use by the people in Dek Island in Ethiopia. Journal of Ethnopharmacology, 124(1), 69–78. https://doi.org/10.1016/j.jep.2009.04.005.

Tesfaye, H., Warkineh, B. (2022). Macrophyte species diversity and distribution in relation to water quality of the Cheleleka Wetland in Ethiopia. African journal of aquatic science 2022 v.47 no.1 pp. 36-46.

Tesfaye. G., and Wolff, M. , (2014). The state of inland fisheries in Ethiopia: a synopsis with updated estimates of potential yield. Ecohydrology & Hydrobiology, 14 (3), pp. 200-219.

Tessema, A., Abdurohman, N. & Goudar, K., (2013). Mattress Making Using Typha latifolia and Cyprus Species of Chefa Wetland in Kemissie, Ethiopia: A Means for Livelihood Improvement. Fish Aquac J, 4: 082. doi: 10.4172/2150- 3508.1000082.

Tongul, I. A., & Hobson, M., (2013). Scaling up an Integrated Watershed Management Approach through Social Protection Programmes in Ethiopia: the MERET and PSNP Schemes, 15-16 April 2013, Dublin, Ireland, Case studies policy Responses, [http://www.mrfcj.org/pdf/case-studies/2013-0416Ethiopia-MERET.pdf].

Tudorancea, C., & Taylor, W. D., (2002). Ethiopian Rift Valley Lakes. Backhuys Publishers, Leiden, The Netherlands, ISBN: 90-5782-114-1. 289 pp.

UNDESA (United Nations Department of Economic and Social Affairs, Population Division). (2017). World Population Prospects: The 2017 Revision, custom data acquired via website. Retrieved from https://population.un.org/wpp/DataQuery/.

UNDP (United Nations Development Programme). (2006). Human Development Report 2006. Beyond scarcity: Power, poverty and the global water crisis, United Nations Development Programme, NY

Verhoeven, J. T., & Setter, T. L., (2010). Agricultural use of wetlands: opportunities and limitations. Annals of Botany, 105: 155–163.

Weller, M. W., (1988). Issues and approaches in assessing cumulative impacts on waterbird habitat in wetlands. Environ. Mgmt. 12:695-701.

WI (Wetland International). (2005). Annual Review. https://www.wetlands.org/publications/annual-review-2005/

Williams, S. J., Stone, G.W., and Burruss, A. E., (1997). A perspective on the Louisiana wetland loss and coastal erosion problem. Journal of Coastal Research, 13, 593.

Woldesenbet, A., (2019). Assessment of the biotic integrity and water quality of Lake Ziway. using benthic macroinvertebrate and diatom based multimetric index. Ph, D. Thesis. Addis Ababa University. 175pp.

Woldu, Z., & Yeshitela, Y., (2003). Wetland plants in Ethiopia with examples from Illubabor, South-western Ethiopia. In: Yilma D. Abebe and Kim Geheb (eds.) (2003). Wetlands of Ethiopia: Proceedings of a seminar on the resources and status of Ethiopia's wetlands. IUCN, Gland, Switzerland.

Woldu, Z., (2000). Plant Diversity in the Wetlands of Illubabor Zone. Report 3 for Objective 2 (Report 4 of 9), Ethiopian Wetlands Research Programme, Sustainable Wetland Management in Illubabor Zone, South-west Ethiopia.

Wolka, K., Tadesse, H., Garedew, E., & Yimer, F., (2015). Soil erosion risk assessment in the Chaleleka wetland watershed, Central Rift Valley of Ethiopia. Environmental Systems Research 4:5 DOI: 10.1186/s40068-015-0030-5.

Wondie, A., (2018). Ecological conditions and ecosystem services of wetlands in the Lake Tana Area, Ethiopia. Ecohydrology & Hydrobiology, 18(2), 231–244. https://doi.org/10.1016/j.ecohyd.2018.02.002.

Wondimagegn, T., (2019). Water quality assessment of Lake Hawassa, Ethiopia, using benthic macroinvertebrate and diatom-based multimetric index. Ph.D. Thesis, Addis Ababa University.

Wood, R. B., & Talling, J. F., (1988). Chemical and algal relations in a salinity series of Ethiopian inland waters. Hydrobiologia, 158: 29-67.

Worku, G., (2014). Shrinkage and Carbon Stock in Wetlands of Fogera Plain, North West Ethiopia. Journal of Environment and Earth Science. 4, No.13, 2014.

Wrona, F.J., Prowse T.D., Reist J.D., Hobbie J.E., Levesque L.M.J., Vincent W.F., (2006). Climate change effects on aquatic biota, ecosystem structure and function. Ambio 35, 359– 369.

Yirgu, Z., (2011). Accumulation of certain heavy metals in Nile Tilapia (Oreochromis niloticus) fish species relative to heavy metal concentrations in the water of Lake Hawassa. MSc thesis, Addis Ababa University.

Zerihun, Y., (2016). Ecohydrology-as a Nature Based Solution to Addressing Water Ecosystems Adverse Effects of Climate Change and Economic Development in Ethiopia [2nd African International Symposium]. http://mucp-mfit.org/wp-content/uploads/YZ-Presentation-ABUJA2.pdf.

5. Rangeland Ecosystem

Contributors

Corresponding Lead Author: Dr. Girma Balcha (PhD)

Lead Author: Adugna Tolera (Professor)

Contributing Authors: Abule Ebro (PhD)

Samuel Tufa (PhD)

Tessema Zewdu (Professor)

Editor: Getachew Gebru (PhD)

External Peer Reviewer: Kidane G/meskel (PhD)

Table of Contents

List of Tables

List of Figures

Executive Summary

Rangelands are defined as uncultivated areas of land that provide the necessities of life for grazing and browsing animals and other essential ecosystem services (well established). They are areas where moisture is sufficient for the growth of grasses and shrubs, but where climatic, anthropogenic and other environmental conditions inhibit or limit the suitability of the land for rain-fed crop production. Ethiopian rangelands occur in arid, semi-arid, and sub-humid zones suitable for extensive pastoral livestock production {5.1}.

Rangelands provide important ecosystem services, which can be classified into provisioning, regulating, cultural, and supporting (well established). They serve as source of feed for livestock and wild animals, food for humans, herbal medicine for both humans and livestock, energy, and gum and incense. The rangeland ecosystem also harbors a wide range of plant and animal biodiversity. It contributes to cultural identity and diversity, cultural landscapes, heritage values and spiritual services. For example, plant species such as *Ficus sycomorus* (locally known as Odaa) and *Pistachia falcata* are highly valued by the Borana pastoralists since they have spiritual and cultural associations. The rangelands are also areas of large wildlife diversity which are potential resources for tourist attraction {5.2.2}.

Rangelands provide important environmental services because of their ability to store carbon that helps in partially stabilizing climate (established but incomplete). Rangeland vegetation help to purify air and water, mitigate droughts and floods, and help in soil formation and maintenance of soil fertility. They facilitate the infiltration of water into the soil and help to maintain air humidity, reduce soil erosion by wind and water. Vegetation cover reduces soil loss as the root systems help bind the soil together, which is one of the most important environmental services in pastoral areas. Livestock husbandry contributes to soil nutrient cycling through feeding on plant species and depositing the residues/manure into the rangelands. However, unmanaged grazing or complete exclusion from grazing often leads to rangeland degradation and loss of biodiversity {5.2.2., 5.4.1.2., 5.4.2., 5.5.2., 5.5.3.}.

The land use/land cover change analysis showed that Ethiopian rangelands have undergone substantial changes since the 1960s (well established). Various rangeland management practices such as the establishment of fenced rangeland or grazing enclosures and haymaking are being practiced by different pastoral communities as a means of stocking feed for the dry season for the core breeding stock, mainly calves and lactating cows, to ensure continuity and sustainability of the pastoral production system. In due course, the expansion of grazing enclosures is leading to increased privatization of the traditional communal grazing lands {5.4.1.2}.

The expansion of various forms of enclosures and associated land-use changes are causing a gradual curtailment of seasonal mobility between wet and dry season grazing areas (well established). The expropriation of dry season grazing and watering areas has led to continuous grazing of the wet season grazing areas throughout the year resulting in loss of vegetation cover and soil erosion. Several anthropogenic pressures have led to the deterioration of the ecosystem, increasing soil erosion and destruction of palatable grasses under the changing climate and global warming. The growing shift towards sedentarization and crop cultivation, and privatization of communal rangelands in pastoral areas are triggering conflict over grazing and watering resources and boundary claims {5.3.2.2}.

Native bush encroachment and expansion of invasive alien species are prominent in rangelands where grazing pressure is high (established but incomplete). Woodland and grassland areas have been converted to some degree of bush encroachment, and the area of bush encroachment has increased due to the transformation of rangelands to other land use types {5.3.3.2}.

Natural and anthropogenic direct and indirect drivers of changes impact the Ethiopian rangelands, and thus rangeland biodiversity and ecosystem services are declining over time (well established). The root causes of these losses and disturbances are attributable to deforestation of important acacia species and inappropriate land-use that led to overgrazing of the limited grazing lands. In order to support the complementarities between pastoralism and rangeland biodiversity, several key investment and policy priorities for a sustainable social-ecological system should consider public investment in transport and market infrastructure, credit facilities, health, and education adapted to mobile lifestyle with policies supporting environmental protection {5.4.1.1, 5.4.1.2}.

The pastoral and agro-pastoral communities (PAP) in Ethiopia employ different techniques to manage rangeland resources (well established). These include mobility, herding, corralling, grazing reserves, the use of fire, etc., although the type/types of practice implemented and the level of implementation varies from one pastoral community to another. Unfortunately, the rich indigenous knowledge (IK) of the community is being lost from time to time because of different external and internal factors. The effects of the low level of awareness and the degradation of the knowledge base are reflected, amongst other things, in bush encroachment, invasion by alien species, deforestation, degradation and loss of wildlife habitats, desert expansion, vulnerability, and risks (e.g., drought); and livestock genetic dilution/losses. The benefits (ecosystem services) from the rangelands are declining, and so are the status and the management of the rangelands {45.5.2, 5.5.5.5}.

The pastoral and agro-pastoral communities employ different strategies, traditional systems and informal institutions for governance and management of rangeland biodiversity and ecosystem services (established but incomplete**)**. Different policies, formal institutions and governances have been imposed on the rangelands and the pastoral communities by the successive governments of Ethiopia, which have implications on rangeland biodiversity conservation and ecosystem services. Consequently, the Ethiopian rangeland biodiversity and ecosystem services are degrading from time to time making groups subsisting on extensive livestock rearing most vulnerable and insecure. Furthermore, the traditional institutions that govern the rangelands are breaking down. Although recent trends show improved attitudes towards pastoralism and pastoral policies, the development policies (e.g., land tenures system; settlement) implemented by the successive governments have negatively impacted the rangeland resources {5.1, 5.6.4.1, 5.6.5}.

Key findings

Rangeland Ecosystem's Benefits to People and Quality of Life

- Rangelands provide important ecosystem services, which can be classified into provisioning, regulating, cultural, and supporting,
- They serve as sources of feed for livestock and wild animals and source of food for humans, herbal medicine, energy, and production of gum and incense,
- Rangelands harbor a wide range of plant and animal biodiversity. They are areas of large wildlife diversity, which are potential resources for tourist attraction,
- Livestock husbandry contributes to soil nutrient cycling through feeding on plants and depositing the residues/manure into the rangelands. However, unmanaged grazing or complete exclusion from grazing often leads to rangeland degradation and loss of biodiversity,
- Rangelands can store carbon that helps in partially stabilizing climate. Rangeland vegetation helps to purify air and water, facilitates infiltration of water into the soil and mitigates droughts and floods, helps in soil formation and maintenance of soil fertility, maintains air humidity, and reduces soil erosion by wind and water and
- Rangeland ecosystem contributes to cultural identity and diversity, cultural landscapes, heritage values, and spiritual services.

Status, trends and future dynamics of rangeland biodiversity and ecosystem underpinning nature's benefits to people

- The land use/land cover (LULC) change analysis in most parts of Ethiopia showed that the rangelands had undergone substantial changes since the 1960s,
- The pastoral areas are showing gradual changes such as the establishment of fenced rangeland or grazing enclosures leading to increased privatization of the traditional communal grazing lands,
- The expansion of various forms of enclosures and associated land-use changes are causing a gradual curtailment of seasonal mobility between wet and dry season grazing areas, which has led to continuous grazing of the wet season grazing areas throughout the year, resulting in loss of vegetation cover and soil erosion,

- Several anthropogenic pressures, under the changing climate and global warming, have led to the deterioration of the ecosystem, increasing soil erosion, loss of palatable grasses and increased bush encroachment, and
- The growing shift towards sedentarization and crop cultivation and privatization of the communal rangelands in pastoral areas are triggering conflict over grazing and watering resources and boundary claims.

Direct and indirect drivers of changes in rangeland biodiversity and ecosystem services

- Major direct drivers in rangeland affecting biodiversity and ecosystem services in Ethiopia are climate change and variability, fire ban, inappropriate rangeland management, land-use change, overexploitation, inappropriate extension service, privatization, and/or sedentarization, encroachment by native and invasive alien species,
- Some of the direct drivers such as land-use change, privatization, sedentarization, and encroachment by native and invasive alien species lead to constrained mobility and population pressure which in turn negatively affect the rangeland biodiversity and ecosystem services. In addition; policy, governance systems, and formal institutions indirectly contribute to weakening of customary institutions leading to changes in rangeland biodiversity and ecosystem services, and
- Because of the combined effects of the above factors, the Ethiopian rangeland biodiversity and ecosystem services have been degrading at an alarming rate which, in turn, led to the extent where the ecosystem services could not support the livelihoods of communities dependent on rangeland resources.

Level of awareness and knowledge about rangeland biodiversity and ecosystem Services

- The decline in and loss of rangeland biodiversity is partly attributed to the low attention given to the sector, which has resulted in a gradual loss of the associated indigenous knowledge (IK),
- The prevailing policy and governance systems in the pastoral areas emphasize poverty reduction and development efforts focusing on resource extraction aimed at short term gains at the expense of long term biodiversity conservation and sustainability,
- The challenges to knowledge (IK and scientific) include epistemological (differing nature of knowledge), institutional (e.g., obstacles erected usually by the government or other

institutions), local culture' barrier to scientific knowledge, weak knowledge development and management system, research and innovation gaps, and

- Addressing the challenges on the level of awareness and knowledge on rangeland biodiversity and ecosystem services amongst many includes provision of targeted training, awareness creation, implementation of an outreach program, developing knowledge management system, engaging diverse stakeholders, and undertaking detailed research in rangeland biodiversity and ecosystem services. Emphasis needs to be given to the development of a knowledge base for payment for ecosystem services (PES).

Impacts of policies, institutional arrangements and governance

- Despite the presence of general biodiversity and environmental policies, institutional arrangements, and governance; the country does not have a clear rangeland policy. Customary institutions that have traditionally been governing the rangelands are getting weaker as they are becoming dominated by formal institutions,
- Limitations related to policies, governance, and institutional arrangements include the lack of clarity in the direction of rangeland development, the gap in properly understanding the scope and depth of pastoral knowledge and the associated little attention given to the knowledge domain,and the weakening of customary institutions; and this resulted in poor governance, and a consequent degradation,
- Despite the vast area of the rangelands and their economic importance, the effort made to support the sector by establishing appropriate institutions has been minimal. Furthermore, a standalone rangeland policy is lacking. These situations contributed to the progressive decline in the conservation status of rangeland biodiversity, and
- There is a lack of adequate research that examines the effectiveness of policies, governances, and institutional arrangements in place taking into account different needs of the government and that of the pastoral communities. This limitation has contributed, though indirectly, to the harm that happened to rangeland ecosystem.

To overcome the above mentioned shortcomings and impacts, there is a need for clear pastoral friendly rangeland policy that promotes improved and resilient rangeland-based livelihoods and that takes into consideration cultural, historical and economic aspects of the pastoral system such as land use and tenure, mobility (domestic and crossborder), trade (particlurly of livestock), conflict resolution, risk mangement, and investment and development.

5.1 Introduction

Rangelands are defined as uncultivated areas of land that provide the necessities of life for grazing and browsing animals. They are areas where moisture is sufficient for the growth of grasses and shrubs, but where climatic and other environmental conditions limit the suitability of the land for rain-fed crop production. The major rangeland types of the world are grasslands, desert shrublands, savanna woodlands, forests and tundra. Over 50% of rangelands are in the arid and semi-arid lands, while they provide about 70% of the global forage for both domestic and wild ungulates (Derner et al., 2006) in the form of grazing and browsing (Holechek et al., 2005). In Africa, rangelands are the major sources of feed for ruminants and constitute about 65% of the total land area (Friedel et al., 2000) which supports 59% of all ruminant livestock in the continent. Ethiopian rangelands are found in arid, semi-arid, and sub-humid zones. However, based on the classical definition of a rangeland, all the Ethiopian national parks and sanctuaries are found in the different areas of the rangeland ecosystem. As such, all the ecosystems covered under different chapters of this book deal with at least some aspect of the rangelands, with the exception of the agroecosystem. Nevertheless, this section covers in depth the arid, semi-arid and sub-humid ecologies, where extensive pastoral livestock production is practiced.

Rangelands, beside their role in providing the feed base for grazing and browsing livestock; deliver other important services such as regulating water flow along catchments, acting as biodiversity reserves, and serving as carbon sinks to mitigate greenhouse gas emissions. Pastoral livestock production is the main means of land use in these environments, where grazing animals are the principal practical method of exploiting natural vegetation. Pastoralism is considered the most appropriate strategy of maintaining the well-being of communities in drylands and other landscapes that are marginal for crop production. In general, rangelands are essential to the livelihood of pastoralists and agro-pastoralists and they are capable of conserving ecosystem services, promoting wildlife conservation, and honoring cultural values and traditions (Neely et al., 2009).

Traditionally, rangelands are used for extensive livestock production, tourism, forestry and other livelihood activities. They play important roles in livestock production in Ethiopia. The Ethiopian rangelands harbor about 28% of cattle, 26% of sheep, 66% of goats, and 100% of the camel population of the country and support pastoral and agro-pastoral communities of about 15 million people (Shitarek, 2012). The Ethiopian rangelands are found mainly in the major pastoral areas of Somali and Afar Regions, Borana and Bale lowlands of Oromia Region as well as in the South Omo Zone of the Southern Nations, Nationalities and Peoples Region (SNNPR). The livestock resources have significant economic and social importance at the household levels, and these make significant contributions to the national economy and foreign currency earnings of the country. Over 90% of the live animal and meat export from Ethiopia comes from the rangelands of the southern and eastern parts of the country.

Rangelands also provide important environmental services because of their ability to store a high amount of carbon stock. Rangelands also offer opportunities for producing high-quality premium and/or niche foods which have high market value compared to similar products derived from intensive livestock production systems. In addition, rangelands are home for a wide range of plant and animal diversity including plants useful for medicine, gum and incense production, and other uses. Numerous wild edible fruits, seeds, tubers, bark, gums and leaves are used by pastoralists as food or medicine.

Rangelands are not only mere grazing lands for livestock production and wild animals, but also are natural resource management systems that provide a wide range of services and nationally and globally valued products. Multiple values are associated with rangelands and pastoral production systems, and only some of these values can be measured while others cannot (WISP, 2007). The direct values of rangelands include measurable products and outputs such as milk, meat, fiber, and hides and skins. A wide range of livestock products are obtained from rangeland livestock production depending on the context, the demands of the producer and the mix of livestock species held. Pastoralists also routinely engage in the marketing of livestock and livestock products in domestic and international markets through both formal and informal channels. Thus, pastoral livestock production makes a significant contribution to the national economy and export earnings of the country.

Indirect values of rangelands include tangible values such as inputs into agriculture (manure, traction, and transport) and complementary products such as gum Arabic, honey, medicinal plants, wildlife, and tourism. They also include less tangible values such as ecosystem services (e.g. biodiversity, nutrient cycling and energy flow), and a range of social and cultural values (WISP, 2007). In general, healthy rangelands are of value to many more stakeholders than pastoralists as they provide benefits to non-pastoralist communities as source of dairy, animal skin and hides, and plant products(such as gum, resins and henna) and also for tourists and the tourism industry. They also provide ecosystem services that have global benefits such as the replenishment of watersheds or the sequestration of carbon. Environmental services such as carbon sequestration, protection of biodiversity, and combating desertification are increasingly valued in the global context (Derner and Schuman, 2007). This review was carried out to elicit the various direct and indirect benefits of rangeland ecosystem to people and quality of life.

Range inventory and monitoring are essential features of a range management plan. The primary purpose of range inventory is to provide an accurate representation of existing conditions of the range. Range monitoring, on the other hand, is an evaluation process usually conducted to determine the response of range vegetation to management programs. Rangeland condition describes an evaluation of the current status of rangeland vegetation. It refers to the state of the health of the rangeland. In addition, range condition is used as a guide to ensure sustainable rangeland use, determine rangeland carrying capacity and adjust stocking rates as well as identify potential responses to rangeland improvement programs. On the contrary, rangeland trend refers to the change in the status of rangeland resources at a site detected by monitoring and is usually expressed as improving, declining or stable. Most importantly, the rangeland trend is an ecological assessment relating current species composition so that improving rangeland trends usually reflect more desirable conditions for livestock production and rangeland stability. Therefore, the rangeland trend is considered upward (improving), downward (declining), or stable range condition or range health.

Understanding the responses of vegetation to different biotic and abiotic factors is crucial to facilitate the management of arid and semi-arid rangeland ecosystem for both biological conservation and sustainable use. This is because proper rangeland management is the manipulation of rangeland components to obtain optimum goods and services on a sustainable basis through protecting and enhancing the soil and vegetation complex in a given rangeland ecosystem (Holechek et al., 2005). Therefore, a thorough knowledge of the status, trend and future dynamics of rangeland ecosystem is essential for a better understanding of rangeland management.

It is important to understand the drivers of change in rangeland biodiversity and ecosystem services to make informed decisions in managing rangeland biodiversity and ecosystem. It is of paramount importance to identify the driving pressures of change to know more about the impacts of natural and anthropogenic activities on rangeland biodiversity and ecosystem services (Yang et al., 2016). Climate change and variability, fire ban, inappropriate rangeland management, land-use change, overexploitation, inappropriate extension service, privatization and/or sedentarization, encroachment by native and invasive alien species, policy, governance systems and institutions are the major factors that cause rangeland biodiversity and ecosystem services to change over time (Fentahun et al., 2018; Harris, 2010; Roselle et al., 2011). The rangeland ecosystem assessment has set out to review existing knowledge about the direct and indirect pressures that drive changes in the Ethiopian rangeland biodiversity and ecosystem services. Direct drivers are factors directly influencing the ecosystem, while indirect drivers are factors affecting the way direct drivers affect those changes. Biodiversity and ecosystem services are sensitive to the way the resources and landscapes are managed and utilized (Callesen, 2016). Analysis of change drivers in rangeland biodiversity and ecosystem services is the primary step to acquire a better understanding on how and why the changes are happening.

High level of awareness and knowledge of actors are among the most important factors that determine the success of rangeland biodiversity and ecosystem services (e.g., ADB, 2014; Venuste, et al., 2017). In addition to provisioning, rangelands provide ecosystem services such as regulating, supporting and cultural services which are not mostly remunerated. Much less attention has been paid to the potential of incentive schemes in rangelands in developing countries like Ethiopia except availing some fund for REDD$^+$ (reducing emissions from deforestation and forest degradation, plus conservation, sustainable management of forests and enhancement of forest carbon stocks). This is partly attributed to the low level of awareness and knowledge regarding payment for ecosystem services. Thus, this requires efforts to raise the level of awareness regarding rangeland biodiversity and ecosystem services among the public at different levels and dedicate due attention to indigenous and local knowledge (ILK) of pastoral and agro-pastoral communities. There is also a need to review, document and apply ILK of the communities, integrating with the mainstream modern knowledge component to solve some critical rangeland problems.

The pastoral communities and their knowledge on biodiversity conservation represent one of the oldest traditionally valuable systems in eastern Africa including Ethiopia (Coppock, 1994; Herlocker, 1999; Abule, et al.,, 2005; Angassa, 2012; Oba, 2012; Tibebu, 2012; Sintayehu et al., 2013; EBI, 2015; Dika, 2016; Minyahel et al., 2017; Yeneaheyu, 2018). The communities and their socio-cultural relationship with biological systems have largely been contributing to the sustainable conservation of biodiversity (Yeneayehu, 2018). Accordingly, natural resource management (NRM), including rangeland biodiversity and ecosystem services in the pastoral areas is conducted according to ILK systems (Herlocker, 1999; Oba, 2012). Such knowledge plays a key role in linking ecological variability, flexible production strategies and local institutions for sustainable NRM (Niamir, 1999; Tibebu, 2012). Therefore, this assessment is based on a critical review of literature and evaluation of information to capture the existing level of awareness and knowledge regarding rangeland biodiversity and ecosystem services in different rangelands of Ethiopia. The nature of challenges to local involvement, particularly the incorporation of indigenous knowledge into decision making on the management of rangeland biodiversity and ecosystem services has been reviewed and documented the consequences for rangeland biodiversity conservation and ecosystem services.

To sustain their system of production, communities residing in the Ethiopian rangelands have implemented strategies such as the customary institutions and rangeland resources governance system. In addition to these; different policies, institutions and governance structure are imposed on the rangelands and the pastoral communities by the successive States in Ethiopia (Diresse, 2010; Huig, 2013; Mohammed, 2015; Getahun, 2016) and these impacted on rangeland biodiversity, ecosystem services and livelihood of the communities.

The past formulation of pastoral-related policies in Ethiopia were based on general misconception and inappropriately premised generalizations about the pastoral mode of life. (Mohammed, 2015). Pastoralists were in the past named as '*Zelan*', which became a derogatory term because, in the present context, the term implies 'to wander around without aim' (Brocklesby et al., 2010). Reasons for this perception towards pastoralists are the characteristic mobility of pastoralists, which is perceived by formal government structures as posing difficulty to administratively control these groups. This perception began to change after 1995, although it is still very far from being adequate.

Over the past three decades, most sub-Saharan African (SSA) countries including Ethiopia have developed national policies, legislations, plans and institutions geared towards biodiversity conservation and management (Ozor et al., 2016). This is a welcome development, but still raise such critical questions as how much of these are well-tailored to rangeland and, whether there is a clear rangeland development policy in the country that guides the management and conservation of rangeland biodiversity and ecosystem services. Recent studies in Ethiopia and other East African countries (EPCC, 2015; Beyene, 2016) support this view and have shown that the management of rangelands for sustainable development remains to be one of the major challenges facing researchers, policymakers and development practitioners. Thus, there is a need to properly review the rangeland policies, institutional arrangements (customary, governmental, and non-governmental), and governance structures and better understand the impact these have on the conservation and management of rangeland biodiversity, use of ecosystem services and welfare of pastoral communities in Ethiopia.

5.2 Rangeland ecosystem's benefits to people and quality of life

The rangelands in Ethiopia provide multiple functions such as a habitat for a wide array of domestic and wild animal species as well as for a diverse range of plant species. Rangeland ecosystem goods and services (EGS) are important to satisfy the needs of humans who are dependent on these resources or who benefit from the resources in one way or another. The ecosystem goods and services include provisioning, regulating, cultural and supporting services. The rangeland ecosystem goods and services may also be grouped into tangible goods, tangible services, and intangible services, the last one being primarily perceptual.

5.2.1 Provisioning services

In the pastoral areas of Ethiopia, livestock products serve as major sources of food (milk, meat, eggs, and blood) and non-food items such as transport services. They are also major sources of cash income and a measure of wealth and social status. Overall, livestock resources have significant economic and social importance at household levels and make significant contributions to the national economy and foreign currency earnings of the country through the export of live animals, meat as well as hides, skins and leather products. The livestock resource in Ethiopia sustains and supports the livelihoods of an estimated 80% of the rural population (FAO, 2004) and it contributes 15 to17% of overall GDP and 35 to 49% of agricultural GDP

(Behnke and Kerven, 2010), and 37 to 87% of the household incomes. Live animals and livestock products such as meat, hides and skins are the third major export items accounting for 11% of the export revenue (Hurrissa, 2009). Over 90% of the live animal and meat export comes from rangeland based livestock production in the pastoral areas. Particularly the pastoral areas in the south and southeastern parts of the country are the prime sources of animals for conditioning in feedlots and for those destined for meat and live animal export (Tolera and Eik, 2020).

Ethiopian rangelands, like other rangelands elsewhere, offer opportunities for producing high-quality premium and/or niche foods with high market value than similar products derived from intensive livestock production systems. Forage diets impart small and some beneficial effects on meat and milk quality, particularly in relation to the fatty acid profile and antioxidant content quality (Dunne et al., 2009; Doreau et al., 2011; Doyle et al., 2001). In recent years, there has been an emergence of social subgroups willing to pay price premiums for foods and other livestock products which are perceived to have been produced in a natural, environmentally friendly, and welfare-friendly manner; particularly in developed countries (Boval and Dixon, 2012). This indicates the potential for pastoral livestock and livestock products from Ethiopian rangelands, because people are willing to pay premium. A good example is the preference of Ethiopian meat consumers for beef from Boran cattle as well as for meat from Blackhead Somali sheep and Somali goats.

Livestock largely depends on rangelands consisting of native vegetation (grasses, bushes, shrubs as well as tree leaves and pods), which may be augmented by crop residues as annual rainfall increases in the agro-pastoral production systems. Thus, the consumption of forage by livestock and wildlife is the main extraction of rangeland ecosystems goods. The rangelands also serve as sources of surface (rivers, ponds, etc.) and ground (wells) water used for drinking and irrigation purposes. Of 327 plant species identified by Gemedo-Dalle et al. (2005) in the Borana rangelands of southern Ethiopia, 76% of the useful plants were identified as forage species, distributed among 45 families and 119 genera. Furthermore, of the 188 forage species encountered in the same study, 41, 25, 19 and 12%, trees and shrubs, grasses, forbs, and % climbers, respectively; including both woody and herbaceous climbers, and 3% sedges (Gemedo-Dalle et al., 2005). Rangelands play an important role in the livelihoods of pastoral communities as inputs for livestock production and as a habitat to a variety of wildlife resources.

Different parts of various plant species are extracted from the rangeland ecosystem for use as sources of food for direct human consumption. For example, most common wild edible plants used by the Afar pastoralists of Ethiopia include species such as *Dobera glabra*, *Cordia sinensis*, and *Balanites rotundifolia*. Similarly, the Borana pastoralists of Ethiopia and Kenya use at least 100 plant species for medicinal purposes (WISP, 2007). Gemedo-Dalle et al. (2005) reported that 41 plant species, distributed among 23 families and 31 genera were identified as sources of food in Borana rangelands of southern Ethiopia. The study further noted that 66% of the edible plant species were trees and shrubs whereas forbs and climbers make up 20% and 15%, respectively. In general, numerous wild fruits, seeds, tubers, bark, gums, and leaves are used by pastoralists for human consumption as food or medicine. According to Gemedo-Dalle et al. (2005), fruits were the parts eaten in about 78% of the food plants identified in their study whereas roots/tubers were reported to be edible in about 15% of the food plants. The most commonly eaten fruits in the Borana pastoral area are the fruits of *Grewia* species, particularly that of *Grewia villosa* (locally known as "Ogomodii") whereas the most preferred tuber eaten by both humans and livestock is the carrot-shaped whitish tuber of *Vigna friesiorum*. In addition to the tuber, the study also indicated that the fruits of *Vigna friesiorum* are also eaten by people while its leaves are used as animal feed. Herders also chew the gum of *Acacia seyal* Del. and *Acacia senegal* as a source of food and chewing gum (Gemedo-Dalle et al., 2005). In addition, it was reported that the inside part of the papery bark of *Acacia hockii* is also eaten.

Various plants are extracted from the rangeland ecosystem for various purposes such as herbal and medicinal uses (Kane, 2006). Herbal medicine is likely to be of increasing importance in the future because of the limited availability and high cost of modern medicine as well as the development of drug resistance with repeated use of conventional drugs. Gemedo-Dalle et al. (2005) reported that 17% of the useful plant species in the Borana rangelands of southern Ethiopia were identified as medicinal plants. These plant species were distributed among 25 families and 34 genera, among which 56, 25, 12, 5, 2%, were trees/shrubs, forbs, woody climbers, succulents and % were grasses, respectively. Leaves and roots were reported to be the most frequently used parts followed by exudates (Gemedo-Dale et al., 2005). Similarly, a survey conducted by Tolossa et al. (2013) in South Omo (on local healers of Aari, Maale, and Bena-Tsemay ethnic groups) documented 91 plant species distributed across 33 families and 57 genera as having medicinal properties against 34 human and livestock ailments complementing previous studies from other ethnic groups in Ethiopia.

Similarly, results of different ethnobotanical studies on medicinal plants have been reported from Afar and Somali Regional States as well. Giday and Teklehaymanot (2013) reported 49 medicinal plants used for treatment of different livestock ailments by the Afar people based on a study conducted in Ada'ar district of the Afar Regional State. Similarly, Alebie and Mehamed (2016) reported 47 medicinal plants; whereas Bilal et al (2017) reported 45 medicinal plants used by traditional healers in the Jigjiga area of the Somali Regional State; and these communities in the Jigjiga district depend on medicinal plants for treatment of a wide spectrum of human ailments. A study by Mesfin et al. (2012) reported on the use of 27 antimalarial plants in the Shinile district of the Somali Region.

Rangeland ecosystem maintains biological diversity and support the production of goods such as forage, timber, biomass fuels and natural fibers which are precursors to many pharmaceuticals and industrial products. Rangelands are home for a wide range of plant and animal biodiversity, including plants useful for medicine, gum and incense production and other uses.

The rangelands are also home for different species and breeds of domestic livestock, notably cattle, camels, sheep, goats, and equine. About 28% of cattle, 26% of sheep, 66% of goats, and 100% of the camel population of the country are found in the rangeland based lowland production systems (Mengistu, 2007). Important livestock breeds such as the Boran cattle breed, the Black Head Somali and Afar sheep, the Somali and Afar goats, the large Somali camels, and small Afar camels are among the most notable livestock resources in the pastoral lowlands. Herd diversity is a critical means of managing the floristic diversity of the rangelands. Hence, pastoralists maintain diverse species of animals to harness a wide range of pasture and browse species, and to optimize the productivity and resilience of their livestock resources (WISP, 2007).

In addition to extensive livestock production, the rangelands also support a diversity of wildlife populations, and hence play important role in wildlife conservation in Ethiopia. Most of the national parks and wildlife reserves are located in the pastoral areas. Discussion with community members in the southern rangelands indicated that the Borana rangelands used to be covered with savannah grasslands and inhabited by diverse wildlife species such as giraffe, elephants, buffalo, rhinoceros, zebra and antelopes. However, nowadays most of the wildlife has disappeared or fled to neighboring Kenya because of the degradation of the ecosystem.

The rangeland ecosystem provides energy in the form of biomass (firewood, charcoal, and agro-industrial by-products such as bagasse from the sugar industry), biofuel feedstocks, animal manure (dried dung and biogas), hydro-power, geothermal, solar and wind energy. Various plants are extracted from the rangeland ecosystem for use as sources of fuel as well as to serve as construction materials. The generation of hydropower energy is possible only in an area where big and perennial rivers are available and the terrain is suitable for hydropower development. Although an adequate year-round water supply is one of the challenges experienced in the pastoral areas of Ethiopia, there are large perennial rivers such as Awash and Omo that cross through some parts of the rangelands, and that could serve for generation of hydropower. The rangelands can also serve as sources of solar and wind energy with a potential of serving as a means of off-grid rural electrification (Benti, 2017).

The Ethiopian rangelands include different landscapes with diverse habitats at different elevations, with different rainfall and vegetation types, ranging from dry grasslands to evergreen forests. The rangelands are areas of large wildlife diversity, which are potential resources for tourist attraction. Available evidence indicates that tourism in the rangeland ecosystem of pastoralist areas is important for the national economy and provides employment and livelihood support to pastoralist groups to conserve wildlife. Most of the Ethiopian national parks, wildlife sanctuaries and game reserves are located in the pastoral areas. The Awash national park is one of the main national parks located in pastoral areas located partly in Afar Region and partly in in Kereyu pastoral area of East Shewa Zone of Oromia Region. Other parks and wildlife sanctuaries located in the rangeland areas include Netchsar, Omo, Mago and Chelbi in Southern Nations, Nationalities and Peoples Region (SNNPR); Yangudi-Rassa, Alledeghi, Gewane and Mille Serdo in Afar; Yabello and Abijata-Shala parks in Oromia; and Geralle in Somali Region (Vreugdenhil et al., 2012). The analysis of Ethiopian official statistics and visitor numbers also indicate that pastoralist areas located in the lowlands and Rift Valley areas support the largest share of the Ethiopian tourism economy.

The participation of pastoralists in tourism-related activities has been suggested as an income diversification strategy that could significantly contribute to their livelihood. When humans derive financial benefits both from wildlife (through tourism) and from livestock (through food production), they may achieve greater economic stability than when income is derived solely from one source. The integrated management of wildlife and livestock can simultaneously improve human health and wildlife conservation with a likelihood of occurrence conflicts. Thus, the need for optimization of human and wildlife benefits which requires the management of ecological and socioeconomic trade-offs, when conflicts occur between stakeholders (Allan et al., 2017). Evidence from diverse countries suggests that revenues from tourism are usually small. In addition, the distribution of payments is usually implemented based on the area of land owned or managed by each pastoralist households. As a result, payments usually reinforce the position of local elite groups, maintaining or increasing inequity within pastoralist communities (Lamprey and Reid, 2004). Although the tourism industry provides employment and small payment opportunities, most of the benefits are captured by middlemen and owners of large tourism facilities, who are often not members of the local communities, indicating that most of the profits are transferred to those outside of pastoralist areas.

In addition to serving as a major source of feed for livestock, rangelands provide a broad set of environmental goods such as firewood, gum, incense, and wild fruits. The pastoral communities protect the trees that give these products. These trees have dual function: feed for browsers and income generation for people through sale of gums and incense. Plants used as sources of gum and resins in Borana rangelands include *Boswellia neglecta* S. Moore, *Boswellia microphylla* Chiov., *Commiphora corrugata, Commiphora kua, Acacia senegal, Acacia drepanolobium,* and *Acacia seyal* (Gemedo-Dalle, 2005). The same study also indicated that the gum of *Acaia senegal* is collected and sold in the local market whereas the gums from *Boswellia* and *Commiphora* species were reported to have high commercial values. *Boswellia* and *Commiphora* species are sources of gums such as frankincense and myrrh that are used for fragrance and flavor. *Acaia senegal* is known for producing Gum Arabic, one of the most important items exported by Sudan (Gemedo-Dalle et al., 2005). The inner wood of *Erythrina melanacatha*, *Lannaea rivae, Delonix elata*, are used by Borana pastoralists to make utensils for food preparation and containers for milk storage.

Goods collected from the rangelands could significantly contribute to household income and the national economy. Pastoralist households show differentiation in type of product collected such as wild fruits, gum and incense, construction material, and fodder resources. Findings suggest that the largest share of the income of the poor is largely derived from the collection of wild fruits, vegetables, and firewood, while the rich, who own larger herd, appropriate more of the grassland resources, because of the higher return from livestock compared to other alternatives. Thus, inequity in livestock ownership explains the different patterns of environmental income, the use of natural resources in pastoralist areas and the pathways in the accumulation of wealth (Ellis, 2000). In addition, there are actual or potential mineral resources, a rich deposit of natural oil and gas in the lowland pastoral areas of Ethiopia (Getachew, 2001; Abule, 2003). Typical examples include the crater lakes that produce minerals for livestock consumption.

5.2.2 Regulating services

Rangeland vegetation play important roles in moderating and regulating local climate by acting as windbreaks, providing shade for animals and people, and storing carbon in the soil and in the vegetation. The predominant discourse on pastoralism and the environment concerns the 'degradation caused by pastoralists' rather than the services provided by pastoralism. However, many environmental services which are provided by pastoralists are poorly understood and are not captured by national accounts or usually go un-valued. Proper livestock grazing in rangelands can contribute to maintaining healthy vegetation, which captures carbon, reduces erosion, maintains soils and facilitates water holding capacity (Savory, 1999). The rangelands may also provide services such as pollination of crops and natural vegetation and protection from the sun's ultraviolet rays. However, the benefits could be lost if the rangelands are mismanaged leading to overgrazing and degradation of the rangelands, resulting in feed and water scarcity.

Effective grazing management has been shown to improve biodiversity and can be a tool to prevent land degradation and desertification. Grazing and animal impact can stimulate pasture growth, reduce invasive weeds, and may improve mulching and mineral and water cycling (Sanderson et al., 2004). Animal feces during mobility also help to transmit plant seeds and multiplication. Rangeland ecosystem health and integrity are much greater where mobile livestock keeping continues to be effectively practiced (Niamir-Fuller, 1999). In quantitative terms, estimated the value of maintenance of biodiversity in grasslands in about USD 7.5 per hectare per year. However, this figure might show variation between sites, considering the inclusion of animal species living in the grassland and the willingness of people living outside pastoral areas to pay for conserving biodiversity.

Carbon dioxide (CO_2) is one of the greenhouse gases associated with climate change and global warming. Hence land uses that offset atmospheric CO_2 emissions through carbon storage in plants and soils are considered environmentally friendly (Lal, 2001). Rangelands provide important environmental services because of their ability to store a high amount of carbon stock. Comparison of different rangeland landscapes shows that shrublands store more total carbon stocks, followed by grasslands and woodlands. Woodlands store the least carbon stocks and this is possibly due to less herbaceous vegetation cover, which does not facilitate an adequate rate of plant material decomposition for soil carbon formation. Thus landscape types with more herbaceous cover are often thought to have a relatively higher rate of organic matter decomposition compared to a woody type of vegetation (Rice, 2005). Well managed grasslands can store up to 260 tons of carbon per ha, thus providing important benefits for climate change adaptation (FAO, 2007). Rangelands can store up to 30% of the world's soil carbon, over and above the substantial amount of above-ground carbon stored in trees, bushes, shrubs, and grasses (White et al., 2000; Grace et al., 2006). These findings depict the importance of pastoral areas in preventing the release of CO_2 that could influence the climate.

Most of the carbon sequestered in the rangelands is stored in the soils. Thus, any anthropogenic activities that might have adverse effects on the soil will have significant implications in reducing carbon stocks in the grazing lands. For example, the cultivation of grazing lands is known to reduce carbon stocks due to the disturbance of the soil surface (Jiao et al., 2009). This accounts the loss of about 95% of the aboveground carbon and up to 60% of the below-ground carbon stock (Reid et al., 2004). Lal (2004) indicated that soil carbon sequestration may serve as a bridge in addressing the global issues of climate change, desertification and loss of biodiversity, linking the three inter-related UN conventions. Increasing the amount of carbon sequestered as soil organic matter can enhance rainfall effectiveness through increased water holding capacity and water source replenishment to better withstand times of drought. The co-benefits of carbon sequestration may also provide a direct link to the Sustainable Development Goals (SDGs) through their effect on food security and poverty alleviation.

The capacity to sequester carbon depends on the climatic zone, the history and the status of land resources such as soil and vegetation. Grasslands store considerably more carbon in the soil than in the vegetation. Compared to forests, grasslands store relatively less carbon per unit area. However, grasslands have the potential for storing a significant amount of carbon because they cover extensive land areas (White et al., 2000). There is a significant potential to improve this function of the rangelands, covering >60% of the landmass in Ethiopia, through rehabilitation and improved range management practices. Currently in the vast extent of rangelands, large areas of the rangeland resources are degraded. Sequestering soil carbon in well-managed grasslands and rangelands provide both mitigation and adaptation benefits. It reduces water losses from evaporation and run-off, thus taking advantage of the rain that does fall, and also can enhance biological diversity (Neely et al., 2009).

In non-equilibrium systems, livestock also play an important role in carbon sequestration through improved pasture and rangeland management (Steinfield et al., 2006), which includes the following mechanisms:

- Proper livestock grazing stimulates grasses for vigorous growth and healthy root systems,
- The grazing process can be used to feed livestock and soil biota through maintaining soil cover (plants and litter) and managing plant species composition to maintain feed quality,
- Providing adequate rest from grazing without over-resting the plants, and
- Understanding rangeland productivity is dependent on the mobility of livestock (Niamir-Fuller, 1999).

Changes in rangeland soil carbon can occur in response to a wide range of management and environmental factors such as improper grazing, fire, fertilization practices and conversion of grasslands to croplands (Neely et al., 2009). Bikila, et al. (2016) studied carbon sequestration potentials of three grazing management practices, namely communal grazing, grazing enclosures (rangelands enclosed for 20 years for dry season grazing) and a rangeland managed for five years after prescribed fire. The study indicated that the below ground carbon stocks were higher compared to the above ground carbon stocks in all the three management systems. Carbon stock in trees, shrubs and in the soil were higher in enclosed rangelands whereas carbons stocks in grasses was higher in rangelands managed by prescribed fire. The total carbon stock was higher in enclosed rangelands (300.4t C ha^{-1}) compared to rangelands managed by prescribed fire

(184.9t C ha^{-1}) and in communally grazed areas (141.5t C ha^{-1}). Thus, rangeland management plays a key adaption and mitigation strategy for addressing climate change and variability.

Large pastoralist areas like tropical savannas and rangelands represent locations with a great potential for carbon store, and pastoralism can be effectively used to promote this potential. A very important knowledge gap remains, however, between understanding the value of rangelands as carbon sinks and understanding how pastoralists can increase soil carbon load through their livestock management practices. There is plenty of evidence that shows that effective animal grazing generates biodiversity and promotes biomass production in the rangelands (e.g. Voisin, 1959; Savory, 1999; Frank and McNaughton, 1993). Additional research is needed to understand how to manage grasslands to promote carbon capture and which mechanisms can best be used to encourage such management practices.

Despite the potentials indicated above, the contribution of pastoral areas in offsetting atmospheric greenhouses gases through carbon storage is seldom appreciated. Instead, rangeland livestock production has often been accused of emitting greenhouse gases through enteric fermentation (Steinfeld et al., 2006; Gerber et al., 2013). Thus, it is important to appreciate the contribution to ecosystem services of livestock production in rangelands, through maintaining a significant amount of carbon stocks in the soils and vegetation so it balances the associated adverse effects of greenhouse gas emission (Herrero et al., 2009).

Rangeland ecosystem supports and enhances life through processes that help purify air and water, mitigate droughts and floods, generate soils, renew the fertility and partially stabilize climate (Daily et al., 1997). Water holding capacity has an important role in several grasslands, and water availability and distribution are essential for pastoralists.

In quantitative terms, an analysis in China provides an idea of the order of magnitude of the value of water holding services. The study estimated the quantity of water held by different grassland types using soil moisture data, thermal inertia information and thickness of the surface layer. Applying shadow prices for water, the research estimates the value of water holding of the grasslands in the Qinghai-Tibetan Plateau at USD 1,524 per/ha/year. The magnitude of the figure suggests that pastoralism has a potential role in maintaining water cycling in healthy rangelands. This further warrants attention in future, particularly given the international significance of many watersheds in drylands. In many developing countries there is not enough quantitative information to assess the water holding capacity of the pastoral systems and the value of the service, so decision making is usually done with a high level of uncertainty.

The Ethiopian rangelands were known to be rich in plant and animal biodiversity. However, the country's rangeland environment is under threat from mismanagement, overexploitation and climate change-related stresses (Epsilon International R&D, 2011). Recent reports show that climate change has historically caused significant shifts in the geographical distribution of species and ecosystems (Seitz and Nyangena, 2009). Thus, climate change is expected to alter biodiversity. Species of plants and animals that are capable of adapting to climate change may survive, whereas those with low adaptive capacity could suffer. Adverse climatic conditions such as drought could cause depletion of assets and impoverishment of communities leading to a change in land use; and unsustainable livelihood practices such as cutting of trees for charcoal burning and sale of firewood and other forest products that eventually leads to deforestation, loss of plant biodiversity, land degradation and ultimately to desertification (Arnella et al., 2004). Climate change also contributes to the decline in population and diversity of wildlife species, particularly in the drought-prone dryland areas.

In general, climate change affects ecosystem health and productivity; in addition to its effect on species diversity (IPCC, 2007). However, all the changes observed in the rangeland areas cannot be attributed only to climate change. Additional factors such as fire, invasive species, and land-use change may also interact and produce a change in several locations.

5.2.3 Cultural services

Rangeland ecosystem contributes to cultural identity and diversity, cultural landscapes, heritage values and spiritual services. Plant species such as *Ficus sycomorus* L. (locally known as Odaa) and *Pistachia falcata* Mart. are highly respected by the Borana pastoralists as they are given high spiritual and cultural considerations. *Ficus sycomorus* (Odaa) is one of the most important plants in Oromo culture as most traditional rituals and meetings are held under the shade of this tree. It is used as an emblem on the flag of Oromia Regional Government and Oromo political parties or organizations (Gemedo-Dalle et al., 2005). The pastoral areas of Ethiopia are also of prime interest in archeological and socio-anthropological studies (Getachew, 2001; Abule, 2003).

Some rangeland plant species are used for traditional cleansing and perfuming, teeth brushing, and washing of clothes. For example, the pastoral women use the smoke of some good-smelling aromatic species for beautification and fumigating their clothes as a traditional adaptive strategy in the dryland environment of the pastoral areas. Some plant species (e.g. *Salvadora persica*, *Lannaea schimperi*, *Indigofera arrecta Sida ovata*, *Hibiscus favifolius* and *Pterolobium stellatum*. *Salvadora persica* was reported to be the best and well-known toothbrush in the Borana area that is also sold in towns. Some plant species are used for cleaning utensils. For example, plants such as *Blepharispermum pubescens*, *Balanites rotundifolia*, and *Boscia mossambicensis* are used for cleansing of utensils used for milking and milk storage (Gemedo-Dalle et al., 2005).

5.2.4 Supporting services

Rangeland vegetation facilitates the infiltration of water into the soil and helps maintain air humidity, reduce soil erosion by wind and water. Vegetation cover reduces soil loss as the root system helps bind the soil together and it is one of the most important environmental services in pastoral areas. The predominant leguminous trees and shrubs in the rangelands contribute to soil fertility by fixing atmospheric nitrogen, retrieving nutrients from below the rooting zones of crops, and reducing nutrient losses by preventing leaching and erosion. Livestock husbandry contributes to soil nutrient cycling through feeding on plant species and inputting the residues/manure into the rangelands.

Dryland species and habitats are highly resilient as they have developed unique mechanisms to cope with low and sporadic rainfall and are capable of recovering quickly from common disturbances such as fire, herbivore pressure, and drought. However, proper grazing management is essential for the health and productivity of rangelands. Controlled grazing allows even distribution of dung and urine, thereby enhancing soil organic matter and nutrients for plant productivity, thus regenerating grasslands and improving livestock production simultaneously. Unmanaged grazing or complete exclusion from grazing often leads to rangeland degradation and loss of biodiversity (Neely et al., 2009).

Moreover, different studies have accumulated evidence that pastoralism does not necessarily generate overgrazing and land degradation because of the specific dynamics of the dryland systems and also the fact that there are collective action institutions regulating the access to the resources (Mearns, 1996). Numerous studies also show that pastoralism plays an important role in many rangelands, maintaining ecosystem health and resilience, promoting water and mineral cycling, protecting biodiversity and protecting against soil erosion. Under-grazing can lead to encroachment of trees and shrubs into grasslands and can lead to greater risk for the soils (Huss, 1996). A regional study in the grasslands of China estimated that the value of soil maintenance is USD 3.00 per hectare per year. This monetary term expression was arrived by using GIS data for vegetation cover; soil loss models; and assuming that the net income of stock-raising is equivalent to the value of the soil loss after consuming the vegetation.

5.3 Status, trends and future dynamics of rangeland biodiversity and ecosystem underpinning nature's benefits to people

5.3.1 Distribution of rangeland ecosystem in Ethiopia

In Ethiopia, the rangeland areas are found around the periphery of the country, which covers about 62% of the total land areas (Coppock, 1994; Mengistu et al., 2018), and support about 9.8 million people (Desta and Coppock, 2004). The dryland areas are classified as marginal arable and non-arable lands mostly found below 1500 meters above sea level with the southwest and the southeastern areas having an altitude of around 1000 meters and the southeastern and southwestern rangelands rising to 1700 meters and above (Coppock, 1994; Napier and Desta, 2011; Mengistu et al., 2018).

Rangelands in Ethiopia support pastoral and agro-pastoral communities of over 12 million people belonging to 29 ethnic groups in 7 regions, covering about 767, 000km^2 that accounts for about 89% of the total landmass of the pastoral areas (Admasu et al., 2010; Mengistu et al., 2018). The major pastoral groups in Ethiopia are the Afar in the northeast, the Borana Oromo in the south, and the Somali in the east and southeast of the country (Desta & Coppock, 2004; Admasu et al., 2010). In addition, there are also smaller groups such as the Hamer, Arbore, Surma and Dassenetch who live in the extreme south of the country, and the Kereyu (Oromo) pastoralists in central Oromia (Coppock, 1994; Abule et al., 2005b; Napier & Desta, 2011).

5.3.2 Status of rangeland biodiversity and ecosystem services

5.3.2.1 Status of herbaceous vegetation

In a rangeland study in the Borana rangelands of southern Ethiopia, 57 herbaceous species were recorded of which 39 were from communally grazed areas, 40 from grazing enclosures and 43 were from rangelands managed by prescribed fire five years ago and that have been grazed only during dry seasons after fire application (Negassa and Zewdu, 2017). Among the herbaceous species identified; the number of grass species, herbaceous legumes and forbs were 24 (42.1%), 5 (8.8%), and 28 (49.1%), respectively. The same study found out that there are 15 perennial and 9 annual grass species in Yabello district of Borana rangelands (Negassa and Zewdu, 2017). Moreover, herbaceous species diversity was higher in the prescribed fire managed rangeland areas than in the other two rangeland management systems. Similarly; in the rift valley of Ethiopia, a total of 46 grass species, 6 herbaceous legumes and 18 herb species were recorded (Tessema et al., 2011) of which 26 species were annual and 20 species were perennial grasses. Herbaceous species diversity was higher in the prescribed fire managed rangeland areas than in the other two rangeland management systems. Moreover, the proportion of highly desirable grass species (to grazers) was lower than desirable and less desirable herbaceous species in most rangelands of Ethiopia, reflecting the gradual disappearance of highly desirable species (Negassa Zewdu, 2017). The major factors causing the decline in the abundance of highly desirable species over time are drought and overgrazing according to several studies (Abule et al., 2005a; Negassa and Zewdu, 2017). Similarly, Tessema et al. (2011) indicated that excessive and extended overuse of rangeland paves the way for invaders or undesirable plants to dominate the area. Abule et al. (2005a) also suggested that overgrazing reduces ground cover, plant height, forage quality and productivity. Moreover, overgrazing tends to reduce perennial grassland vegetation types and allow invasion by annual forbs and grasses (Holechek et al., 2005).

According to the study conducted in the rift valley of Ethiopia (Tessema et al., 2011) lightly grazed areas had higher aboveground biomass of herbaceous species compared with the heavily grazed areas (Figure 1c). The percentages of bare ground were lower for light grazing sites compared with heavily grazing sites (Figure 1a). Similarly, the percentage of basal cover of herbaceous species was larger on lightly grazed sites (Figure 1b). There was even no measurable herbaceous biomass left around the Awash National Park (ANP) at the end of the dry season, due to heavy grazing.

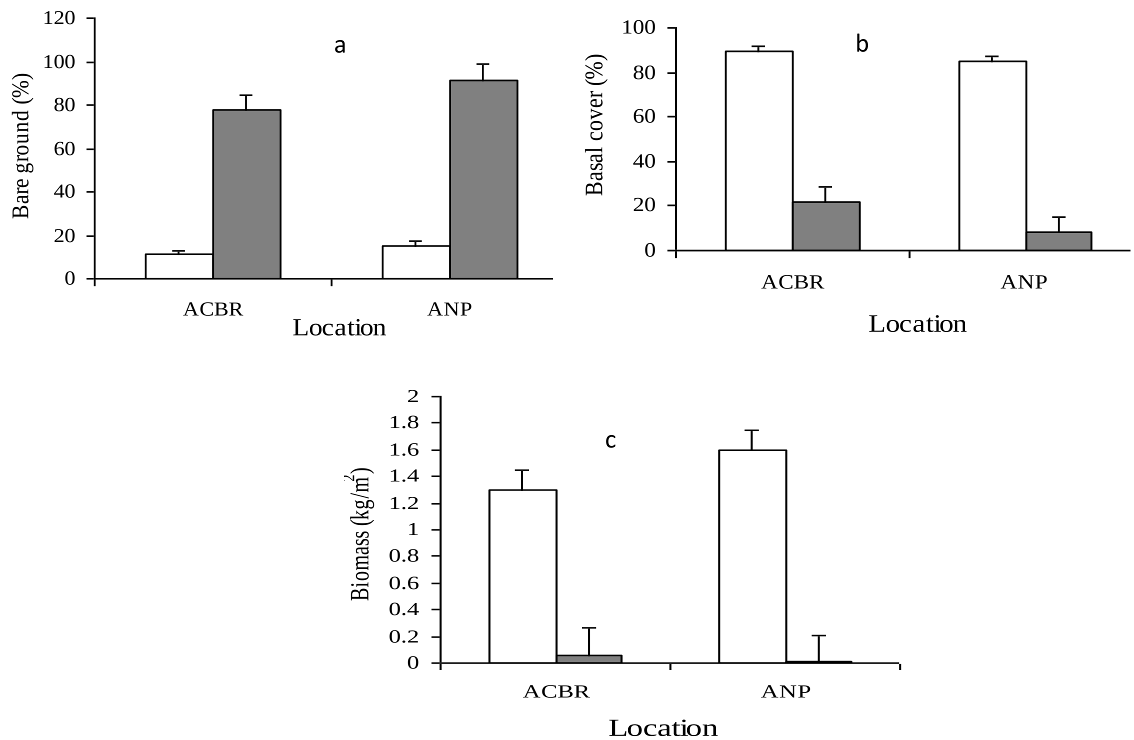


Figure 1. Effect of light (open bars) and heavy grazing (grey bars) pressures on the percentages of bare ground (a), basal cover (b), and standing biomass (kg/m^2) (c) of herbaceous species at two locations, Abernosa Cattle Breeding Ranch (ACBR) and Awash National park (ANP) in a semi-arid savanna of Ethiopia (Tessema et al., 2011)

5.3.2.2 Status of rangeland degradation

The gradual curtailment of seasonal mobility between wet and dry season grazing areas coupled with increasing livestock and the human population has created pressure on the already fragile rangeland ecology due to overgrazing (Figure 2). Due to the expropriation of dry season grazing and watering areas, the wet season grazing areas are continuously grazed throughout the year, leading to severe degradation which is manifested in terms of loss of vegetation cover and soil erosion. Soil erosion has become a serious problem in areas that are exposed to constant trampling by animals which destroys the soil structures and aggravates water runoff. In Borana, soil erosion is severe around *Surupa* and *Fichawa* areas leading to the formation of gullies in many places. The result is a lack of adequate vegetation cover and a decline in animal productivity.

Figure 2 The status and the extent of vegetation degradation in the Borana rangelands of southern Ethiopia (Photo by Tessema Zewdu)

5.3.3 Trends in rangeland ecosystem in Ethiopia

Understanding the complexity of impacts of land use/land cover (LULC) changes, landscape patterns as well as their driving forces and impacts on human and ecological processes is crucial for designing appropriate natural resource management and decision-making processes (Abate and Angassa, 2016). Analyzing landscape patterns and the changes over time is an effective way of assessing the impacts of LULC change on ecosystem functions. It also provides an important insight in understanding the spatial patterns in relation to land use processes depending on the existing socio-economic and biophysical conditions.

5.3.3.1 Land use/land covers change

According to the LULC analysis of the Borana rangelands of the Oromia region of Ethiopia, between 1984 and 2016, these rangelands had undergone substantial changes during the last 35 years (Table 1; Figure 3). In between 1984 and 2016, considerable increase in bushland cover and bare land from 43.5% - 70.2% and from 4.78% - 6.81%, respectively has been observed. Moreover, there was a decrease in grassland cover and forest land from 18.7% - 0.33% and from 3.9% - 0.41%, respectively in the same period. Similarly, there is a decrease in woodland cover and water bodies in the Borana rangelands in the last three decades (Table 1; Figure 3). On the contrary, there was also an increase in area coverage of cultivated land for opportunistic agriculture and settlement, indicating that there was a gradual change in land use land cover in Borana rangeland area for various purposes as a result of the change in anthropogenic and climatic factors. The perceptions of local communities indicate that recurrent drought, increased human population and expansion of cultivation are largely responsible for the observed LULC changes in the study area.

Table 1. Land use and land cover change (LULC, ha) in Borana rangelands of southern Ethiopia in the last four decades, between 1984 and 2016 (Tessema Zewdu unpublished data)

LULC types	**1984**		**2000**		**2016**	
	Area (ha)	%	Area(ha)	%	Area(ha)	(%)
Bare land	178178	5	223712	6	253722	7
Bushland	1619821	44	2484029	67	2607840	70
Cultivated land	621117	17	567369	15	679763	18
Forest land	145064	4	28631	0.8	15412	0.4
Grassland	697363	19	44163	1.2	12311	0.3
Settlement	428	0.01	1476	0.04	4361	0.12
Water body	141	0.004	91	0.002	60	0.002
Wood land	462122	13	374763	10	150764	4
Total	**3724233**	**100**	**3724233**	**100**	**3724233**	**100**

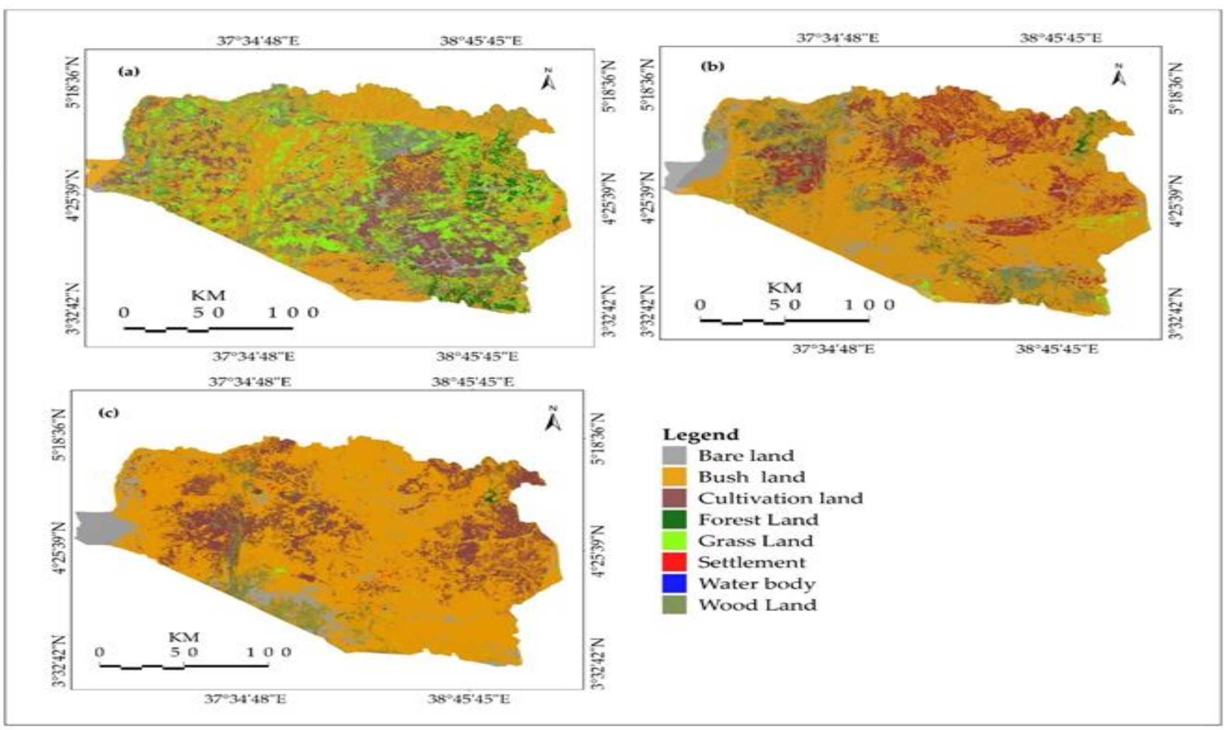


Figure 3. Land use and land cover change (LULCC) of the Borana rangelands of southern Ethiopia, a = 1984; b = 2000; C = 2016 (Tessema Zewdu unpublished data)

Similarly, Abate and Angassa (2016) indicated that the woody land cover; which is mainly composed of Acacia, Grewia, and Commiphora species showed increase by 9% and 15 %, respectively in Yabello and Arero districts over 35 years. Cultivated lands, bare lands, and settlement areas increased by 2%, 5%, and 3%; and 6%, 7%, and 6%, in Yabello, and Arero, respectively. On the contrary, the grassland cover decreased by 8% and 34% in Yabello and Arero districts, respectively. Of the total land area, the land covered by the woody vegetation in Yabello was 29% in 1967, 31% in 1987 and 36% in 2002 (Abate and Angassa, 2016), a consistent increasing pattern throughout the analysis period. This suggests that the expansion of other land use/cover types were at the expense of grassland cover; the main feed particularly for cattle, resulting in negative effects on local ecology and community. This has forced the local communities to expand cultivation on marginal semi-arid lands that possibly resulted in the ecological disturbance of grazing land environments. This probably suggests that once a critical level of grassland degradation is reached, the irreversible condition could occur and the rate of woody vegetation expansion could be dominant, indicating that significant grassland deterioration took place before the 1987 period with a steady increase in woody vegetation.

In their study, Abate and Angassa (2016) reported that the Borana rangelands had faced a significant decrease in grassland cover since the 1960s; associated with a significant change in all the Land use/Cover dynamics and its implications in the other recognized land use/cover systems. This might have generally resulted in the deterioration of the habitat in terms of increasing the area prone to soil erosion and the declining of grass cover and other desirable vegetation species resulting directly in the deterioration of the productivity and carrying capacity of the rangeland. As a result, pastoral communities shifted to a change in land use patterns such as expansion of cultivated land, opting for more income-generating activities (e.g., sell of firewood to nearby urban centers), and/or rearing of more drought resistant animals. These activities could further drive ecological disturbance to irreversible conditions unless proper interventions are made in time.

In the Afar rangelands, a rapid reduction in woodland cover (97%) and grassland cover (88%) took place between 1972 and 2007 (Tsegaye et al., 2010), Table 2. On the other hand, bushland cover increased more than threefold, while the size of cultivated land increased more than eightfold. Bare land increased moderately, whereas bushy grassland and scrubland remained stable. According to accounts from local people, major events that largely explain the changes include: (1) severe droughts in 1973/74 and 1984/85; (2) increase in dry years during the last decade and (3) immigration and increased sedentarization of pastoralists. If the present land-use/cover change were to continue coupled with a drier climate, people's livelihoods will be highly affected and the pastoral production system will be under increasing threat.

Table 2. Land-use/cover in 1972, 1986 and 2007 in Northern Afar rangelands, Ethiopia (Tsegaye et al. 2010)

Land use	Absolute area cover (km^2)			Cover change between periods (%)[a]			The proportion of dry season grazing land (%)[b]		
	1972	1986	2007	1972-1986	1986-2007	1972-2007	1972	1986	2007
Woodland	208.13	70.07	7.02	-66.50	-89.98	-96.64	3.17	0.03	0.07
Bushland	98.55	236.5	375.7	139.98	58.86	281.22	0.51	2.71	1.50
Bushy grassland	444.01	322.97	409.23	-27.26	26.71	-7.83	41.56	21.62	16.50
Grassland	194.30	44.79	22.85	-76.95	-48.99	-88.24	25.58	10.47	2.89
Scrubland	1490.6	1660.7	1530.1	11.41	-7.86	-88.24	25.58	10.47	2.89
Cultivated land	7.68	18.22	67.24	137.22	269.11	775.62	2.35	5.90	24.53
Bare land	61.82	152.86	93.99	147.29	-38.51	52.05	0.00	0.23	0.04
Total	2506.1	2506.1	2506.1						

[a] cover change between periods was calculated as 100 x ($A_{final\ year}$ – $A_{initial\ year}$) /$A_{initial\ year}$, where A = area of the land use/cover type

b proportion of each land use category in the dry season grazing land (total area = 125.44 $km^{2)}$

Some of the similarities between the Borana and Afar rangelands is that there was a considerable increase in bushland cover and bare land, as well as there was a decrease in grassland cover and forest land in the last three to four decades. Similarly, there had been a decrease in woodland cover and water bodies in both Borana and Afar rangelands in the last three decades. The other similarity between the Afar and the Borana rangelands of Ethiopia is that there is an increase in cultivated land for opportunistic agriculture and settlement in the expense of grazing lands as a mechanism for coping recurrent drought and feeding the ever-increasing human population. However, there is a paucity of information for the Somali region, and other rangelands in terms of LULC in contrast to Borana and Afar rangelands.

5.3.3.2 Encroachment of indigenous bush species

Rangelands in semi-arid savanna areas are characterized by the presence of dominantly grass species with a discontinuous to some extent very open woody layer (Frost et al., 1986; Scholes and Archer, 1997). Tree-grass interactions have been regarded as fundamentally unstable systems in savannas (Sankaran et al., 2004). Thus, semi-arid rangelands in Africa can be described by state-and-transition models, often with three stable states, the first one being a state with ample herbaceous cover, perennial grasses and scattered trees; the second one as a state with a poor cover of annual grasses, absence of perennial grasses, and the third state with a high proportion of bare soil and/or often bush encroached (Tessema et al., 2011). However, semi-arid rangelands in Africa are highly dynamic over temporal and spatial scales and vary with changes in rainfall, soil nutrients, fire and herbivory. Accordingly, the encroachment of woody plants into grasslands, and the conversion of savannas and open woodlands into shrublands has been a phenomenon widely reported in the past several decades. Accordingly, the increase in a number of new woodland communities started in the mid to late 1800s and continued throughout most of the 1900s (Van Auken, 2000).

Bush encroachment is another feature of range degradation, which is characterized by the invasion of undesirable woody species and unpalatable forbes and loss of grass layer. Bush encroachment is prominent in rangelands where grazing pressure is high. Estimates show that about 50% of the *Borana* rangeland is covered by unwanted bushes, mainly *Commiphora africana* (Oba, 1998). The process indicating the progression of bush encroachment in the rangelands of Ethiopia due to various biotic and abiotic factors is presented in Figure 4. The largest shifts in semi-arid rangelands were from woodland to severe bush encroached grassland, moderate to severe bush encroached grassland, severe bush encroached grassland to other, grassland to severe bush encroached grassland, severe to moderate bush encroached grassland and grassland to moderate bush encroached grassland (Yuan et al., 2018). Among them, the grassland was mainly shifted to the shrub grassland, due to shrub cleaning and governance in the low altitude area. In addition, a large amount of grassland has been shifted to severe bush encroached grassland. In conclusion, woodland and grassland areas were mainly converted to some degree of bush encroachment, and the area of bush encroachment has increased due to the transformation of grasslands (Abate and Angassa, 2016).

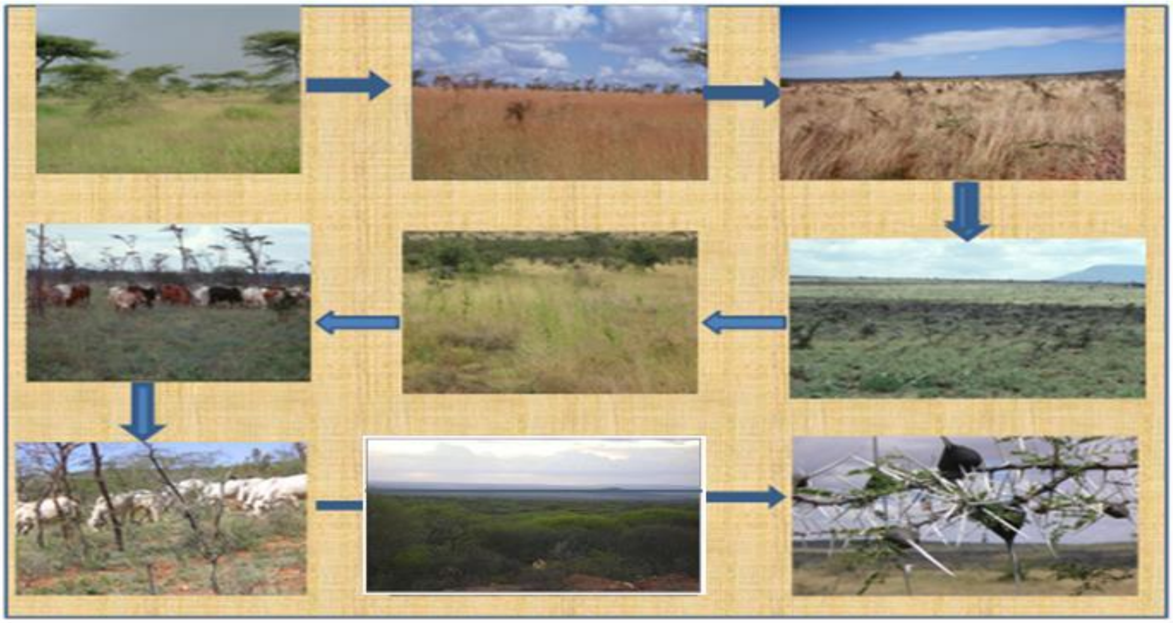


Figure 4 Schematic diagram showing the progression of bush encroachment in the rangelands of Ethiopia as a result of various biotic and abiotic factors (Photo by Tessema Zewdu)

Bush encroachment was subsequently recognized for many savanna vegetation types during the first half of the twentieth century and has emerged as one of the top challenges for rangelands (Roques et al., 2001). In the past 50 years, evidences indicate that savannas, throughout the world, are being altered by the proliferation or an increase in density, cover and biomass of woody plant species, both indigenous and exotic, in savannas and grassland areas is known as bush encroachment (Ward, 2005; Van Auken, 2000). In the earlier times, bush encroachment was recognized as a directional increase in the cover of only indigenous woody species in savannah areas, but at present it includes the proliferations of both indigenous and/or exotic woody species.

The most common indigenous woody plant species encroaching semi-arid rangelands, in the pastoral areas of Ethiopia, are those found in the genus of Acacia, Dichrostachys and Grewia (Gemedo et al., 2006). The list of the most common native woody species of trees and shrubs are collected from various literatures to indicate how the grasslands and savannah rangelands are severely encroached by diversified woody plant species in the semi-arid areas (Table 3). It is believed that bush encroachment spreads rapidly following the ban on the use of fire and due to seed dispersal through camel and goat dung. Traditionally, pastoralists use fire (i.e., rotational burning of the range) as a tool for range management to control undesirable plant species. Burning removes moribund grass, renews the pasture and reduces tree saplings (Bikila et al., 2014). However; following the official banning of fire, the woodlands have thickened with tree regeneration out,-competing the herbaceous layer in most rangelands of Borana, southern Ethiopia.

Table 3. The most common encroacher indigenous woody species in the semi-arid rangelands (Belayneh & Tessema, 2017)

Family	Species	Source
Fabaceae	*A. mellifera, A. brevispica, A. bussei, A. reficiens, A. drepanolobium*	Abule et al., 2007; Gemedo et al., 2006 Tefera et al, 2007
	Dichrostachys cinerea	Tessema et al., 2011
	Ormocarpum mimosoides	Tefera et al., 2007
Tiliaceae	*Grewia flava, G. bicolor, G. tenax, G.villosa, G. tembensis*	Gemedo et al., 2006
Anacardiaceae	*Rhus natalensis*	Gemedo et al., 2006
Anacardiaceae	*Lannea floccose*	Tefera et al., 2007
Combretaceae	*Terminalia brownie, T. prunioides, T. sericea*	Abule et al., 2007
Combretaceae	*Combretum molle*	Tefera et al., 2007
Celastraceae	*Maytenus spp.*	Tefera et al., 2007
Euphorbiaceae	*Acalypha fruticosa,*	Gemedo et al., 2006
Burseraceae	*Commiphora africana*	Tefera et al., 2007
Aloaceae	*Aloe schimperiana*	Tefera et al., 2007
Rubiaceae	*Gardenia volkensii*	Tefera et al., 2007

5.3.3.3 Expansion of invasive species in the rangelands

Invasive alien species re-engineer natural and semi-natural habitat integrity and have global consequences mainly on ecosystems goods and services, while ultimately affecting the livelihoods of local households (Ketema et al., 2018). They are the most serious threats to the health and sustainability of rangelands in Ethiopia like *Parthenium* species and *Lantana camara* in the rangeland of the Ethiopian Somali region, *Prosopis juliflora* in Afar rangelands (Dubale, 2008). These species are a great concern in Ethiopia, posing particular problems on biodiversity of the country's agricultural lands, rangelands, national parks, waterways, lakes, rivers, power dams, roadsides and urban green spaces with great economic and ecological consequences. The major impacts of the invasive species include disruption of the general ecology of an ecosystem; changing the fire regime, water and nutrient cycling and affecting the biogeochemical processes of landscapes. The principals among these are *Parthenium hysterophorus*, *P. juliflora*, *Eichhornia crassipes*, *Argemone Mexicana*, and *Lantana camara*. This makes the management of rangelands challenging since most nutrient-rich palatable grasses, the main feed source for grazers like cattle and small ruminants, are increasingly out-competed by invasive plant species since the grassy floodplains are converted into irrigated farmlands.

5.3.3.4 Types of rangeland enclosures in Ethiopia

The pastoralists in most parts of Ethiopia are currently experiencing a decline in forage quality due to the loss of good grazing species and lack of adequate forage for their livestock during dry seasons. As a result, many pastoralists in Ethiopia are focusing on the use of grazing enclosures to conserve forage resources for dry seasons (Bikila et al., 2016).

In Borana, the number and size of range enclosures have steadily increased since the 1990s (Napier and Desta, 2011; Table 4), often supported by NGOs with the objectives of rehabilitating degraded or bush-invaded rangelands, and providing a pasture reserve for animals during the extended dry season or drought periods. Customary institutions still play a role in determining the size and location of communal *Yabbii* grazing enclosures, but the relevance of this type of enclosure has to be viewed in the context of the rapid growth of private and cooperative enclosures.

Seera Yabbii: Borana pastoralists' traditional enclosures are called *Seera Yabbii* (in local Oromo language); literally it means "traditional enclosures, or protected grazing areas, kept for young calves). They are relatively small, around 10 hectares or less, and had a very specific purpose - to conserve pasture or put aside a section of the rangeland for milking cows, calves and sick animals during the dry season or at times of drought. The size varied depending on the anticipated rainy season, the number of young or sick calves anticipated in the coming year for a given *Olla*s (which means "village" in Oromo language), and the local forage conditions. For example, if drought is expected, the *Seera Yabbii* would be bigger, if sufficient rain is expected; the *Seera Yabbii* would be smaller. *Seera Yabbii* is established on relatively productive lands and is not fenced. These days, it has mostly been replaced through the introduction of *Kalos* (semi-private/communal enclosures).

Semi-private/communal enclosures (Kalos): These are referred to as semi-private/ communal Kalos since although they are organized based on a community or group of communities, they are fenced, either physically (using thorn bush) or socially (through by-laws or community agreement), and therefore they exclude some people from what was previously open rangeland. There are different types of semi-private/communal *Kalos*; and can be categorized as community-initiated, NGO-initiated or facilitated and government-initiated/facilitated Kalos.

Community-initiated Kalos are owned and managed by groups of *Ollas*, but the decision to enclose, the enclosure location and size and the use of the enclosure are traditionally decided by the *rheera* council. The *Rheera* is the third-highest Borana decision making structure related to geographic area and represents a cluster of O*llas*. The *rheera* council is the decision-making body for natural resources management and is followed by the O*lla* leader and elders at the village level. When these *Kalos* were first introduced, their purpose was similar to the *Seera Yabbii*. Now they are mostly fenced and are used to feed different types and ages of cattle (not just calves only), including for commercial purposes. Since the number and size of *Ollas* are expanding, one large *olla* may now have its own *Kalos* or a cluster of *Ollas* or a *Rheera* with a large pastoral population may decide to establish several *Kalos*. Once agreed, all the *Olla* residents in the *rheera* help to establish the *Kalos*. Where there are several enclosures in a *rheera*, the day to day decisions about use and access are made at the O*lla* level. Non-resident users of the *Kalos* are not part of the decision-making process but under the traditional Borana water and pasture management system, pastoralists from other areas are allowed to use the *Ollas* by agreement of the host communities. Community-initiated *Kalos* were relatively smaller than NGO- or government-facilitated *Kalos* but are increasing both in number and size.

NGO-facilitated Kalos have mostly been established on degraded lands, with various aims including clearing bush and rehabilitating severely degraded lands, providing reserve pasture for core herds during dry seasons and drought and providing a short-term source of income for communities through paying cash or food-for-work for bush clearing and fencing activities. Different NGOs use different establishment and management modalities described further below:

Government-initiated Kalos have been largely linked to the Productive Safety Net Programs with similar aims to NGO-facilitated Kalos viz. clearing and rehabilitating unproductive rangeland and providing cash or food-for-work as a short-term food security measure. As discussed below, there are plans to scale these up and establish much larger *Kalos* across the Borana rangelands.

Private enclosures (Locally called *Dhunffaa* in Oromo language**):** Under traditional law, it is not allowed to fence open rangeland in Borana and there are only a few large-scale private enclosures, mainly around Yabello town and the Web well in Arero Woreda. These are for commercial livestock fattening/marketing enterprises. However, it is allowed traditionally - as long as the applicant goes through the elder system and secures elders' approval -or by the local authority in particular the *Kebele* office, to fence land for farming. The practice has grown whereby individuals fence a large area purportedly for crop cultivation, but then plant crops on a small part of the land and keep the rest as pasture for rent or hay production and sale (Figure 5). This type of enclosure is expanding all over the Borana lowland. Most of these 'farmlands' are located in the flat valley bottoms, taking the most productive and fertile land from the common range.

Figure 5. Private hay production and cut-and-carry along cropland boundaries (Photo by Dawit Abebe)

Table 4. Types of enclosures and their drivers in Borana rangelands of southern Ethiopia (Napier & Desta, 2011)

Type of enclosure	Drivers of the enclosure process
*Seera Yabbii (*protected grazing for calves)	• Part of the traditional herd and rangeland management system to enhance calves growth and protect milking cows and sick animals; relatively good pasture land was enclosed • Unlike the other forms of enclosure, these have tended to disappear, as larger Kalos emerged
Communal fenced Kalos (community, NGOs and government)	• Drought and related feed shortage, pushing people to protect pasture for certain categories of livestock • Population growth (human and livestock) and increased competition for accessible land • Increasing awareness of enclosures (following Guji experience) • Expansion of cropland, encroaching into former grazing areas and • increasing competition for pasture • Bush encroachment and weakening of customary institutions for NRM, leading to the introduction of bush clearance and rangeland rehabilitation programs supported by NGOs and government; relatively degraded land is enclosed
Private Kalos	• Individual profit and political power • Farmland expansion • Commercialization of livestock production and associated business • opportunities from enclosing accessible land • Promoted by government policy • Diversification as a drought response • Destitution and drop out of pastoralism – livelihoods diversification
Cooperative Kalos (includes cooperatives and informal groups)	• External promoters (government, NGOs) • Economic incentives, profit-making • Transfer of land to private ownership

Cooperative enclosures (*Waldaa*): Cooperative ranches were first established in the 1980s by SORDU, notably the Sarite-Orbati Cooperative ranch, which is not functioning currently, and the Dubluq-Higo cooperative ranch which is ongoing. The main purpose of the ranches is to generate income for the cooperative members by providing access to grazing for livestock traders. The Dubuque-Higo ranch is located 12-15 km from the Dubluk livestock market which makes it easily accessible to traders. There are reportedly five big ranches (two of which are cooperative ranches) in the Borana rangelands currently, occupying around 33,000 hectares. Only members and those that pay a fee are allowed to use the grazing in the ranches. Before, these were open areas including important grazing and watering resources for the Borana pastoral system. More recently, the government has been promoting cooperative-owned and managed enclosures, linked to safety net programs. For example, in Dire and Miyo, safety net programs were used to clear bush and rehabilitate land which was then handed over to individual cooperatives. There are also cases of areas cleared through NGO cash-for-work programs subsequently being handed over by the local government to cooperatives. The main purpose of these cooperative *Kalos* is to generate income for the members through the production and sale of hay, or livestock fattening. Recently about 250 hectares have been allocated to the Oda Roba Pastoral Union in Moyale and application has been submitted by the Utuba Gumi Livestock Marketing Share Company in Yabello to enclose 1,000 hectares. Regarding participation, many of the cooperatives, associations, and union members involved are not pastoralists, but people with business interest in towns.

Government-initiated kalos: these have been largely linked to the Productive Safety Net Programs with similar aims to NGO-facilitated *kalos* viz. clearing and rehabilitating unproductive rangeland and providing cash or food-for-work as a short-term food security measure. There are plans to scale these up and establish much larger *Kalos* across the Borana rangelands.

In Somali areas, the types of rangeland enclosures varied from location to location (Table 5). In Harshin, Kebribayah and Jigjiga, much of the land has already been privatized and enclosed, while in parts of Shinile zone, there are still large areas of open common grazing land. The NGO focus has been more on supporting fodder production in relatively small enclosed areas as a source of income for poorer farming/pastoralist households. At present, customary institutions seem to have little control over rangeland management. Broadly, there are four types of enclosures (*seera*) in the Somali regional state: private; government; communal and/or NGOs supported in some areas, and cooperative in the others. The Tufts fieldwork for this review identified two types of private enclosures – "*seera*" within an existing farm, and "*beer*" outside the farm. The development and prevalence of these different types vary across the region, as described below.

The Issa of the Somali region strongly believe that all resources in their areas are communal property and it is relatively more difficult to establish private enclosures when compared to other areas. However, there have been examples of private enclosures happening in Issa areas. This is raising questions about the strength and role of the customary institutions in natural resources management. A recent study suggested that the trend in rangeland enclosure reflects a weakening of pastoral institutions ability to negotiate with agro-pastoralists and government actors (Napier and Desta, 2011). Although the regional government limited the size of private enclosures in 2008/9, the social barriers to establishing them are not as strong as before. Elder pastoralists suggested that because of drought and land degradation, people have come under pressure to find an alternative livelihood and enclose land as a way of securing additional incomes.

Most of the rangeland in Harshin is already permanently divided and enclosed by individuals. A study in 2009 estimated that 80% of pasture lands in Harshin are enclosed (Napier and Desta, 2011). In most parts of the district, rangeland was divided without consensus in a spontaneous grabbing of land. In some cases, this was to reserve dry season grazing for an individual's livestock, and in others, to earn an income by selling pasture/hay to others (Napier and Desta, 2011). Oxfam GB worked with two communities in Harshin which had seen that land division elsewhere had led to some people obtaining huge areas of land and others none or little (Napier and Desta, 2011). It was found out that the above trend is seemingly an unstoppable. Consequently, the respective customary institutions have decided to initiate private enclosures of land to control the process and share land equitably (Napier and Desta, 2011). In these communities, the customary institutions were drawn into land distribution for private use which is extremely uncommon in a pastoral system. The Harshin elders explained that they no longer have the power to prevent land privatization and that nowadays their role in land use decision-making and natural resources management is limited to managing access disputes between neighboring enclosures.

The traditional management practices and control of enclosures in Harshin comprise of:

- *Private enclosures* are mainly reserve areas set for individual's livestock; they are managed by individuals and there is no specific law governing them (e.g. size, location),
- Government *enclosures* are usually on degraded lands identified by the government which they then ask the community to enclose. They recruit and pay people to work in the area,

- *Cooperative enclosures* are managed by cooperative committee, according to bylaws developed by the members in Harshin through the support of NGOs for cooperatives in facilitating the development of their bylaws, and
- *Area or seasonal enclosures* are common rangelands that are put aside for later use by the community. These are based on traditional areas known by the name of the sub-clan, which were not physically enclosed. Many of these enclosures are being replaced by private, cooperative or government enclosures.

Although enclosures are now regarded as permanent features, elders from Harshin explained: "*Whatever the type of enclosure, mobility is important for pastoralists and the enclosures don't work when livestock comes from other areas. In our area, herders coming from other areas are allowed to use any of the enclosures during drought time though some of the cooperatives may demand pastoralists from elsewhere that they need to pay; most allow access because of fear of conflict and also to help them, especially when there is a serious drought.*"

According to elders, private enclosures emerged in Degehabur over the last 15 years. The enclosures were started by people who had minimum herds of cattle, camels, and shoats and needed to find other sources of livelihood, so they enclosed land near towns and riverine areas and started farming. Some earn income by renting the pasture, for example, to shoat or camel traders from the livestock market in Degehabur who need to hold animals for a few days. Also in Degehabur, there are communally owned lands, divided between clans and sub-clans. Within the agreed, demarcated territory of a sub-clan, individual sub-clan members can enclose land. There are also cooperative enclosures in Degehabur, mainly in riverine areas or farms. They are bigger than private enclosures and can include members from different sub-clans.

Like Afdem in Shinile zone, Aware is a more 'pure pastoral' area - land enclosure so far is minimal and evident only in relatively small areas. According to elders, most of the communities are not interested in having enclosures. However, community leaders have started to orient people about enclosures since there are areas of open rangeland that they don't want people to enclose and there are also areas where people have claimed inheritance rights and then enclosed land (Napier and Desta, 2011). According to the elders, the main problem is with people who enclose areas and then do not allow others to graze there. They said that awareness needs to be created so that these areas are return back to communal grazing area status and to improve the areas so that they are more productive and produce more grass (Napier & Desta, 2011).

Table 5. Types of enclosures and their drivers in the rangelands of the Somali region eastern Ethiopia (Napier & Desta, 2011)

Type of enclosure	Drivers of the enclosure process
Community (community, NGOs, and government facilitated)	• Not common in Harshin, Degehabur or Kebribayah areas of Somali region • For rehabilitation of degraded rangelands, supported by NGOs and government offices
Private enclosures	• To secure dry season feed reserve for livestock in times of increasing scarcity of natural resources • To diversify income and take advantage of increasing commercialization; for some, the driver is poverty, for others income and profit • Increasing livelihoods diversification into farming, firewood collection and charcoal production
Cooperative enclosures	• Recurrent drought leading to the enclosure of large areas as a reserve pasture for dry seasons and drought • Government policy (e.g. Shinile and Dollo Ado): promotion of • commercial enterprises, supported by the Agriculture and Livestock

Rangeland privatization, division, and enclosure are increasing across the pastoralist areas of Ethiopia. Moreover, private and communal enclosures are expanding in both Borana and Somali pastoralist/agro-pastoralist areas. However, the main beneficiaries are people with relatively more livestock and the benefits for poorer pastoralists seem to be limited. Enclosures represent the fragmentation of the rangelands. On the one hand, wealthier individuals and households drive the process by enclosing land for commercial livestock production. In contrast, poorer pastoralist/ex-pastoralist households seek to diversify their livelihoods through enclosing land for farming, fodder production or other income-generating activities. Others enclose land to protect it from the increasing numbers of households who don't own land or livestock and depend on charcoal production, sale of firewood or other 'destructive' uses of rangeland resources. In Borana, the enclosure of communal rangelands for private and selected group use for commercial purposes were '*improving their way of life and changing the pastoral production system*'. In Somali region, in some areas where most of the land is already privatized, some poor households who managed to enclose farmland are benefitting from farming, fodder production or renting pasture. For others, with no land and a few livestock, it is becoming more and more difficult to graze open rangelands.

Communal enclosures promoted by NGOs and government are becoming increasingly popular for regenerating rangeland as well as creating pasture reserves to protect animals during extended dry periods or drought. So long as they have been established by the consensus of the community, they are accessible to all traditional users, though are limited in time and space (i.e. not permanent). They are managed with the involvement of customary institutions, and may be a valuable tool for rangeland management and disaster risk reduction. However, those with more livestock tend to benefit relatively more. There is a need to come up with workable modalities on whether wealthier households (or private investors, commercial enterprises, or cooperatives) could bear more of the costs of exclusion (e.g. fencing, guarding) or the costs of rehabilitation of the enclosed land that they will benefit from later, rather than being subsidized by NGOs or government.

5.4 Direct and indirect drivers of changes in rangeland biodiversity and ecosystem services

Drivers associated with rangelands are any natural or anthropogenic factors that directly or indirectly cause changes in rangelands' biodiversity and ecosystem services.

5.4.1 Direct drivers of change in rangeland biodiversity and ecosystem services

Direct drivers of change are those with a clear impact on the processes that take place in the rangeland ecosystem. In many cases the impact of direct drivers is measurable. Some examples of direct drivers are climate change and variability (reduced precipitation, frequent drought, and flooding), rangeland fire ban, inappropriate rangeland management, land-use change (e.g. the conversion of rangelands to croplands), overexploitation (deforestation, overharvesting, wildlife poaching), inappropriate extension service, privatization, sedentarization and encroachment by native and invasive species. These direct drivers, particularly the land-use change, causes encroachment on the potential grazing land leading to overgrazing and this may be termed as population pressure. Rangeland ecosystem drivers often interact with each other, with one driver changing how another driver impacts the ecosystem positively or negatively. In rangelands, one of the largest impacts of habitat change has been the conversion of land to crop use. This type of habitat change has taken place across the entire world. Only places that are unsuitable for cultivation such as deserts, boreal forests, and tundra have remained primarily unaffected by this type of habitat change.

5.4.1.1 Natural direct drivers

Natural direct drivers of rangeland biodiversity and ecosystem services will alter the extent to which the ecological resources may be maintained. In Ethiopia, climate change and variability is the main natural direct driver of rangeland biodiversity and ecosystem services. The impact of climate change on biodiversity cannot always be differentiated from the effects of other human activities. Recurrent drought has been a major issue throughout history in the Ethiopian rangelands, and strategies to cope with, and adapt to these droughts are embedded in communities' indigenous knowledge (Riche et al., 2009). The large ecological and societal consequences of changing biodiversity should be minimized to preserve options for future solutions to climate change (Chapin III et al., 2000). Further, future climate conditions will have an overall negative effect on soil biological activities (Siebert et al., 2019). In Ethiopia, the intervals between drought events have been decreasing (see also Figure 6), leading to increased drought frequency owing to climate change (Masih et al., 2014). Uncertainty as to the degree and scale of changes in conditions that might occur owing to climate change causes a problem for rangeland managers as they seek to adapt to changes and mitigate effects of climate change and variability (McCollum et al., 2017).

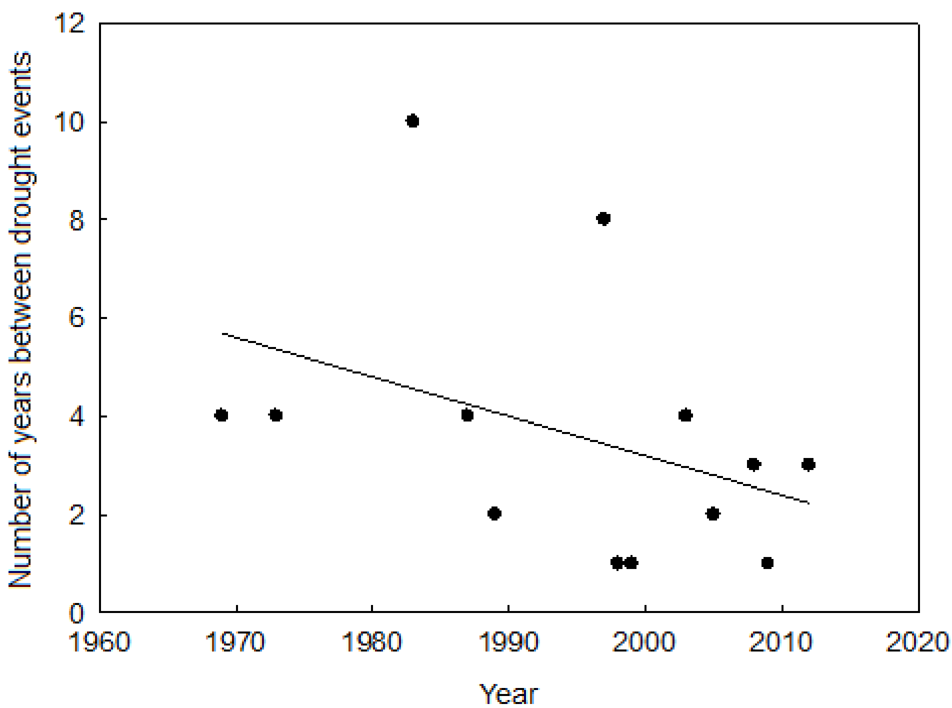


Figure 6. The year intervals between drought events. Filled circles indicate the number of non-drought years between consecutive drought years in Ethiopia (based on 1965-2012 rainfall data, Tuffa and Treydte, 2017)

5.4.1.2 Anthropogenic direct drivers

The most important factors that cause rangeland degradation are anthropogenic in origin (Bekele and Kebede, 2014). Anthropogenic activities have altered ecosystems more rapidly and extensively than ever, largely to meet rapidly growing demands which have been considered important drivers of ecosystem degradation and biodiversity loss (Guo et al., 2010). Anthropogenic activities are altering the composition of biological communities through a variety of activities that increase rates of species invasions and species extinctions, at all scales, from local to global (Hooper et al., 2005). These authors further acknowledged that the changes in biodiversity have a strong potential to modify ecosystem properties and the goods and services they provide to humanity. This is because ecosystem properties depend greatly on biodiversity in terms of the functional characteristics of organisms present in the ecosystem and the distribution and abundance of those organisms over space and time. For instance, Prosopis species in Afar was intentionally introduced (Sertse et al., 2005; Bekele et al, 2018) and has become a big challenge to the inhabitants of the pastoral community and their livelihood. Another anthropogenic challenge is pastoral sedentarization which encroaches the wild animals' habitat in the rangelands that led to reduced wildlife abundance through both the direct displacement effects due to settlement and the indirect effects of persistent grazing on grassland biomass and growth rates, leading to constrained seasonal mobility of livestock, reduced grass biomass and slower grass recovery after very dry periods (Groom et al., 2013). The typical example of this is habitat loss of Ethiopian Grevy's zebra (Kebede et al., 2012; Figure 7).

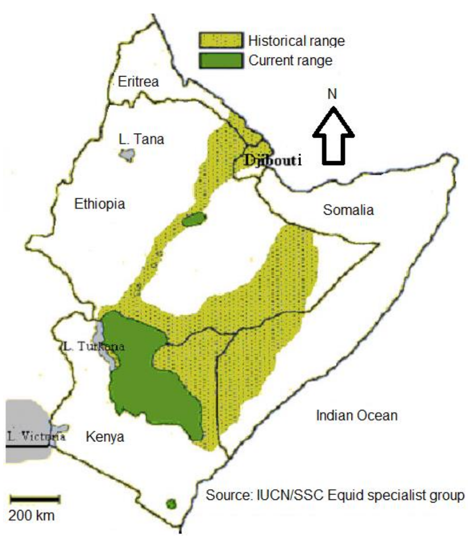


Figure 7 . Current and historical range of Grevy's zebra (Lelenguyah, 2012)

Land-use changes contribute to rangeland degradation and weaken the traditional practices of rangeland management. Therefore, appropriate management measures that halt the impact of land-use changes and its implication for the livelihoods of pastoralists need to be thoroughly thought (Abate and Angassa, 2016).

Like in many countries of the world), Ethiopian rangelands' biodiversity is decreasing owing to the conversion of rangeland into cropland (Alkemade et al., 2013). For instance, huge rangeland areas have been leased to international and local investment for large-scale production of food and agrofuels. This is because much of the land let out is classified by the government and other elites as 'unused' or 'underutilized', overlooking the spatially extensive use of land in pastoralism (Moreda, 2017). Most of the time, however, investments only focus on reducing risks and not on building long-term adaptation strategies (Muricho et al., 2019). Furthermore, there are small scale fragmented farms encroaching into many Ethiopian rangelands, overtaking potential grazing areas (see Figures 8, 9, 10, 11 and 15). The figures indicate that important vegetation covers such as forests and grasslands has been reducing in the rangelands while cultivated and bush lands have been increasing over time. Such land-use and land-cover changes have negative impacts on rangeland biodiversity and ecosystem services.

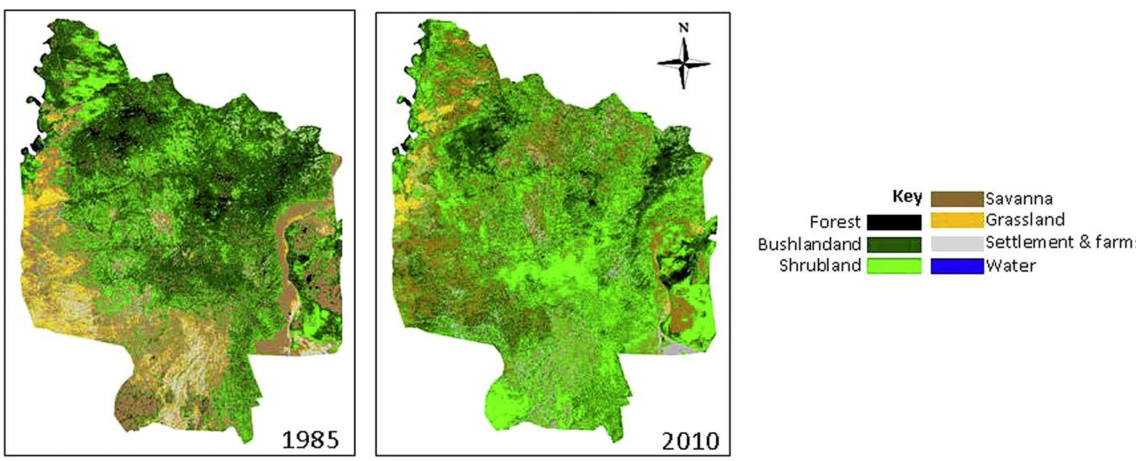


Figure 8. The dynamics of land-use changes in Hamer district, southwestern Ethiopia in 1985 and 2010 (Belay et al., 2013)

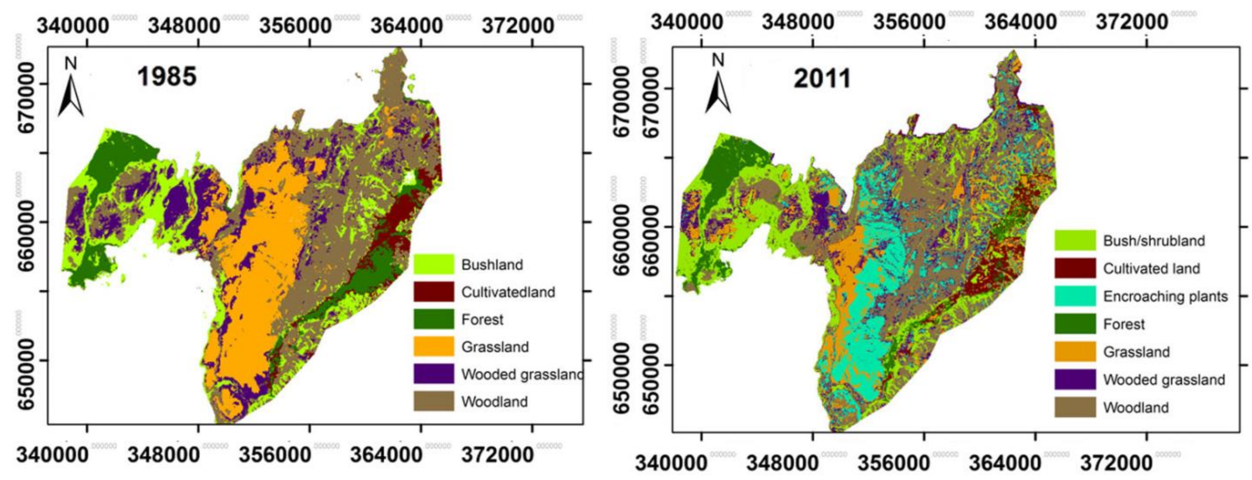


Figure 9. Terrestrial land cover maps of Nech Sar National Park of 1985 and 2011 (Fetene et al., 2016)

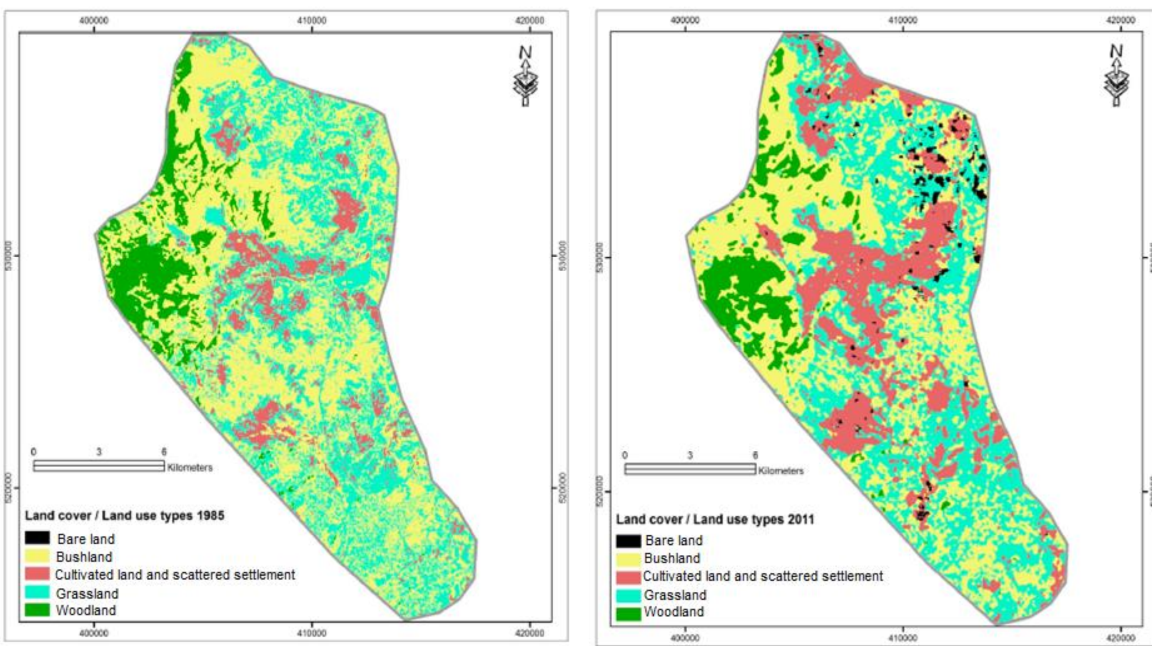


Figure 10. Land cover classes and land cover changes in Dharito, Borana rangeland between 1985 and 2011 (Elias et al., 2015)

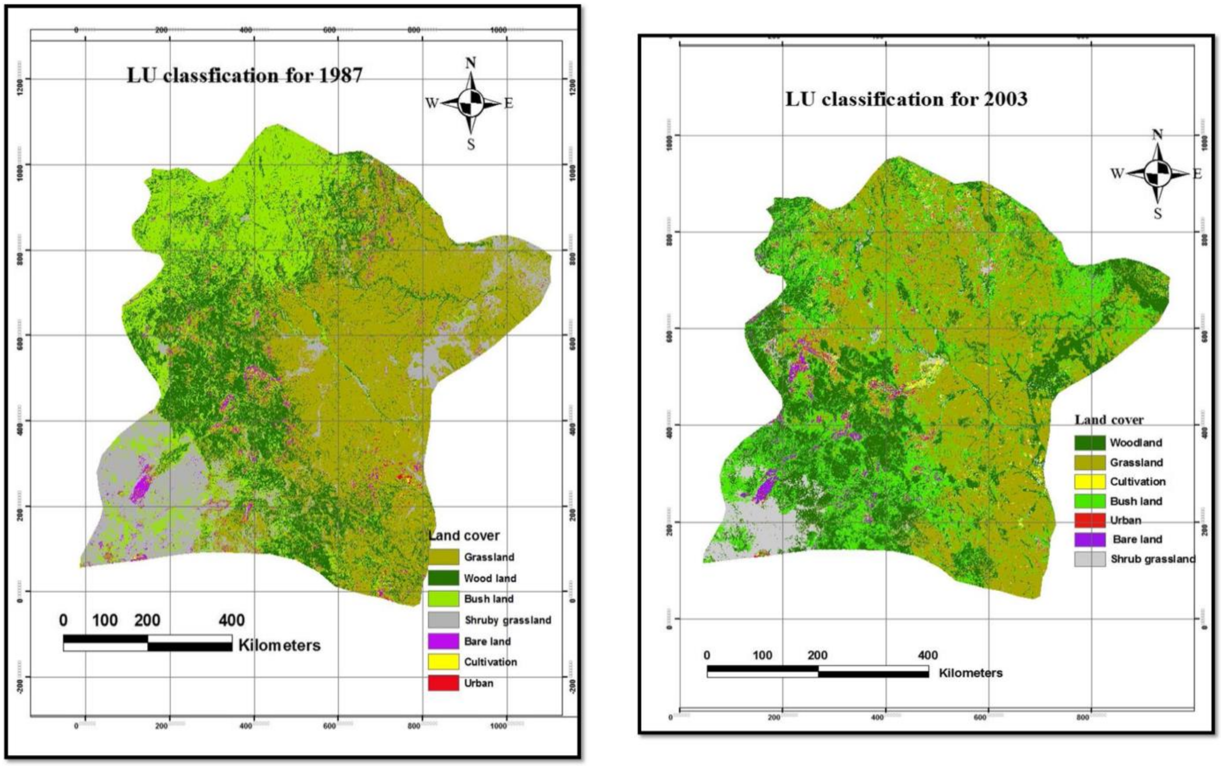


Figure 11. Land use and land cover change classification map of Yabello district, Borana rangeland, in 1987 and 2003 (Abate and Angassa, 2016)

However, such conversion of rangelands to croplands has not enabled food self-sufficiency, but it has resulted in fragmented grazing lands (Tache and Oba, 2010). Rather, these types of land-use changes contributed to rangeland degradation and weaken the traditional practices of rangeland management (Abate and Angassa, 2016). In Borana, under the low state of soil nutrients and rainfall cultivation is neither sustainable nor environmentally friendly and this will lead to further degradation (Tefera et al., 2007). In Yabello most of the rangeland was changed into the agricultural area and the remaining part was exposed to overgrazing and become seriously degraded (Fenetahun and Yong-dong, 2019). Land-use intensity significantly lowers soil biological activity (Siebert et al., 2019). Land-use change has a significant negative impact on wild-animal habitat, species-habitat interactions, range reduction, migratory routes and distribution (Erena et al., 2019). Land-use change does not affect only rangeland ecosystem directly, but it also affects the future migration of many animal species (Gitay et al., 2001). Land-use change from rangelands to cultivated land is one of the main challenges affecting the management of Ethiopian rangelands (Elias et al., 2015). Land-use change has been identified as one of the most important drivers of change in biodiversity, ecosystems and their services (Reyers et al., 2009). Changes in land use result from interactions between various socioeconomic and cultural pressures and biophysical factors which have important direct and indirect effects on land-cover change (Bestelmeyer et al., 2015). Neither population nor poverty alone constitutes causes of global land-cover change. Rather, peoples' responses to economic opportunities drive land-cover changes (Lambin et al., 2001). In the face of climate change and ongoing land-use change, people's livelihoods will be highly affected and the pastoral production system will be under increasing threat (Tsegaye et al., 2010). Many ecosystems are currently managed to exploit only one service (Figure 12). However, managing multiple services can increase ecosystem benefits (Figure 13).

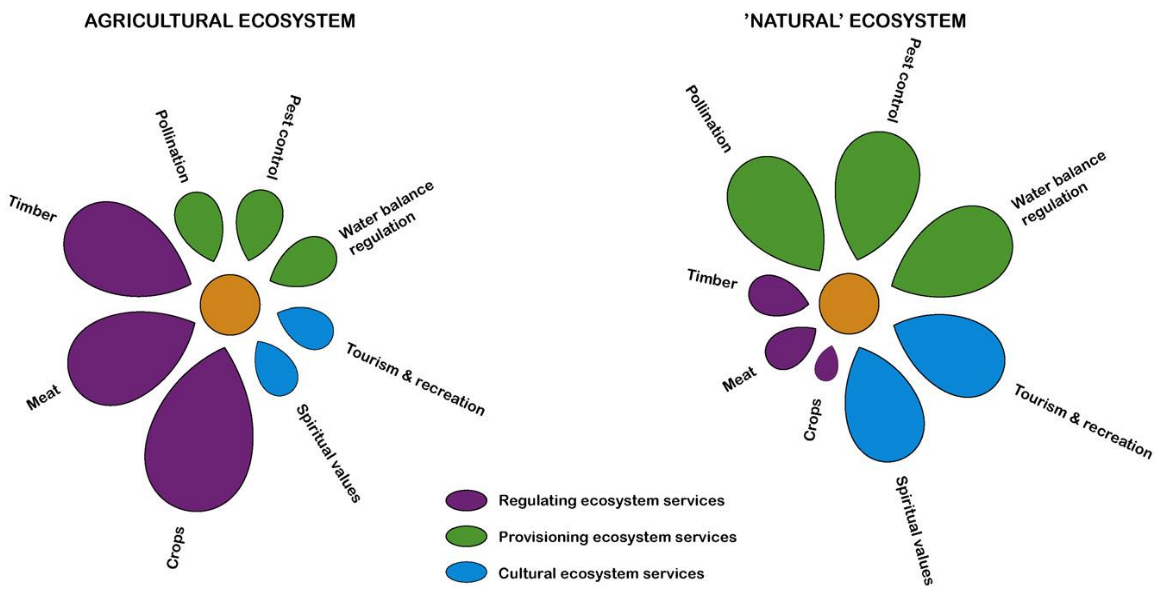


Figure 12. Agriculture increases provisioning ecosystem services at the expense of regulating and cultural ecosystem services that are often higher in less human-dominated ecosystems (Gordon et al., 2010)

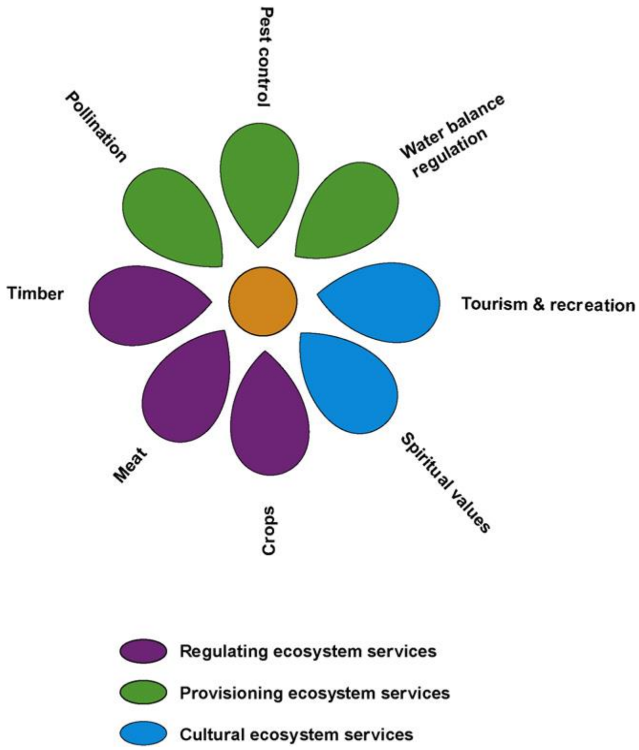


Figure 13. Agricultural systems designed to produce multiple ecosystem services can increase synergies among these and therefore reduce the number of trade-offs. Attention should be paid to provisioning, regulating, and cultural services in this design (Gordon et al,. (2010)

Livestock production is the most important agricultural activity in global rangelands, making forage supply an essential ecosystem service. Changes in structure and composition of forage species in rangelands often result from the effects of continuous grazing by large herbivores (Kipkosgei et al., 2018) over congested grazing areas under constrained mobility. Most rangelands are expected to experience increasing overgrazing, indicating that future rangelands will be less resilient to grazing pressures (Ferner et al., 2018). Today, overgrazed rangeland areas are characterized by less perennial grasses and more annual grasses (D'Odorico et al., 2012).

Climate change and herbivory are considered the main drivers of ecosystem change in the grazing system (Baruch and Jackson, 2005; Soininen et al., 2018). Overgrazing is the most important factor affecting vegetation in all rangelands of the world with a critical impact on rangeland biodiversity and species composition (Sharafatmandrad et al., 2014). The number of species was higher at lightly grazed sites than at heavily grazed sites (Tessema et al., 2012). Overgrazing reduced species diversity (Angassa, 2012). Annual grasses characterized the severely grazed areas while moderately and lightly grazed areas were characterized by an increase in abundance of perennial species (Gebremeskel and Pieterse, 2015). Restoration of overgrazed rangelands will require a definite commitment and full participation of all stakeholders, namely pastoralists, government and non-governmental organizations that are directly or indirectly involved in rangeland resources utilization, management, conservation and other related activities (Abule et al., 2005).

The extension services in rangeland management are guided by the definition of rangelands. While rangeland scientists define rangelands based on cover use, much of the rest of the world defines them negatively based on the limitations to crop cultivation (Herrick et al., 2012). Thus, there is a need to revisit and work on extension services based on the definition of rangeland scientists. Extension services have always been scarce in pastoralist areas (Jenet et al., 2016). A poor extension service in pastoral and agro-pastoral areas of Ethiopia is one of the main challenges (Little et al., 2010a).

The future of pastoralism is now being challenged by the new wave of large-scale agricultural investment and villagization programs (Seide, 2017). The government of Ethiopia continues to advocate for the sedentarization of pastoralists in the rangelands (Hagmann and Speranza, 2010), even though sedentarization leads to overutilization of the rangeland resources (World Bank, 2005) and loss of biodiversity. Hence, privatization and sedentarization constrain pastoral mobility resulting in overgrazing, which leads to loss of biodiversity and ecosystem services. The loss of biodiversity and ecosystem services, in turn, leads to declining pastoral livelihoods. Another form of privatization is related to rangeland enclosures. Enclosing the rangelands privately could constrain mobility as land-use change does to rangelands.

Fire ban was perceived as the major factor that caused encroachment of woody plants (Kamara et al., 2002; Gemedo-Dalle et al., , 2006a) in Borana rangelands and consequent biodiversity loss. Lack of fire combined with overgrazing led to the woody bush proliferation and reduced grass forage for cattle on the Borana plateau (Forrest et al., 2014). In the absence of fire, the growing prevalence of enclosures in Borana rangeland systems may be encouraging the proliferation of woody vegetation at the expense of more desirable pasture species (Negassa and Zewdu, 2017). Rangelands in east Africa are generally fire dependent ecosystem; and hence, maintenance of an effective fire regime, through the production of fine fuels, is crucial for sustaining herbaceous diversity and production in the unstable rangelands which are prone to invasion by unpalatable woody and herbaceous vegetation (Brown and Archer, 1999; Laris et al., 2015). Periodic burning can be very helpful to control bush encroachment in the semi-arid rangelands (Pratt et al., 1997). It has been recommended, therefore, that reintroduction of fire is necessary for sustainable use of the Borana rangelands (Angassa and Oba, 2008).

Climate change is a major threat to biodiversity, ecosystem services, and human well-being; and hence, effective solutions for climate change mitigation will require science to truly engage with society and support decision-making processes at all levels (Pettorelli, 2012). It is considered one of the main drivers of ecosystem change in rangelands (Baruch and Jackson, 2005; Soininen et al., 2018). A diversity of adaptation options will be required in rangelands to enhance social and ecological resilience (Ash et al., 2012). However, the intersection of climate change and rangeland in developing countries is a relatively neglected research area, and little is also known about the interactions of climate and climate variability with other drivers of change in rangeland biodiversity and ecosystem services (Thornton et al., 2009). Climate change can cause a loss of biodiversity and ecosystem services (Figure14).

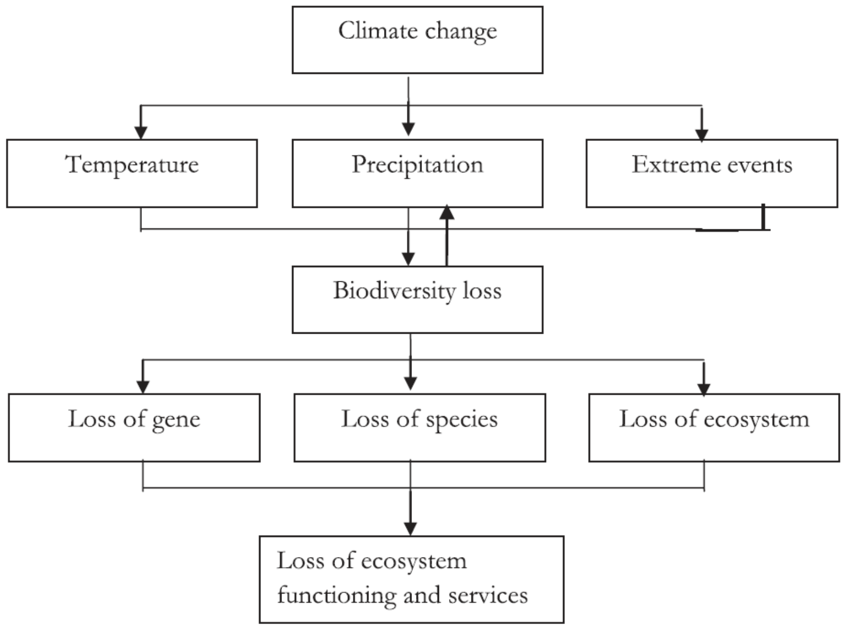


Figure 14. Climate change and its impacts on biodiversity, ecosystem services and biodiversity loss (Sintayehu, 2018)

Bush encroachment in rangelands has increased worldwide over the past 100-200 years (Archer et al., 2017). Bush encroachment has been among the major threats to Borana pastoralists' livelihoods and ecosystem (Gemedo-Dalle, et al., 2006a). It reduces rangeland herbaceous biodiversity and plant biomass and density while it increases the rangeland total carbon stock (Gobelle and Gure, 2018). Encroaching species can be alien or native. However, not all alien species are equal threats to biodiversity, depending on how they fit into ecosystems (West et al., 1993). Global warming has enabled alien species to expand into regions in which they previously could not survive and reproduce (Walther et al., 2009). In Ethiopia, *Prosopis juliflora* and Parthenium are invasive alien species, which are negatively affecting the biodiversity of many rangeland areas (Lind et al., 2016). Encroachment by native species is causing an enormous problem and leading to the loss of important species. For instance, rangelands in southern Ethiopia have been undergoing a rapid regime shift from herbaceous to woody plant dominance in the past decades (Figure 15), reducing indigenous plant biodiversity, altering ecosystem function and threatening subsistence pastoralism (Liao, et al., 2018). Some of the important contributing factors to bush encroachment in Borana rangelands are overgrazing, expansion of cultivation and reduced mobility of livestock due to the settlement of the pastoralists in the communal land (Tefera, et al., 2007b). Furthermore, reduced use of the indigenous range and water management strategies of Borana pastoralists might have contributed to woody vegetation encroachment (Gemedo-Dalle, et al., 2006a).

To minimize the problem of bush encroachment, bush control should start with key areas where sapling populations have invaded and should not be indiscriminate but selective (Abule, et al., 2007). The priority of any bush control program must be towards minimizing the abundance of these woody plants (Tefera, et al., 2007a).

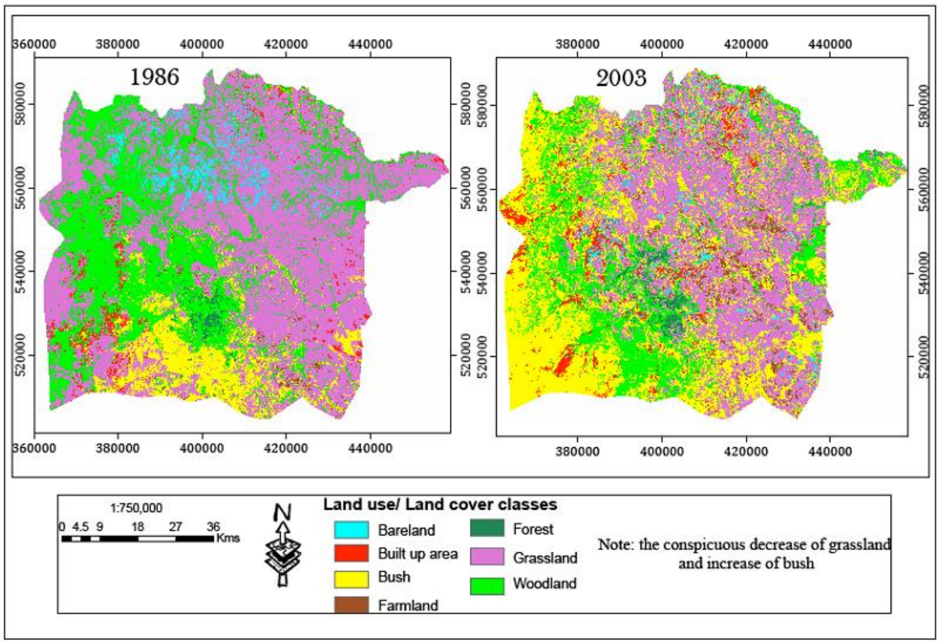


Figure 15. Land use/land cover change in Yabello district, between 1986 and 2003 (Gurmessa, et al., 2013)

5.4.2 The link between natural and anthropogenic drivers

To strengthen links to policy and management, ecological knowledge needs to be integrated with the understandings of the social and economic constraints of potential indigenous management practices in the rangelands (Hooper et al., 2005). The response of ecosystem functions to land-use intensity depends strongly on climate, and thus more severe changes in ecosystem functioning occur in the arid lowlands. The interactions between climate and land use explained 54% of the variation in biodiversity and ecosystem functions whereas only 30% of the variation was related to a single driver (Peters et al., 2019).

Positive drivers of change are those factors which bring about 1) a resilient system that continued to support millions of people, 2) significant contribution to the national economy, 3) potential for carbon sinks and 4) conservation of biodiversity and ecosystem services. Pastoralists employ indigenous knowledge to manage rangeland resources and have contributed to the sustainable enhancement of rangeland biodiversity and ecosystem services (Seid, et al., 2016). The fast human population increase puts high pressure on rangeland due to increasingly high grazing pressure on shrinking rangeland (Fust and Schlecht, 2018). Under this condition, integrating the scientific and indigenous rangeland management is needed to maintain the long term productivity of the rangeland ecosystem, especially where precipitation is highly erratic and forage quantity and quality of the pasture are highly dynamic.

5.4.3 Indirect drivers of change

Any driver other than physical and biological is considered indirect (Nelson et al., 2006). Indirect drivers operate by influencing the impact of direct drivers. They operate by impacting one or more direct drivers, in essence, they determine how strong a direct drivers act (IPBES, 2018). This subject is addressed in detail in section 4.6 of this chapter.

5.4.3.1 Policy

The link between science and policy is not linear: new findings leading to a change of scientific paradigms do not necessarily result in a change in policy and practice (Scoones, 2018). For example, ecologists recommend the mobile types of lifestyles that most suit to the rangeland ecosystem in Ethiopia although the Ethiopian government has a settlement policy that encourages the sedentarization of pastoralists (Little et al., 2010a). Generally, policy interventions are not pastoral sensitive; and were unable to bring the desired result. Rather, they have created pressure on the pastoralists and the pastoral economy, since they do not consider pastoralism as a viable way of life (Gebeye, 2016),indirectly contributing to the loss of biodiversity and ecosystem service in the Ethiopian rangelands.

Biodiversity and ecosystem services of Ethiopian rangelands are decreasing mainly due to overgrazing and conversion of rangeland into cropland (Alkemade et al., 2011; Tuffa, et al., 2017; Tuffa, et al., 2018), bush encroachment (Gemedo-Dalle, et al., 2006b) as well as recurrent drought (Tuffa and Treydte, 2017). The land rights of Ethiopian pastoralists have become less secure over time (Little et al., 2010b). Most Ethiopian rangeland ecosystems have already experienced major biodiversity losses. Therefore, unless adequate policy interventions are implemented, the prospect is that this trend will continue in the future.

5.4.3.2 Governance systems

In Ethiopia, changes in government are often characterized by policy changes that have very important implications for different production systems in diverse sections of the country, including the rangelands. For instance, land policies before the Derg regime paid little attention to pastoral areas, nationalized the land, established state farms and ranches, initiated settlement programs (sedentarization of pastoralists) and peasant associations, forced livestock sales, laid a ban on fire and provided special support for cultivation. During the regime that followed, there are some evidences of disruption of the social system and values of mobile pastoralism (Kamara et al., 2002). Inappropriate interventions led to biodiversity loss, consequently reducing benefits from ecosystems to humans (Gebeye, 2016). Most recently, the pastoral policy developed by the Ministry of Peace, shows signs of the need to support pastoral livelihoods and ensuring mobility.

The institutions in charge of rangeland management and development have frequently been not properly set up and lacked the required capacity and orientation to deal with the future (Foran and Howden, 1998). Innovative development approaches should be based on integrating indigenous knowledge strategies into formal legislation, but this requires official recognition from the Ethiopian government (Homann, et al., 2008). Pastoralism is not only about rangeland management, but it encompasses other important elements such as the people's knowledge and their livestock which are important for the sustenance of the system. So far, there has never been any government structure dedicated to pastoralist development and that cascades from top to end-users in Ethiopia. Had such structure existed, the unlikely impacts of interventions on the existing socio-cultural aspects and ecology, under the pretext of transforming or modernizing would have been minimized (Gebeye, 2016).

In Ethiopia; rangeland resources, pastures and water have been largely owned by the community and administered by a council of elders and clan representatives (World Bank, 2005). However, the traditional management systems in administrating the rangeland resource are being weakened (Flintan, et al., 2011) while private and semi-private enclosures are expanding and uncontrolled crop cultivation is increasing (Napier and Desta, 2011). The customary institutes are, however, increasingly delegitimized and thus are becoming incapable of coping with new challenges such as massive immigration, political marginalization and de facto land privatization (Homann et al., 2008; Bassi and Tache, 2011). Pastoralists and other stakeholders enter into an institutionalized process of negotiation that builds on indigenous knowledge and organizational structures; and that facilitates validation and implementation of newly generated knowledge (Homann et al., 2008).

Indigenous knowledge of pastoralists about ecology and social organization leads to rangeland management strategies that are appropriate under unreliable rainfall in African rangelands in general (World Bank, 2005), and the Ethiopian rangelands in particular. It is important to direct investments to strengthen pastoralists' efforts towards building resilience (Muricho et al., 2019) particularly in the face of environmental shocks (Tuffa and Treydte, 2017). Indigenous knowledge on the use and management of rangeland resources is a valuable source of information for conservation and sustainable utilization of rangeland biodiversity (Gemedo-Dalle, et al., 2005). For instance, the indigenous ecological knowledge of Borana pastoralists could still provide the basis for sustainable rangeland resource utilization and rehabilitation of degraded rangeland (Dalle, et al., 2005). Overlooking pastoralists' technical and organizational capacities has contributed to land degradation, erosion of social structures, and poverty (Homann et al., 2008). To address rangeland degradation problems, there is a strong need to substantially increase the investments; and strengthen the policy support for sustainable rangeland management in Ethiopia (Mussa, et al., 2016). The existence and value of customary institutions coupled with the indigenous knowledge of environmental monitoring systems suggests that governments should give serious attention to harnessing this indigenous knowledge and tools to monitor the rangelands, for quick decision-making. Therefore, governments should integrate the indigenous rangeland management knowledge into the systems of resource management (Oba, 2012).

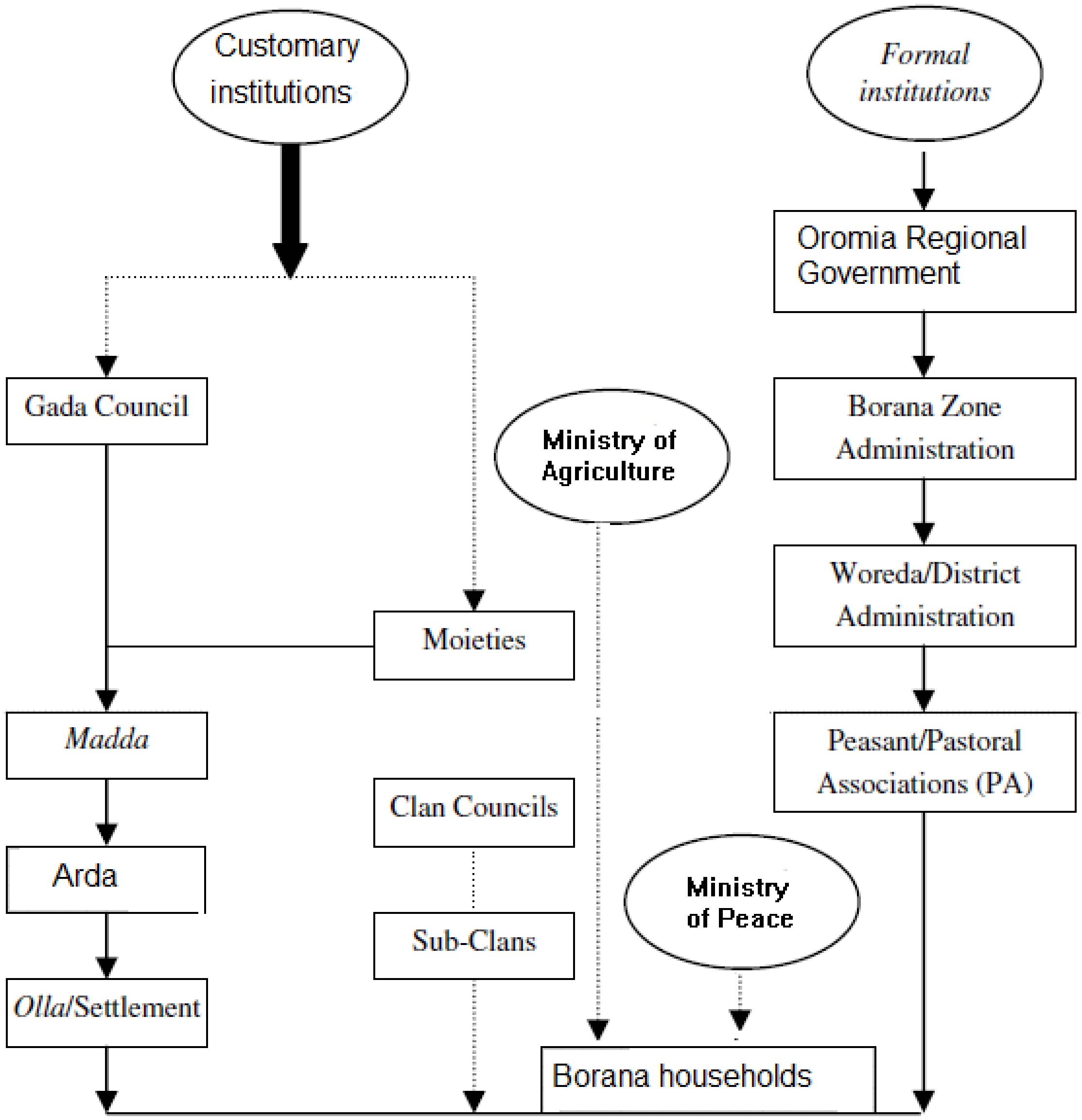


Figure 16. formal and customary institutions in Borana (modified from Kamara, et al., 2002, 2004)

Understanding and alleviating poverty in Africa continues to receive considerable attention from politicians, international celebrities, academics, activists and practitioners; although there is surprisingly little agreement on what constitutes poverty in rural Africa, how it should be assessed and what should be done to alleviate it. What is not needed is another development stereotype that equates pastoralism with poverty, thereby empowering outside interests to transform rather than strengthen pastoral livelihoods (Little et al., 2008). Past research demonstrated the high degree of articulation and efficacy of customary governance as opposed to the failure of sate-centric attempts to protect specific areas within the broader landscape (Bassi and Tache, 2011). The customary institutional frameworks and negotiation procedures are seriously affected by the imposed government structures which has jeopardized the flexible management system of rangeland resource and pastoralists' ability to adopt organizational and management structures to the changing environment, making use of indigenous knowledge (Homann, et al., 2008). Limited awareness and knowledge by decision-makers resulted in rangeland degradation and woody plants encroachment which led to a shortage of forage resources, less application of indigenous ecological knowledge, the gap between customary and formal systems and trends of disobeying traditional rules and regulations by the young generation (Dalle, et al., 2005).

5.4.3.3 Insecurity

Like in other African pastoral communities, insecurity in the pastoral areas of Ethiopia emanates from the conflicts arising between different resource users due to resource scarcity (Opschoor, 2001). Furthermore, natural population growth, and large refugee flows due to regional insecurity has increased pressure on and competition over resources (Ridgewell, et al., 2007). Given these current trends, pastoralists in Ethiopia are facing several challenges that threaten the sustainability of their traditional practices. These challenges cause stress, and are further aggravated by climate change variables such as the increasingly recurrent drought, floods, erratic rainfall patterns and high temperatures (Stark, e al., 2011). Range scientists can provide valuable input and direction on issues of rangeland degradation; provide guidance in methods and realistic opportunities for rangeland improvement to local users, government and development organizations and work to provide pastoralists with adaptive management in variable environments in order to reduce the stress. However, conflicts and poverty can create situations where a long-term goal of sustainable rangeland use is overwhelmed by short-term needs of safety and food security. Thus, conflicts can create situations where sustainable rangeland use is overridden by short-term goals (Bedunah and Angerer, 2012). Despite the challenges, providing science-based information and training on sustainable management can still make a difference where conflicts are not too severe. Such actions can also help promote societal stability. Therefore, peace agreements founded on traditional systems and mediated by customary institutions have the highest chances of success towards managing conflicts related to rangeland resources (Zerga, 2015). Formal and customary institutions need to be integrated by identifying their respective roles and responsibilities related to conflicts prevention and resolution (Flintan, et al., 2011). Otherwise, where rangelands are dominant land use types and critically important in the livelihoods of a significant portion of the population, severe rangeland degradation and/or conflicts over rangeland use can create significant social, economic, and environmental problems (Bedunah and Angerer, 2012).

5.5 Level of awareness and knowledge about rangeland biodiversity and ecosystem services

5.5.1 Level of awareness of different actors

In Ethiopia, the lack of awareness at different levels is playing a tremendous role in the decline/loss of rangeland biodiversity and ecosystem services. The effects are reflected in deforestation, degradation and loss of habitat/wildlife, parks and sanctuaries; decreasing seedling viability, poor recruitment, risk of local extinction; bush encroachment and invasion by alien species; desertification encroachment/desert expansion; vulnerability and risks (e.g., drought); ecological shifts and shrinking-expansion of ecosystems; livestock genetic dilution/losses and adaptation, mitigation and managing risks (Nigatu et al., 2004; EPCC, 2015). Many of the conservation areas in Ethiopia (national parks, wildlife sanctuaries, wildlife reserves, controlled hunting areas, open hunting areas, and community conservation areas) are found in the rift valley and the rangelands. Thus, many of the national parks of Ethiopia such as Awash, Abijata-Shalla, Nech Sar, Mago, Omo, Maze, Chebera-Churchura, Kafeta-Sheraro, Alatish, Geralle, and Gambella are located in the rangelands. Similarly, many of the wildlife sanctuaries such as Yabello, Babile Elephant, Senkile Swayne's Hartebeest, and wildlife reserves namely Mille-Sardo, Gewane, Alledeghi, Awash west, Chew-Bahr, and Tama are all found within the dryland areas. These protected areas make the rangelands a considerable base for an expanded eco-tourism (Beruk, 2008; Melaku, 2011; Alemneh, 2015). Yet, habitat loss and poaching are critical problems to the wildlife industry in Ethiopia (Alemneh, 2015; EPCC, 2015). The Ethiopian wildlife is commonly blamed by tourists to be more of paper parks (Anteneh, et al., 2012). Thus, raising awareness at national and regional levels can play a part in solving the problems which is also one of the key elements on the Convention of Biological Diversity. It has also been stated in the National Biodiversity Strategy and Action Plan 2015-2020 (EBI, 2015) that the general public and decision-makers have limited awareness of biodiversity and ecosystem services. Policymakers are occupied with poverty reduction and development issues that may have short term gains but will harm biodiversity in the long run (EPCC, 2015; EBI, 2015). Given this, the

EBI has coordinated formulation of the above national strategy and action plan that contains 18 targets under five overarching goals: addressing the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society, reducing the direct pressures on biodiversity and promote sustainable use, improving the status of biodiversity by safeguarding ecosystems, species and genetic diversity, enhancing the benefits to all from biodiversity and ecosystem services, and enhancing implementation through participatory planning, knowledge management and capacity building.

Community perception plays a significant role in rangeland resource management. Pastoralism played a vital role in food production and sustaining its inhabitants in the arid environment for millennia. However, national policies and development interventions in East African pastoral systems including Ethiopia have often overlooked pastoralism while centered on the modernization of the agricultural sector for economic development and poverty reduction (Amaha, 2006; Abule and Alemayehu, 2015; Minyahelet al., 2017;). Different studies related to the perceptions of the communities and the decision-makers regarding the rangeland resources were undertaken in Afar, Borana/Oromia, Somali, and other rangeland areas of Ethiopia.

In Afar, different researchers have contributed to better understanding of the community perceptions/awareness regarding rangeland biodiversity (Yoseph, 2007; Mohammed, 2009; Minyahelet al., 2017; Yihew et al., 2017). The findings of these studies indicated that the benefits (ecosystem services) from the rangelands are on a decline, and so are the status and the management of the rangelands. The livestock and wildlife resources and the conservation areas are in a state of degradation. The Afar pastoral communities surrounding conservation areas have a positive attitude for wildlife and the park, however, the attention given to develop these rangelands is very low, and inappropriate development interventions have put rangelands under severe pressure (Minyahel et al., 2017).

Studies were also undertaken in the Somali rangelands which assessed parameters similar to those indicated for Afar (Amaha et al., 2008; Selam, 2008; Helen, 2009). The findings indicated that there are changes in vegetation ecology and the later has drastically altered the livestock species composition in favor of camels and small ruminants rather than cattle. Traditional coping mechanisms, as reported by the communities are failing due to increasing environmental and rangeland degradation and lack of national policies to minimize or solve the problems.

Studies regarding the benefits of rangelands, status and management of biodiversity were undertaken in the Borana rangelands also (Gemedo et al., 2005; Getachew, 2007) and in the rangelands of SNNPR (Muluneh, 2008; Admasu et al., 2010; Worku and Lisanework, 2016). The overall results obtained are similar to those described for Afar and Ethiopia Somali. In general, the studies undertaken in different parts of Ethiopia reveal the strong need for awareness creation on the degradation of the rangeland biodiversity and its ecosystem services, at both the national and regional levels (EPCC, 2015).

5.5.2 Importance of knowledge in rangeland biodiversity and ecosystem services

Knowledge is important to better understand the benefits of rangelands, and the status, and management of biodiversity which helps develop modality for payment to the ecosystem services. It also plays a key role to reverse the loss of biodiversity and degradation of the rangelands. To this effect, the knowledge systems for management of rangeland biodiversity and ecosystem services is based on the local indigenous and scientific knowledge, where the former has played an important role in the management of rangelands for centuries. This sub-section addresses both of the knowledge systems but with more emphasis on the indigenous knowledge (IK) of the communities as it is the foundation of the rangeland management practices by pastoral communities.

Indigenous/local knowledge is the skills, practices and technologies that are an integral part of the production system and are area and culture specific skills and practices concerning natural resources management (NRM) and many other issues developed by indigenous people over the centuries (Tick, 1993; Herlocker, 1999; Warren, 1991; Berkes, 2008; Ross et al., 2011; Getahun, 2016; Nguyen and Ross, 2017). Such knowledge evolves *in situ,* thus is specifically adapted to the requirements of the local people and conditions (Herlocker, 1999; Getahun, 2016). Indigenous knowledge is passed on orally from one generation to another. It differs from the mainstream conventional knowledge domain in that it is neither generated through universities, government research and private industry nor is formally documented (Tick, 1993; Herlocker, 1999; Getahun, 2016; Nguyen and Ross, 2017; Yeneayehu, 2018). It is accumulated in communities and saved through folk mythologies, legends, songs, community rules, religious rituals and so forth (Hoang and Le, 1998; Le, 2015; Tibebu, 2012; Getahun, 2016; Nguyen and Ross, 2017; Yeneayehu, 2018). One of the principal differences between local and scientific knowledge is that of scale: while IK is limited to the specific local area scientific knowledge is applied across different areas.

Indigenous/local knowledge (IK) is not only about ecological relationships but is also about laws, governance, and other issues (McGregor, 2004; Berkes, 2008; Getahun, 2016; Yeneayehu, 2018). It is also creative and experimental, constantly incorporating outside influences and inside innovations to meet new conditions. Thus, IK is embedded in a dynamic system in which spirituality, kinship, local politics and other factors are tied together and influence one another (Emery, 2000; Langill, 1999; IIRR, 1996; Getahun, 2016; Dika, 2016).

The Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES) as one of its operating principles, included the following commitment: "Recognize and respect the contribution of indigenous and local knowledge to the conservation and sustainable use of biodiversity and ecosystems Sahai (1996) emphasizes that ILK is the foundation of modern science in the field of NRM and conservation where communities' knowledge is worthy of recognition (Gadgil, et al., 1993; Gadgil et al., 2003; Berkes, 2008) although there are different debates behind its importance and applications (Nguyen and Ross, 2017). These researchers point out that ILK explains ecosystem dynamics leading to important applications in ecological restoration and rehabilitation. Ecosystems and natural resources are complex adaptive systems and, as a result, there is a need for flexibility in NRM (Berkes et al., 2000; Folke, 2004). Thus, ILK will contribute to the monitoring and evaluation of management decisions and human uses of ecosystems (Watson et al., 2003; Donovan and Puri, 2004; Moller et al., 2004). Incorporating ILK into projects can contribute to local empowerment and provide valuable input for alternative management strategies. Ignoring ILK often led to rangeland management and development failures as witnessed from past rangeland development interventions in Ethiopia (Gebremeskel, et al., 2019), East Africa (Oba and Kaitira, 2006; Roba and Gufu, 2009; Oba, 2012; Ismail et al., 2012) and in many other countries (Agrawal, 1995; Nyong et al., 2007; Al-Roubaie, 2010; Le, 2015).

Given the importance of ILK, pastoralists' management of their knowledge may therefore play a critical role in the conservation and management of rangeland ecosystem goods and services.

According to Roba and Gufu (2009), most of the rangeland management practices in Africa have excluded local pastoralists' knowledge. The statement below describes the importance of ILK in rangeland management of Ethiopia:

"The main reason for the continuous functioning of ILK is that herders put the knowledge to continuous use (Grice and Hodgkinson, 2002). In the words of a Somali elder 'a rangeland cannot be rangeland without pastoralists' knowledge and a pastoralist cannot practice pastoralism without rangeland' (Bouh and Mammo, 2008), the two are mutually interrelated (Oba, 2012)".

The pastoral and agro-pastoral (PAP) communities in the different Regional States of Ethiopia employ different techniques to manage rangeland resources, including mobility, herding, corralling, grazing reserves, the use of fire and others as part of their indigenous practices in relation to range livestock management practices, although the type/types of practice implemented and the level of implementation varies from one pastoral community to another (Herlocker, 1999; Blench et al., 2003; Abule 2003; Amaha, 2006; Angassa, 2007; Tibebu, 2012; Seid et al., 2016; Minyahel et al., 2017). It is known that pastoral communities' in different areas have some common management techniques although they vary in some of their management practices. Furthermore, the PAP communities in Ethiopia also possess detailed knowledge of rangeland plants and their uses, which could be valuable in the assessment, conservation, utilization of rangeland biodiversity (Solomon, 2003; Abule et al., 2005; Amaha, 2006; Kidane, 2006; Ketema et al., 2017). Traditional pastoral rangeland management practices such as the use of seasonal grassland reserves and livestock mobility influence vegetation composition, coverage and abundance in rangelands. These management practices also offer tools for biomass and soil carbon restoration, contributing to the mitigation of climate change which can influence biodiversity resources (Admasu, 2006; Admasu et al., 2010; Teshome, 2016; Bikila et al., 2016; Seid et al., 2016). The most common indigenous practices are described in subsequent sections with emphasis on their importance in rangeland biodiversity conservation and ecosystem services.

5.5.2.1 Mobility and herding

Communities residing in the rangelands of Afar, Somali, Oromia, and in other parts of Ethiopia use mobility to respond quickly to fluctuations in resource availability, dictated by the dry land's scarce and unpredictable rainfall although it is constrained by many problems in recent times (Niamir, 1999; Amaha, 2006; Angassa, 2007; Muluneh, 2008; Tibebu, 2012; Huig, 2013). It is the mobility and flexibility of pastoral production systems that enable them to make the best use of patchy and fragile environments that prevail in drylands, i.e., landscape-scale management of pastoralism (Amaha, 2006; Mohammed, 2009; Admasu et al., 2010; Behnke and Kerven, 2011; Angassa et al., 2012; Aboud et al., 2012; Niemi and Manyindo, 2010). The livestock mobility inherent to pastoralism is crucial for rangeland maintenance, improvement and regeneration (Getachew, 2007; Huig, 2013; Seid et al., 2016). Mobility was also used to minimize the risk of livestock disease and raiding (Abule e al., 2005; Amaha, 2006; Getachew, 2007). Generally, it is documented that such management practices enrich species diversity, maintains vegetation cover and reduces soil loss in Ethiopia (Amaha, 2006; Teshome et al., 2010) and other parts of the world (Niamir, 1991; Gómez-Sal et al., 1992; Aboud et al., 2012; Mantano and Malo, 2006; Davies et al., 2012; McGahey et al., 2014).

5.5.2.2 Corralling and grazing reserves

Pastoralists have also influenced savanna ecology through their creation and abandonment of livestock bomas (thorn fence corrals that pastoralists traditionally use to protect their livestock at night). The importance of bomas, as a long term sources of nutrient-rich, ecosystem hotspots with distinctive plant communities, are well documented in different pastoral areas of the world including Ethiopia (Coppock, 1994; Muchiru et al., 2008); Veblen and Young, 2010; Porensky and Veblen, 2012; Porensky and Veblen, 2015; Seid et al., 2016). Pastoralists also set aside part of their rangelands as physically or socially fenced grazing reserves (Gemedo, et al., 2005; Huig, 2013), although this is not common among all pastoral groups in Ethiopia. Grazing reserves are commonly used as dry-season reserves to feed mainly calves and sick animals for instance in the Borana areas of Ethiopia. Compared to the open communal grazing areas, grazing reserves exhibit a greater composition of palatable grass species and this was witnessed through different studies in Borana of Southern Ethiopia (Gemedo et al., 2005; Solomon et al., 2007; Huig, 2013).

5.5.2.3 Use of fire

The Borana pastoralists used to control bushes by fire, which was mainly undertaken to control undesirable plants species, reduce tick infestation and improving the quality and quantity of pasture (Boka, 1993; Yigezu, 1993; Getachew, 2007; Solomon et al., 2007; Huig, 2013). Traditionally, burning was undertaken every three years (Huig, 2013) and fires on the Borana Plateau are best conducted during January or February, the peak of the long dry-season. Controlled burning suppresses the encroachment of woody species and promotes the growth of palatable grasses, creating a favourable environment for livestock but also for wildlife species (Seid et al., 2016). However, the ban of fire resulted in a severe bush encroachment in the Borana rangelands of Ethiopia (Getachew, 2007).

The traditional rangeland management practices of pastoralists like the use of fire and livestock mobility can be used to mitigate climate change and rising atmospheric carbon dioxide concentrations (Tibebu, 2012; Bikila et al., 2016). For instance, a study by Bikila et al. (2016) revealed enclosures to have higher carbon sequestration potential (300.38 t C ha^{-1}) than communal rangelands (141.5 t C ha^{-1}) and fire prescribed rangelands (184.93 t C ha^{-1}).

5.5.2.4 Range livestock management practices

Several studies have shown that the PAP communities in Ethiopia have indigenous rangeland management practices, knowledge of rangeland conditions and range management strategies (Angassa and Beyene, 2003; Gemedo et al, 2005; Huig, 2013; Minyahel et al., 2017). The mechanisms of grazing management like division of herd into Warra (home based herd consisting lactating cows and small stocks) and Fora herds (satellite herd consisting of dry cows), and demarcation of grazing and settlement areas are practiced by the Borana pastoralists. Conservation of grazing area was undertaken by making thorny bush fences around standing hay (Coppock, 1994; Huig, 2013). Thus, the traditional land tenure and resource management is often closely associated with social-cultural practices as exemplified by the Borana of southern Ethiopia, who have traditionally maintained a balanced relationship among people, livestock and rangeland; by regulation of human reproduction, a transhumant grazing system, a common property regime for water and, most important, by regulating the use of water. A growing body of literature (Oba, 1998; Angassa and Beyene, 2003; Yosef, 2007; Angassa and Oba, 2008; Farm Africa, 2009; Admasu et al, 2010; Angassa, et al., 2012; Mohammed, 2004, 2010; Sulieman and

Ahmed, 2013) have emphasized the need to inform policy-makers and development practitioners to recognize community's knowledge on sustainable management of the environment as related to the rangeland management practices.

The pastoralists in Ethiopia also practice other innovative adaptation measures like maximizing the number of female animals while keeping males at the minimum. This strategy ensures fast recovery of the herds following exceptional harsh drought incidence (Herlocker, 1999; Tibebu, 2012). There are also rangeland management practices in Borana and Afar such as the strategic use of dry and wet seasons grazing areas. Although the young generation in the pastoral communities have limited ecological knowledge and showed less interest to learn and apply traditional resource management strategies, they are being involved as interpreters in extending the knowledge (Huig, 2013).

5.5.2.5 Uses of herbal medicines, biodiversity management and climate change

The knowledge of PAP communities in Ethiopia also extends into aspects such as uses of herbal medicines, biodiversity conservation and management, climate changes and many others (Tibebu, 2012; Teshome, 2016; Tizita, 2016; Yeneayehu, 2018). A study by Yeneayehu (2018) on the role of ILK in biodiversity conservation in Gursum Woreda, Eastern Hararghe Ethiopia, revealed that the communities have a vast stock of knowledge on plant-based pharmacopeia for both human, plant and animal health, prediction and early warning of rainfall, weather forecasting, time-testing coping mechanisms, food production and storage techniques. Thus, the author argued that evidence of culture, spiritual, social and ethical norms possessed by indigenous people have often been the determining factors for sustainable use and conservation of biodiversity. Yeneayehu (2018) concluded that it is the lack of prioritization for indigenous people as well as the destruction of their socio-cultural values and their knowledge on the biodiversity conservation that explains the degradation of biodiversity. This is also true in other pastoral and agro-pastoral areas of Ethiopia.

Although the pastoral communities have detailed ecological knowledge that helped them to devise adaptive strategies to make use of scarce natural resources for centuries keep the natural environment in balance and preserve the biodiversity of rangeland ecosystem, the proper implementation of this knowledge is affected by different external and internal factors. Attributed to combination of these factors, the ILK is disappearing at an alarming rate although the reasons vary from one pastoral community to another. For instance, for the Afar pastoralists, the conflict with Issa, the increased development interventions, the establishment of conservation areas and the ongoing commercial irrigation agriculture were the main reasons for the disruption of the pastoral traditional management system (Unruh, 2005; Minyahel et al., 2017).

The scientific knowledge has also made impressive progress in biodiversity conservation and the management of ecosystem services. Such progresses include *in situ* and *ex situ* conservation techniques, advances in genetics, molecular sciences, and the use of GIS and remote sensing in evaluating and monitoring of rangeland biodiversity and ecosystem services.

5.5.3 Integration of indigenous and scientific knowledge

In Eastern Africa, including Ethiopia, and perhaps more widely, there is a disconnect between rangelands science and pastoralist rangelands management. Pastoralists and rangeland scientists have plenty to offer each other but the challenge is the failure of scientists, practitioners and pastoralists to communicate effectively with the other (IUCN, 2011). Pastoralists require support to make informed choices over the techniques and technologies they adopt whereas science needs to relate to indigenous knowledge and must be incorporated into local governance frameworks. On the other hand, on the advising side need a methodology through which they can understand local knowledge and work with pastoralists to use this knowledge to make sense and use of new science and technology. To this effect, there is a study undertaken by Oba (2012) to harness pastoralists' indigenous knowledge for rangeland management in Ethiopia (case study Afar), Kenya, and Tanzania. The study developed and evaluated a methodological framework for conducting joint assessments with pastoralist range scouts. The framework had four components: a selection of ecological and anthropogenic indicators, indicator integration, evaluation of indicator outcomes and regional decision-making systems. The feedbacks between different components were used for information transfer. The scouts conducted rangeland assessments using ecological and anthropogenic indicators. Pastoralist scouts assessed rangeland degradation and trends using historical knowledge of the landscapes. The finding confirmed comparable knowledge systems among the three pastoral communities. It was known that the methods can be applied across regions where pastoralism still dominates the rural economy. The system of indigenous rangeland assessments and monitoring could rapidly provide the information needed by policymakers. Harnessing pastoralists' indigenous rangeland knowledge has implications for participatory research, verifying and testing methods as well as sharing information to promote practical rangeland management. Harnessing pastoral indigenous knowledge with wildlife was undertaken in neighboring Kenya (Gordon et al., 2016).

Integration of knowledge sources; including local, professional and scientific will be essential to support adaptation and especially transformation (Reid et al., 2010; Weible et al., 2010). Knowledge systems entail the technologies and institutions that motivate and harness diverse sources of information for decision-making (Cash et al., 2003). They provide the means to use local knowledge, research products (e.g., climate forecasts and remotely sensing data), and the collaborative development of new information (Polasky et al., 2011). Knowledge systems circumscribe databases that contain information as well as the personal interactions that facilitate the use of the information. Such knowledge systems are critical to the development of effective management strategies and policies because, ideally, they can incorporate information derived from both successes and failures to facilitate social learning (Reed et al., 2010).

5.5.4 Knowledge communication and outreach strategy

Communication is a key component in biodiversity conservation and the utilization of ecosystem services. Communication can facilitate pastoral development that seeks to establish sustainable NRM involving pastoralists, development workers, researchers, input suppliers, local authorities and national decision-makers.

Pastoralists in Afar, Somali, Borana and other parts of Ethiopia have traditional communication systems used to share experiences on ecology, climate and other important issues (Tibebu, 2012; Huig, 2013; Seid et al., 2016). For instance, there is a traditional exercise named "*Dagu*". "*Dagu*" is a long-established traditional information sharing culture, when one person meets another person from a different locality (whether they are strangers or they know each other), they spend the first minutes exchanging information and narrating about their livestock, pasture and any new incidence one might have observed during his journey. *Dagu* is an organized information exchange network system in the Afar study area that helps to assess the availability of pasture and information exchange, which serves as the traditional early warning system in their locality. Through *Dagu*, the clan leader passes the information for the community to take measures in readiness for adverse weather conditions, for example by slaughtering their calves to cope up with the coming drought (Tibebu, 2012). Similarly, traditional communication among Somali pastoralists is through word of mouth/oral communication. Thus, the co-ordination of strategies in natural resource use with other users ultimately depends on the social networks that are developed within and among different user groups (Niamir-Fuller and Turner, 1999). With the recent advancement in information communication technology, other devices like mobile technology are spreading in the different pastoral areas of Ethiopia.

Efforts have been made by the Ethiopian government and development partners to share knowledge and understand the impact of different interventions (e.g., gender-responsive approaches, new knowledge) at the local and national levels. Furthermore, research centers and universities are opened in pastoral and agro-pastoral areas of Ethiopia which can potentially contribute to the knowledge development system. However, the level of contribution of these organizations to the knowledge communication and outreach strategy of rangeland biodiversity and ecosystem services needs to be closely examined. A lot more has to be done to apply the use of information communication technology (ICT) in rangeland biodiversity conservation and management. Outreach strategies and coordination that take into consideration the variability among the different pastoral areas and the involvement of different actors require strong effort. Currently, the extension staff and services on conservation and utilization of rangeland biodiversity provided for PAP in Ethiopia are not well-tailored to address problems and to bring the required changes.

5.5.5 Challenges to the application of knowledge

The major challenges that hindered the proper integration of ILK and the mainstream modern knowledge are described below.

5.5.5.1 Epistemological barriers

Epistemology is the study or a theory of the nature and grounds of knowledge especially regarding its limits and validity. Epistemological barriers are those associated with the differing nature of knowledge in different ontological frameworks. McGregor (2004) and Ross et al. (2011) argue that a lack of recognition of ILK is one of the obstacles to the participation of local communities in NRM. Studies undertaken in the pastoral areas of Ethiopia (Houde, 2007) i.e., Afar (Mohammed, 2009), Somali (Amaha, 2006), Oromia (Dika, 2016; Yeneayehu, 2018), and other parts of Ethiopia have witnessed this gap, though there is some improvement in recent times. Berkes (2008) contends that the knowledge difference between ILK and western science may result in the rejection of ILK by scientists and managers which is also the case for pastoral areas of Ethiopia. However, recent studies in the Afar Region of Ethiopia and other east African countries have shown the presence of many things to be shared between the two knowledge sources (IUCN, 2011; Oba, 2012). On a global scale, ILK was not formally recognized in policy or legislation until recently (McGregor, 2014), and it is still open to misinterpretation in many countries, and Ethiopia is not an exception. A narrow definition of 'tradition' can be another important barrier to the involvement of ILK in rangeland management. For some people, 'tradition' refers only to ways that are 'old' and 'outdated' and so traditional knowledge is often dismissed as irrelevant in the modern world (Oba, 2012; Minyahelet al., 2017). However, traditions always change over time, and that is why the pastoral communities in Ethiopia and elsewhere have survived (Oba, 2012). Another barrier arises when ILK is not "proven to the satisfaction of scientists and resources management bureaucrats" (Ross et al., 2011). This also results in structural and methodological problems for ILK owners working in cooperation with government agencies (Houde, 2007). Local communities recognize that they need to expand their knowledge base to include science, which will allow them to contribute to management. But, they also want to see two-way knowledge-sharing, as advocated by Stevenson (2006), where scientists also learn about local traditions. In Ethiopia, there is weak two-way communication and knowledge-sharing when there is such a vast chasm between indigenous/local ways of knowing and scientific ways of knowing, because the attention given to the pastoralists' knowledge is very less (Dika, 2016; Yeneayehu, 2018).

Generally; ILK is being transformed globally, but when it comes to ILK on ecology, it is being eroded. This translates into loss of knowledge on ecology, and as a result of this loss and in the face of the profound and ongoing environmental changes, both cultural and biological diversity are likely to be severely impacted as well as the local resilience capacities show decline. The larger implication of these results is that because of the interconnection between cultural and biological diversity, the loss of local and indigenous knowledge is likely to critically threaten the effective conservation of biodiversity, particularly in community-based conservation local efforts (Aswani et al., 2018).

Bohensky and Maru (2011) indicated: “Four critical stages of knowledge integration are likely to enable a more productive and mutually beneficial relationship between indigenous and scientific knowledge: new frames for integration; greater cognizance of the social context of integration; expanded modes of knowledge and evaluation; and involvement of inter-cultural “knowledge bridges”.

5.5.5.2 Institutional barriers

Institutional barriers are those obstacles erected, usually by governments or other institutions which interfere with the way local people participate in mainstream management situations (Nguyen and Ross, 2017). A typical example is kebele leaders interfering with the customary institutions in Ethiopia. Research undertaken in Ethiopia (Huig, 2013; Getahun, 2016) and globally (Ross et al., 2011; Aswani eta l., 2018) argue that bureaucratic arrangements and government structures may be difficult for local people to negotiate. Besides, governments have greater power and control than local people. Therefore, the state has the power to deny or restrict the involvement of local people in NRM. Consequently, "ILK is not ready to be trusted in this particular power game" (Briggs, 2005), which is quite evident in Ethiopia. Moreover, globalization has become a significant challenge to the incorporation of ILK into NRM (Sachidananda, 2008). The globalization of economics, technology and transportation has linked different areas and ecosystems leading to global environmental degradation which needs to be addressed on a global scale (Ross et al., 2011) which is also affecting Ethiopia. As it is the case in different countries including Ethiopia the State is at the center of the land and other resources. Therefore, the State has the power to deny or restrict the involvement of ILK and local people in management (Briggs, 2005; Ross et al., 2011). Although Ethiopia has laws and regulations that require the involvement of local communities in a range of development projects, there are no clear guidelines on how to achieve such community involvement particularly in Megaprojects that affect the livelihood of the pastoralists.

5.5.5.3 The cultural barrier to knowledge

According to Lertzman (2002), Oba (2012), Getahun (2016), both ILK and scientific knowledge are empirical and dynamic. However, local culture and laws are based around cultural traditions and stories while scientific knowledge is based around scientific principles and development needs and ideologies (Ross et al., 2011; Ngeyen and Ross 2017). Traditional knowledge sees the connection between natural and supernatural elements (Sillitoe, 2002; Getaneh, 2016; Yeneayehu, 2018) which is not the case in scientific knowledge. Nevertheless, the need for transferring useful indigenous knowledge and practices in Ethiopia cannot be undermined.

5.5.5.4 Weak knowledge management system

One of the critical problems in rangeland biodiversity conservation and ecosystem services in Ethiopia is the weak knowledge management system (e.g., lack of proper use of knowledge from different sources, organizing and synthesizing into usable format). For instance, lack of capacity and decision support tools to check adverse development and its impacts on biodiversity (UNDP, 2015; EBI, 2015).

5.5.5.5 Research and innovation gaps

In Ethiopia, compared to the diverse nature of the Ethiopian PAP communities, detailed research into usable ILKs is needed. This in particular should take into account the different rangeland biodiversity and ecosystem services and the ILK's recognition as a valuable usable knowledge by the public at large. Also the aspect of integrating ILKs with the scientific knowledge, in particular, is not properly addressed. In general, in developing countries like Ethiopia, the relationship between management practices and environmental services is often not well understood or easily quantified because of the low level of research undertakings.

Owing to the importance of ILK and the importance of its integration with scientific knowledge, where necessary, there is a need for detailed research into usable ILKs taking into account the diverse nature of the rangelands and the communities living in the Ethiopian rangelands. In Ethiopia, rangelands are under-researched compared to the other ecosystems. Until recently, the rangelands were largely considered as marginal contributors to the national economy, and hence were grossly ignored. It is only recently that the dry land/rangeland systems received research and development attention.

5.5.6 Suggested interventions to address the challenges

In Ethiopia, it is clear that there are some opportunities for the involvement of ILK and local communities in rangeland biodiversity conservation and ecosystem services. These opportunities arise from three different stakeholders: government (e.g., efforts by the different organizations like EBI, research institutions, Universities, and many others); local communities and from civil society organizations. Communities in the pastoral areas have more access to information technology than in the past. There are different communication and community-related development projects that aim to raise awareness, and build knowledge and management capacity for pastoral communities. In addition, better transportation and communication technologies like telephone and the internet have created an opportunity for people to deliver their ideas and comments to developers and decision-makers. Furthermore, the pastoral communities' depth of understanding about local resources in general and rangeland biodiversity conservation and ecosystem services, in particular; is an advantage when it comes to their involvement in development projects as well as in decision-making processes.

There are several civil society organizations (CSOs) and international organizations working in rangeland and pastoral development issues in Ethiopia, despite the problems that existed in relation to the CSO regulations. The current revised regulations will enable CSOs to work on advocate on biodiversity issues, and through capacity building to ensure involvement of local people in managing rangeland biodiversity and ecosystem services. These organizations not only raise their voices in advocacy for local people but also create platforms from which local people can participate, together with other stakeholders, in the management of local resources. Suggested interventions to address the barriers are listed below.

5.5.6.1 Provision of training, awareness, and implementation of an outreach program

For a better understanding of rangeland biodiversity and the proper utilization of ecosystem services, provision of training, raising awareness, and implementation of outreach strategies are needed at Federal and Regional levels.

5.5.6.2 Develop knowledge management systems

The development of the knowledge system needs to look into 1) increasing connectivity across databases so that various information sources can be linked and discovered, 2) linkages of information to spatial data so that information can be searched by location and obtained via mobile devices, 3) advances in remote sensing and spatial data products to better reflect processes of interest, (4) the development of user-friendly modular modeling tools that can be matched to local concerns and information, and (5) updating training curricula for rangeland.

5.5.6.3 Engage diverse stakeholders

Various stakeholders value rangeland biodiversity and ecosystem services differently, and thus management actions may favor some services over others. Consequently, protocols are needed to assess potential trade-offs and synergies between ecosystem services as a basis for decision-making (Bennett et al., 2009). The issue of engaging diverse stakeholders is well taken by Federal and Regional offices, in Ethiopia. It is also duly considered by EBI (2015) and globally by the Convention on Biological Diversity (Hana, 2008). The critical issue, among other things in Ethiopia, is how to bring stakeholders on a sustainable basis, and developing the manner of coordination.

5.5.6.4 Undertake research and innovation

Due emphasis needs to be given to research and innovation as related to the level of awareness and knowledge about rangeland biodiversity and ecosystem services. Furthermore, detailed studies are needed in ecosystem services in general and the mechanism of payment for ecosystem services in particular (e.g., carbon sequestration potential) as there is a need to develop knowledge for appropriate mechanisms of payment for ecosystem service.

Payments for ecosystem services (PES) are one of the potential mechanisms to provide land users in rangelands with incentives to increase the supply of positive externalities of rangeland utilization (e.g., biodiversity) and decrease the supply of negative externalities (e.g., soil erosion or carbon emissions). PES schemes make payments conditional upon performance. Conditionality may apply to system inputs (e.g., management practices), states of the agricultural system (e.g., vegetation cover rates), or the system's outcomes (e.g., rural development outcomes). Payments may be in various forms such as financial assistance, technical assistance, or other in-kind benefits (ADB, 2014). Yet, incentives for improved ecosystem services from rangelands have received little attention in Ethiopia.

In line with ecosystem service payment, other studies like issues of land tenure, mechanism of linking public investments in livestock and rangeland management with environmental outcomes, and modalities for community engagement need to be undertaken. In a number of cases; lack of land tenure, particularly, has limited the ability of land users especially the poor, to participate in and benefit from PES schemes; but PES schemes can also help to secure tenure for the poor. The PES schemes that fail to integrate social with environmental objectives could lead to loss access to natural resources and essential livelihoods assets and many PES programs are unable to address existing deficiencies in the broader governance context which impact on the welfare of the poor (ADB, 2014). The legal framework for land use and herder organization can potentially, but not in all situations, present an obstacle to developing and implementing effective PES system (ADB, 2014). Scientific knowledge of biophysical processes and the effects of management on biophysical processes can usually inform the design of PES schemes. In many developing countries, a robust knowledge base on rangelands is either absent or is thin. Thus, improving the knowledge base for PES for instance by synthesizing past experiences on technological options and undertaking research to fill gaps is essential. Identifying and assessing options for PES modalities is also vital. There is potential to maintain and increase the provision of rangeland ecosystem services by linking the investments in national and regional livestock programs. Prior to the PES implementation, there is a need for ensuring community benefits, and also the community stakeholders should be fully informed and consulted in the PES design processes.

It is important to note that land users' decisions are affected by a range of factors, not all of which can be addressed through PES schemes. PES schemes are, therefore, one among many policy options for addressing environmental management (ADB, 2014).

5.6 Impacts of policies, institutional arrangements and governance in biodiversity conservation and ecosystem services

5.6.1 Rangeland development projects and their implications on biodiversity conservation

Major rangeland/livestock development projects were undertaken since the 1960s in Borana (Oromia), Afar, and Somali. The Arero livestock development pilot project (ALDPP) was launched in 1965 by the Ethiopian government and USAID with the main objective of demonstrating the long term value of a coordinated rangeland management development scheme through pond construction and controlled grazing that can be scaled up in other rangeland areas of Ethiopia. The project was undertaken from 1965 to 1975 and covered an area of about 1600 to 2400 km^2 within a 50 km radius of Yabello town. However, the interventions were not well-fit to the traditional communal property rights and the mobility-based traditional milk-meat system of the Borana pastoralists (Coppock, 1994; Solomon, 2006). The newly constructed large water bodies rather attracted permanent settlements resulting in severe local overgrazing.

The Third Livestock Development Project (TLDP) was executed for eight years starting from the end of 1975. It was jointly financed by the World Bank, African Development Fund and the Ethiopian government. The intention was to increase the benefits from the lowlands for the national economy by increasing livestock off-take. It was designed to rehabilitate and develop northeast rangeland development unit (NERDU), Jijiga rangeland development unit (JIRDU) and southern rangeland development unit (SORDU). These sub-projects were designed to develop infrastructure (roads, market facilities and veterinary clinics) and natural resources (water and rangeland) to stimulate animal production, offtake, and increase the income and welfare of the pastoral communities (UNDP/RRC, 1984). Inventory and monitoring of the rangeland resources were undertaken. The project undertook a vegetation description of Jigiga (JIRDU), middle Awash (NERDU), and the Borana area (SORDU). These activities contributed to biodiversity conservation.

The South Eastern Rangelands Project (SERP), which covered 245,000 km^2 areas in Ethiopian Somali started in 1990 with a loan agreement between the African Development Bank (ADB) and the Federal Government of Ethiopia. It undertook different interventions (introduction, demonstration, and implementation of proven range management practices, rangeland monitoring, and evaluation, forage development, development and utilization of fodder banks, testing and establishing dryland grazing reserves). About 6,500 plant species were collected, identified, and manual for rangeland monitoring and evaluation was developed which contributed to biodiversity conservation (Kuchar, 1995; Esayas et al., 2019).

Beginning from 2011, there are livelihoods and drought resilience intervention projects that took place in pastoral areas of Ethiopia. These included the Inter-Government Agency for Development (IGAD) initiative, the Regional Pastoral Livelihoods Resilience Project (RPLRP), Drought Resilience and Sustainable Livelihood Project (DRSLP), Pastoralist Areas Resilience Improvement through Market Expansion (PRIME), Enhanced Livelihoods in the Mandera Triangle (ELMZT) and the EU Resilience Building Program in Ethiopia (EU RESET). These recent projects promote livelihoods, develop livestock resources, and protect and rehabilitate natural resources in a balanced manner. Their contribution to the conservation and management of biodiversity and ecosystem services is to be seen in the coming years.

5.6.2 Significance of policies, governance, and institutional arrangements

Policy can hinder or promote biodiversity conservation and ecosystem services. Inappropriate policy retards and even destroys the management and conservation of biodiversity and ecosystem services. Studies have shown that polices that supported communal land tenure tend to result in positive outcomes for pastoral livelihoods and the conservation of rangeland environments (Notenbaert et al., 2012; McGahey et al., 2014).

Studies in different parts of Africa, including Ethiopia (McGaheyet al., 2014; Beyene, 2016), indicated that most rangelands are managed communally and sustainable management, therefore, depends on the application of rules and regulations to govern uses often by a large number of resource users. Institutions (customary, government, and non-government) encompass all formal and informal interactions among stakeholders and social structures that determine how decisions are taken and implemented, how power is exercised, and how responsibilities are distributed (Ostroom, 1990; 2009). Furthermore, institutions play a significant role in influencing people's perceptions about the importance of rangeland benefits, their behavior, and thus decisions about the way they interact with nature (Sara, 2016). The nature of those rules and regulations, and how they are developed is key to the success of common property regimes (CPRs).

One area of the significance of policies, governance, and institutional arrangements is when it comes to payment for rangeland ecosystem services. If Ethiopia wants to undertake rangeland ecosystem service payment the most important determining factors are: policy and regulation, legal frameworks, customary natural resource governance, land tenure regimes, governance, institutions and the knowledge base. These factors influence the PES structure (buyers, sellers, intermediaries and knowledge providers), which in turn affect the three dimensions used to evaluate PES effectiveness i.e. environmental, cost, and social effectiveness (Pappagallo, 2018).

5.6.3 Pastoral and land development policies in Ethiopia

5.6.3.1 Pastoral policies

The earlier formulation of pastoral policies and strategies in Ethiopia has been based on general misconception and inappropriately premised generalizations about the nature of pastoralism and the pastoral mode of life (Mohammed, 2015; Esayas et al., 2019). The motivations of successive Ethiopian government plans and approaches in the context of pastoral regions have always been based on national security considerations and to extract surplus for national economic development. Pastoralists have been stereotyped as irrational, backward and destructive users of land, regressively stuck in the tradition of roaming the rangelands. In light of these perceptions, government interventions in the pastoral areas were primarily aimed at rectifying these wrongly assumed pitfalls of commercialization targeted to increase off-take through the provision of modern veterinary services, construction of access roads, establishment of ranches and water development for animals, and development of stock routes, holding grounds and market facilities (Esayas et al., 2019). It was a top-down approach that disregarded the socio-ecological views, interests, motivation and practices of the pastoral communities (lacks participatory approach).

Following the establishment of the Federal Government in 1991, the 1995 Constitution recognizes the rights of the pastoralists, and this manifest a major shift from the previous regimes in terms of incorporating the issues of pastoralists for the first time in Ethiopia (Getahun, 2016). There are also high-levels policy documents such as Poverty Reduction Strategy Paper (PRSP), Sustainable Development and Poverty Reduction Program (SDPRP) (2002-2005), the Plan for Accelerated and Sustainable Development to End Poverty (PASDEP,2006-2010), GTP I, and GTP II. Some of the other major interventions by the government included the formation of the Pastoral Affairs Standing Committee (PASC) in the House of Peoples' Representatives (HPR), the establishment of a directorate within the Ministry of Federal Affairs (currently under the Ministry of Peace) responsible for coordinating multi-sectoral support including pastoral development endeavors in pastoral regions; establishment of research institutes focusing on pastoral development, and the recognition and observance of Ethiopian Pastoralist Day, EPD (Abule and Alemayehu, 2015). The short-medium development policy admits the importance of investing in pastoralism to improve the food security situation of pastoralists and the usefulness of pastoral IK to manage rangeland resources. The long term policy, however, advocates for the settlement of pastoralists based on irrigation development, which will likely have an impact on the conservation and management of biodiversity and ecosystem services.

Regarding the policies of pastoral and agro-pastoral development, a recent review by Esayas et al. (2019) revealed that there are continental (African Union Pastoral Policy Framework/AUPPF) and Regional policy frameworks (IGAD-IDDRSI) and pastoral policies in Ethiopia. The African Union (AU) pastoral framework developed in 2010 is the first continent-wide policy initiative, which aims at securing, protecting, and improving the lives, livelihoods and rights of the African pastoralists. The Inter-Governmental Authority for Development (IGAD, 2016) engagement with pastoralism, within the framework of the IGAD Drought Disaster Resilience and Sustainability Initiatives (IDDRSI), was developed in 2013. The objective of IDDRSI is to develop a framework for managing disasters and build resilience in the horn of Africa. Ethiopia's post-1991 development endeavors have involved a continuous process of creating the legal framework, design and implementation of different social policies, strategies and programs.

Recently, the Ministry of Peace (2019) developed a pastoral development policy and implementation strategy draft document for the pastoral areas of Ethiopia, which was endorsed by the federal Parliament. This document is divided into four main areas namely, analyzing the current pastoral development policies and the directions of these policies; a vision of the pastoral development, main objectives of the policies and pillars of the pastoral development policies, and policies and implementation strategies of the 13 pastoral development sectors (including beyond sectoral issues) as part of the economic and social development, capacity development and good governance in the pastoral areas. It is expected that the pastoral development policy will contribute to improving the livelihood of the pastoral communities, the contribution of which will be seen in the future.

5.6.3.2 Land policies

In Ethiopia, the historical development of land tenure policies can be distinguished into three government regimes (Diresse, 2010; Huig, 2013; Mohammed, 2015: Beyene, 2016). These are the Imperial regime before 1974, the Derg regime (1974 to 1991) and the land tenure system since 1991. The policy makers in the different government regimes since the 1960s have consistently encouraged settlement and crop farming in pastoral areas (Getachew, 2001; Rahmato, 2007; Diresse, 2010; Huig 2013).

Until the l974 revolution, Ethiopia had a complex land tenure system. This land tenure system include (1) the *Rist* system, which was usually called communal tenure practiced in the northern parts of the country; (2) the *Gult lordship* system, usually called private land (central and southern parts of the country); (3) the nomad areas, usually called state-owned land and found in the eastern and southern part (Huig, 2013; Beyene et al., 2021). Generally, during the Imperial period, the land tenure in Ethiopia was a feudal system directed towards individualized property (Omiti, 1999; Kebede, 2002).

The Constitution during the Imperial period gave a decisive power to the state both as a landlord in its own right and according to Article 130 of the 1955 Constitution "all property not held in the name of any person including all forests and grazing lands" are state domain (Rahmato, 2007; Diresse, 2010). The Imperial State made extensive land grants to different classes (e.g., members of the royal family, nobility, armed forces, police, top government officials, civil servants and notable businessmen). The constitution resulted in much of the land utilized by pastoralists in the country to fell under the state domain, which gave the state control over nearly 65% of the land (Rahmato, 2007). For example, the appropriation of large tracts of land for non-pastoral use from the land that belongs to Afar and Kereyu pastoralists for mechanized farms, settlement schemes in the Awash River Valley is a reflection of the coercive action of the Imperial State (Getachew, 2001; Hundie, 2006; Rahmato, 2007; Yemane, 2008). The 1960s was characterized by the emergence of large-scale commercial farms, (Mrema et al., 2008). The land privatization resulted in the eviction of a large number of peasants, the spread of tenancy, the emergence of absentee landlordism, and displacement of pastoralists (Getahun, 2016). However, the influences of policy in the Borana zone were very limited (Kamara et al., 2004).

The 1975 land reform of Derg, appropriated all land and abolished the diverse tenure arrangements of the imperial regime (Getahun, 2016). The land reform destroyed the feudal order; changed landowning patterns, particularly in the south, in favor of peasants and small landowners; and provided the opportunity for peasants to participate in local matters by permitting them to form associations (Rahmato, 1994). The outcome is the establishment of state farms, cooperatives, and small-holder farms (Omiti et al., 1999). The proclamation (No. 31 of 1975) gave "the state the right of ownership of all rural land and other resources, and that prohibits private ownership of land" (Direse, 2010). Since the proclamation, all agricultural land became the collective property of the Ethiopian people. This change especially affected the people in the highlands, because the lowlands were hardly affected by the elite and landlords (Huig, 2013).

Regarding pastoral areas, Article 26 of the land reform in 1975 states that "nomadic people shall have possessory rights over the lands they customarily use for grazing or agricultural purposes". In this article, the state took away the authority of pastoralists' customary institutions (i.e., absolute rights to the land were turned into possessory rights with the ultimate right vested in the state), but was not successful at the end (Rahmato, 2007). Other policy measures in the pastoral areas were pastoral settlement programs, forced livestock sales and provision of special support for cultivation (Kamara et al., 2004) which have negative implications on the management of biodiversity. Although land appropriation continued for the establishment of state farms in Awash Valley, customary rights to land and community institutions in other areas remained largely unchanged (Rahmato, 2007).

The land and agricultural reform in Ethiopia resulted in the establishment of peasant associations (PAs) where each PA served an area of 800 ha. The PAs were responsible to implement land reform, administer public property, establish service co-operatives, build schools and clinics and execute villagization programs (Rahmato, 1984). The implications of this, for instance, in Borana pastoral communities, as studied by Kamara et al. (2004) and reviewed by Huig (2013) were limited access to grazing areas outside the *Arda* (the madda is further sub-divided into sub-grazing units called *Arda* which consists of a few encampments that have jurisdiction over some form of grazing area, cultivated land and to a lesser extent, on water resources) because of the new boundaries, loss of *Forra* (grazing area reserved for bulls and cows that do not lactate) grazing areas became accessible for members of the new PA but were formally from a different traditional *Madda* (traditional pastoral units of resource allocation; madda are centered around permanent water sources, usually traditional deep wells) and increased conflict over grazing and water management regulation by pastoralists and traditional decision-makers and young chairmen of the PAs.

A settlement was stimulated by the government through PAs as sedentary life was considered as a good strategy to lead an easier administration and promote cultivation. The settlement resulted in competition between the pastoralists and farming communities over the same resources (Alemayehu, 1998). It also brought a breakdown of traditional territorial organizations. Ranch expansion in the Borana rangeland had positive effects (e.g., controlled conservation of Borana breeds and production of heifers for national breeding programs) and negative effects (e.g., sites selected were in good rangelands, which implied the lack of attention to pastoralists' need). Thus, some pastoralists were pushed out of their land without consent and traditional management strategies were endangered (Alemayehu, 1998).

The land reform by the government also resulted in problems related to land fragmentation, insecurity of tenure and shortages of farm inputs and tools. In general, fragmentation of land holdings, tenure insecurity, land degradation, and inefficient allocation of land by the way of restrictions on land transfer, and to some extent lack of appropriate land use and administration were among commonly cited problems concerning the land policy of the Derg Regime. According to Herlocker (1999) ownership of land is one of the key factors in biodiversity conservation and management.

Following the fall of the Socialist regime in 1991, the Federal Government's land policy is quite similar to that of the previous regime (Diress, 2010). The government announced the continuation of the land policy of the Derg regime under the Constitution of 1995 that approved and confirmed the state ownership of land in Ethiopia (Getahun, 2016). In effect, land is state property and peasants have only use rights, and the land they possess cannot be sold, exchanged or mortgaged. The Constitution guarantees the rights of peasants and pastoralists of free access to land, and the right of individuals to claim compensation for improvements they make on land, including the right to bequeath, transfer or remove such improvements when the right to use the land expires (Art. 40 (7) and (8). Moreover, Regional Governments have to administer land and other NRs according to federal laws (FDRE Constitution 1995, Art.52). Despite the difficulty to translate into concrete measures, the present Constitution recognizes pastoral land in a better way and declares (Article 40) that Ethiopian pastoralists "have the right to free land for grazing and cultivation as well as the right not to be displaced from their lands". Yet, the government is still facilitating the gradual conversion of pastoralists into more sedentary livelihoods (Hundie and Padmanabhan, 2008).

Different land administration and use laws were enacted successively by the FDRE government. For instance, Federal Land Administration and Use Law were enacted in 1997 giving the Regional Governments the power of land administration. The 2005 law makes provision for the registration and certification of tenure rights (Proc No.456/2005, Art.6) and it declares that the government can decide to transfer “communal land” (i.e., land communally held by pastoralists) to private holdings if it deems it necessary (Article 5 No. 3). In the 2005 law, pastoralists were recognized. Yet, collective land rights were denied resulting in favor of privatization (Huig, 2013). While there are policies and legal measures, land-related problems such as tenure insecurity, restrictions on transfer and lack of adequate land administration system still prevail (Getahun, 2016). In Ethiopia, several policy designs are intended for a good cause, but have ended up with significant negative consequences in dryland areas. These policy agendas include resettlement program, investment policy and the crop-focused rural development strategies (EPCC, 2015).

According to Beyene (2016), the land use proclamations of the regional governments in Ethiopia are, in most cases, a direct copy of the Federal Policy and fail to contextualize pastoral issues. Possible loss of land use rights if individuals do not properly manage the land or cause damage to the land, is underlined by land management rules. However, its application in the communal pastoral lands remains unclear. To this effect, there is also no specified institution responsible for the implementation and monitoring of the policies and proclamations to determine how effective they are. Currently, there are different pastoral land management activities, which are mainly project-based. However, the traditional customary system seems to be ignored. The governments at different levels address the issue of tenure security through issuing holding certificates. The questions are how such a certificate is applied to communal rangelands belonging to pastoralists and whether compensation has ever been paid to pastoralists and agro-pastoralists. Many scholars argue that pastoral communities have no guarantee of secure land-use rights for an unlimited period, and thus land may remain vulnerable to further degradation due to lack of incentive resulting from lack of ownership.

In the article “The law is to blame”, Wily (2011) argues a weak legal status of communal rights is a problem that allows governments to exploit citizens’ rights and especially those which are unfarmed and by tradition held in common, resulting to loss of land of the majority rural poor”.

5.6.4 Institutions involved in the conservation and management of rangeland biodiversity

Institutions are defined as the rules and norms that structure human interaction, including their enforcement characteristics and sanctioning mechanisms (North, 1990) and they are broadly divided into customary, government and non-government (Getahun, 2016). An important characteristic of an effective institution of property rights is the extent to which the privileges of right holders are recognized by society at large, and defended by system of the authority (Bromley, 1991; Agrawal and Elbow, 2006). Unfair and unstable property relations create insecurity which invites conflict, blocks investment and discourages sustainable NRM (Agrawal and Elbow, 2006). Even with clear land tenure regimes or laws that might support improved rangeland management and pastoralism, weak implementation and enforcement due to weak institutions means that it essentially fails to recognize pastoralists as a collective entity, and poses a risk to the operationalization of ecosystem service payment schemes (Silvestri et al., 2012; Badola, et al., 2013). This section addresses the institutions (customary, government and non-government) involved in biodiversity conservation and rangeland ecosystem services.

5.6.4.1 Customary institutions and laws

Communal access to resources is governed by customary laws and institutions. They have developed flexible resource management systems to be implemented by the communal land management institutions (Beyene, 2016). Thus, customary institutions are rules governed by behavioral norms and include sanctions, taboos, traditions and code of conduct (Mowo et al., 2011). Taboos are believed to play an active role in nature conservation (Murphree, 1994) that is highly adaptive from an ecological perspective and contributes to biodiversity conservation (Colding and Folke, 2001). Customary institutions are institutionalized arrangements rooted in the local culture of indigenous people and are responsible for safeguarding resource governance in a given locality (Kisiaya, 2018).

In Ethiopia, a range of traditional institutions and management arrangements have been, and still are, employed to determine access to the use and management of rangelands, forests, and water resources. There are customary institutions that address environmental management in the pastoral areas of Ethiopia, and these include the *Gadaa* traditional authority, among the Borana Oromo communities as well as the *Gereb* herding and grazing arrangements between the Afar pastoralists and the Tigrayan farmers and others. This, to a large extent, reflects the correlation between biological diversity and the cultural diversity which is found in biodiversity hotspots of Ethiopia (EPCC, 2015).

In Afar, pastoralists have traditional NRM strategies such as the management of rangeland and livestock for dry and wet seasons and these are important in biodiversity conservation and management (Tibebu, 2012). The Afar traditional institution, which is a legal system that makes decisions, governs the management and utilization of rangeland. It has a hierarchical structure starting from a household head to clan leaders at the top level. This institution is the highest decision-making body of all the clans and defines the mobility of the community between dry and wet seasons. The mobility decisions are made following an assessment made by young scouts assigned to undertake the assessment. The scouts inform the community on the situation with due consideration on the availability of feed both in quality and quantity. They also provide an estimate on how long the feeds and water could potentially sustain the livestock. Following this, elders decide on the number of livestock and length of stay at a particular place. The herd is split into the base site and mobile herds. Adults manage the less productive livestock, including camels which are sent to a new location and they try to avoid overgrazing to allow regeneration of pasture. The grazing pastern in these areas is regulated by availability of water, pasture, and the size and structure of herds. According to Tibebu (2012), community members who failed to respect the traditional rules and instruction are fined.

The traditional customary institution systems in Oromia and more specifically in the Borana rangelands were studied by different scholars (Legesse, 1973; Coppock, 1994) and also reviewed by many (Huig, 2013; EPCC, 2015; Getahun, 2016). The institutions and organizations relevant to biodiversity management and conservation are briefly described in subsequent section.

The Gada resource management system, taboos, sacred areas and informal institutions contribute to sustainable land and biodiversity management. The Borana Gada system, that has been recognized by UNESCO as an intangible cultural heritage of the world in 2016, has embedded a hierarchical rangeland management institution. The most important part of the rangeland management institution is the obligation for animal movement to be regulated according to the patterns outlined by elders based on range availability, rangeland condition and seasonal carrying capacity of the natural resources of the Borana plateau to avoid degradation (Watson, 2003). In this way, the informal institution has managed the rangelands for generations (Getahun, 2016).

The customary laws and regulations of the Gada system are included inherent to all Borana people, and thus respected by the whole society (Yigezu, 1993). The Gada system regulates the use of the Borena natural resources, maintaining peace among the multitudes of users, and protecting them and their cattle from external invasion (Coppock, 1994; Watson, 2003). It comprises a decentralized social organization to govern resource use. The structure begins from a village level unit at the micro level in the social organization through *Kora Olla* (village council), *Kora Ardaa* (area/county council), and *Kora Gossa* (clan council) to *Gumi Gayo* (the pan Borena assembly). A consensus on important community issues such as redefinition and enforcement of rules, regulations and norms is reached through open and participatory discussions in assemblies beginning from the village council and terminating at the macro (*Gumi Gayo*) level. *Gumi Gayo* (an assembly of all Borena people and/or their representatives) is held every eight years to discuss issues such as resource conflicts and cardinal rules, including those that have been violated and to collectively devise the future of the Borena society. Gada used to play a lead role in managing dryland resources, at least for a few hundred years (EPCC, 2015).

Getahun (2016) studied the role of different traditional values in conserving and management of rangeland biodiversity. These include the role of sacred areas, resource and habitat taboos. For instance, sacred taboos help to conserve biodiversity through protecting unnecessary and unregulated removal of trees. Taboos prohibit use of something because of its sacred nature and it is one of traditional practice which is vital for the sustainability of natural resources including forests, aquatic wetland and agricultural ecosystems across landscape continuum; spanning from households through farms, village, commons, and wilderness. There are studies in Africa that suggest that incorporating cultural norms and taboos into conservation programs may provide incentives to communities to conserve natural resources. East Africa also has a good record of the effectiveness of taboo and social norms in wildlife conservation (Kideghesho, 2008; Kassilly and Tsingalia, 2009). In Ethiopia, detailed review regarding taboos and other cultural values needs to be undertaken and incorporated in biodiversity conservation and management.

5.6.4.2 Government organizations

Government organizations (formal institutions) include the written or codified constitutions, judiciary laws, policies, rights and regulations enforced by official authorities (Leftwich and Sen, 2010). The management of natural resources in Ethiopia is shared between the Federal

Government and the Regional States. The Federal Government is empowered by the Constitution to enact laws on the conservation and utilization of land and natural resources (art 51(5) and following up and ensuring the implementation of laws, policies, directives and decisions adopted by the Parliament, and initiating and submitting to the Parliament draft laws relating to the conservation and utilization of natural resources. The Regional States, on the other hand, have the power to administer natural resources as per the laws issued by the Federal Parliament (art 52(2/d). Some of the major institutions that govern the conservation, sustainable use, and access and sharing of benefits arising from the use of the country's genetic resources and associated community knowledge are described below.

The lead federal institution involved in biodiversity conservation is the Ethiopian Biodiversity Institute (EBI). Other major actors include the Ministry of Peace (formerly called Ministry of Federal Affairs and Pastoral Development), Ministry of Agriculture, Ethiopian Institute of Agricultural Research, Ethiopian Wildlife Conservation Authority, Higher Learning Institutions, Ministry of Culture and Tourism, Regional Bureaus of Agriculture, Environment, Forest, Climate Change Commission as well as corresponding institutions in the National Regional States. The activities of these are financed by the budgets allocated from the Federal (Ministry of Finance) and Regional Governments. Some Regional institutions do have roles that are directly or indirectly involved in biodiversity conservation and management.

In addition to the Constitution of 1995, Ethiopia is the 54th signatory to the Convention on Biological Diversity (CBD) and ratified the convention in 1994 (Negarit Gazetta 98/1994). Ethiopia has also acceded to Nagoya Protocol on Access to Genetic Resources and this will eventually enhance implementation of the National Access and Benefit Sharing (ABS). The country has ratified international and regional treaties including CBD, The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), Convention on International Trade in Endangered Species of Wild Flora Fauna (CITES), Convention of Migratory Species (CMS), World Heritage, Euroasian Migratory Waterbirds (AEWA) and acceded to the Nagoya Protocol.

Among the government organizations, some details on the roles and responsibilities of the Ethiopian Institute of Biodiversity (EBI); and the Ministry of Peace are described here. The EBI as a primary national entity in charge of ensuring the conservation and sustainable use of the country's biodiversity of Ethiopia, namely: plants, animals, and microbial biodiversity, and fair and equitable share of benefits arising from the use of the genetic resources and associate community knowledge (EBI, 2015). In line with this; EBI initiates policy and legislative proposals on the conservation of biodiversity, explores and surveys the diversity and distribution of the country's biodiversity resources, ensures the conservation of the country's biodiversity using *in situ* and *ex situ* methods, and give permits for those who need to access genetic materials from the country. According to the National Policy on Biodiversity Conservation and Research (IBCR, 1998), based on national legislation, the institute has the responsibility and duty to implement international conventions, agreements, and obligations on biodiversity to which Ethiopia is a party. The roles and responsibilities of the EBI have been refined through time (e.g., re-establishment and restructuring of Ethiopian Biodiversity Institute, Regulation 291/2013 and the EBI has updated National Biodiversity Strategy and Action Plan in 2015.

Different initiatives, plans, regulations, and proclamation like climate-resilient green economy, sustainable land management, Growth, and Transformation Plan–II (GTP-II), the Conservation Strategy of Ethiopia (EPA, 1997), Development Conservation and Utilization of Wildlife (Proclamation No. 541/2007), Access to Genetic Resources and Community Knowledge, and Community Rights Proclamation (No. 482/2006) and Regulation (169/2009) are handled by different government organizations.

The Ministry of Peace oversees the National Intelligence and Security Service (NISS), the Information Network Security Agency (INSA), the Federal Police Commission, and Finance Security and Information Center. It also oversees the National Disaster Risk Management Commission, the Administration for Refugee and Returnee Affairs, Ethiopian Foreign Relations Strategic Studies Institute, and the Main Department for Immigration & Nationality Affairs. Though not directly, the Ministry is involved in conservation and management of biodiversity, and has a big role in Federal & Pastoralist Development Affairs which covers about 60% of Ethiopia's land area. Some of the interventions such as settlement and encouraging crop farming were advocated by the former Ministry of Federal Affairs and Pastoral Development. The effects of such interventions are discussed in section 5.4.2.

In conclusion, despite the presence of different organizations and legal frameworks, rangeland biodiversity is degrading from time to time because of the lack of clear rangeland policy. Moreover, frequent changes at Ministerial offices, lack of proper coordination, and frequent staff turnover are implicated as affecting the biodiversity conservation efforts.

5.6.4.3 Non-government organizations and professional societies

Various international organizations, including International Livestock Research Institute, International Center for Agricultural Research in the Dryland Areas, and the Food and Agricultural Organizations of the United Nation; and national and local non-government organizations are directly or indirectly involved in biodiversity-related activities in Ethiopia. Some of the local and international NGOs include CARE Ethiopia, SOS Sahel, Save the Children, OXFAM GB, Mercy corps, Action for Development (AFD), USAID, Afar Pastoralist Development Association (APDA), Consortium of Christian Relief and Development Association (CCRDA), Gayo Pastoral Development Initiative, Pastoralist Concern, Ethiopian Society of Animal Production, Ethiopian Veterinary Association and Pastoral Forum Ethiopia.

Both the local and international NGOs, given their long time presence with local communities and institutions, have developed valuable experience concerning environmental management. These development organizations are also involved in participatory rehabilitation. The international research organizations based in Ethiopia undertake different rangeland management planning, community-based rangeland management, mapping guidelines for participatory rangeland management, rangeland rehabilitation and improvement, water development and conduct various kinds of research in rangeland, livestock, pastoralism, biodiversity conservation, and management, and these have contributed towards a better understanding of the rangeland and the pastoral production systems.

5.6.5 Governance of rangeland biodiversity

Institutions and governance structures are considered indirect drivers of change in the ecosystem, through their effects on the direct anthropogenic drivers (MEA, 2005; Diaz et al., 2015). Effective governance needs rules and regulations not only locally, but nationally, and in many cases internationally. It also requires governance systems to be aligned at these different levels, without undermining the self-enforcing nature of effective local governance; and whilst maintaining a principle of subsidiarity. In addition to local arrangements for communal resource management, governance in Ethiopia is influenced by policies at the Federal and Regional levels. Governance of the rangelands is also influenced by other stakeholders, some of which may be peripheral to the rangelands. Effective governance, therefore, requires institutional arrangements to enable cross-sectoral planning and resource allocation.

In one or another way, different studies have shown that the social fabrics on which rangeland governance depends are being eroded or weakened in different PAP areas of Ethiopia. For instance, studies by Amaha (2006) in Somali Region, Kidane (2006), Diresse (2010) and Minyahel et al. (2017) in Afar; Admassu et al. (2010), Kinfe (2011) in SNNPR and Angassa (2007) and Oba et al. (2012) in Borana have reported the decline in the informal governance structures, negatively affecting the biodiversity resources of the studied areas.

On the other hand, studies in different countries have revealed the possibility of reviving the governance elements. Pastoral governance has been successfully strengthened by taking advantage of decentralization in many countries, including Kenya, Tanzania, Botswana, Morocco, Jordan and Lebanon. In Mongolia, greater local governance over natural resources in pastoral areas demonstrates how community organizations have improved environmental conditions through customary decision making, scheduled seasonal movements, and lobbying for improved roads and repairs to wells that have improved access to unused pastures (McGahey et al., 2014).

The institutional framework for the governance of ecosystem services has vertical and horizontal dimensions. In the vertical dimension, institutions are differentiated by a hierarchy of international, national, regional, and local levels. The horizontal dimension distinguishes institutions by different sectors which include the environment, agriculture, water, energy, institutions, encompassing the broad spectrum of actors from the governmental, inter-governmental, non-governmental, private sectors and civil society. Assessing laws, institutions, and governance frameworks in a cross-cutting manner allow for a comprehensive and creative assessment of the opportunities for operationalizing payment for rangeland ecosystem services (Pappagallo, 2018).

Up until the very recent times, Ethiopian law has had certain constraints on the work and political space of Civil Society Organizations (CSOs) in the country (Townsend, 2019). This had its own impacts on the operation SCOs with regard to the conservation and management of the rangelands and component biodiversity. The current government, however, has revised a series of legal provisions and issued new laws, including the Charities and Societies Proclamation of 2009. Given the welcome development and changes in the CSO regulations in Ethiopia, there is sufficient playing ground to increase the role of the CSOs in rangeland biodiversity conservation and management.

The role and involvement of the private sector institutions in rangeland biodiversity conservation and management in Ethiopia is very negligible. However, elsewhere outside Ethiopia, private sector's role in rangeland biodiversity conservation and management is well documented (Davies et al., 2012). It can be said that in Ethiopia, there is no policy ground and governance structure that will bring on board the private sector involvement in rangeland biodiversity conservation and management.

5.6.6 Policies, governances, and institutional arrangement key challenges

The land policy of the Ethiopian government and the customary practice for rangeland management are neither complementary nor independently strong. These just co-exist in a state of confusion resulting in increased land degradation and policy gaps (Beyene, 2016).

Generally in Ethiopia, pastoral traditional knowledge and customary institutions are dominated and ignored, and considered weak to manage natural resources. The, changing biophysical, socio-economic and political conditions in recent decades are also threatening the role and the strengths of customary institutions and practices. Traditional norms are increasingly violated. The breakdown of the customary institutions and the social fabrics, on which rangeland governance depends, has negatively impacted rangeland biodiversity and ecosystem services, leading to their increased disappearance; and eventually affecting the livelihood of the communities (Amaha, 2006; EPCC, 2015; Yihew et al., 2017; Minyahelet al., 2017).

There is lack of adequate research that examines the effectiveness of policies, governances and institutional arrangements from the perspective of needs of the government and that of the pastoral communities.

“While the relevance of biodiversity information for national development is acknowledged by stakeholders, there are still major obstacles including the lack of funding for data mobilization, weak institutional capacity, lack of individual competencies and inadequate training on techniques for mobilizing biodiversity data and information. Advocating for value-added and demand-driven biodiversity information has the potential to garner policy support and legitimacy to reach the level of importance required for investment, capacity development and specialized institutions for biodiversity conservation” (Ozor et al., 2016).

One of the greatest challenges Ethiopia faces is the lack of the ability to responsibly use and sustainably manage its rangeland resources, given the changing circumstances due to climate change. Climate change has the power to influence policies, governances and institutional arrangements. The inadequacy in providing environmental education to the public and the communities at large is another problem that deserves due attention.

5.6.7 Policy, institutional arrangement, and governance related recommendations

Studies in Ethiopia (Beyene, 2016; Ozor et al., 2016; Esayas et al., 2019) and other developing countries (Swidererska et al., 2008) discussed policies, governance and institutional arrangement for rangelands that can contribute to biodiversity conservation and improved rangeland ecosystem services.

Policy

- Pastoral friendly policies that facilitate improved and resilient pastoral and agro-pastoral livelihoods are crucial. These could include policies on land use and tenure, mobility and trade that enhances cross border as well as domestic livestock trading. There is a need for land tenure with a robust pastoral land-use policy designed to avoid the collision between the expansion of large scale irrigation schemes and mobile pastoral livelihoods. It is very important to positively consider pastoral mobility as a core livelihood strategy and central element of the policy,
- Policies should recognize the role and authorities of the customary institution in governing resources and managing and resolving conflicts and administering traditional social protection facilities such as sharing and reciprocities/acknowledge the legitimacy of indigenous pastoral institutions,

- The need for considering cultural and historical aspects when designing policies to revitalize rangelands and thereby the socio-economic life of pastoralists. There is a need to examine policy and institutional options that promote accessibility (security of tenure), stability and indigenous knowledge of rangeland management supported by the adoption of improved technologies,
- Policy studies and guidelines on biodiversity planning have emphasized the importance of policy as a cyclical learning process, informed by the ground realities and experience and regularly reviewed to reflect new evidence and perspectives. ,
- Policy and plans should not be separated from practices; instead, they should be linked to it, and
- Developing modality and policy for ecosystem service payment from the rangelands.

Institutional arrangement

- Establishing the institution for rangeland development, preferably aligned to a ministry close to the function, and that could be cascaded from the federal to the lost level possible,
- Strengthening the capability of local organizations and knowledge systems,
- Providing CSOs and the private sector an institutional space in which they operate, and
- Enhancing social networks.

Rangeland governances

- Encouraging participatory approach,
- Developing accountable decision-making and effective representation
- Fostering collaborative learning,
- Strengthening community-based conservation and governance at the national level,
- Creating good alignment with governance at the international level as deemed necessary, and
- Ensuring representation of the local community.

5.7 Conclusions

Ethiopian rangelands are integral parts of pastoral systems, which play important roles in livelihood of the pastoralists, livestock production, maintenance of plant and animal biodiversity, and as sources of food and herbal medicines. Livestock production in the rangelands generates significant economic benefits and contributes to soil nutrient cycling. Rangeland ecosystem also provides many ecosystem services such as carbon sequestration and climate regulation. The co-benefits of carbon sequestration may be directly linked to the Sustainable Development Goals (SDGs) through its effect on food security and poverty alleviation. In addition, rangeland ecosystem contributes to cultural identity and diversity, cultural landscapes, heritage values and spiritual services. They also serve as areas of tourist attraction and focal sites of archeological and socio-anthropological studies. Rangeland vegetation facilitates the infiltration of water deep into the soil profile and helps maintain air humidity, reduce soil erosion by wind and water.

The rangeland condition in Ethiopia is deteriorating, leading to land degradation, defined as a decrease in plant species diversity, plant height, vegetation cover and plant productivity. Rangeland condition is used as a guide to ensure sustainable land use, determine carrying capacity and adjust stocking rates, and identify potential responses to range improvement programs. Degradation of rangelands causes a reduction in total vegetation cover and palatable plant species, and causes an increase in undesirable and unpalatable plants, as well as deterioration of soil quality, affecting plant regeneration capacities and constrains restoration of denuded lands. Due to the expropriation of dry season grazing and watering areas, the wet season grazing areas are continuously grazed throughout the year leading to severe degradation which is manifested as loss of vegetation cover and soil erosion. Bush encroachment is prominent in rangelands where grazing pressure is high and also where the transformation of rangelands to other land-use types occur, bush encroachment shows an increase.

The drivers of change in rangeland biodiversity and ecosystem services in Ethiopia include land-use change, constrained mobility, inappropriate extension services, and encroachment by native and invasive species. Policies fostering agricultural expansion can increase the overall pressure on rangeland biodiversity, leading to loss of ecosystem services and hence livelihoods of communities who depend on rangeland resources. Sustainable use of the Ethiopian rangelands in the future will require a greater focus on regulating the expansion of private enclosures, the encroachment of crop farming and ranching, as well as the reintroduction of prescribed fire to control the expansion of bush and weeds. Thus, dealing with drivers of change in rangelands and reducing the loss of biodiversity and ecosystem services is direly needed.

Rangeland biodiversity and ecosystem services are degrading at faster rates because of problems related to rangeland policy, institutional arrangement and governance. Pastoral communities do not have a long term secure land use right. There is no clear modality and policy established on payment for ecosystem services generated from the rangelands of the country, which is partly attributed to the lack of knowledge and awareness on mechanisms of payment. Communal access to resources were used to be governed by customary institutions and laws, however, there is a breakdown or weakening of the traditional institutions and resource utilization systems, and the social fabrics necessary for rangeland governance in different pastoral and agro-pastoral areas of Ethiopia, are also getting loose. Therefore, there is a need for intervention ,and possible interventions include pastoral friendly rangeland policy (e.g., land use and tenure policy, mobility promoting policy, a policy that recognizes the roles and authorities of the customary institutions, the policy that considers cultural and historical aspects, policy for payment of ecosystem sevices from the rangeland ecosystem); empowering communities; strengthening the capacity of local institutions; and ddeveloping accountable decision-making and effective representation and strengthening governance at different levels. Furthermore, rangeland development should have its own institution or should be aligned with the ministry close to it in function.

The lack of recognition, and the decline as well as the disappearance of the indigenous knowledge (IK), has also attributed to the failure to properly augment usable IK with scientific knowledge. Suggested interventions include the provision of training/education, awareness creation, and implementation of outreach program, developing/strengthening knowledge management systems, engaging diverse stakeholders, and undertaking detailed research on usable IK and how to integrate it with the scientific knowledge; and undertaking detailed research and innovation. Recognition and use of indigenous knowledge must be an integral part of the development of policy relating to rangeland resource management. Knowledge and power-sharing between local communities and other bodies could also lead to a better communication between stakeholders for a sustainable and resilient rangeland ecosystem.

To cope with climate variability, the pastoral communities in Ethiopia are undertaking various rangeland management practices. These practices include the establishment of fenced rangeland or grazing enclosures for the core breeding stock, mainly calves, to ensure continuity and sustainability of pastoralism. They have also recently introduced haymaking and large enclosures as fodder banks for use during the dry season. Many pastoralists in Ethiopia are focusing on the use of grazing enclosures to conserve forage resources for dry seasons. This is a welcome development; however, individual enclosures could pose a problem in a system which works on reciprocity and sharing of grazing resources. The growing shift towards sedentarization, the increasing trend of crop cultivation, and the privatization of the communal rangelands are, therefore, triggering conflict over grazing and watering resources; and boundary claims among different pastoral communities or resource user groups. It is emphasized here that any development interventions in the pastoral area should be carefully planned in a manner that does not disrupt the pastoral production system. Moreover, there is a need to strengthen and empower the customary institutions to tap into their rich indigenous knowledge and governance systems in regulating access to and use of communal resources, as a mechanism of resolving conflict over rangeland resources.

5.8 References

Abate, T and Angassa, A., (2016). Conversion of savanna rangelands to bush dominated landscape in Borana, Southern Ethiopia. *Ecological Processes* [online]. **5**(6). [Viewed 02 January 2020]. Available from: DOI 10.1186/s13717-016-0049-1.

Aboud A., Kisoyan, P.K., Said, M.Y., Notenbaert, A., de Leeuw, J., Gitau, J.W., Manzano, P., Davies, J.M., Roba, G.M., Omondi, S.O. & Odhiambo, M.O., (2012). Natural resource management and biodiversity conservation in the drylands of eastern and central Africa. Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), Entebbe, Uganda, 91 pp. [accessed on 24 August 2016]. Available from: http://cmsdata.iucn.org/ downloads/asareca_wisp_full_report.pdf.

Abule, E. and Alemayehu, M., (2015). State of rangeland condition and trends in Ethiopia. In: Alemu Y., Getnet, A. and Lemma, G. (eds). *Proceedings of the conference on pasture and rangeland research and development in Ethiopia*. Pp. 3-25.

Abule, E., (2003). Rangeland evaluation in relation to pastoralists' perceptions in the Middle Awash Valley of Ethiopia. Ph.D. Dissertation, University of the Free State, Bloemfontein, South Africa, 297p.

Abule, E., Smit, G.N. and Snyman, H.A., (2005b). The influence of woody plants and livestock grazing on grass species composition, yield and soil nutrients in the middle Awash valley of Ethiopia. *Journal of Arid Environments* [online].**60**:343-358. [Viewed 02 January 2020]. Available from: https://doi.org/10.1016/j.jaridenv.2004.04.006.

Abule, E., Snyman, H. A. and Smit, G. N., (2005). 'Comparisons of pastoralists perceptions about rangeland resource utilisation in the Middle Awash Valley of Ethiopia', 75, pp. 21–35. doi: 10.1016/j.jenvman.2004.11.003.

Abule, E., Snyman, H.A. and Smit, G.N., (2005a). Comparisons of pastoralists perceptions about rangeland resource utilization in the middle Awash valley of Ethiopia. *Journal of Environmental Management* [online]. **75**:21-35.[Viewed 02 January 2020]. Available from: https://doi.org/10.1016/j.jenvman.2004.11.003.

Admasu, T., (2006). Pastoralists Perceptions on Range-Livestock Management Practices and Rangeland Assessment in Hamer and Benna-Tsemay Districts of South Omo Zone. An M.Sc. Thesis Presented to the School of Graduate Studies of Haramaya University, Ethiopia. 159p.

Admasu, T., Abule, E. and Tessema, Z., (2010). Livestock-rangeland management practices and community perceptions towards rangeland degradation in South Omo zone of the Southern Ethiopia. *Livestock Research in Rural Development* Volume 21 Numberhttp://www.lrrd.org/lrrd22/1/tere22005.htm.

Aggarwal, S. and Elbow, K., (2006). The Role of Property Rights in Natural Resource Management, Good Governance and Empowerment of the Rural Poor. USAID Contract No. PCE-I-00-99- 00001-00, Task No. 13.

Agrawal, A., (1995). Indigenous and scientific knowledge: Some critical comments. *Development and Change*. **26**(3), 413-439.

Alemayehu, M., (1998). The Borana and the 1991-92 drought: A Rangeland and Livestock Resource Study. Institute for sustainable development, French Catholic committee against hunger and for development. Addis Ababa, Ethiopia. 90p.

Allan, B.F., H. Tallis, R. Chaplin-Kramer, S. Huckett, V. A. Kowal, J. Musengezi, S. Okanga, Ostfeld, R. S., Schieltz, J., Warui, C. M., Wood, S. A., and Keesing, F., (2017). Can integrating wildlife and livestock enhance ecosystem services in central Kenya? *Front Ecol Environ* doi:10.1002/fee.1501.

Al-Roubaie, A., (2010). Building Indigenous knowledge capacity for development. *World Journal of Science, Technology and Sustainable Development*. **7**(2), 113-129.

Amaha, K., (2006). Characterization of Rangeland Resources and Dynamics of the Pastoralist Production Systems in the Somali Region of Eastern Ethiopia. PhD Dissertation. University of the Free State. Bloemfonttein.

Amaha, K., Snyman, H.A. and Smit, G.N., (2008). Impact of rangeland degradation on the pastoral production systems, livelihoods and perceptions of the Somali pastoralists in Eastern Ethiopia. *Journal of Arid Environments*. (72), 1265–1281.

Angassa A., Oba, G. and Stenseth, N.C., (2012). Community-based knowledge of indigenous vegetation in arid African landscapes. *The Journal of Sustainable Development* (8),70–85.

Angassa, A. and Beyene, F., (2003). Current range condition in southern Ethiopia in relation to traditional management strategies: the perceptions of Borana pastoralists. *Tropical Grasslands*. **37** (1), 53–59.

Angassa, A. and Oba, G., (2007). Effects of management and time on mechanisms of bush encroachment in southern Ethiopia. *African Journal of Ecology*[online].**46**:186-196. [Viewed 02 January 2020]. Available from: https://doi.org/10.1111/j.1365-2028.2007.00832.x.

Angassa, A. and Oba, G., (2008). 'Herder perceptions on impacts of range enclosures, crop farming, fire ban and bush encroachment on the rangelands of Borana, Southern Ethiopia', *Human Ecology*, **36**(2), pp. 201–215. doi: 10.1007/s10745-007-9156-z.

Angassa, A., (2012). 'Effects of grazing intensity and bush encroachment on herbaceous species and rangeland condition in southern Ethiopia', Land Degradation & Development, 25(5), pp. 438–451. doi: 10.1002/ldr.2160.

Angassa, A., Sheleme, B., Oba, G., Treydte, A., Linstädter, V., Sauerborn, J., (2012). Savanna land use and its effect on soil characteristics in southern Ethiopia. *Journal of Arid Environments* [online]. **81**:67-76. [Viewed 02 January 2020]. Available from:https://doi.org/10.1016/j.jaridenv.2012.01.006.

Arnella N W, Livermoreb, M J L, Kovatsc S, Levyd P E, Nichollse R, Parry F M L and Gaffing S R., (2004). Climate and socio-economic scenarios for global-scale climate change impacts assessments: characterising the SRES storylines. *Global Environnemental Change* 14: 3–20.

Aswani, S., Lemahieu, A. and Sauer, W.H.H., (2018). Global trends of local ecological knowledge and future implications. PLoSONE. 13(4): e0195440.https://doi.org/10.1371/journal. pone.0195440.

Badola, R., Chandola Barthwal, S. and Ainul Hussain, S., (2013). Payment for ecosystem services for balancing conservation and development in the rangelands of the Indian Himalayan region. In: Ning, W., Rawat, G., Joshi, S., Ismail, M. and Sharma, E. High-altitude rangelands and their interfaces in the Hindu Kush Himalayas (p. 175). ICIMOD. Retrieved from http://lib.icimod.org/record/28910/files/16HAR.pdf.

Behnke, R., and Kerven, C., (2010). Replacing pastoralism with irrigated agriculture in the Awash Valley, north eastern Ethiopia: counting the costs. Paper presented at the International Conference on the Future of Pastoralism. 21- 23 March 2011. Addis Ababa, Ethiopia.

Bennett, E.M., Peterson, G.D. and Gordon, L.J., (2009). Understanding relationships among multiple ecosystem services. *Ecology Letters*.(12),1394–1404.

Benti, N.E., (2017). Combining Wind and Solar Energy to Meet Demands in Somali Region of Ethiopia (A case of DEMBI District). Amercian Journal of Modern Energy, 3(4): 73-83.

Berkes, F., (2008). Sacred ecology. New York: Routledge. Routledge, 2nd edn, 2008), pp. xviii + 313, ISBN: 0-415-95829-6.

Berkes, F., Colding, J. and Folke, C., (2000). Rediscovery of traditional ecological knowledge as adaptive management. Ecological Application. 10(5), 1251-1262.

Beyene, T., (2016). Policies and Proclamations Relevant to Pastoral Areas Land Management for Ethiopia, Kenya and Uganda. Regional Pastoral Livelihoods Resilience Project (RPLRP). Review Report | December 2016.

Beyene, T., Bazezew, A., and Belay, M., (2021). Effects of the current land tenure on augmenting household farmland access in South East Ethiopia. Humaninties & Social Sciences Communications, 8 (35). Available from: https://www.nature.co/articles/s41599-021-00709-w.pdf.

Bikila, N. G., Tessema, Z. K. and Abule, E. G., (2016). 'Carbon sequestration potentials of semi-arid rangelands under traditional management practices in Borana, Southern Ethiopia', *Agriculture, Ecosystems and Environment*. Elsevier B.V., 223, pp. 108–114. doi: 10.1016/j.agee.2016.02.028.

Bilal, A.I., Fenta, T.G., Gebre-Mariam, T. and Asres, K., (2017). Ethnomedicinal uses of plants among Somali ethnic group, Jigjiga Woreda, Somali Regional State, Eastern Ethiopia. Ethiop. J. Health Dev. **31(3)**: 188-199.

Blench, R.M., Daniel, P. and Hassan, U., (2003). Report on Fadama user conflicts in Kebbi and Imo states. Unpublished report to the World Bank.

Bohensky, E. L., and Maru, Y., (2011). Indigenous knowledge, science, and resilience: what have we learned from a decade of international literature on "integration"? Ecology and Society. 16(4),6.http://dx.doi.org/10.5751/ES-04342-160406.

Boka, A., (1993). Forms of Community Participation in Pastoral Areas with Particular Emphasis on Boran Society. Conference on Pastoralism in Ethiopia. Addis Ababa.

Bouh, A.M. and Mammo, Y., (2008). Indigenous conflict management and resolution mechanisms on rangelands in Somali Regional State, Ethiopia. Nomadic Peoples. (12), 109–121. 10.3167/np.2008.120107.

Boval, M. and Dixon, R.M., (2012). The importance of grasslands for animal production and other functions: a review on management and methodological progress in the tropics. Animal 6(5): 748-762.

Briggs, J., (2005). The use of Indigenous knowledge in development: Problems and challenges. Progress in Development Studies. 5(2), 99-114.

Brocklesby, M. A., Hobley, M., and Scott-Villiers, P., (2010). Raising Voice-Securing a Livelihood: The Role of Diverse Voices in Developing Secure Livelihoods in Pastoralist Areas in Ethiopia. Institute of Development Studies at the University of Sussex Brighton.

Bromley, D. W., (1991). Environment and Economy. Property Rights and Public Policy. Oxford: Blackwell.

Callesen, I., (2016). 'Biodiversity and ecosystem services in life cycle impact assessment – Inventory objects or impact categories?' *Ecosystem Services*. Elsevier, 22(September), pp. 94–103. doi: 10.1016/j.ecoser.2016.09.021.

Cash, D. W., et al., (2003). Knowledge systems for sustainable development. Communicated by Susan Hanson, Clark University, Worcester, MA, March 7, 2003 (received for review February 25, 2003).

Colding, J. and Folke, C., (2001). Social taboos: 'Invisible' systems of local resource management and biological conservation. *Ecological Applications*. **11**(2).

Coppock,, D.L., (1994). The Borana Plateau of Southern Ethiopia: Synthesis of Pastoral Research,Development and Change, 1980-1991. ILCA Systems Study No. 5. International Livestock Centre for Africa (ILCA). Addis Ababa, Ethiopia. 374 pp.

Daily, G. (ed)., (1997). Nature's Services: Societal Dependence on Natural Ecosystems. Washington, DC: Island Press.

Davies, J., Poulsen, L., Schulte-Herbrüggen, B., Mackinnon, K., Crawhall, N., Henwood, W.D., Dudley, N., Smith, J. and Gudka, M., (2012). Conserving dryland biodiversity. International Union for Conservation of Nature, Nairobi, 84 pp. [Viewed on 24 August 2016]. Available from: www.iucn.org/sites/dev/files/content/documents/conserving_drylands_biodiversity_iucn_unccd_book_0.pdf.

Derner, J.D., and Shuman, G.E., (2007). Carbon Sequestration and Rangelands:A Synthesis of Land Management and Precipitation Effects. *Journal of Soil and Water Conservation* [online].62(2).[Viewed 02 January 2020]. Available from: https://www.researchgate.net/publication/43261980.

Derner, J.D., Boutton, T.W. and Briske, D.D., (2006). Grazing and ecosystem carbon storage in the North American Great plains.Plant and Soil [online].280:77-90.[Viewed 02 January 2020]. Available from: DOI 10.1007/s11104-005-2554-3.

Desta, S. and Coppock, D.L., (2004). Pastoralism under pressure: tracking system change in southern Ethiopia. Human Ecology [online]. 32: 465-486. [Viewed 02 January 2020].

Diaz, S. and et al., (2015). The IPBES Conceptual Framework-connecting nature and people. www.sciencedirect.com. 14,1–16.

Dika, G., (2016). The Role of Indigenous Knowledge in Rangeland Management in Yabello Woreda, Southern Oromia, Ethiopia. Arts Social Science journal.)7), 172. doi:10.4172/2151-6200.1000172.

Diresse, T., (2010). Afar pastoralists in a changing rangeland environment. Philosophiae Doctor (PhD) Thesis. Department of Ecology and Natural Resource Management Norwegian University of Life Sciences.

Donovan, D. and Puri, R., (2004). Learning from traditional knowledge of non-timber forest products: Penan Benalui and the autecology of Aquilaria in Indinesian Borneo. *Ecology and Society*. **9**(3). www.ecologyandsociety.org/vol9/iss3/art3/.

Doreau, M., Bauchart, D. and Chilliard, Y., (2011). Enhancing fatty acid composition of milk and meat through animal feeding. *Animal Production Science* 51: 19-29.

Doyle, P.T., Stockdale, C.R., Wales, W.J., Walker, G.P. and Heard, J.W., (2001). Limits to and optimizing milk production and composition from pastures. *Recent Advances in Animal Nutrition* 13: 9-17.

Dunne, P.G., Monahan, F.J., O'Mara, F.P. and Moloney, A.P., (2009). Colour of bovine subcutaneous adipose tissues: a review of contributory factors, associations with carcass and meat quality and its potential utility in authentication of dietary history. Meat Science 81: 28-45.

EBI (Ethiopian Biodiversity Institute). (2015). National Biodiversity Strategy and Action Plan. Addis Ababa, Ethiopia.

Emery, A.R., (2000). Integrating Indigenous Knowledge in Project Planning and Implementation. World Bank, 159 p.

EPA (Environmental Protection Authority). (1997).Conservation Strategy of Ethiopia (CSE), Addis Ababa, Ethiopia.

EPCC (Ethiopian Panel on Climate Change). (2015). First Assessment Report, Working Group II Biodiversity and Ecosystems, Published by the Ethiopian Academy of Sciences.

Epsilon International R&D. (2011). A Climate Change Country Assessment Report foe Ethiopia. Unpublished report submitted to Forum for Environment.

Esayas, N.G.M., Solomon, D. and Girma, K.K., (2019). Pastoral Development in Ethiopia. Trends and the Way Forward. Development and Knowledge Learning.

FAO (Food and Agriculture Organization). (2004). Livestock Sector Brief. Livestock information sector analysis and policy branch, FAO, Rome.

FAO. (2007). Adaptation to Climate Change in Agriculture, Forestry and Fisheries: Perspective, Framework and Priorities. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

FARM Africa. (2009). A livelihood baseline survey in Amibara and Gewane woredas of Afar Region. The Afar Prosopis Management Project document. Final report 1., 119 pp.

FDRE (Federal Democratic Republic of Ethiopia). (1995). Constitution of the Federal Democratic Republic of Ethiopia, Addis Ababa, Ethiopia.

Federal Negarit Gazeta. (1994). Biodiversity Convention Ratification. Proclamation No.98/1994. Berhanena Selam Printing Enterprise, Addis Ababa, Ethiopia. Retrieved from http://www.ebi.gov.et/regulation/.

Fenetahun, Y., Xu, X., & Wang, Y., (2018). Assessment of Range Land Degradation, Major Causes, Impacts, and Alternative Rehabilitation Techniques in Yabello Rangelands Southern Ethiopia.

Folke, C., (2004). Traditional ecological knowledge in social-ecological systems. *Ecology and Society*. **9**(3). www.dlc.dlib.indiana.edu/dlc/handle/10535/3323.

Frank, D. A. and McNaughton, S. J., (1993). Evidence for the promotion of aboveground grassland production by native large herbivores in Yellowstone National Park. *Oecologia* 96:157-161.

Friedel, M.H., Laycock, W.A. and Bastin, G.N., (2000). Assessing rangeland condition and trend. In: Mannetje L't and Jones RM (eds) Field and Laboratory Methods for Grassland and Animal Production Research. CABI Publishing, Wallingford, UK. pp. 227–262.

Frost, P.G., Medina, E., Menuat, J.C., Solbrig, O., Swift, M. and Walker, B.H. (eds.), (1986). Response of savannas in stress and disturbance, Biology international special issue 10. IUBS, Paris.

Gadgil, M., Berkes, F. and Folke, C., (1993). Indigenous knowledge for biodiversity conservation. Ambio. 22(2/3), 151-156.

Gadgil, M., Olsson, P., Berkes, F. and Folke, C., (2003). Exploring the role of local ecological knowledge for ecosystem management: Three case studies. In F. Berkes, J. Colding, and C. Folke (Eds). Navigating social-ecological systems: Building resilience for complexity and change, 189-209 pp. Cambridge University Press.

Gebremeskel, E. N., Solomon, D. and Girma, K. K., (2019). Pastoral Development in Ethiopia: Trends and the Way Forward. Development Knowledge and Learning. World Bank, Washington, DC. License: Creative Commons Attribution CCBY 3.0 IGO.

Gemedo, D., Johannes, I. and Brigitte L.M., (2005). Indigenous ecological knowledge of Borana pastoralists in southern Ethiopia and current challenges. *International Journal of Sustainable Development and World Ecology*. (12), 1–18.

Gemedo-Dalle, T., Maass, B. L. and Isselstein, J., (2005). 'Plant Biodiversity and Ethnobotany of Borana Pastoralists in Southern Oromia, Ethiopia', *Economic Botany*, **59**(1), pp. 43–65. doi: 10.1663/0013-0001(2005)059[0043:PBAEOB]2.0.CO;2.

Gemedo-Dalle, T., Maass, B. L. and Isselstein, J., (2006a). 'Encroachment of woody plants and its impact on pastoral livestock production in the Borana lowlands, southern Oromia, Ethiopia', *African Journal of Ecology*, **44**(2), pp. 237–246. doi: 10.1111/j.1365-2028.2006.00638.x.

Gemedo-Dalle, T., Maass, B. L. and Isselstein, J., (2006b). 'Rangeland condition and trend in the semi-arid Rangeland condition and trend in the semi-arid Borana lowlands , southern', *African Journal of Range & Forage Science*, **23**(1), pp. 49–58. Available at: http://www.tandfonline.com/loi/tarf20.

Gerber, PJ, H Steinfeld, B Henderson, A Mottet, C Opio, J Dijkman, A Falcucci, and Tempio, G., (2013). Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Rome: Food and Agriculture Organization of the United Nations (FAO).

Getachew K., (2001). Dimensions of pastoral poverty in Ethiopia. In: PFE Proceedings of the second National Conference on pastoral development in Ethiopia. Poverty reduction strategy and pastoral development, May 22-23, 2001. Addis Ababa, Ethiopia. 66-80pp.

Getachew, H., (2007). Impact of Land Use/Land Cover Dynamics on the Ecology of Borana Rangelandss, Ethiopia. M. Sc. Thesis, Haramaya University. 134p.

Getachew, K.N., (2001). Among the Pastoral Afar in Ethiopia: Tradition, Continuity and Socioeconomic Change. International Books, The Netherlands. pp. 205.

Getahun, F., (2016). Dynamics and role of institutions for sustainable land and biodiversity management in BER, Oromia, Ethiopia. An M.Sc. thesis in natural resources and environmental studies program with specialization in Natural Resource Economics and Policy. Wondo Genet College of Forestry and Natural Resources. 113 p.

Giday, M. and Tekelhaymanot, T., (2013). Ethnobotanical study of plants used in management of livestock health problems by Afar people of Ada'ar District, Afar Regional State, Ethiopia. 9:8. http://www.ethnobiomed.com/content/9/1/8.

Gómez-Sal, A., Rodríguez, M.A. and De Miguel, J.M., (1992). Matter transfer and land use by cattle in a Dehesa ecosystem of Central Spain. *Vegetation*. **99**(1), 345–354. doi:10.1007/97894-017-2836-2_36.

Gordon, O.O., Caleb, M. and Paul, K.M., (2016). Application of Indigenous Knowledge Systems in Wildlife Management: A Case Study of the Samburu Pastoral Community in Kenya. *International Journal of Applied Science and Technology*. **6**(1). February 2016.

Grace, J., San Jose, J., Meir, P., Miranda, H. And Montes, R., (2006). Productivity and carbon fluxes of tropical savannas. *J. Biogeogr*. 33: 387-400.

Grice, A.C., Hodgkinson, K.C., (2002). Challenges for rangeland people (2002). In Global rangelands progress and prospects. In: A.C. Grice, and K.C. Hodgkinson (eds). Wallingford, U.K. CABI Publishers.1–9.

Hana, H.M., (2008). The implementation of the Convention on Biological Diversity, 14 December, 2008, Cairo, Egypt.

Harris, R.B., (2010). Rangeland degradation on the Qinghai-Tibetan plateau: a review of the evidence of its magnitude and causes. Journal of Arid Environments, 74(1), pp.1-12.

Helen, A., (2009). Utilization practices, Biomass production and nutritional characterization of Major Feed Resources in Gursum district, Somalia Region, Eastern Ethiopia. An M.Sc. thesis, Haramaya University, Ethiopia.

Herlocker, D., (1999). Rangeland Ecology and Resource Development in Eastern Africa. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Nairobi, Kenya. 393p.

Herrero, M, P Thornton, P Gerber, and Reid, R., (2009). Livestock, livelihoods and the environment: Understanding the trade-offs. *Current Opinion in Environmental Sustainability* 1: 111-120.

Hoang, X.T. and Le, T.C., (1998). Knowledge of local community in mountainous areas in agriculture and natural resources management. Hanoi: Agriculture Publisher.

Holechek, J.L., Pieper, R.D., Herbel, C.H., (2005). Range Management Principles and Practices. 5th edition.Pearson Prentice Hall, Upper Saddle River, New Jersey, USA.pp. 321.

Houde, N., (2007). The six faces of traditional ecological knowledge: Challenges and opportunities for Canadian comanagement arrangements. *Ecology and Society*. **12**(2). www.ecologyandsociety.org/vol12/iss2/art34/.

Huig, M., (2013). Rangeland management in the Borana pastoral system: A historical review of land management and development in the Borana zone, Ethiopia. Master thesis Soil Physics and Land Management Group, Wageningen University, the Netherlands.

Hundie, B., (2006). Explaining changes of property rights among Afar pastoralists, Ethiopia. Discussion paper, ICAR (Institutional Change in Agriculture and Natural Resources), Berlin.

Hundie, B., and Padmanabhan, M., (2008). The Transformation of the Afar Commons in Ethiopia: State Coercion, diversification, and Poverty Rights Change Among Pastoralists. Collective Action and Property Rights (CAPRi) Working Paper No. 87.

Hurrissa, B., (2009). Donor supported livestock marketing initiatives: the experiences and achievements of SPS-LMM Program in Ethiopia. Paper presented at the Regional Symposium on Livestock Marketing in the Horn of Africa: Working Towards ‘Best Practices’, 21-23 October, 2009. Kenya Commercial Bank Training Centre, Karen, Kenya.

Huss, D.L., (1996). The role of domestic livestock in desertification control. FAO, series: arid and semi-arid zones n° 2/ing. Rome.

IBCR (Institute of Biodiversity Conservation and Research). (1998). National Policy on Biodiversity Conservation and Research, Addis Ababa, Ethiopia.

IIRR (International Institute of Rural Reconstruction). (1996). Recording and using indigenous knowledge: a manual. Silang, Philippines.

IPCC (Inter-governmental Panel on Climate Change). (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of IPCC.

Ismail, S.S., Lars O, E., Øystein, H., Tormod, A., Ephraim, M., and Daniel, M., (2012). The role of indigenous knowledge and perceptions of pastoral communities on traditional grazing management in north-western Tanzania. *African Journal of Agricultural Research*. **7**(40), 5537-5547.

IUCN (International Union for conservation of Nature). (2011). Briefing note, Indigenous Rangelands Monitoring: harnessing pastoralist knowledge in the Horn of Africa.

Jiao, Y, Z Xu, and Zhao, J., (2009). Effects of grassland conservation to cropland and forest on soil organic carbon and dissolved organic carbon in the farming-pastoral ecotone of inner Mongolia. *Acta Ecologica Sinica*: 150-154.

Kamara, A. B., Swallow, B. and Kirk, M., (2004). 'Policies, Interventions and Institutional Change in Pastoral Resource Management in Borana, Southern Ethiopia', *Development Policy Review*, **22**(4), pp. 381–403.

Kane, C.W., (2006). Herbal Medicine of the American Southwest: A Guide to the Medicinal and Edible Plants of the Southwestern United States. Tuscon, AZ, Lincoln Town Press.

Kebede, B., (2002). Land tenure and common pool resources in rural Ethiopia: A study based on fifteen sites. *African Development Review*. (14), 113-149.

Ketema, T., Lisanework, N., Solomon, M. and John, B., (2017). Floristic composition in the rangelands of Gambella, Southwestern Ethiopia. *International journal of Advanced research*. **5**(6), 111-122.

Kidane, G.M., (2006). Rangeland potential, quality and restoration strategies in North Eastern Ethiopia: PhD Desseration, University of Stellenbosh, RSA. 424pp.

Kisiaya, S., (2018). Indigenous Institutions and Rangeland Sustainability in Northern Tanzania. *Tanzania Journal of Sociology*. (4), 107-120.

Kuchar, P., (1995). Range monitoring and evaluation range survey methods. South East Rangeland Project (SERP). Technical report. Richard Wooderoofe and Associates.

Lal, R., (2001). Potential of desertification control to sequester carbon and mitigate the greenhouse effect. *Climate Change* 51: 35-72.

Lal, R., (2004). Carbon sequestration in dryland ecosystems. Environ. Manag., 33(4): 528-544.

Lamprey, R. H. and Reid, R. S., (2004). Expansion of human settlement in Kenya's Maasai Mara: what future for pastoralism and wildlife? *Journal of Biogeography* 31: 997-1032.

Langill, S., (1999). Indigenous knowledge: a resource kit for sustainable development researchers in dryland Africa. Ottowa: People, Land and Water Program Initiative, IDRC.

Le, T.C., (2015). Human Ecology and sustainable development. Hanoi: Hanoi National University Publisher.

Leftwich, A. and Sen, K., (2010). 'Beyond Institutions: Institutions and Organisations in the Politics and Economics of Poverty Reduction-Thematic Synthesis of Research Evidence', IPPG Research Consortium on Improving Institutions for Pro-Poor Growth, University of Manchester.

Legesse, A., (1973). Gada: Three Approaches to the Study of African Society. New York, The Free Press.

Lertzman, K., (2002). Science and Indigenouns peoples’ knowledge (Summary). In: H. Michel, and D.V. Gayton (Eds). Linking Indigenous peoples’ knowledge and Western science in natural resource management. Conference Proceedings. Canada: Southern Interior Forest Extension and Research Partnership. SIFERP Series 4, pp. 29-32.

Little, P. D. et al., (2010a). Future Scenarios for Pastoral Development in Ethiopia , 2010-2025 Report Number 2 Pastoral Economic Growth and Development Policy Assessment, Ethiopia.

Little, P. D. et al., (2010b). Retrospective Assessment of Pastoral Policies in Ethiopia , 1991-2008 Report Number 1 Pastoral Economic Growth and Development Policy Assessment, Ethiopia.

McGahey, D., Davies, J., Hagelberg, N. and Ouedraogo, R., (2014). Pastoralism and the Green Economy: a natural nexus? International Union for Conservation of Nature, Gland, Switzerland/United Nations Environment Programme, Nairobi, 58 pp. [Viewed on 5 August 2015]. Available from: iucn.org/wisp.

McGregor, D., (2004). Coming full circle: Indigenous knowledge, environment, and our future. The American Indian Quarterly, 28(3), 385-410.

McGregor, D., (2004). Traditional knowledge and water governance: the ethics of responsibility. Alternative volume 10, ISSUE 5, 2014.

MEA (Millennium Ecosystem Assessment). (2005). Ecosystems and human well-being: synthesis. Island Press, Washington, DC. [Viewed on 24 August 2016]. Available from: ww.millenniumassessment.org/documents/document.356.aspx.pdf.

Mengistu, A., (2007). Directions in pastoral and agro-pastoral research and development in Ethiopia. In: Pastoral Livestock Systems: Opportunities and Challenges as a Livelihood Strategy. Proceedings of the 15th annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, October 4-6, 2007. pp. 1-17.

Mengistu, A., Kebede, G, and Feyissa, F., (2018). Status of Ethiopian rangelands: with special Reference to Southern Rangelands. *International Journal of Agriculture and Biosciences* [online], 7(3):175-181. [Viewed 02 January 2020]. Available from: www.ijagbio.com.

Mesfin, A., Giday, M., Animut, A. and Teklehaymanot, T., (2012). Ethnobotanical study of antimalarial plants in Shinile district, Somali Region, Ethiopia, and in vivo evaluation selected ones against plasmodium beeghei. Journal of Ethnopharmacology. 139(1): 221-227.

Ministry of Peace. (2019). Pastoral development policy and implementatiobn strategies, Addis Ababa. Ethiopia. 130 pages.

Minyahel, T., Ayana, A., Aster, A. and Alemayehu, M., (2017). Perception and attitude of pastoralists on the use and conservation of rangeland resources in Afar Region, Ethiopia. *Ecological Processes*. (5)18.

Mohammed, A., (2009). Pastoral Perceptionsabout Range-livestock Management Practices, Range Condition Assessment and Chemical Composition of Major Feed Resources in Chifra District of Afar Regional State, Ethiopia, M.Sc. thesis, Haramaya University, Ethiopia.

Mohammed, Y., (2004). Pastoral and land tenure issues and development in the middle of Awash valley. Msc Thesis. Addis Ababa university, Addis Ababa, Ethiopia, 130 p.

Mohammed, Y., (2010). Is it a silent travel to death? Case of the Subaltran children of Lucy. Uppsala, Sweden.

Mohammed, Y., (2015). Pastoral Development Pathways in Ethiopia; the Policy Environment and Critical Constraints. Brief for GSDR 2015.

Moller, H., Berkes, F., Lyver, P.O. and Kislalioglu, M., (2004). Combining science and traditional ecological knowledge: Monitoring populations for co-management. *Ecology and Science*. **9**(3). www.ecologyandsociety.org/vol9/iss3/art2/.

Mrema, G. C., et al., (2008). Agricultural Mechanization in Sub-Saharan Africa: Time For a New Look. Agricultural Management, Marketing and Finance Occasional Paper 22. Rome, FAO.

Muchiru, A.N., Western, D.J. and Reid, R.S., (2008). The role of abandoned pastoral settlements in the dynamics of African large herbivore communities. *Journal of Arid Environment*. **72** (6), 940– 952. doi:10.1016/j.jaridenv.2007.11.012.

Muluneh, T., (2008). Range and livestock management practices and condition assessment of the rangelands in Mursi-Bodi (Salamago district) of SNNPR, Ethiopia. An M.Sc. thesis, Haramaya University, Ethiopia.

Murphree, M., (1994). The role of institutions in community-based conservation. In Western D, Wright, R,M., Strum, S.C. (eds) *Natural Connections: Perspectives in Community-based Conservation*. Island Press, Washington D.C. and Covelo, California, pp. 403-427.

Napier, A. and Desta, S., (2011). Review of Pastoral Rangeland Enclosures in Ethiopia. PLI Policy Project, USAID, Ethiopia.

Neely, C., Bunning, S. and Wilkes, A., (2009). Review of evidence on drylands pastoral systems and climate change: Implications and opportunities for mitigation and adaptation. Land and Water Discussion Paper 8, FAO, Rome.

Negassa, B. and Zewdu, T., (2017). 'Changes in vegetation structure and aboveground biomass in response to traditional rangeland management practices in Borana, southern Ethiopia', *African Journal of Range & Forage Science*, **34**(1), pp. 21–31. doi: 10.2989/10220119.2017.1331934.

Nguyen, T.H. and Ross, A., (2017). Barriers and opportunities for the involvement of indigenous knowledge in water resources management in the Gam River Basin in north-east Vietnam. Water Alternatives. 10(1), 134-159.

Niamir M., (1991). Traditional African range management techniques: implications for rangeland development. ODI Pastoral Development Network Paper No. 31d. Overseas Development Institute (ODI), London. URI: http://hdl.handle. net/10919/66423.

Niamir, R.N., (1999). Traditional African Range management techniques: implications for rangeland development. ODI Pastoral Development Network Paper No. 31d. Overseas Development Institute (ODI), London. URI: http://hdl.handle. net/10919/66423.

Niamir-Fuller, M. and Turner, M.D., (1999). A review of recent literature on pastoralism and transhumance in Africa. In: Managing mobility in African rangelands: the legitimization of transhumance (M. Niamir-Fuller, ed.). Intermediate Technology Publications, London, 18–46. doi:10.3362/9781780442761.002.

Niamir-Fuller, M., (1999). Managing mobility in African rangelands: The legitimization of transhumance. International Technology Publications, London, UK. 240 p.

Niemi, E. and Manyindo, J., (2010). Economic Importance of Goods and Services Derived from Dryland Ecosystems in the IGAD Region. IUCN, Gland, Switzerland.

North, D., (1990). Institutions, Institutional Change and Economic Performance. Cambridge University Press, Cambridge, UK.

Notenbaert, A.M., Davis, J., Leeuw, J.D., Said, M., Herrero, M., Manzano, P., Waithaka, M., Abdilahi, A., and Omondi, S., (2012). Policies in support of pastoralism and biodiversity in the heterogeneous drylands of east Africa. *Research, Policy and Practice* (2)14

Nyong, A., Adesina, F. and Elasha, B.O., (2007). The value of Indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. *Mitigation Adaptation Strategies for Global Change*. **2**(5), 787-797.

Oba, G, and Kaitira, L.M., (2006). Herder knowledge of landscape assessments in arid rangelands in northern Tanzania. *Journal of Arid Environments*. (66), 168-186. doi:10.1016/j.jaridenv.2005.10.020.

Oba, G., (1998). Assessments of indigenous range management knowledge of the Borana pastoralists in southern Ethiopia. Borana Lowland Pastoral Development Program/GTZ, Consultancy Paper, Negelle/Borana May 1998.

Oba, G., (2012). Harnessing pastoralists' indigenous knowledge for rangeland management: three African case studies. *Pastoralism: Research, Policy and Practice*. **2**(1). doi:10.1186/2041-7136-2-1.

Omiti, J.M., Parton, K.A., Sinden, J.A., and Ehui, S.K., (1999). Monitoring changes in land-use practices following agrarian de-collectivization in Ethiopia. *Agriculture Ecosystems & Environment*. 72, 111-118.

Ostrom, E., (1990). Governing the Commons: The Evolution of Institutions for Collective Action. The Political Economy of Institutions and Decisions. Cambridge University Press, London.

Ostrom, E., (2009). Beyond Markets and States: Polycentric Governance of Complex Economic Systems. Prize Lecture on December 08, 2009. Workshop in Political Theory and Policy Analysis, Indiana University, Bloomington, IN 47408, and Center for the Study of Institutional Diversity, Arizona State University, Tempe, AZ, U.S.A.

Ozor, N., Acheampong, E.M. and Ayodoton, B., (2016). Review of policies, legislations and institutions for biodiversity information in sub - Saharan Africa. *International Journal of Biodiversity and Conservation*. **8**(6), pp. 126-137, June 2016 DOI: 10.5897/IJBC2015.0938 Article Number: 439954E58743 ISSN 2141-243X.

Pappagallo, L, (2018). Operationalizing payments for ecosystem services for pastoralists in rangeland settings. ILRI-ICARDA, 89p.

Polasky, S., Nelson, E., Pennington, D. and Johnson, K., (2011). The impact of land-use change on ecosystem services, biodiversity and returns to landowners: a case study in the state of Minnesota. *Environmental and Resource Economics*. **48**(2), 219-242.

Porensky, L.M. and Veblen, K.E., (2012). Grasses and browsers reinforce landscape heterogeneity by excluding trees from ecosystem hotspots. *Oecologia*. **168**(3), 749–759. doi:10.1007/ s00442-011-2123-9.

Porensky, L.M. and Veblen, K.E., (2015). Generation of ecosystem hotspots using short-term cattle corrals in an African savanna. *Rangeland Ecology and Management*. **68**(2), 131–141. doi:10.1016/j.rama.2015.01.002.

Rahmato, D., (1984). Agrarian Reform in Ethiopia. Motala, Sweden, Motala Grafiska AB.

Rahmato, D., (1994). ‘Land Policy in Ethiopia at Crossroads’. In Land Tenure and Land Policy in Ethiopia after the Derg. Proceedings of the Second Workshop of the Land Tenure Project Dessalegn Rahmato, ed. University of Tronheim: Trondheim.

Rahmato, D., (2007). Customs in Conflict: Land Tenure Issues Among Pastoralists in Ethiopia. Discussion paper, Forum for Social Studies. Addis Ababa, Ethiopia.

Reed, M.S., Evely, A.C., Cundill, G., Fazey, I., Glass, J., Laing, A., Newig, J., Parrish, B.,Prell, C., Raymond, C. and Stringer, L.C., (2010). What is social learning? *Ecology and Society*.**15**(4), r1 [online] URL:http://www.ecologyandsociety.org/vol15/iss4/resp1/.

Reid, R.S., Bedelian, C., Said, M.Y., Kruska, R.L, Mauricio, R.M., Castel, V., Olson, J. and Thornton, P.K., (2004). Global livestock impacts on biodiversity. In: Livestock in a changing landscape, Volume 1: Drivers, consequences, and responses. Edited by: H. Steinfeld, H.A. Mooney, F. Schneider, L.E. Neville (eds). Washington D.C: Island Press. Pp 111–138.

Rice, CW., (2005). Dynamics and management. In Carbon cycles in soils, 164-170. Manhattan: Kansas State University.

Roselle, L. et al., (2011). Rangelands: An Introduction to Wild Open Space.

Ross, A., Sherman, K.P., Snodgrass, J.G., Delcore, H.D. and Sherman, R., (2011). Indigenous people and the collaborative stewardship of nature: Knowledge binds and institutional conflicts. Walnut Creek, Canada: Left Coast Press.

Sachchidananda, (2008). Indigenous knowledge of tribals: Implications for development. In S.N. Choudhary, and K.K. Basa, (Eds). Tribes and their indigenous knowledge: Implications for development, pp. 19-24. Delhi, India: Pratibha Prakashan.

Sahai, S., (1996). Importance of Indigenous knowledge in IPR [Intellectual Property Rights] system. *Economic and Political Weekly*. **31**(47), 3043-3045.

Sanderson, M. A., Skinnerm R. H., Barker, D.J., Edwards, G.R., Tracy, B.F. and Wedin, D.A., (2004). Plant Species Diversity and Management of Temperate Forage and Grazing Land Ecosystems. *Crop Science*. 44:1132-1144.

Sankaran, M., Ratnam, J. and Hanan, N.P., (2004). Tree-grass coexistence in savannas revisited-insights from an examination of assumptions and mechanisms invoked in existing models. *Ecology Letters* [online]. 7: 480-490.[Viewed 02 January 2020].

Sara, M.A., (2016). Improving governance for biodiversity conservation, ecosystem services and stakeholder participation in protected areas. Doctoral thesis, Barcelona.

Savory, A., (1999). Holistic Management: A New Framework for Decision Making. Island Press: Washington, D.C.

Scholes, R.J. and Archer, S.R., (1997).Tree-grass interactions in savannas. *Annual Review of Ecological Systematics* [online]. 28: 517-544.[Viewed 02 January 2020].

Seid, M. A., Kuhn, N. J. and Fikre, T. Z., (2016). 'The role of pastoralism in regulating ecosystem services', Rev. Sci. Tech. Off. Int. Epiz., 35(2), pp. 435–444. doi: 10.20506/rst.35.2.2534.

Seitz, J. and Nyangena, W., (2009). Economic impact of Climate Change in East African Community (EAC). Final report. Global 21 Consulting and GTZ.

Selam, M., (2008). Rangeland degradation and livelihood vulnerability of the pastoralists in Erer district of Shinile zone, Eastern Ethiopia. M.Sc. thesis, Haramaya University, Ethiopia. 111pp.

Shitarek, T., (2012). Ethiopia Country Report.

Sillitoe, P., (2002). Maggots in their ears: Hunting incantations and Indigenous knowledge in development. *Journal of Ritual Studies*. 16(1), 64-71.

Silvestri, S., Osano, P., de Leeuw, J., Herrero, M., Ericksen, P., Kariuki, J., Njuki, J., Bedelian, C. and Notenbaert, A., (2012). Greening livestock: Assessing the potential of payment for environmental services in livestock inclusive agricultural production systems in developing countries. ILRI Position Paper. Nairobi, Kenya: ILRI.

Sintayehu, W., Nigussie, D., Mengistu, K. and Anteneh, B., (Eds.), (2013). Biodiversity Conservation and Ecosystem Services for Climate Change Mitigation and Sustainable Development. Workshop Proceedings, 20 – 22 December 2012. Haramaya University, Haramaya, Ethiopia.

Solomon, D., (2006). Pastoralism and Development in Ethiopia. Economic focus, Addis Ababa, Ethiopia.

Solomon, T. B., Snyman, H. A. and Smit, G. N., (2007). 'Cattle-rangeland management practices and perceptions of pastoralists towards rangeland degradation in the Borana zone of southern Ethiopia', *Journal of Environmental Management*, **82**(4), pp. 481–494. doi: 10.1016/j.jenvman.2006.01.008.

Solomon, T.B., (2003). Rangelands evaluation and perceptions of the pastoralists in the Borana zone of Southern Ethiopia. PhD Dissertation, University of the Free State, Bloemfontein, South Africa, 329p.

Steinfield, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. and de Haan, C., (2006). Livestock's Long Shadow: Environmental Issues and Options. FAO, Rome, Italy.

Stevenson, M.G., (2006). The possibility of difference: Re-thinking co-management. *Human Organization*. **65**(2),167-180.

Sulieman H, Ahmed, A., (2013). Monitoring changes in pastoral resources in eastern Sudan: a synthesis of remote sensing and local knowledge, http://www. pastoralismjournal.com.

Swiderska, K., Roe, D., Siegele, L., and Grieg-Gran, M., (2008). The Governance of Nature and the Nature of Governance. Policy that works for biodiversity and livelihoods.

Teshome A., Ebro A., Nigatu, L., (2010). Traditional rangeland resource utilization practices and pastoralists' perceptions on land degradation in south-east Ethiopia. *Tropical Grasslands*. (44), 202–212.

Teshome, A., (2016). Contribution of Indigenous Knowledge to Climate Change and Adaptation Response in Southern Ethiopia. *Journal of Earth Science & Climatic Change*. (7),377. doi: 10.4172/2157-7617.1000377.

Tessema, Z.K., de Boer, W.F. Baars, R.M.T. and Prins, H.H.T., (2011). Changes in soil nutrients, vegetation structure and herbaceous biomass in response to grazing in semi-arid savanna of Ethiopia. *Journal of Arid Environments*. 75: 662-670.

Tibebu, S., (2012). Assessing the rationale and competence of pastoral community innovative adaptation to climate change in Ethiopia. *Ethiopian e-journal for research and innovation foresight*. **4**(2), 3-37.

Tick, A.W., (1993). Recommendation and action plan. *Indigenous knowledge and development monitor*. **1**(2), 24-19.

Tizita, E.E., (2016). The role of indigenous people in the biodiversity conservation in Gamo area of GamoGofa zone, Southern Ethiopia. *International Journal of Biodiversity and Conservation*. **8**(10), 244-250.

Tolera, A. and Eik, L. O., (2020). Stratified Livestock Production and Live Animal and Meat Export from Ethiopia: Lessons from the Experience of a Donor Funded Project. In: Singh, B.R., Safalaoh, A., Amuri, A.A., Eik, L.O., Sitaula, B.K. and Lal, R. (Eds.). Climate

Impacts on Agricultural and Natural Resources Sustainability in Africa. Springer Nature, Switzerland. pp.301-311.

Tolossa, K., Debela, E., Athanasiadou, S., Tolera, A., Ganga, G. and Jos Houdijk, G. M., (2013). Ethno-medicinal study of plants used for treatment of human and livestock ailments by traditional healers in South Omo, Southern Ethiopia. *Journal of Ethnobiology and Ethnomedicine* 9:32 http://www.ethnobiomed.com/content/9/1/32.

Townsend, D., (2019). Ethiopia's new civil society law. BLOG, Published on 11 March 2019.

Tsegaye, D., Moe, S.R., Vedeld, P, Ermias Aynekulu, E., (2010). Land-use/cover dynamics in Northern Afar rangelands, Ethiopia. *Agriculture, Ecosystems & Environment* [online].139:174-180. [Viewed 02 January 2020]. Available from: https://doi.org/10.1016/ j.agee.2010.07.017.

UNDP. (2015). Mainstreaming incentives for biodiversity conservation in the Climate Resilient Green Economy Strategy. Addis Ababa, Ethiopia.

UNDP/RRC (United Nations Devlopment Programme/Relief and Rehabilitation Commission). (1984). A study of Nomadic Areas of Ethiopia. Study Report Part I-VI, Addis Ababa, Ethiopia.

Unruh, J. D., (2005). Changing conflict resolutions in the Ethiopian pastoral commons: The role of armed confrontations in rule-making. *GeoJournal*. (64), 225–237. 10.1007/s10708-005-5650-2.

Van Auken, O. W., (2000). Shrub Invasions of North American Semiarid Grasslands. *Annual Review of Ecology and Systematics*, vol. 31, 2000, pp. 197–215. *JSTOR*, http://www.jstor.org/stable/221730.

Veblen, K.E. and Young, T.P., (2010). Contrasting effects of cattle and wildlife on the vegetation development of a savanna landscape mosaic. *Journal of Ecology*. **98**(5), 993–1001. doi:10.1111/ j.1365-2745.2010.01705.x.

Venuste, N., Olivier, H., and Valens, N., (2017). Knowledge, Attitudes and Awareness of Pre-Service Teachers on Biodiversity Conservation in Rwanda. *International Journal of Environmental and Science Education*. **12**(4), 643-652.

Voisin, A., (1959). Grassland Productivity. Island Press California.

Vreugdenhil, D. Vreugdenhil, A. D., Tilahun, T. Shimelis, A., Tefera, Z., (2012). Gap Analysis of the Protected Areas System of Ethiopia, with technical contributions from Nagelkerke, L., Gedeon, K. Spawls, S., Yalden, D., Lakew Berhanu, and Siege, L., World Institute for Conservation and Environment, USA.

Warren, D. M., (1991). "The Role of Indigenous Knowledge in Facilitating the Agricultural Extension Process". Paper presented at International Workshop on Agricultural Knowledge Systems and the Role of Extension. Bad Boll, Germany, May 21-24.

Watson, A. Alessa, L. and Glaspell, B., (2003). The relationship between traditional ecological knowledge, evolving cultures, and wilderness protection in circumpolar north. *Conservation Ecology*. **8**(1). www.ecologyandsociety.org/vol8/iss1/art2/.

Watson, E., (2003). Examining the potential of indigenous institutions for development: a perspective from Borana, Ethiopia. *Development and Change*. (34), 287–309.

Weible, C.M., Pattisona, A. and Paul, A., (2010). Sabatierb Harnessing expert-based information for learning and the sustainable management of complex socio-ecological systems. *Environmental science & policy*. (13), 522–534.

White,R., Murray, S. and Rohweder, M., (2000). Pilot analysis of global ecosystems: Grassland ecosystems. Washington D.C., World Resources Institute. 112 p.

Wiley, L. A., (2011). 'The Law is to Blame': The Vulnerable Status of Common Property Rights in Sub-Saharan Africa. *Development and change*: **42(**3), 733-757.

WISP (World Initiative for Sustainable Pastoralism). (2007). Squandered Wealth: a global economic review of pastoralism. WISP Policy Issues Paper 2.

Worku, B. and Lisanework, N., (2016). Pastoral Perceptions towards Livestock and Rangeland Management Practices in Kuraz District of South Omo Zone, South Western Ethiopia. *Journal of Natural Sciences Research*. **6**(1). www.iiste.org. ISSN 2224-3186 (Paper), ISSN 2225-0921 (Online).

World Bank. (2005). 'Integrating the Indigenous Knowledge of Borana Pastoralists into Rangeland Management Strategies in Southern Ethiopia', *Development*, (81).

Yang, Y. et al., (2016). 'Comparative assessment of grassland degradation dynamics in response to climate variation and human activities in China, Mongolia, Pakistan and Uzbekistan from 2000 to 2013', *Journal of Arid Environments*. Elsevier Ltd, 135, pp. 164–172. doi: 10.1016/j.jaridenv.2016.09.004.

Yemane, B., (2008). Natural resource and environmental management considerations and climate healing steps in Ethiopia. In: Adi, S. and Temsgen, D. (Eds.). Proceedings of the Fourth National Conference on Pastoral Development in Ethiopia: Millennium Development Goals and Pastoral Development: Opportunities & Challenges in the New Ethiopian Millennium. 29-30 August, 2007. Pastoralist Forum Ethiopia (PFE), Addis Ababa, Ethiopia, pp 60-91.

Yeneayehu, F., (2018). The Role of Indigenous People Knowledge in the Biodiversity Conservation in Gursum Woerda, Eastern Hararghe Ethiopia. *Annals of Ecology and Environmental Science*. **2**(1), 29-36.

Yigezu, T., (1993). A Case Study With Particular Reference To The Boran Pastoralist System In Ethiopia. Conference on Pastoralism in Ethiopia. Addis Ababa, Ethiopia.

Yihew, B., Tessema, Z. and Mengistu, U., (2017). Perception and attitude of pastoralists on livestock-wildlife interactions around the Awash National Park, Ethiopia. Implication for biodiversity conservation. *Ecological Processes*. (6)13.

Yoseph, F., (2007). Pastoralists perception towards range resource utilization and range condition assessment in Gewane district of Afar Regional State, Ethiopia. M.Sc. Thesis. School of Graduate studies, Haramaya University. 65-66 pp.

6. Agroecosystem

Contributors

Corresponding Lead Author: Feleke Woldeyes (PhD)

Lead Author: Zemede Asfaw (Professor)

Contributing Authors: Abraham Assefa (Mr.)
Anteneh Girma (PhD)
Tesfaye Abebe (PhD)

Editor: Melesse Maryo (PhD)

External Peer Reviewer: Zebene Asfaw (PhD)

Table of Contents

List of Tables

List of Figures

Executive summary

Ethiopia is agroecologically diverse with up to 32 major agroclimatic/agroecological zones wherein diverse agrobiodiversity thrives in different agricultural systems and multiple agroecosystem services accrue to people (established but incomplete**).** Agroecosystem of Ethiopia occurs in different biomes of the country, especially in Afro-alpine and Sub-Afro-alpine forests, *Combretum-Terminalia* and *Acacia-Commiphora* woodlands, and associated grasslands. The agroecosystem evolved through a transformation of natural vegetation during millennia of practices of agrarian societies where the country's multi-ethnic people interacted with the environmental elements leading to the formation of varied agricultural landscapes, biophysical features and climatic regimes. Agroecological zones were initially recognized by indigenous agroclimatic typology and later systematized by the use of elaborate modern agroclimatic data where elevation, thermal zones, rainfall regimes and length of the growing period were factored in. This process resulted in 32 major zones described and mapped leading to recognition of arid, semi-arid, humid, semi-humid, per-humid, tepid and cool/cold zones. Agricultural land management is practiced in all zones albeit rudimentary nature in the latter case, which is found at high altitudes (3200-3700m asl). Agricultural areas span zones of the plough and seed (grain) culture, vegeculture and perennial crop-based mixed culture, shifting cultivation and pastoral complexes as described earlier, which eventually got mixed and went through continued transformations. In most of these systems, agroforestry has evolved as an important sustainable system, particularly in the southern part of the country. These agricultural systems sustained biocultural assets, characteristic agrobiodiversity and agricultural productivity with crop and livestock genetic resources that came under dynamic state being impacted by continued natural and human-induced pressures. Future production and conservation strategies need to target specific agroecosystem sub-types with due consideration of associated local contexts {6.1}.

Agroecosystem of Ethiopia are unique in being situated within a Vavilovian centre of origin and/or diversity of crop species/varieties and livestock breeds, and are agrobiodiversity-rich systems (well established). Ethiopia holds an important position in global agrobiodiversity dividends. Diversity in agroclimate, agroecology, culture, geomorphologic and topographic features shaped to be suitable habitats for crop diversification due to prolonged natural and human-induced processes. Farming communities applied their indigenous and local knowledge

(ILK) and practices shaping resourceful agroecosystem sub-types in the diverse zones. Ethiopian agroecosystem sub-types are key ecosystem units from a global perspective as well because of the country's reputations for crops origin, diversity, and evolution. Ethiopia is endowed with huge within species crop diversity and diversity within livestock breeds. Genetic resources that originated within Ethiopia diffused globally as demonstrated by *Coffea arabica* which soon became a key global commodity commanding cultures, economies, and social fabrics. Ethiopia is a mega-centre of crop species/landraces that donated crops and related germplasm conferring nutritional quality, including a protein with high lysine contents and disease resistance. *Eragrostis tef* (*Teff*) with its gluten free nature is praised as the super food grain, and *C. arabica* is a global favorite luxury. Ethiopian agriculture is still overly small scale and traditional with high potential for climate adaptation/mitigation and deliverance of agroecosystem benefits. The grain production and vegeculture (perennial crop-based) zones, led by *Teff* and *Enset*, respectively, are crop domestication sites. The former transformed to the mixed agropastoral system, estimated to account for about 70% of the agricultural systems in Ethiopia, which is also polycultural in many respects, while the latter intensified to a highly polycultural farming system accounting for about 20%. The description and classification of agrecological zones and agricultural systems need refinement for better management of land, crops, livestock, associated vegetation and other resources. In this, agroecosystem services that accrue from the various agroforestry types found in Ethiopia need special attention since it showed a widely expanding trend. Agriculture must be adaptable to the prevailing dynamics by promoting agrobiodiversity conservation and diversification coupled with enhancement of critical crops and underutilized crop species/varieties in an integrated agroecological system that emulates sustainable food system approaches {6.1}.

Agriculture in Ethiopia is built on plentiful agrobiodiversity and supports diversified livelihood systems through systematized data, modernized use and management remain to be growing concerns (established but incomplete). Diverse agroecological conditions enabled the evolution of agricultural systems in Ethiopia that care for a large variety of crops of wide functional categories and diverse livestock breeds that in turn generated varied livelihood systems. The central and eastern highlands are gene centres of many kinds of cereals, pulses and oil crops while the southern and south-western parts are well known for the system described as vegeculture zone in earlier classification to contrast with the granoculture system of the north and central parts. The dynamics of farming system over the years led to the expansion of the perennial crops-dominated complex. This zone is recognized by high frequency of *Enset*, yam, taro; coffee; many spices and other crops occurring as parts of farm fields, homegardens and parkland agroforestry systems and related complexes. The terraced traditional Konso agricultural landscape demonstrates traditional agroforests and other polyculture systems. Other examples include the Gedeo homegarden-agroforestry and the coffee forests in the south west and south eastern parts of the country. The granoculture zone is differentiated by the dominance of grain crops, including diverse cereals, legumes, oil seeds and associated crops. However, components of one zone are gradually diffusing into the other and thus gravitating to the mixed complex. Genetic diversity contributing to the global gene pool abounds in the cases of major crops (*Sorghum bicolor*, *Triticum durum*, *Hordeum vulgare)* and many Ethiopian domesticates (*Coffea arabica*, *Eragrostis tef, Guizotia abyssinica, Brassica carinata, Ensete ventricosum, Coccinia abyssinica,* and *Plectranthus edulis*). Diversification of many early introductions (*Pisum sativum, Hordeum vulgare*, *Zea mays, etc.*) gave rise to new variants and endemic forms as in *Pisum sativum* var. *abyssinicum* and the deficiens group of *Hordeum vulgare* ssp. vulgare that evolved upon secondary diversification. The animal agrobiodiversity is known for abundance and uniqueness of breeds (cattle, sheep, goats, camels, honey bees and equines) ranking first in Africa and fifth in the world in cattle and being among the top 10 countries in equines, sheep, goats, and honeybee colonies. The long history of plant and animal use coupled with biophysical factors, indigenous agricultural innovations and introductions claim shares to the elevated agrobiodiversity that developed under small scale farming and plays key livelihood functions and ecological services, which has started dwindling due to weak conservation and research patronage. Indigenous knowledge of agrobiodiversity and agroecological farming, held in the oral literature, is threatened due to lack of valorization, documentation, and socioeconomic transformation, which requires taking on board through sustainable development initiatives {6.2.1, 6.2.3 }.

Agriculture constitutes the largest sector of the economy in Ethiopia, and the country has diverse agroecosystem sub-types upon which the economic and social systems are based (well established). The largest proportion of Ethiopia’s population is engaged in agriculture and related activities. Agriculture serves the subsistence needs of Ethiopians, and contributes as a major source of foreign exchange. Ethiopia’s exports are mainly based on agricultural products namely, coffee, pulses, flowers, hides, and skins, *Chaat* and others. However, Ethiopian agriculture is faced with some constraints that include; degradation of natural resources (land, water, vegetation, etc.) due to erosion, soil mining, deforestation, pest and disease incidence, and climate change. Consequently, agricultural productivity is very low, and this has forced the country to import some crop products such as wheat, sugar, and cotton. In the livestock sector, Ethiopia has the largest livestock population in Africa, but its contribution to the national economy is small with little value addition to livestock products {6.3.1 }.

The types of crops cultivated in the different localities of Ethiopia are determined by agroecological conditions of the sites, and the cultural preferences of the people living in the areas (well established). For thousands of years, Ethiopian farmers have been engaged in crop domestication and breeding efforts to select species and varieties that adapt to the local climate and meet their needs. Due to the differences in the cultural background of the people and the farming practices they adopt, different types of agroecosystem exist under the same agroecological zone. A typical example is the presence of two different systems in the *Woina Dega* of the country: Cereal-based systems are dominant in the midlands of north and central Ethiopia, while perennial-based systems are common in the same zone in southern Ethiopia. Traditionally, Ethiopians recognize five major agroecological zones, namely *Bereha* (arid lowlands), *Kolla* (semi-arid lowlands), *Woina Dega* (mid lands), *Dega* (highlands), and *Wurch* (cold highlands). The two extremes, *Bereha* and *Wurch*, are mostly unsuitable for crop cultivation due to aridity (the former) and low temperature (the latter). The *Kolla* zone is dominated by pastoral and agropastoral livelihoods, but dryland crops such as rain-fed sorghum, finger millet and sesame, as well as irrigated commercial crops such as sugarcane, cotton and fruits, are grown. The *Woina Dega* is the most suitable for cultivation of diverse species of crops, and the Dega agroclimatic zone is the next most suitable {6.2.1, 6.3.1 }.

Ethiopia has 14 major agroecosystem sub-types that can be grouped into three categories, namely 1) Pastoral and agropastoral systems, 2) Cereal crop-based systems (also called seed farming complex) and 3) Perennial crop based systems (also called *Enset* planting complex) (established but incomplete). The pastoral and agropastoral systems are predominant in the arid and semi-arid areas of eastern and southern Ethiopia, serving the livelihoods of millions of people, and contributing to the national economy. The livestock include cattle, camel, small ruminants (goats, sheep), and equines. Animal holding of households is decreasing significantly due to shortage of feed and recurrent drought. Crop production is being introduced in the pastoral areas with or without irrigation. Introduction of farming techniques and market linkages in some pastoral areas, has contributed to the livelihood diversification and improvement of household food security. Due to the arid climate and shortage of rainfall, pastoral communities are mostly food insecure and vulnerable to climatic shocks. The cereal based systems cover very large areas in the north, central, eastern and parts of southern Ethiopia. Different cereals, pulses, oil crops and others are managed in integration with livestock. Under the cereal-based systems, ten distinct agroecosystem sub-types are identified, namely: *Lowland sesame mixed*, *Western lowland maize mixed*, *Sorghum mixed*, *Sorghum-Chaat mixed*, *Eastern highland maize mixed*, *Western highland maize mixed*, *Highland livestock maize mixed*, *Highland Teff mixed*, *Highland wheat mixed* and *Highland barley mixed* agroecosystem sub-types. The major constraints in the cereal-based systems are erosion on hilly landscapes, water logging on Vertisols, soil fertility depletion, and shortage of wood for fuel and construction purposes. These problems call for interventions on sustainable land management practices. The perennial crop-based systems are dominant in the south and southwestern parts of Ethiopia, where *Enset* is grown in integration with coffee, shade trees, cereals, fruit trees and other annual and perennial crops. These systems are the most diverse in species and cultivars, and they are economically reconsidering these pieces of evidence to indicate the opposite and ecologically sustainable. Two distinct agroecosystem sub-types are identified in this category, namely *Enset-coffee-cereals mixed* agroecosystem sub-type and *Enset-barley mixed* agroecosystem sub-type. The former occurs in the *Woina Dega*, where *Enset* is grown in association with coffee (*Bunna*), cereals, pulses, root and tuber crops, vegetables, spice and condiments as well as livestock and trees. We should not undermine the tree component of *Enset* coffee systems. Farmers in the south and southwest establish a complex system through their indigenous local knowledge (ILK) on forest plant sociology which helped them produce using a vertical approach from which scientists developed agroforestry science. The latter is dominant in the *Dega* where *Enset* is grown around homes along with vegetables and root crops, while barley and other cereals and pulses are grown in the farm fields away from home. Livestock are important components in these systems, but their number is decreasing due to a shortage of feed. Livestock management is largely based on cut- and-carry system of feeding {6.3.2)

Biodiversity of Ethiopian agroecosystem is generally high, but the magnitude varies across the different agroecological zones, land use and management systems (established but incomplete). In the north, central and eastern parts of Ethiopia, where cereals and pulses have been cultivated for millennia, there is high inter-specific and intra-specific diversity of cereals such as barley, *Teff*, wheat, sorghum, as well as pulses and oil crops. In most cereal growing lowlands and midlands, scattered trees such as *Faidherbia albida* are maintained in cereal fields for environmental protection and wood provision. In the south and southwestern parts of Ethiopia where polyculture farming has been widely practiced for a very long time, the agroecosystem sub-types exhibit a rich diversity of perennial and annual crops, as well as trees. Intraspecific diversity of the dominant native perennial crops, *Enset* and coffee is also very high. In these systems, species richness of cultivated crops that range from 41 to 92 species, with an average number of 14-19 crop species per farm, are reported. Furthermore, a very high diversity of *Enset* landraces that range from 26 to 312 is documented. The diversity of trees reported in the agroecosystem reach as high as 186 {6.3.1, 6.3.2 }.

Ethiopia's rich diversity of crop species, landraces, and cultivars is making contributions to the welfare of its people and the world at large, but there are still some underutilized species that have great potential to improve food security, and livelihoods of the people (established but incomplete*).* Ethiopia's native crop, coffee, which is the country's most important cash crop, is also Ethiopia's gift to the world. *Teff*, which is the most important food crop in Ethiopia, is becoming increasingly popular in the world as a healthy food. These and other crops are not being produced to the limits of their potential. The agricultural biodiversity resources of Ethiopia also include several under-utilized crop species such as yam (*Dioscorea* sp.*),* taro (*Colocasia esculenta*), Ethiopian potato (*Plectranthus edulis*) and *Amochi* (*Arisaema schimperianum*). These crops have huge potential to improve the food security of communities. They are known to have certain qualities of drought tolerance, disease resistance, and high yield, but their cultivation is restricted to some localities in southern Ethiopia. Hence, their potential to improve food and nutritional security and climate change adaptation need to be realized {6.3.1, 6.3.2}.

Agroecosystem, agricultural biodiversity, and its services to human wellbeing are seriously affected by natural drivers of change resulting in disasters identified to have a significant effect on biodiversity for food and agriculture in Ethiopia (well established). Ethiopia has been experiencing many drought seasons that caused shortage of food since 1974. The main impacts of drought include crop damage, loss of pasture and water sources, loss of livestock, food shortage, disease outbreaks, asset depletion, malnutrition, and migration. In the recent past, El Niño-induced drought due to below-average autumn rains in the southern and southeastern parts of the country affected millions of people, and required emergency food assistance, safe drinking water, livestock support, and treatment to children to combat severe acute malnutrition. The flood destroyed crops, trees and other important structures on agricultural land, killed domestic animals, and became the cause of displacement of hundreds of thousands of people in different parts of the country. Acidification is another natural process that usually occurs because of nitrate leaching in most of the high rainfall areas such as the western, southern and even the central highlands of the country. Soil acidity can cause slow decomposition of organic matter and so results in limited availability of macro and micronutrients *{6.4.1.1 }.*

Ethiopia's agroecosystem, agricultural biodiversity and its services to human wellbeing are highly vulnerable to climate change and the spread of invasive alien species, which negatively affect crop and livestock production and productivity (well established). Ethiopia has been getting warmer over the last 30 years with an increasing trend of extreme warming indicators in most parts of the country while there is a seasonal variability of rainfall regime. The two main rainy seasons *Belg* (February-May) and *Kiremt* (June-September) together showed a total loss of more than 150 mm of rainfall per year. These changes will negatively affect both crop and livestock production and productivity. This is due to shortened growing period, increased water stress, increased loss of soils and plant nutrients, increased scarcity of livestock feed and water, increased 'heat load' on livestock; flood and drought damages on crops and livestock, decreased grazing and browsing resources in some areas. It also affects reduction in the length of growing seasons of some crop varieties that resulted in the loss of many long-duration varieties altering agroecosystem and leading to changes in crop pests and spread of diseases. The threats that biological invasions pose to biodiversity and agroecosystem-level processes translate directly into economic consequences such as losses in crops and forage species of grazing lands. The introduction of most invasive alien species in Ethiopia happened unknowingly, however, some of them occur for various reasons including agroforestry and fencing purposes but the proliferation of invasive alien species into the agricultural production system is rapid and complex. The major socioeconomically important species include water hyacinth (*Eichhornia crassipes*), prosopis (*Prosopis juliflora),* parthenium weed (*Parthenium hysterophorus*), and lantana weed (*Lantana camara)* The impacts of these invasive plants include destroying the fishery industry, irrigation, livestock watering and reduction of biodiversity, obstacles to navigation and ecotourism, clog canals of hydroelectric power plants and will generally cause serious environmental imbalance. This is due to the invasive capacity, allelopathic effects, strong competitiveness, and health hazards to humans and animals {6.4.1.2}.

Ethiopia's agroecosystem, agricultural biodiversity and its services to human wellbeing are negatively affected by unsustainable utilization of resources either in the form of overexploitation or excessive use of nutrients with dire consequences of soil erosion, water depletion, acidification, and salt accumulation (well established). In Ethiopia, organic matter and nutrient depletion often occur together in the same area due to overexploitation. Most farmers in Ethiopia do not return animal dung and crop residues to the farm. Organic matter depletion is driven by competing uses of crop residues and manure as livestock feed and fuel, respectively. Ethiopia is also working to increase productivity through investment in the intensive use of improved technologies such as fertilizer. Unless proper caution is taken, a substantial portion of the nutrients applied is not used by plants and is carried off the field in runoff and such losses of reactive nutrients like nitrogen can damage ecosystem services. Thus, the increased fertilizer use coupled with the expansion of irrigated farms, inadequate provision of drainage systems, and poor water management practices have increased the areas of salt-affected and acidic soils. Excessive water extraction alters hydrological regimes and threatens food security. It also results in land- use changes, which in turn triggers soil erosion and degradation. Soil erosion, in turn, causes soil nutrient loss and reduction of agricultural productivity and leads to environmental problems caused by flooding, water pollution and reservoir sedimentation. It is estimated that Ethiopia loses more than 1.5 billion tons of fertile soil only from highlands each year through heavy rain and flooding; this lost soil could have increased the country's crop production by an estimated 1.5 million tons per year {6.4.1.2}.

Ethiopia is confronting with extension challenges: there is a need to increase production and productivity to provide food for the growing population and reducing poverty, while managing agroecosystem services in a sustainable manner to maintain human wellbeing (well established*)*. Rapid population growth, urbanization, and the resultant demand for food are driving land use and land-cover change in Ethiopia, leading to the loss of the agroecosystem capacity to sustain biodiversity and provide ecosystem services to people. It is a fact that rapid population growth, especially the increase in rural population density (RPD) is still one major challenge to Ethiopia's socio-economic development, including agroecosystem sustainability. The Ethiopian subsistence agriculture has not only suffered from continuous decline of cultivated land, but also from farm fragmentation which is associated with decreasing farm income on a per hectare basis, even under increasing fertilizer use. Diminishing farm size leads to a reduction of sustainable land management practices such as shortening of fallow cycles and rotation, with a consequence of declining soil fertility. The increasing human population, not only influences agricultural farm size, but also tremendously helps to increase the number of livestock which induces a decline in the capacity and quality of rangelands. To meet the increasing demand for food, production systems are expected to rely progressively on heavy inputs of fertilizers, pesticides, water, and the improved varieties Indiscriminate use of exotic improved varieties has been the cause of displacement and final extinction of indigenous crop varieties and livestock breeds in the country. These coupled with the quick degradation of ILK's low level of education and extension services in the country are directly linked to the intensity and scale of natural resource extraction where it has immense effects on agroecosystem and ecosystem services delivered to human wellbeing {6.4.2, 6.4.4.2}.

There is an increasing level of awareness and knowledge about nature's benefit, status, and management of biodiversity and ecosystem services in the agroecosystem (established but incomplete). The level of awareness and knowledge on the ecosystem services, and evolutionary values of agroecosystem goods and services is documented in the earlier works on crop and livestock evolution, plant geography, and genetic resources. Knowledge on agrobiodiversity, biogeographic patterns, and population genetics is developed through *ex situ* conservation in genebanks at the national scale and *in situ* conservation through the continuation of on-farm production, local and regional consumption, and agroecosystem functioning. Knowledge is also developed through the characterization, and monitoring of the status and levels of agrobiodiversity at key spatial scales. Agroecosystem sub-types are managed and governed by humans to optimize the provision of food, fibre, and fuel. Encouraging but not enough recognition has been given to the knowledge and values of indigenous peoples and local communities in the community-based initiatives for the conservation of agrobiodiversity. There is an enhanced recognition of tradeoff in the provision of material goods from agroecosystem has come at the high cost of unprecedented declines in natural resources due to degradation and biodiversity loss that affect the integrity of agroecosystem and distinctness of local ecologies and communities. The impact of global environmental and socio-economic challenges on agrobiodiversity has received more significant focus these days than ever before. Gobal climate change and its role in both undermining agrobiodiversity and strengthening its usefulness is a key knowledge infrastructure. Similarly, research on urbanization and migration associated changes in land use and land cover has been documented for its impact on biodiversity and ecosystem services. More efforts are required to enhance the awareness of communities, policy makers, development partners and private sectors on the importance of biodiversity and agroecosystem services. Research on agrobiodiversity and agroecosystem services needs to become more multidisciplinary, more participatory and more focused on interactions between different components of biodiversity for food and agriculture. Knowledge gap on the biological, ecosystem, and evolutionary values, management and governance , including the role of indigenous people and local communities, and impact of policies entails the development of methodologies and indicators to capture and disseminate the data for real-time decision making {6.1, 6.5.1, 6.5.2, 6.5.3}.

Ethiopia has put in place a number of policies and planning frameworks that slowly better support the conservation and sustainable use of biodiversity and agroecosystem services (established but incomplete). The National Biodiversity Strategy and Action Plan (NBSAP) 2015-2020 is an overarching framework on biodiversity for all stakeholders to value biodiversity and ecosystem services, reduce the pressures on biodiversity and ecosystems, improve the status of biodiversity and ecosystem services, and ensure access to genetic resources and fair and equitable sharing of benefits arising from their use. Seed policy together with Plant Breeders Right, and Access to Genetic Resources and Community Knowledge, and Community Rights are also typical governance mechanisms for the generation and distribution of agrobiodiversity through the market and non-market practices, as well as combined traditional and new cultural practices. The policy and strategy on animal breeding together with National Biodiversity Strategy and Plan of Action for Conservation and Sustainable Utilization of Animal Genetic Resources ensure the conservation of farm animal genetic resources diversity for present and future generations and halt the loss and erosion of these crucial resources. Ethiopia's Climate Resilient Green Economy (CRGE) Strategy and sustainable land management entail a mix of policies and instruments that together ensure nature conservation, ecological restoration and sustainable use, sustainable production (including food, materials and energy), and climate change adaptation that address the major drivers of biodiversity loss and nature deterioration {6.6.1 }.

The Ethiopian Government has demonstrated commitment to the conservation of biodiversity and agroecosystem services through institutional capacity building and funding but more is expected at all levels (established but incomplete). There is a limited capacity for enhanced and improved implementation and enforcement of effective existing policy instruments and regulations for the management of biodiversity and ecosystem services. There are overlaps of responsibilities along with the governance structures that contributed to the limited implementation capacity. The mandate overlaps are also confused with mandates that stretched across the governance structures which led to undesirable outcomes for agroforestry practices that contain elements of agriculture and forestry, but have not been sufficiently mainstreamed in the existing policy framework of both sectors. Policies showing very high coherence are confined to sector-specific policy arenas that address agriculture and natural resources, including forestry and water. It is understood that the focus of the agriculture policy and strategy drive the growth of the national economy, and this tends to continue to negatively affect biodiversity and ecosystem services. While the purpose of public policy is expected to strike balance between economic growth needs and the long-term benefits of sustainable environmental and natural resources management. Achieving sustainable use of biodiversity and ecosystem service in agroecosystem entails fundamental reform to design and implement policy action to apply sustainable intensification in agriculture that helps to protect agroecosystem and associated biodiversity from the effects of negative drivers and support its sustainable use. Such policy directions must include limiting excessive population growth, promotion of agroforestry and agroecological practices, proper use of inorganic fertilizers, policy directions that help to return crop residues and animal dung to the farm and encouraging and facilitating the use of organic fertilizers while removing policies that may encourage excessive use of inorganic fertilizers and minimize post-harvest losses and food wastes {6.6.2 }.

Key findings

1. Ethiopia is agroecologically diverse with up to 32 major agroclimatic zones wherein diverse agrobiodiversity thrives in different agricultural systems and multiple agroecosystem services accrue to people. The agroecosystem sub-types within these zones have sustained the biophysical and indigenous sociocultural assets of the area with the characteristic agrobiodiversity, mainly the rich crop and livestock genetic resources that came under dynamic state being impacted by natural and human-induced pressures. Future production and conservation strategies need to target specific agroecosystem sub-types with due consideration of relevant local contexts including the prospects of agroforestry that have possibilities of further expansion and larger coverage. Natural ecosystems found adjacent to farmed landscapes (crop fields, homegardens, agroforestry systems, plantations, parklands) are reservoirs of plant, animal and microbial genetic sources critical for maintenance and enhancement of agrobiodiversity and should be seen as essential components of the wider scope of agroecosystem in conservation planning and implementation. The agroecosystem sub-types of Ethiopia are unique in being situated within a Vavilovian centre of origin and/or diversity of crop species/varieties and livestock species and breeds. The system needs enhancement of critical crops and underutilized species/varieties to increase efficiency and create sustainable food systems. Agriculture is erected upon plentiful agrobiodiversity and supports rich livelihood systems. Systematized data, modern use, and management of agrobiodiversity remain growing concerns given their critical roles in food system improvement and agroecosystem enhancement. Indigenous knowledge of agrobiodiversity and agroecological farming, held in the oral literature, is threatened due to lack of proper documentation, valorization and socio-economic transformation, which require taking on board through continued sustainable development initiatives.

2. Agriculture constitutes the largest sector of the economy in Ethiopia, and the country has diverse agroecosystem sub-types upon which the economic and social systems are based. The types of crops cultivated in the different localities of Ethiopia are determined by the agroecological conditions of the sites, and also the cultural preferences of the people living in the areas. Ethiopia has 14 major agroecosystem sub-types that can be grouped into three categories, namely 1) Pastoral and agropastoral systems, 2) Cereal/grain crop-based systems

(also called seed farming complex) and 3) Perennial crop-based systems (also called *Enset* planting/*Enset* and hoe or vegeculture complex). The biodiversity in the Ethiopian agroecosystem is generally high, but the magnitude varies across the different systems. Ethiopia's rich diversity of crop species, landraces and cultivars is making contributions to the welfare of its people and the world at large, but there are still knowledge and yield gaps, particularly in the cases of underutilized species that include many crops and wild useful plant species with potentials to improve food security and livelihoods of the people.

3. Agroecosystem, agricultural biodiversity and their services to human wellbeing are seriously affected by natural and anthropological drivers of change resulting in disasters identified to have significant effects on biodiversity for food and agriculture in Ethiopia due to climate change which contributes to recurrent droughts, floods and acidification, among others. They are highly vulnerable to climate change and the spread of invasive alien species, which negatively affect crop and livestock production and productivity as well as human health. They are negatively affected by unsustainable utilization of resources either in the form of overexploitation or excessive use of nutrients with dire consequences of soil erosion, water depletion, acidification and salt accumulation. Ethiopia is confronted with new extension challenges and there is a need to increase production and productivity to provide food for the growing population and reduce poverty while managing agroecosystem services sustainably to maintain healthy human ecology and socio-economic wellbeing.

4. There is an increasing level of awareness and knowledge about nature's benefit, status, and management of biodiversity and ecosystem services in the agroecosystem. Agroecosystem is managed and governed by humans to optimize the provision of food, fibre, and fuel. There is a heightened level of awareness and knowledge that some management practices can also be the source of numerous dis-services to biodiversity and ecosystem services. Advanced work to enhance awareness and generate knowledge on the tradeoff that would occur between the provision of materials goods and other ecosystem services, including indicators and metrics to be used in the assessments of the disservices in terms of spatial scale, temporal scale and reversibility. The role of indigenous peoples and local communities is encouraged more than ever before in the management and governance of agrobiodiversity. More is required to develop and implement approaches to recognize and work with ILK in agroecosystem.

5. Ethiopia has put in place a number of policies and planning frameworks that slowly better support the conservation and sustainable management of biodiversity and agroecosystem services. The Ethiopian Government has demonstrated commitment to the conservation of biodiversity and agroecosystem services through institutional capacity building and funding; but still more needs to be done at all levels to garner the best out of nature's gifts entrenched in agroecosystem.

6.1 Introduction

The highest level of reciprocal interaction between human societies and nature is seen in agroecosystem or ecosystems of the agricultural landscapes. This chapter of the Ethiopian National Ecosystem Assessment (NEA) is devoted to agroecosystem on account of its utmost importance to people and the environment. In this era of the scramble for more agricultural production in quantity and quality, there is a strong drive towards transformative change (Dí'az et al., 2019) and such changes in agrarian societies like Ethiopia need to target agroecosystem in order to fully understand their contributions to people and quality of life as a basis for the much sought science-informed interventions. The knowledge on Ethiopian agroecosystem was analyzed with the associated agrobiodiversity and the agroecosystem services to visualize nature's benefits to people and facilitate planning for the years ahead. This introduction provides standard definitions of relevant terms highlighting the contributions of the agroecosystem of Ethiopia to people and quality of life. Further highlights are given about the status of the main agroecosystem with their agrobiodiversity and ecosystem goods and services; drivers of change; awareness and knowledge as well as policy and institutional arrangements. Accordingly, the chapter is structured under five subchapters, each examined about agroecosystem mainly targeting the following core aspects:

- Contributions of agroecosystem to people and quality of life,
- Status and trends of major agroecosystem, characteristics, roles, and constraints,
- Drivers of agroecosystem, agrobiodiversity, services, and dynamism,
- Awareness and knowledge on agroecosystem and their benefits to people, and
- Policies and institutional arrangements relevant to agroecosystem.

Analysis of sources of knowledge drawn up from peer-reviewed publications as well as the relevant gray literature shows that agrobiodiversity is fundamental to people who rely on the biophysical environment and agroecosystem services for their livelihoods since women and men farmers not only use agrobiodiversity to meet daily needs, but also have indispensable roles as its generators, and custodians (FAO, 2008). They also maintain special agrobiodiversity information and practices through their indigenous and local knowledge (ILK), which is a tool for achieving food security and sustainable rural development (FAO, 2008). In this assessment, the ILK relating to agroecosystem and agrobiodiversity (FAO, 2008; Hill et al., 2019) has also been sourced and collated from relevant publications scattered in localized theses and recent publications. Ethnobotanical/ethnobiological, ethnoagricultural and/or ethnoecological papers that reported research results at the interface of biology, anthropology and agriculture (Asfaw and Nigatu, 1995; Asfaw, 1997, 2000; Asfaw and Woldu, 1997; Maryo, 2013; Woldeyes et al., 2016; Adal, 2017; Ruelle et al., 2019) were inspected. The indigenous and local biological, agricultural and ecological knowledge made available in Ethiopia in a protracted manner, particularly during the last two decades, and which elaborate on land use/land cover changes and the status of crop and livestock diversity (EBI, 2014, 2015) were given due attention. It has been emphasized recently that multiple knowledge systems are crucial to understand human-environment interactions (Zimmerer et al., 2019), and this is more so in the cases of agrobiodiversity, agriculture and food systems in areas of rich agrobiodiversity as in Ethiopia. Due attention was focused on the status of major categories of relevant resources, including crops, livestock, crop wild relatives, associated biotic forms seen across landscapes, farming/agricultural systems, soil types and agroclimatic regimes. The extent of the knowledge and challenges along with implications for science policy-making were examined and discussed against the background of recent literature on the Ethiopian environment (EAS, 2013, 2015, 2017) and focusing on agrobiodiversity and agroecosystem services (Cromwell, 1999; Di Falco and Chavas, 2009).

Agroecosystem

Agroecosystem is agricultural ecosystem, which essentially include the biophysical and human components and interactions where ecological principles govern the system being stirred or guided by farmers'decision-making processes and actions. Thus, an agroecosystem, an important term that appeared in the literature quite recently, is the basic unit of study in an agroecological setting (SOCLA, Undated). It refers to a spatially and functionally coherent unit of the agricultural platform that includes the living and nonliving components involved in that unit as well as their interactions centered on the human activity of agriculture (Altieri 1995, 2002, 2015; Garbach et al., 2014). An agroecosystem includes the region that is impacted by agriculture (Anon, 1996) and which usually results in changes by simplifying the ecological niches. Other related terminologies that have been commonly used in agricultural literature sources are ‘farming system’ and ‘agricultural system’ (Westphal, 1975). These terminologies, defined below, share common conceptual frameworks although they are not exactly the same to the term agroecosystem in meaning and concept in the strict sense.

Farming system is defined as a unique and reasonably stable arrangement of farming enterprises that the household manages according to well-defined practices in response to physical, biological and socioeconomic environments and in accordance with the household's goals, preferences and resources; and that farmer households are central to the system (Shaner et al., 1982). This same source further elaborates that the factors involved combine to influence output and production methods with more commonality within a system than between systems; and that farming system is part of larger systems and can be divided into subsystems, for example, cropping systems. According to Fresco and Wesphal (1988), farming system is a decision-making unit comprising the farm household, cropping and livestock systems that transform the land, capital, and labour into useful products that can be consumed or sold.

Agricultural system is a term broadly applied to a system that produces crops used as food, feed, fibre, energy and combinations of these and others along with various livestock types and breeds adapted to the system. The social, economic and political components that are associated with the system are considered parts and parcel of the agricultural system. The term farming systems often refer to broadly similar resource bases for which similar development strategies and interventions would be appropriate as in the seed farming system, the *Enset* planting system, the homegarden system commonly encountered in Ethiopia. Thus, in the Ethiopian context, a farming system is taken as a natural grouping of activities on the landscape that draws on natural features of the land, the socio-environmental and cultural aspects further reflecting the living record of farmers’ adaptation strategies that allowed them to overcome long-term climatic and associated changes in vegetation and associated land resources (Amede et al., 2017). Different levels of integration of crops, livestock, tools and labour with natural cycles of rainfall and soil fertility, as well as with the social dynamics are among important markers of the various agricultural and farming systems. The two concepts are highly intertwined and are closely related to the much ecological-based agroecosystem.

Agricultural systems and farming systems occur within broader units designated as agroecosystem that take into account these human activities with the ecological and other local contexts. Agroecosystem is ecological system whereby communities of plants, animals and microbial organisms live in dynamic interaction with their physical and chemical environments that have been modified by people to produce food, fibre, fuel, and other products of food systems meant for humans consumption and processing (Altieri, 2002).

From these definitions, a farming system is understood in the context of its socioeconomic perspectives. Its focus is on the farm household and how the latter allocates its resources to achieve its goals of production and consumption. Furthermore, it deals with how to manage a mix of enterprises (crop, livestock, agroforestry, fisheries and so on) to which the farming family allocates its resources to attain family goals, taking the farm as an enterprise. On the other hand, the agroecosystem has ecological perspectives as it considers the farm and the associated units as ecological systems. The interactions between the living and non-living components, as well as the relations in and outside the farm are stressed. Despite these differences, they have a lot of similarities since each concept mainly deals with farming activities and their interactions with the environment.

Agroecosystem service is a collective term for the goods, services and functions that humans obtain from agroecosystem and these are enhanced by agrobiodiversity (Altieri et al., 2015). Environmental sustainability is best understood when viewed in the context of the concept of ecosystem services, which in this chapter is adopted for agroecosystem services with the strict specification that it captures the services that accrue from agroecosystem. Wiggering et al. (2016) underlined the need to emphasize and re-conceptualize agroecosystem services further underscoring that the terminology should conveniently capture the multiple provisioning, regulating, supporting and cultural services provided to people by agroecosystem. While these services are critical to people, human dis-services to agroecosystem have also been observed in some situations as they were seen undermining their contributions by reducing their availability.

Agrobiodiversity refers to the sum total of the variety and variability of organisms and processes in agricultural landscapes that are useful to food and agriculture. It is a component of biodiversity initially referred to as agricultural biodiversity and consists of the variety and variability of animals, plants, and microorganisms at genetic, species, populations and ecosystem levels that are required to provide sustainable agroecosystem and agricultural production (Brush, 1991). As an important centerpiece component of overall biodiversity, agrobiodiversity alludes to the variability within and among crop and livestock systems, including wild relatives and interacting species. Agrobiodiversity contributes to sustainable livelihood security at local, national and global levels. Varieties of crops and livestock breeds, wild relatives and species that interact with and support these biotic components including pollinators, symbionts, pests, parasites, predators, decomposers, competitors and microorganisms together with the whole range of environments in which agriculture is practiced line-up with the concept (Rudebjer et al., 2011; Zimmerer et al., 2019).

The following key areas highlight the core concerns that generally guided the assessment of the agroecosystem found in Ethiopia alongside the natural ecosystems of the country:

- Characterize and show the contributions of agroecosystem to environmental health, economy, livelihoods, food security, and quality of life and the linkages to and interdependencies with natural ecosystems,
- Show the status, trends, and potential future dynamics of agrobiodiversity components that impact agroecosystem's contributions to people and quality of life,
- Identify the direct and indirect drivers of changes and dynamism in agroecosystem with their agrobiodiversity and services,
- Assess the gaps and needs in awareness and knowledge to be addressed in the short and long-term perspectives in order to better understand impacts and responses to the contributions of agroecosystem and agrobiodiversity to people and environments,
- Synthesize policy gaps and generate relevant ideas/options for possible interventions by decision-makers in scaling up agroecosystem services to the sustainability of agroecosystem itself, the economy, livelihoods, food security, and quality of life, and
- Chart out clear roles for the Ethiopian Government, organizations, institutions, and development partners by crafting relevant public policies favourable to agroecosystem health and the quantity and quality of agrobiodiversity-related resources alongside other national priorities through mainstreaming and other suitable efforts.

Agroecosystem is production area constructed on different pillars of resource management and use patterns than natural ecosystems mainly because human involvement, as a driving force, is high and the concept itself was introduced into the ecological literature quite recently. For the entire world, including Ethiopia, the Ethiopian agroecosystem sub-types are key ecosystems because they are places where important crops had originated, had been domesticated, diversified, and continued to evolve (Vavilov, 1951; Harlan, 1969; Westphal, 1975). Ethiopian agriculture is overly small-scale and traditional, and its diversity and potentials make it of high importance for adaptation and mitigation under a changing climate (Altieri and Nicholls, 2013). Agroecosystem is a place where agricultural innovations have come about and taken shape, and Ethiopia is among the few Vavilovian centers wherein a rich assemblage of genetic diversity of crops abounds. This has been acknowledged and verified since the 1920s through repeated explorations and researches by various scholars (Vavilov, 1951; Harlan, 1969; Worede, 1991; Worede et al., 2000). Recently, researchers also started zooming down on specific agroecosystem and culture zones dealing with aspects of Ethiopian agroecosystem and agrobiodiversity (Abebe, 2005; Woldeyes, 2011; Maryo, 2013). The values of the genetic resources that originated in Ethiopia have gone beyond to other countries and continents and some (Example: coffee, *Teff*) have turned into being key global commodities; the former controlling cultures, economies and social orders and fabrics in many countries and the latter recently emerging as the super food grain as scientific research discovered its benefits to human health and nutrition.

The Ethiopian center is thus a mega-centre of crop species and local landrace diversity that has donated important gifts to world agriculture in terms of heirloom crop species/varieties and valued germplasm (Worede et al., 2000; Gorfu and Ahmed, 2013; EBI, 2015) with special nutritional qualities, disease resistance, high protein with high lysine contents from some farmers' varieties (landraces) of sorghum (Teshome et al., 1997; EBI, 2015), barley (Asfaw, 2000; Lakew and Assefa, 2011; EBI, 2015) and other qualities from durum wheat (Asmamaw et al., 2019), Arabica coffee (Koehler, 2017; Tadesse, 2017), among others. *Teff (Eragrostis tef*), one of Ethiopia's domesticates (Ketema, 1993; Jifar et al., 2018), has been internationally nicknamed as the super food grain that along with coffee (*Coffea arabica*) and others constitute the priceless gifts of Ethiopia to the rest of the world (Harlan, 1969; Worede et al., 2000; IBC, 2012; EBI, 2014, 2015). The Barley Yellow Dwarf Virus (BYDV) resistant gene, originally sourced from Ethiopian barley collections, generates annual income worth 160 million USD to California's barley production (EBI, 2015). The EBI (2015) also noted that the high lysine gene of sorghum originating from a variety cultivated by generations of small-scale farmers in

Ethiopia and traced to the local farmers' variety called *Wetet Begunche* (that translates as milk in the buccal cavity/mouth) is known to provide 12 million USD annually in Canada; *Teff* collected from the Dessie area and hence called *Dessie Teff* has been given Plant Breeders' Rights protection by the US Plant Variety Protection Act until 2016 in the USA. The same document indicated that after the introduction of the Ethiopian Access to Genetic Resources and Community Knowledge, and Community Rights Proclamation in 2006, access and benefit-sharing agreements have been signed using Material Transfer Agreement under the bilateral system with foreign companies for the use of the endemic crop, *Teff* and the endemic wild shrub, *Vernonia galamensis* subsp. *galamensis* var. *ethiopica.*

The document drew attention to the fact that Ethiopia being an accumulation centre of plant genetic resources, its contribution to the country's economic wealth has not been encouraging due to the absence of adequate capacity to characterize and evaluate germplasm and identify novel genotypes and make them available for use; and lack of a system to review and synthesize research results and identify aspects which could be useful in developing the resources. Future strengthening of these aspects is a worthwhile effort.

Ethiopian agroecosystem also maintain a rich assemblage of zoological agrobiodiversity components seen in terms of the breeds and the genetic diversity of livestock which has been shown to be not only unique but also suited to the environment and the livelihood systems in the different agro-ecological zones (EBI, 2015). On the other hand, the agricultural productivity and diversity of the agroecosystem is declining and the present assessment is tasked with the work of bringing forth some innovative and transformative changes that would be capable of reversing the prevailing negative trends.

Agroecosystem contains natural as well as human-generated assets and contribute to people's wellbeing and quality of life. The people of Ethiopia, and the world at large, need to begin to deeply feel how agroecosystem is key assets that need to be treasured, managed and sustainably utilized. They can be measured by applying the agrobiodiversity index (Sthapit et al., 2017) as a tool and monitored to be able to take timely actions. The people can commit to caring for agroecosystem and agrobiodiversity in the spirit of Wilson's (1984) Biophilia hypothesis, which advocates holding-onto and amplifying the innate love of people for life and life-like processes (nature); i.e., keep tightly and strongly to the innate human tendency that affiliate with other life forms and life-like processes. The present generation in Ethiopia (as in other countries), would need to work on strengthening the human-nature bondage in general and that with the agroecosystem and agrobiodiversity in particular. Thus, while working on increasing productivity and restoring agroecosystem health, the human-agroecosystem bondage has to be strengthened. These are of high concern in view of Ethiopia being placed among Sub-Saharan African countries in which the road towards 2050 is projected to be narrow (Agrimonde-Terra, 2018). Among the reasons for this is the divergence between trends in land use and food security resulting mainly from fast growing population and urbanization for which priority actions are needed to reverse the situation. It is obvious that agrobiodiversity found in Ethiopia is vital with diverse roles in economic, ecological and social fabrics and with the agroecosystem services they are the bases for sustainable development (EBI, 2014, 2015). It is, therefore, important to see the status of nature's contributions to people and quality of life with reference to agroecosystem since healthy agroecosystem and rich agrobiodiversity are the basis of sustainable food systems and copious provision and supply of agroecosystem goods and services.

6.2 Agroecosystem's benefits to people and quality of life

'Mother Nature' has been and will continue to be the supplier of the goods and services needed by people for day-to-day functions and for improving their livelihoods and heightening the quality of life. A study made on the values of ecosystems identified 17 ecosystem services further providing illustrated elaboration on their functions (Costanza et al., 1997); and it is interesting to note that all of these are provided by agroecosystem. Natural assets are worked by humans providing tremendous contributions to people through the set of resources obtained from the special type of ecosystem known as agroecosystem. The services provided by agroecosystem has more immediate and more critical roles to people particularly in food production, provision of raw materials and genetic resources as well as cultural services and many other service types. With humankind's thoughtful and attentive actions and adoption of sustainable modes of conservation and utilization, as it happened over extended period in the past, agroecosystem and the associated agrobiodiversity units are the main assets of agrarian societies like Ethiopia. The part of nature that comes within the bounds of agroecosystem provides most of these contributions which vary between different agroecosystem sub-types. The Ethiopian agroecosystem is known to be the major providers of the food and other requirements needed by the people of Ethiopia for consumption, various resources for export and other services as well as for improving the quality of life.

6.2.1 Concepts and components of agroecosystem

There is a growing realization in recent years that agroecosystem be treated on their own having been considered distinct from natural ecosystems in many ways. Agroecosystem is best understood when described along with the related terms such as agrobiodiversity, agroecology and agroecosystem services. Proper definitions and conceptualizations are tacit steps towards basic understanding and progression to science-informed actions. Relevant concepts and components related to agroecosystem are described categorically in order to have a clearer and fuller understanding of the key elements and by extension those of Ethiopian agroecosystem together with their goods, services, and functions.

Concepts

The term agroecosystem emerged relatively recently and started serving as a unifying concept for the terms agrobiodiversity, agroecology and agroecosystem services. Agroecosystem is the ecological homes in which crop and livestock systems along with related species thrive and produce food and other resources for humans, and on a larger scale they include systems where agricultural practices, food production, distribution and consumption impose impacts on their health seen at the macro scale (Foley et al., 2011). The bulk of the food system in all agricultural societies is produced within the agroecosystem. The circumscription of an agroecosystem is not restricted to the immediate site of agricultural activity (Example: the farm), but rather includes the region that is impacted by this activity, usually by changes to the complexity of species (taxa) and energy flows, as well as to the net nutrient balance. Thus, an agroecosystem is an ecosystem under agricultural management that is connected to other ecosystems. However, the concept of agroecosystem is in many ways different from all the four natural ecosystems described in chapters 1-4 (Mountain ecosystem, Forest and woodland ecosystem, Aquatic and wetland ecosystem and Rangeland ecosystem) of the Ethiopian National Ecosystems Assessment (NEA), particularly because, unlike all the others, it is highly managed by humans and is an open ecosystem while natural ecosystems are closed or are ecosystems at least free of conscious and active human management (Altieri, 2002).

Agroecosystem is the ecosystem in which humans have exercised deliberate selectivity on the composition of living organisms in addition to changing landforms, soil condition and composition of agrobiodiversity elements. They are ecological systems whereby communities of plants, animals and microbial organisms live in dynamic interaction with their physical and chemical environments that have been modified by people to produce food, fibre, fuel and other products of food systems meant for human consumption and processing (Altieri, 2002). Thus, they are distinct from unmanaged ecosystems since they are intentionally altered and intensively managed for purposes of providing food, fibre and other products. Inherently, agroecosystem has human communities and economic and environmental/ecological dimensions. Most Ethiopian agroecosystem is managed by smallholder farmers who often employ ILK and traditional skills and practices. All smallholder farmers in Ethiopia used to follow indigenous agroecological farming practices with progressive alteration due to the promotion of improved agricultural practices that went on percolating piece by piece. On this line, research results show that farmers in Latin America consider agroecology the main technological strategy for use with smallholders (SOCLA, Undated). The main advantages of agroecological farming approaches as providers of methodologies, participatory social actions while they are culturally acceptable with sound ecological and economic optimization of production units geared to the needs of smallholder farmers.

The main characteristics of the Ethiopian agroecosystem collated from published and unpublished sources have been assessed and presented in the different sections. An agroecosystem can be conceptually extended to the area impacted by agricultural activities including subtle manifestation of diminishing the complexity of species assemblages, the dynamism and energy flows as well as the status of soil nutrients.

Agriculture's long-term costs to agroecosystem services such as habitat loss, soil erosion, nutrient run-off, and impacts to human health originating from practices such as the use of pesticides and fertilizers would ultimately undermine the natural base upon which agricultural livelihoods depend. Jarvis et al. (2007), in the book entitled 'Managing Biodiversity in Agricultural Ecosystems', emphasized that inappropriate or excessive use of inputs such as pesticides and fertilizers can cause damage to biodiversity within agricultural ecosystems and compromises future land productivity. It is further shown that human appropriation of energy that is assisted by technological advancement can have direct negative impacts on not only human well-being but also ecosystems and biodiversity as less energy will be available for non-human species (Hussain and Miller, 2013). ,

Components

The early conception of agroecosystem in Ethiopia can be traced back to the times when ancient Ethiopians realized differences in agroclimatic conditions and classified land into *Kolla*, *Woina Dega* and *Dega* with further authentication to five main traditional core agro-climatic zones given as *Bereha*, *Kolla*, *Woina Dega*, *Dega* and *Wurch* going from low to high altitude and from hot to a cold area. Scientific measurements of main climate factors were applied to delimit the five main agroclimatic zones given in the first column of Table 1. Taking these basic zones and adding the highest zone (Alpine/high *Wurch* or *Qure)* and considering it as the main stratum and superimposing on it three moisture levels (dry, moist and wet and only the first two of these levels to the first zone (*Bereha),* 17 zones were produced (Tessema, et al., 2007). These are commonly used in agroecological profiling of an area for purposes of agriculture, forestry, soil and water conservation, tree planting and for decision-making in the identification of suitable crops and cropping systems as well as recommendations for land use. This agroecological classification was initially based on ILK with traditional designations and nomenclature where variations in altitude, thermal and precipitation were used as main criteria. The recent and elaborate nine agroecological classification was developed based on ILK and science-informed climatic criteria (temperature, rainfall), length of growing period, type of farming system and land productivity level) superimposed onto it and further expanded by adding the terms arid, semi-arid, sub-moist, moist, sub-humid, humid and per-humid indicating the length of the growing period. The thermal zones have also been classified as hot, warm, tepid, cool, cold and very cold climates, and applied for zonation. This led to the recognition of 18 major and 49 minor AEZs (Tessema, 1993, 2007; Hurni, 1998; MoA, 2000). A more accurate and better fitting classification evolved which ended up partitioning the country into 32 major agroecological zones (EIAR, 2011) given in the sixth column of Table 1 and considered a better framework for agroecosystem and agrobiodiversity assessment and management.

Table 1. Agroecological Zones of Ethiopia placed in the traditional agroclimatic zones with their altitudinal ranges and average annual temperature and rainfall

Traditional agroclimatic zones	Altitude (m.a.s.l)	Mean annual temperature (^{0}C)	Mean annual rainfall (mm)	Major Agroecological Zone according to Recent Classification (EIAR 2011)		Total area (ha)	Percent-age
				Symbol of AEZ	Name of AEZ		
Bereha (hot arid)	< 500	>27.5	< 300	A1	Hot arid lowland plains	12,202,265	10.79
				SA1	Hot semi-arid lowlands	449,789	0.40
Kolla (warm semi arid)	500 -1500	20.0 – 27.5	300-900	A2	Warm arid lowland plains	22,356,361	19.76
				M1	Hot moist lowlands	672,104	0.59
				M2	Warm moist lowlands	17,109,776	15.12
				PH1	Hot per-humid lowlands	13,088	0.01
				SA2	Warm semi-arid lowlands	3,114,607	2.75
				SH1	Hot sub-humid lowlands	1,893,410	1.67
				SM2	Warm sub-moist lowlands	10,890,128	9.63
Woina dega (cool sub-humid)	1500-2300	16.0 -20.0	900-2200	A3	Tepid arid mid highlands	488,143	0.43
				M3	Tepid moist mid highlands	9,101,288	8.05
				H2	Warm humid lowlands	2,592,647	2.29
				H3	Tepid humid mid highlands	3,001,630	2.65
				PH2	Warm per-humid lowlands	765,390	0.68
				PH3	Tepid per-humid mid highland	152,281	0.13
				SA3	Tepid semi-arid mid highlands	218,624	0.19
				SH2	Warm sub-humid lowlands	8,046,859	7.11
				SH3	Tepid sub-humid mid highlands	7,504,025	6.63
				SM1	Hot sub-moist lowlands	637,276	0.56
				SM3	Tepid sub-moist mid highlands	5,850,115	5.17
				SM4	Cool sub-moist mid highlands	1,314,156	1.16
Dega (Cool and humid)	2300-3200	11.5 – 16.0	900-1400	H4	Cool humid mid highlands	926,331	0.82
				M4	Cool moist mid highlands	1,963,109	1.74
				SH4	Cool sub-humid mid highlands	589,049	0.52
				H5	Cold humid sub-afro-alpine to afro-alpine	62,620	0.06
Wurch (Cold and moist)	3200-3700	< 11.5	900-1400	H6	Very cold humid sub-afro-alpine	50,577	0.04
				M5	Cold moist sub-afro-alpine to afro-alpine	78,829	0.07

				M6	Very cold moist sub-afro-alpine to afro-alpine	15,246	0.01
				SH5	Cold sub-humid sub-afro-alpine to afro-alpine	68,815	0.06
				SH6	Very cold sub-humid sub-afro to afro-alpine	34,889	0.03
				SM5	Cold sub-moist mid highlands	76,819	0.07
				SM6	Very cold sub-moist highlands	18,021	0.02
Qure or high *Wurch* (very cold highland)	>3700	< 11.5	>1400		Very cold sub-moist highlands (usually lumped with *Wurch* and no separate measurements of its own)		
				WB	Water body	870,795	0.77
					Total	113,129,062	100.00

Modified from Tessema et al. (1993); Hurni (1998); MoA (2000); Tessema, et al. (2007); EIAR (2011), further aligned and integrated with the traditional nomenclature

The above classification is still made more elaborate by adding the length of the growing period (arid <45, semi-arid 45-60, sub-moist 61-120, moist 121-180, sub-humid 181-240, humid 241-300, and per-humid >300 days). The earlier classification categories being broader encompass from 2 (*Bereha*) to 12 (*Woina Dega*) categories of the recent classification as could be seen by comparing columns one and six in Table 1. The reasons for the variations are related to the use of different criteria or giving more importance to some criteria than to others. More refinement and perfection is still required through further fine-tuning the criteria and objectivising through ground-truthing. Though not properly published, the 32 zones help to systematically identify and classify variations for assessment and valuation of the contributions and potentials of each agroecological zone. The basis for agroecosystem recognition in the Ethiopian case and the path that the agro-ecological zonation took over the years has been elaborated in Table 2.

Table 2. Origin of agroecological zones in Ethiopia from ILK and refinement by scientific data

No.	Designation and Types	Timeline (source)	Basis of Classification
1	Traditional agroclimatic zones known with the common vernacular Amharic terms: *Kolla*, *Woina Dega*, *Dega* and with other equivalent vernaculars in other major Ethiopian language	Pre-1990	ILK - colloquial use is still serving as a common means of communication among rural folks
2	Expansion of the traditional agroclimatic zones to include *Bereha* (lowest), *Kolla*, *Woina Dega*, *Dega* & *Wurch)* (highest) climatic factors being superimposed on each zone.	1990s (Hurni, 1998; MoA, 1998, 2000)	ILK plus altitude and precipitation, used by researchers
3	Further expansion of agroclimatic zones and qualification with moisture conditions described as arid, semi-arid, sub-moist, moist, sub-humid, humid and per-humid considering *Bereha, Kolla, Woina Dega, Dega* and *Wurch*	1990s (Hurni Hurni, 1998; MoA, 1998, 2000; Tessema et al., 2007)	ILK plus altitude and precipitation level
4	Putting all the factors together (altitude, rainfall and thermal zones) and adding the condition regarding the length of the growing period, resulted in 18 major and 49 minor agroecological zones	Post-1990 (MoA, 1998, 2000)	Altitude, precipitation, thermal zones, length of growing period
5	Further refining produced 32 agroecological zones qualified with the climatic factors of hot, warm, tepid, cool, cold and very cold as seen in Table 2	Modern AEZs (MoARD,2005; EIAR, 2011),	Altitude, precipitation, thermal zones, length of growing season
6	Still further refinements by adding land productivity factors to distinguish high, medium, and low potential crop zones subdivide the country into significant productivity potential zone as high potential perennial crop zone, high potential cereal crop zone, low potential cereal crop zone, pastoral zone, and other minor zones	Refined modern AEZs (EIAR, 2011)	Altitude, precipitation, thermal zones, length of growing period, land productivity

An agroecosystem is usually viewed as a subset of a conventional ecosystem where there is always active human action and contains lower associated biodiversity than that of natural ecosystems found in the same agroclimatic zone or in areas where similar potential vegetation types occur. Conversion of natural ecosystems to agroecosystem usually comes about through modification of the ecological complexity, including by ecosystem niche simplification, which reduces the biodiversity and simplifies the ecological relations that should have existed in that particular environment. Rising global concerns call to transition to an integrated approach by connecting development with environmental sustainability (Steffen et al., 2015) is coming up with alarms to countries like Ethiopia. The way out is to enhance their time-tested human-nature bondage as seen in their traditional management of homegardens within the scope of the local cosmovision in parts of Ethiopia (Woldeyes et al., 2016) and other tropical areas that mimic the surrounding natural ecosystems and preserve more species even after the area is converted to agricultural landscapes with more 'useful' biodiversity (Galluzzi et al., 2010). Tropical homegardens, including some of those found in Ethiopia (Asfaw and Nigatu, 1995; Abebe, 2005) are seen as 'agrobiodiversity hotspots' or 'agrobiodiversity islands' amid agricultural landscapes.

Ethiopia is well known for treasuring and maintaining affluent agrobiodiversity since a long time ago which tradition continued for generations (Vavilov, 1951; Harlan, 1969; Westphal, 1975; Worede et al., 2000) and most of it is still surviving and providing agroecosystem services (EBI, 2015). Agricultural land management systems in Ethiopia are represented by landscape types with four main food production systems; namely, the plough and cereal culture well developed in the north and central parts, the vegeculture (perennial crop-based) zone represented by the hoe and *Enset* complex of the south and southwest, the shifting cultivation of the west and the pastoral complex of the lowlands (Westphal, 1975; Brandt et al., 1997). These are the farming systems that evolved during the long history of agricultural innovation and adoption by the people in parts of the country (Westphal, 1975) and now are found in a dynamic situation enhanced by changes in the environment and human action. The grain production zone and the vegeculture (perennial crop-based) zone are the sites where some of the crops were domesticated falling within the natural zones of *Teff*, *Noog* and *Dagussa* (finger millet) and *Enset* in the latter case. *Enset* is one of the important food crops domesticated in Ethiopia (Vavilov, 1951; Harlan, 1969). It is now believed that more than 20 million people in Ethiopia use it as food and for most of these it is a major staple or co-staple food plant. It is also a fibre and income crop as both its food and fibre products are widely marketed since long time ago and its proportional contribution to household income has been growing progressively. The culture of *Enset* cultivation leads to continuous enrichment of the soil with manure and domestic compost. Such farming systems, where continued intensification takes place, may eventually put more pressure on agroecosystem productivity (IPBES, 2018) unless they are designed by considering some best practices from small-scale agriculture around the world (Vandermeer, 2011). Deeper studies on the traditional *Enset* cultivation system may offer solutions that could increase productivity with continued intensification.

The basic concept embodied in the term agroecosystem, though not very well characterized in many instances, is the science of agroecology (Altieri, 1995, 2002, 2015; Garbach et al., 2014; SOCLA, Undated) that is derived from ecological science. Ethiopian farmers have practiced agroecological farming for generations through their traditional use of legumes in crop rotation, intercropping, polyculture farming, organic agriculture, parkland agroforestry wherein leguminous crops are mixed, trees are retained, crop residues are used as surface mulch and manure is applied to homegardens and field farms. Ethiopian homegardens used to be diversified spots, as in other areas (Galluzzi et al., 2010**)**, which continued to use compost and green manures, applied biocontrol of insect pests (Tadesse and Mesfin, 2010) such as growing some plants as live fence species and as borders/margins to the main crops, leaving trees around the field to attract birds that feed on insect pests and diseases. During ethnobotanical field studies in Mareqo area local farmers explained that they intercrop maize in the fields of hot/chili pepper to prevent disease infestation. Maryo (2013) reported observing farmers growing the endemic Ethiopian plant, *Pycnostachys abyssinica, and Canna indica* close to *Enset* plantations to discourage incidence of bacterial wilt in Kambatta Tembaro. Thus, these farmers are in a way applying traditional push-pull technology in their indigenous and local agricultural practices, which need further intensification and innovative scaling up. The soil conservation and plant management practices of the Konso cultural communities in southern Ethiopia and Erob in northern Ethiopia that go back to millennia are very elaborate (Asfaw et al., 2015); the scientific merits of such traditional practices have to be well explicated. Other cultural groups have also adopted various methods of land and vegetation protection suitable for their respective areas. All these are done to enhance yields and sustain soil fertility and health with minimal dependence on outside inputs including inorganic chemicals and energy. Agroforestry is widely practiced in

Ethiopia much more intensively in southern and southwestern Ethiopia. Its economic, social, environmental and cultural values are much more realized with high potential some than in other areas. For instance, planting *Acacia polyacantha* trees was found to positively and significantly influence household income, in which case the aggregated monetary value of the different products from *Acacia polyacantha* contributed 13.7% to the total household income, which is significant (Emiru et al., 2019). The historical and current way of segregating forest land from agrarian communities tends to lead to conflicts that reduce land productivity and increase inequity. Adoption of agroforestry can be seen as an institutional response to contested resource access, and can allow for gender and social equity enhancement as well as is a source of empowerment. For example, if a person wants to get married to a girl in the Gedeo community, he should be able to produce evidence indicating possession/ownership of the adequate number of trees on his farm. In the absence of this precondition, elders will not bless the anticipated marriage. In related cultures, the number of *Enset* plants in a person's farm plays such an important social role as a means of bonding families together, keeping together husbands and wives and social groups. In Kaffa, farming households explain that the house of a working man must not be seen from a distance; it must be covered in a grove of *Enset* and other woody plants. This shows the high social values of agroforestry among rural households. Some trees on-farms and borders are used for important rituals with key socio-cultural and spiritual fulfillment values in addition to their uses as fruit, medicine, fodder and browse, shade for humans and domestic animals and fencing.

What we see in agroforestry practices is the principle of agroecology, the application of ecological concepts, principles and practices to the design and management of sustainable agroecosystem (Altieri, 1995, 2002, 2015; Garbach et al., 2014; SOCLA Undated); the incipient practice of which has seasoned with Ethiopian farmers. The 10 elements of agroecology described in FAO (2018a) deal with the diversification of biodiversity; co-creation and sharing of knowledge; building synergies and enhancing key functions across food systems and supporting production and multiple agroecosystem services; efficient and innovative agroecological practices; recycling; resilience of people, communities and ecosystems; valuation of human and social values by protecting and improving rural livelihoods, equity and social well-being; availability of diversified and culturally appropriate diets; responsible governance and circular and solidarity economy. These elements clarify what makes agroecosystem distinct from other ecological systems and guide the transition to the much desired sustainable agricultural practices providing an underpinning of the concept. The guide underlines that agroecology is fundamentally different from other approaches to sustainable development as it is based on bottom-up and territorial processes that help to deliver solutions by context.

Agroecological innovations are based on the co-creation of knowledge, combining ILK from traditional, practical and local knowledge of producers and agroecosystem 'managers' with conventional science. By enhancing their autonomy and adaptive capacity, the agroecology approach empowers producers and communities as key agents of change and seeks to transform food and agricultural systems, addressing the root causes of problems in an integrated way and providing holistic and long-term solutions. It involves an explicit focus on the social and economic dimensions of food systems. As an important guide for countries to transform their food and agricultural systems, mainstreaming sustainable agriculture on a larger scale needs to focus around some key elements including diversity; synergies; efficiency; resilience; recycling; co-creation and sharing of knowledge while tightly holding on to human and social values; culture and food traditions and working under responsible governance (FAO, 2018a). In this assessment report, the agroecosystem of Ethiopia have been examined by looking at indicators of the agroecosystem, input and output changes with time, relationships between agroecosystem services and dis-services and resource contributions to people and, the quality of life with regards to the major services.

Formed through modification of natural ecosystems, agroecosystem has been going through gradual progression into natural ecosystems and this has been going on since the dawn of agriculture, which was believed to go as far as 10,000-12,000 years ago with a progressive reduction of agrobiodiversity. New evidence is now pushing the earliest interaction between humans and biodiversity as far back as 23,000 years (Snir et al., 2015). Observations show that land use/land cover changes resulted in farmlands and settlement areas pushing into natural ecosystems and causing shrinkage of the latter. Agroecosystem is under agricultural management and connected to natural ecosystems of forests, wetlands, grasslands, and mountains into which they periodically advance and this happened for decades in Ethiopia and resulted in continued agroecosystem expansion as a consequence of growing population and human needs.

An agroecosystem is a system resulting from the actions of people during the processes of agricultural development where natural systems are modified for the purpose of crop production. An ecosystem, whether natural or agricultural, is a complex and dynamic system of communities of plants, animals, microorganisms and the non-living components of the environment interacting as a functional unit and the same concept holds for agroecosystem in the agricultural landscapes. The major change that takes place when natural ecosystems are converted to agroecosystem involves niche simplification accompanied by reduction of species and modification of the physical and chemical compositions of the landscape. Agroecosystem is sites where plants come through natural dispersal and diffusion or intentional human-mediated introductions from different ecosystems as well as from different countries and continents. Plants originating under adaptations to different ecosystems are brought up and made to grow in an agroecosystem and survive with domestic animals also coming from different areas. Some farming systems have managed to retain *in-situ* plants within the farms and homegardens and achieved sustainability for thousands of years as observed in the Gedeo landscape of southern Ethiopia (Kippie, 2002).

An agroecosystem is a home to agrobiodiversity, the entire spectrum of biodiversity found within agricultural systems which is a rich gene centre in countries like Ethiopia. Crop diversity is a major component of agrobiodiversity shown to be high in Ethiopia by generations of researchers (Ketema, 1993; Teshome et al., 1997; Asfaw, 2000; Lakew and Assefa, 2011; EBI, 2015; Koehler, 2017; Tadesse, 2017; Jifar et al., 2018; Asmamaw et al., 2019). These and other sources make reference to the fact that agrobiodiversity is high in wheat, barley, sorghum, *Teff*, peas, beans, linseed, Arabica coffee, finger millet, cowpea, lentil, *Enset*, clovers ,and oats as well as in wild relatives of sorghum, *Teff*, Arabica coffee, finger millet ,and *Enset* among others. The level of diversity is estimated to be medium to high in overall crop diversity, diversity in Ethiopian domesticates, crop landraces, species and genetic diversity, livestock breeds, ecosystem stability/resilience, habitat heterogeneity and carbon stock while being low or medium in trophic interaction, human support to ecological processes, net productivity, resistance to stresses, natural population regulation and biomass accumulation.

6.2.2 Agrobiodiversity: origin, components, dimensions and contributions

The concept of agrobiodiversity encompasses the variety and variability of living organisms that contribute to food and agriculture in the broadest sense coupled with cultivating crops and rearing animals within agroecological complexes that harbour pollinators, symbionts, pests, parasites, predators, decomposers and competitors. Its hierarchy comprises genes, populations, species, communities, ecosystems and landscape components as well as human interactions with all these. Domesticated biodiversity is located in agricultural landscapes being complemented by wild relatives and germplasm stored in gene banks and breeders' collections. Agrobiodiversity is all about the variety of life and the associated ecological processes within agricultural landscapes. It is a vital showpiece of biodiversity, which contributes to nutrition, livelihoods, and maintenance of habitats. Agrobiodiversity encompasses the whole spectrum of agriculturally important biological variability with all its compositional, structural and functional components, which in its broader scope ranges from genes to organisms and their habitats as well as the cultural diversity of human communities. It is the economically most valuable asset and figures out as the component into which rich indigenous and local as well as conventional scientific knowledge is integrated.

The origin of the concept of agrobiodiversity (initially referred to as agricultural biodiversity) emerged subsequent to the modern concept of biodiversity after the latter entered wider circulation since the early 1980s (Wilson, 1984). The concept took a long time to be seriously taken as worthy of scientific merit and attention because its knowledge pool was not available in the earlier published literature and thus had to be researched and developed from studies of farmers' knowledge, practices and skills. In this connection, a project sponsored by IPGRI (now Bioversity International) and titled "Strengthening the scientific basis of *in-situ* conservation of agrobiodiversity" went underway in the 1990s in nine countries of the world, including Ethiopia to address the gap in knowledge that existed then (Jarvis and Hodgkin, 1999) and a curriculum support manual for teaching the science of agrobiodiversity was later produced (Rudebjer et al., 2011). In a similar manner, the science of ecology started dealing with the specificity of agroecology and that led to the development of the agroecosystem concept.

The knowledge about agrobiodiversity that developed over generations and existed in the oral literature had to be written up in a scientific format and with this objective, a lot of research has been undertaken globally (Zimmerer et al., 2019). The early studies of these practices and the associated knowledge systems and description in a modern way appeared in the works of Brush (1991), Worede (1991), Altieri (1995), Worede et al. (2000) and others. As in any other concept, the understanding of agrobiodiversity preceded the new nomenclature. It is noted that the concept of agrobiodiversity can be felt and understood as being deeply embedded within the broader parent concept 'biodiversity' before the term is annotated in the scientific literature. Though the term agrobiodiversity *per se* was not mentioned and generally not known to be published until 1994 (Brookfield and Padoch, 1994), it had, however, existed in parallel with the broader term usually by being referred to as agricultural biodiversity or biodiversity of the agricultural system. We see that even though the term was not mentioned in Worede (1991) and Brush (1991), both these authors wrote about crops and crop wild relatives which are the major components of agrobiodiversity, as verified in their later discourses. Recognizing the urgency of biodiversity losses (UNCED, 1992; Thrupp, 1998), particularly from traditional agricultural landscapes, agrobiodiversity was addressed in a comprehensive manner by the 3rd conference of the parties of the Convention on Biological Diversity (CBD) in 1996 (Jarvis and Hodgkin, 1999; Jarvis et al., 2007), and subsequently, the roles and major contributions of agrobiodiversity were recognized (Munzara, 2007). Research results on agrobiodiversity started being widely published around the end of the 1990s and the beginning of 2000s (Lenne and Wood, 1997; Collins and Hawtin, 1999). The Convention on Biological Diversity (UNCED, 1992) and the International Treaty on Plant Genetic Resources for Food and Agriculture (FAO, 2008) were the key documents that created a formal international legal mandate for agrobiodiversity conservation.

Agrobiodiversity plays a key role in ecosystem functioning and is a good indicator of the status of agroecosystem health (FAO, 2013). It ensures many functions including provision of food and fibre, pollination of crops, biological crop protection, animal husbandry and maintenance of proper structure and fertility of soils as well as protection of soils against erosion, nutrient cycling, control of pests and diseases and regulation of water flow and distribution. Zimmerer et al. (2019) elaborated an expanded view of agrobiodiversity named the novel Agrobiodiversity Knowledge Framework that comprises of four themes (ecology and evolution; governance; food, nutrition and health; and global environmental and socioeconomic changes). Agrobiodiversity is a vital subset of biodiversity that encompasses the genes and species of all living organisms (plants, animals, and microorganisms) in the agroecosystem in which they thrive interacting with each other and with the abiotic components. The concept map in Figure 1 depicts agroecosystem services as a function of agrobiodiversity with particular reference to Ethiopia in which agrobiodiversity can be viewed under four tiers (levels of description, functions, threats and actions) with further branching and re-branching. The illustration makes the structural, compositional and functional components of agrobiodiversity and the encompassing agroecosystem complete and clearer. Each of the four tears has elaborate components and subcomponents and shows how complex the agroecosystem with its component agrobiodiversity and agroecosystem services could be. Under levels of description, the figure shows the ecosystem, species, genetic and cultural aspects of agrobiodiversity seen across plants, animals, microbials including the agroforestry systems with trees, shrubs, crops and livestock as well as domesticated wild stocks; the functions of agrobiodiversity are seen under the biological resources, ecosystem functions and services further highlighting the social and cultural benefits along with the treats and actions needed to maintain the agrobiodiversity at all levels and ensure optimal reaping of the much needed benefits.

The contributions of agrobiodiversity to sustainability include the provision of healthy diets and nutrition, facilitation of the development of sustainable agriculture and forestry and promoting climate change adaptation, biodiversity conservation and resilient livelihoods. Ethiopia's climate-resilient green economy strategy (CRGE), which considers biodiversity and ecosystem services for setting the foundations and implementing its activities (FDRE, 2011), requires being firmly tied to agroecosystem and agrobiodiversity conservation and sustainable utilization a bit strong statement. With the emphasis on the agroecosystem approach, key contributions are expected through increasing agricultural productivity and production combined with sustainability and food security (FDRE, 2011). Despite the incorporation of Ethiopia's CRGE strategy into government strategic documents, grassroots level integration in smallholders' farms is yet to bear fruits worthy of mention (Negash and Achalu ,2008; Kassa et al., 2011; Hillbrand, 2013).

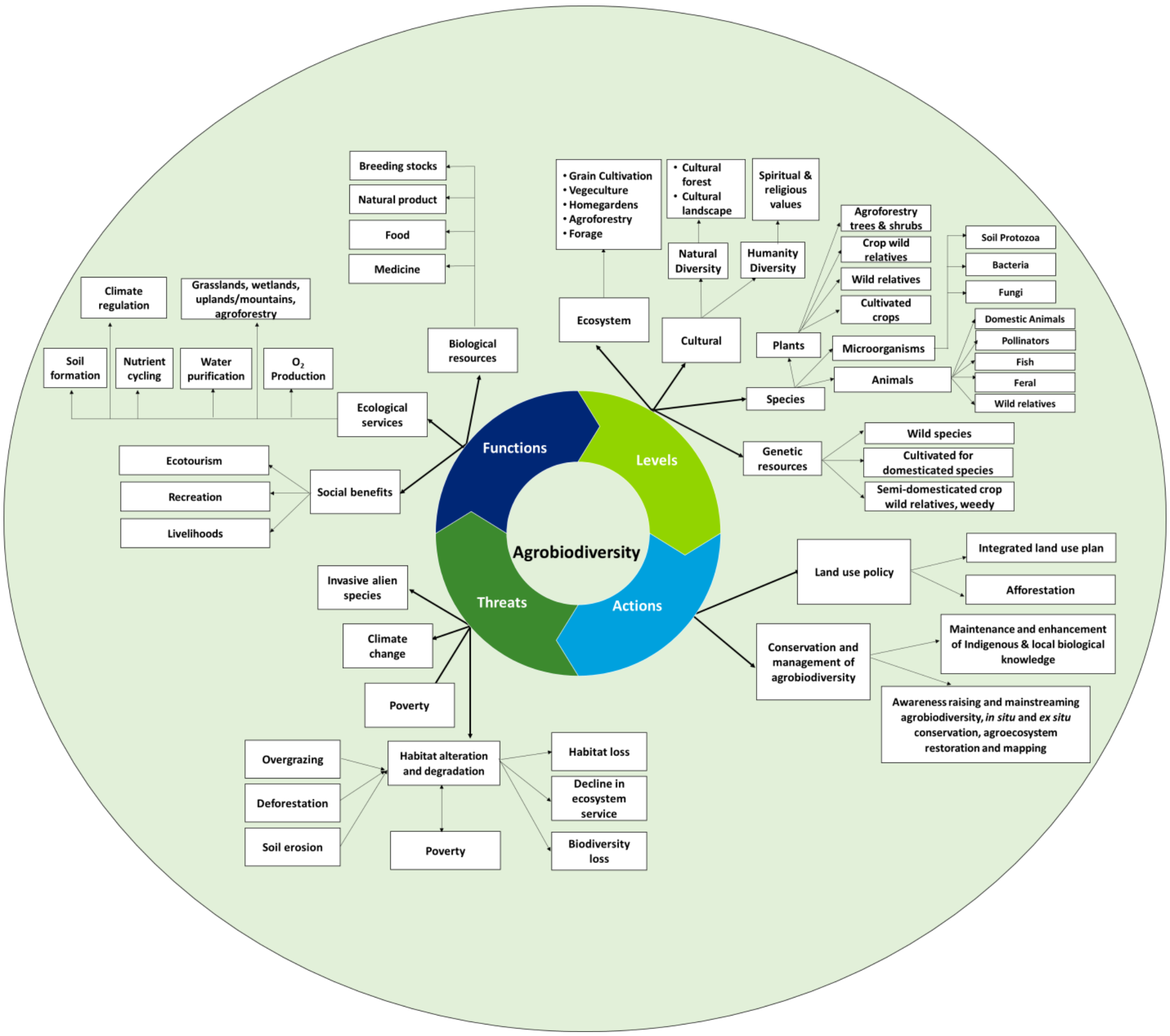


Figure 1. Agroecosystem service as a function of agrobiodiversity (Synthesized from various sources cited in this chapter)

Ethiopia holds an important position in global agrobiodiversity share and that is partly due to the diversity in agroclimatic, agroecological and sociocultural settings in addition to its geographical location and topographic variations. This makes Ethiopia a country of wide agroecosystem contrasts offering a rich assemblage of multiple agroecosystem goods and services to people and life. Paradoxically, however, Ethiopia is one of the countries that faces a major challenge today and, given the current trend and possibly into the foreseeable future, in maintaining or enhancing the beneficial contributions of its agrobiodiversity to its people and for enhancing the quality of life. The Agroecosystems Specialist Group (IUCN's Commission on Agroecosystem Management (CEM)) promotes sustainable agricultural practices and agrobiodiversity management under changing climatic conditions and encourages ecosystem-based approaches and resource conservation technologies for transforming agriculture as a sustainable enterprise (CEM Newsletter, 2017).

The agrobiodiversity that exists today has resulted from the natural and human selection processes and the inventive development of farming communities that went on for millennia, being constantly reshaped by the knowledge and practices of the people in a wide range of ecological settings and dynamic processes. Agrobiodiversity is threatened mostly by the spread of modern agriculture and the globalization of food markets (Wolff, 2004). The conflicts between agriculture and biodiversity can be circumvented by adopting and enhancing sustainable farming practices and changes in agricultural policies and institutions. A plausible way out is to make agriculture adaptable to the changes and the ensuing dynamics of the human-environment nexus; and this could be partly realized through agrobiodiversity conservation, diversification and enhancement backed by genetic improvement of critical crops and underutilized plant species/varieties within an efficient agroecological system (Altieri et al., 2012). Historical pieces of evidence and current observations show that biodiversity maintenance integrated with agricultural practices can have multiple ecological and socio-economic benefits, particularly to ensure food security. Global agriculture is turning its face with increased attention to underutilized crops that have the potential to enhance global food security (Jacobsen et al., 2015), and it is known that Ethiopia is rich in such plants and can contribute significantly to realize this objective. To meet Ethiopia's future food security and sustainability needs, food production must grow substantially including by utilizing its underutilized species and orphan crops while, at the same time, agriculture's negative environmental impacts must be reversed dramatically by halting its expansion, improving yields, increasing cropping efficiency, making necessary adjustments on diets and reducing wastages in the manner rationalized by Foley et al. (2011) in their model of the global eco-agri-food system.

Efforts to understand and expand the knowledge base related to Ethiopia's agrobiodiversity went through various developmental stages. Early works (1768-1975) on Ethiopian plant explorations mostly remain hidden as unpublished reports, personal diaries and narratives of historical, cultural and biological nature. All along, Ethiopian farmers remained keen in nurturing and using plant resources while being conscious about diversity including facilitating the maintenance of germplasm for continuous cultivation, storage and sharing; and thus, ensuring continuity of diversity in crops and livestock. The earliest accounts on the useful plants of Ethiopia can be inferred from the exploration reports of James Bruce, who visited Ethiopia from 1769-1772 primarily to locate the source of the Blue Nile but his expedition had collected and produced illustrations of about 200 species of useful plants of Ethiopia including *E. ventricosum, E. tef, C. arabica, Hagenia abyssinica* and *Brucea antidysenterica*. Missionaries from Europe and other parts of the world have had some early subtle and dubious "bioprospecting" operations among the key events of early times where foreigners including military generals ended up being plant collectors. Some of these wrote on plants from Ethiopia, collected and described many crop species and varieties, and discussed agricultural systems. Extensive and targeted germplasm collections were made by N. I. Vavilov in the late 1920s (Vavilov, 1951), identifying Ethiopia as an important global centre of crop origin and diversity. The agricultural writings of Hufnagel (1961); the classical article on the origins of Ethiopian crops by Harlan (1969) and the description of the agricultural systems of Ethiopia by Westphal (1975) are important milestones in documentation of agriculture and crops in Ethiopia. Bilateral agreements between Ethiopia and European countries and the USA facilitated repeated germplasm collection and transfer to the respective countries. While these materials became instrumental for breeding in those countries and got transferred to other countries of the world (under the old banner that said any germplasm is a global resource) and which resulted in significant crop improvement, though very unfortunately no samples or experiences were left behind or no feedback of research results reverted to the country of origin.

Gene bank activities started in the late 1970s and resident researchers began investigations on botanical resources, notably on seed collection and storage at the then Ethiopian Plant Genetic Resource Centre (PGRC), which later on went through changes with respect to its scope and designation being finally transformed to the present Ethiopian Biodiversity Institute (EBI). On the botanical side, specimen collection and building the Ethiopian National Herbarium and writing the modern Flora of Ethiopia at Addis Ababa University went ahead, particularly through the Swedish-supported Ethiopian Flora Project between 1980 and 2009 (Kelbessa and Demissew, 2014). The Ethiopian Flora Project produced ten big books organized in eight volumes with detailed taxonomic accounts of the plant resources of Ethiopia including the crops, crop wild relatives and other useful plant species. Generations of scholars have had their shares in these activities, giving attention to plant agrobiodiversity such that more and more agricultural scientists and biologists, including graduate researches got involved in agrobiodiversity research.

Contemporary studies relating to agrobiodiversity that include crop genetics, ethnobotany, agricultural systems; biotechnology, biodiversity and conservation have been undertaken in the country to varying extents as noted in the first Ethiopian national biodiversity strategy and action plan (IBC, 2005) and other publications. Furthermore, published works in Ethiopian agrobiodiversity integrated with ethnobotany, ethnoecology and related areas in general and on selected crops and others have been published; though the coverage when seen in a broader scope and the depth of treatments of the agroecosystem and the agrobiodiversity resources of the country are a small portion and not comprehensive enough. While it is noted that a number of recent works focused on the diversity of specific crops and selected areas have been published over the last few years, comprehensive system-based approach focused to the full coverage of the Ethiopian agrobiodiversity is not available. For example, in 2018, the Ethiopian Journal of Biological Sciences dedicated its entire volume 18 (Supplementary issue) to the proceedings of the International Workshop on *E. ventricosum* where 12 papers in which 28 authors were involved have been published (Demissew and Friis, 2018). The *Enset*-based agricultural landscape has recently received research attention wherein studies focused to south-central Ethiopia (Maryo, 2013) and the *Enset* belt landscape referred to as *Enset*-based agroecosystem by Gebre (2015) that described a rich assemblage of agrobiodiversity providing a good deal of agroecosystem services. Another study by Bemata (2018) was devoted to the agro morphological and molecular characterization of *Enset* landraces. The *Enset* area in Ethiopia is very extensive, including the tropical homegardens in the south and southwest as well as those described as agroforestry homegardens (Abebe, 2005). The extensive review by Burrell et al. (2019) alluded to *Enset's* high food security enhancing potential.

The plant agrobiodiversity of Ethiopia is predominantly found in the varied and complex farming systems having been shaped over generations. The major agricultural areas are found in the highlands where the major centres of crop genetic diversity (Unruh, 2001) for a number of important crop species exist. The 'hotspots' of Ethiopia's plant agrobiodiversity are embedded in the farming systems and the zones where the various cultural groups are located. Some of the crops enjoying intraspecific diversity were domesticated within the country while others were introduced early (16^{th} century) and cultivated in the various microenvironments and microclimates over the millennia and the latter have led to the recognition of the country as a secondary center of crop diversification for those crops. The mixed system of agriculture (estimated to about 70%) is practiced in all parts of Ethiopia, except the pastoral areas, being highly dependent on rain, and sometimes in some areas reinforced by agro-silvo pastoral system integrating crops, forest and livestock production in what could be dubbed as climate-smart agriculture (FAO, 2013). The major and minor agricultural systems of Ethiopia have been described from different parts by different authors (Westphal, 1975; Worede 1991; Worede et al., 2000; Amede et al. (2017) at different time scales. The major agricultural systems are the grain farming; the vegeculture or the *Enset* complex circumscribed in various ways by other researchers as perennial crop-based systems; the pastoral and agropastoral system; the agroforestry and parkland agroforestry system and mixed types. Detailed classification as the agroecosystem occur today and descriptions of this system are given in subchapter two of this chapter.

Ethiopia has produced its second National Biodiversity Strategy and Action Plan (EBI, 2015) wherein its wealth of plant and animal agrobiodiversity have been treated in details going deep into the cultivated plants, the crop wild relatives, the wild useful plants, the livestock, the microbial resources and the cultural diversity. In this new document, the EBI drew special attention to the need for assessing the status and trends of the agricultural biodiversity including the underlying causes of change by identifying adaptive management techniques, practices and policies; building capacity; increasing awareness and promoting responsible actions through mainstreaming agrobiodiversity into national plans and strategies with the goal of ensuring the conservation and sustainable use of Ethiopia's biodiversity in general and the agrobiodiversity in particular including by enhancing institutionalization of community seed banks (Tsegaye, 2003) and botanical gardens in collaboration with national and international partners. The present assessment ties in very well with the nationally set goals and direction as depicted in the EBI (2015) document. While this is a good start, further actions are desired including developing the agrobiodiversity index (Bioversity International, 2016: Sthapit et al., 2017) and promoting biophilia (Wilson, 1984) and awareness of citizens. Contributions of such index to ensure safe and healthy diets, sustainable production and plant breeding, healthy seed system and conservation options for ensuring sustainable food systems is well anticipated. It would be necessary to develop country-level or major agroecosystem-level Agrobiodiversity Indices to facilitate monitoring of the status of existing agrobiodiversity and to take the timely response and appropriate actions. Such indices can be computed by drawing on inputs from existing databases, crowdsourcing data, screening of public and private policies and reports, factoring in contributions of agrobiodiversity to global goals, consulting scorecards and accessing information from various sources and using it to report on commitments to global goals, stakeholders and the general public (Sthapit et al., 2017). Adoption of such an indexing system will be in the best interest of Ethiopia, a country widely acclaimed as an agrobiodiversity centre, but gradually sliding towards becoming a worrisome hotspot burdened with multifaceted threats.

The rich wild plant flora of Ethiopia has sustained high diversity of agricultural practices among many ethnic groups making the country one of the important global centres for early plant domestication, cultivation and introduction. Ethiopia's importance in genetic resource richness coupled with its uniqueness in cultivated flora stands out vividly. Its location at the gateway to Asia and Europe in the tropical upland of the Horn of Africa is believed to have facilitated the exchange of crops and genetic material over an extended period allowing endogenous crops to be subsequently joined by those received from Asia, South and Central America, Europe and the rest of Africa. Many crops emerged by a combination of drawing from wild species or from external sources through long processes of experimentation, innovation, domestication and introduction; and such prolonged and frequent manipulation of plants from different environments together produced a collection of ancient cultigens referred to as farmers' varieties or 'landraces' of the crops cultivated on a regular basis as staple foods; others cultivated in a rather intermittent manner as space and other conditions allow (Some oil crops, pulses, fruits, roots/tubers; and still others cultivated much less frequently by few cultures only (*A. schimperanum*).

The growth and transformation that Ethiopia is going through (infrastructural developments in roads, dams and in market systems and communication networks) and major investments in cropland expansion, irrigation and food processing facilities observed in recent years would likely continue given the high population growth and policies that are keen to realize industrialization led by production of agricultural commodities and the desire to lift the national economy to the level of a lower middle-income country. Ethiopia is a country with unique biocultural landscapes that spawn unique cultures and life ways. This fact had for years created unity between the land, crops and livestock (including the resources that are currently dubbed variously as orphan crops, neglected and underutilized species) on the one side and the people on the other. However, as time went on, the disparity between population size and level of development put more charges on the land that reduced the potentials and the annual returns in many areas which needs urgent actions. The agrobiodiversity in Ethiopia is threatened by biophysical, ecological and socio-cultural transformations that the country has been undergoing for decades. This is affecting the land, the entire biodiversity and local cultures and indigenous botanical/biological and ecological knowledge, which may be further compounded by drought and climate change effects that are mainly linked to the vagaries of both development and underdevelopment. Unimproved traditional farming practices in many areas join hands with large scale mechanized farming in some others leading to drastic changes in land use pattern, making the future of Ethiopian agrobiodiversity rather shaky as shown in a group session presented at the Conference of the International Society of Ethnobiology held in Kampala (Uganda) in 2016.

The age-old on-farm conservation of agrobiodiversity that had sustained a rich assemblage of useful plants with a high proportion of food system plant species and genetic stocks within a wide range of agroecological complexes that was supposed to flourish faces the hurdle of survival. The future of rural communities is tied with adaptability and sustainability in which agrobiodiversity is a key ingredient as it provides regulating and supporting services in addition to production services. The official area of land said to be covered by the agricultural landscape in Ethiopia is about 19% but the estimate ranges from 30-40% of the land area with an annual increase through expansion into forests, woodlands, grazing areas including marginal lands with steep slopes and wetlands as general observation and few studies indicate. For example, farmers in the Wonchi area (central Ethiopia) recalled that the wetland has been shrinking due to encroachment by farming and overgrazing while the forests are being squeezed from top and below by agriculture and settlement to hang on a narrow rocky inaccessible cliff (Asfaw and Chekol, 2018). Recent research has shown early evidence of a rock shelter at a prehistoric high-altitude residential site on the Bale Mountains of southeast Ethiopia dated to 47 to 31 thousand years ago with a clear sign of hunter-gatherer people using the natural resources food system including endemic species (Ossendorf et al., 2019). Ecosystems are the basis of life; and their proper functioning and delivery of services and conservation of biological diversity are all important to the success of human activities. High level of agrobiodiversity in agroecosystem makes agricultural production more sustainable and economically viable.

The work on the Flora of Ethiopia and Eritrea (1989-2009) documented that the Ethiopian landscape is home to over 5,757 species (including subspecies) of vascular plants belonging to 238 families and having about 10% endemicity (Kelbessa and Demissew, 2014). The numbers of non-vascular plant species (bryophytes and algae) in the country have not been estimated yet. With all these plant resources, Ethiopia stands among the few plant-wealthy countries of Africa and the country is a showcase of abundant and unique overall biodiversity. Poncet et al. (2009) recorded about 841 species under the category of "useful" plants that are found in the ecosystem occurring in the country. However, ethnobotanical studies undertaken over the years and that appeared in theses/dissertations and publications of different nature have catalogued more species of plants considered useful by communities including more than 1000 species of traditional medicinal plants (Asfaw and Wondimu, 2007), more than 400 species of wild edible plants (Lulekal et al., 2011), a substantial number of cultivated plant species and varieties and many other useful plants including forage species, honeybee forage, technology plants and many others found in and around the agroecosystem (Asfaw, 1997; EBI, 2015). These numbers are increasing as new unpublished data are being continuously added. Thus, agrobiodiversity in Ethiopia hinges upon a rich flora and fauna that went through the long period of human civilization, crop cultivation and domestication and livestock rearing and acknowledged long agricultural history. All these are behind the rich agrobiodiversity that includes many crop varieties and livestock breeds and genetic stocks (EBI, 2015). Ethiopia's location within two global biodiversity hotspots (Eastern Afromontane and the Horn of Africa Biodiversity hotspots) and the ecological setups (12 major natural vegetation types and some subtypes) as well as the rich biocultural diversity (about 70 endemic language groups and a few others spoken across borders) and presence of about 32 agroecological zones had their shares in the making of the agrobiodiversity. Thus, the taxonomically diverse flora contains about 188 crop species cultivated in the country distributed in 50 families as compiled from published and unpublished reports. Analysis of the data retrieved on the cultivated flora displays richness in the grass (Poaceae) and legume (Fabaceae) families that contribute 20 cultivated species each and which are critical in food and agriculture; the cabbage (*Brassicaceae*) and rose families (*Rosaceae*) with 11 species each; the cucurbits (*Cucurbitaceae*) with 10 species; the labiates (*Lamiaceae*) and the solanaceous plants (*Solanaceae*) with 9 species each; the *Apiaceae*, *Rutaceae* and the composites (*Asteraceae)* with eight species each while the remaining 40 families had from five to one species each.

Plants recognized as cultivated and others closely associated with the farmed landscapes or the richness in botanical agrobiodiversity with intuitive expert estimate come close to 2000 species, which is about 30% of the total vascular plants so far documented for Ethiopia. These include the food system species adding to about 25% of the flora of the country. The main botanical agrobiodiversity features collated from various published and unpublished works and expert observations are summarized in Table 3.

Table 3. Highlights of main plant agrobiodiversity elements in Ethiopia

Major useful plant group	**Number of species (source)**	**Species of high interest (economic, cultural, biological)**
Vascular plants • Dicotyledons • Monocotyledons	5,757 species (Analysis of Flora of Ethiopia and Eritrea as given in Kelbessa and Demissew, 2014)	**Important cereal crops**: *Eragrostis tef, Sorghum bicolor, Hordeum vulgare, Triticum* spp. **Important legume crops:** *Vigna unguiculata, Pisum sativum* var. *abyssinicum, Phaseolus vulgaris* **Important root/tuber crop**s: *Ensete ventricosum, Coccinia abyssinica, o*ther **Important stimulant crops***:* *Coffea arabica* **Important oil seed crops:** *Guizotia abyssinica, Brassica carinata, Carthamus tinctorius* **Important spice crops:** *Aframomum corrorima, Piper capense* Others categories and species
Endemicity	About 600 species, 10% of the flora (Kelbessa and Demissew, 2014)	
Useful plants	841 species (Poncet et al., 2009)	
• Food system species	600 species (Poncet et al., 2009)	
• Wild edible plants	400 species (Lulekal et al., 2011)	
• Medicinal plants	1000 species (Asfaw and Wondimu, 2007)	
Cultivated plants	188 species (collated from different works)	
Crop Diversity Crops of multi-farmers' varieties	Synthesis from Asfaw (1997, 2000); Teshome et al. (1997); Borrell et al. (2020)	
Crops with high genetic diversity	Wheat (Harlan, 1969; Worede et al., 2000), barley (Asfaw, 2000), sorghum (Teshome et al., 1997), *Teff* (Ketema, 1993; Assefa et al., 1999), Arabica coffee (Tadesse, 2017), peas, beans, linseed, finger millet, cowpea, lentil, *Enset*, clovers, oats	
Crops for which Ethiopia is a primary gene accumulation center	*Teff* (Ketema, 1993; Assefa et al., 1999), Arabica coffee, Noog, Ethiopian mustard, Enset, Anchote, Ethiopian field pea (Harlan, 1969; Worede et al., 2000)	
Crops introduced relatively recently and known to be genetic diverse	Maize, common bean (Harlan, 1969)	

6.2.3 Characteristics of agriculture and agroecosystem goods and services

The major agricultural resource base potentials of Ethiopia can be seen under land resources, crop and livestock resources, another biodiversity (genetic resources), water resources and agro-ecological resources (EAS, 2017) and other, associated agrobiodiversity elements found within the agroecosystem. For ages, the agrobiodiversity wealth of Ethiopia went on being described with admiration by researchers from around the world (Vavilov, 1951; Harlan, 1969; Worede, 1991; Worede et al., 2000).

Diverse agro-ecological conditions enabled Ethiopia to grow a large variety of crops, which include cereals (*Teff*, sorghum, wheat, maize, barley, finger millet); pulses (faba bean, field peas, lentils, chickpeas and haricot beans); oil seeds (sesame, linseed, *Noog*, rapeseed); different types of fruits and vegetables as well as coffee and *Enset* (CSA, 2011). The central and eastern highlands of Ethiopia are rich gene centres of many cereals, pulses and oil crops while the southern and south-western parts are particularly well known for the vegeculture system mainly with *Enset*, yam, and taro and variously called the Enset complex and the perennial crop-based system; coffee; many spices including Ethiopian cardamom (*Aframomum corrorima)*, long pepper *(Piper capense)* and many other crops in the fields, parkland agroforestry systems, homegarden agroforestry systems and other types of homegardens. The Konso landscape in south-western Ethiopia where traditional agroforestry is combined with polyculture farming by bringing in important trees like *Moringa stenopetala* and *Terminalia brownii* under cultivation is still another variant of the complex agroecosystem that occurs in the country. The botanical agrobiodiversity of Ethiopia in particular has made far conspicuous contributions to the development of global agriculture as it is widely acclaimed as a centre of origin and genetic diversity of many crops. Thus, contributing to the global gene pool of major crops such as coffee (*Coffea arabica*); sorghum (*Sorghum bicolor*); durum wheat (*Triticum durum*); barley (*Hordeum vulgare*). Some crops ennobled within Ethiopia (*E. tef, G. abyssinica,* and *B. carinata*) though with relatively short history of diffusion and others (*E. ventricosum* and *C. abyssinica*) are rich in local farmers' varieties. Many introduced species of crops (*H. vulgare, Z. mays* and *P. sativum*) have shown proliferation of diversity secondarily including by forming endemic varieties and forms as in *Pisum sativum* var. *abyssinicum*, the *deficiens* group of barley and others. Thus, Ethiopia not only ennobled new crops but also added value to crops introduced in early times by developing new varieties and genotypes that are secondarily donated to the rest of the world.

The zoological agrobiodiversity is likewise known both for the abundance and uniqueness of breeds of cattle, sheep, goats, camels, and equines among others. Livestock husbandry is an integral part of the farming systems in Ethiopia, a country known to have the largest livestock.

Ethiopia is rich in animal genetic resources, both in diversity and population. The agricultural sample survey report (CSA, 2017) revealed that about 59.5 million heads of cattle, 60.90 million sheep and goats, 2.16 million horses, 8.44 million donkeys, 0.41 million mules and 1.21 million camel population play major food, agriculture and economic roles. Moreover, 59.5 and 5.92 million chicken and honeybee colonies respectively were registered. Ethiopia ranks first in Africa and fifth in the world in cattle population and among the top 10 countries in the world in equines, sheep and goat populations as well as honeybee colonies (FAO, 2015). The contribution of livestock to the agricultural gross domestic product (GDP) is about 25% (MoFED, 2010) together with draft power services, they provide up to 45% of the agricultural GDP (IGAD, 2011). More recent data (Shapiro et al., 2017) show that the direct contribution of livestock to the GDP is estimated at ETB 150.7 billion/yr, which amounts to 17% of the total GDP and 39% of the agricultural GDP. This rises to about 21% of the national GDP and 49% of the agricultural GDP, if the contribution of processing and marketing (35.6 billion) is taken into account. If the indirect contribution in terms of organic fertilizer and traction (37.8 billion) is taken into account, the contribution of livestock to the GDP will rise to 25.3%. Though a lot remains to be done in characterization and identification of animal genetic resources, the available recent data show that there are about 28 cattle, 9 sheep, 8 each of goat and horse, 7 each of camel and chicken, 6 donkey and 5 honeybee breeds (EBI, 2015). Livestock resource is the source of social and economic values including food, draught power, fuel, manure, cash income, security and investment in both the highlands and more so in the pastoral farming systems of the lowlands. The abundance and diversity of livestock is related to the country's varied topographic, agroclimatic features and biocultural diversity. The livestock and the crop sectors significantly contribute to the country's income and are more realized in the highlands.

The long history of plant and animal use coupled with agricultural innovations and introductions claim shares in the observed agrobiodiversity that developed under small scale farming, and plays key livelihood functions and immeasurable ecological services. This diversity lately went into a dwindling phase due to weak conservation and research patronage. Factors influencing the transformation of the more diverse agroecosystem to minimized agrobiodiversity include climate, population density, culture, markets and associated conditions. Seen in another dimension, the threats are afflicted by the maladies of development and underdevelopment, which further forecast a precarious future. It is seen that homegardens have come of age being widely practiced and regarded efficient farming systems in southern Ethiopia as they allowed interactions and synergies between crops, trees, livestock and other associated agrobiodiversity resources. Traditional homegardens are evolving in response to changes in socio-economic and biophysical factors leading to altered cropping patterns, farm size and component interactions that would likely affect their future sustainability and existence. Given the diversity exhibited in homegarden types found in southern Ethiopia and the trend in the shift from food crop-based to cash crop-based system, the need to design interventions for improvement to a more sustainable system has been discussed (Mellisse et al., 2018a,b), further underlining that efforts have to be directed to sustainable production and agrobiodiversity conservation. The knowledge on agrobiodiversity is essentially held by the oral literature of farmers and these are further threatened due to lack of documentation coupled with demographic transformation. The assessment results are expected to highlight key insights on how agroecosystem should be managed to be able to rip the best sets of goods and services while enhancing their integrity (Tsiafouli et al., 2017). The support to be obtained from positive drivers of agrobiodiversity such as biotechnology, nanotechnology, and information and communication technology offer promise to address key concerns related to agriculture, food safety, human, plant and livestock disease control, environmental safety and sustainable use of natural resources (Husen et al., 2012).

The earliest incipient concept of ecosystem services can be traced back to observations by the Greek philosopher, Plato, around 400 BC. Sources indicate that he had described how forests provided important services and how forest loss resulted in drying up of springs and soil erosion (Garbach et al., 2014). This provides evidence that people developed some awareness about the critical services of forests long before the dawn of industrial agriculture prior to the time when the concepts of ecosystem and ecology entered into scientific discourses. More recently, the importance of agroecosystem services, parallel with the general ecosystem services, went on being progressively realized. Though initially understood as means of production only, the roles of agroecosystem in the provision of a multitude of agroecosystem services over and above the usual production services went on building up as research went on advancing. The goods and services that humans obtain from agroecosystem are the core issues in agroecosystem services, and agrobiodiversity enhances agroecosystem functions and services (Altieri et al., 2015; Wiggering et al., 2016) further achieving management regimes that enhance both agricultural production and provision of multiple agroecosystem services (Tsiafouli et al., 2017). The use of the concept of agroecosystem services as distinct from natural ecosystem services is favoured as it can accommodate both the ecology-based agroservices concept as well as the specificity sanctioned to it by managed agricultural ecosystems for adoption and implementation by agricultural production systems and related policy advancement. Agroecosystem services can be visualized by building on the four major ways as conceptualized in the Millennium Ecosystem Assessment (MEA, 2005) and integrated with the IPBES Conceptual Framework (Dí'az et al., 2015) that attempts to connect nature and people, further customizing it for agroecosystem and agrobiodiversity.

Agroecosystem services that are useful to human wellbeing have been grouped (Example: Garbach et al., 2014) as follows: (1) provisioning services that include the production of food, fuel, fibre, timber, water and other harvestable biomass products and such services are also placed under agroecosystem goods; (2) regulating services that include climate regulation, flood control, disease control, waste decomposition, production regulation through pollination by animals. Pollination by animals covers about 60-90% of all angiosperms (Klein et al., 2007) and comes to about the same proportion for cultivated plants. This shows the extreme importance of the natural ecosystems in which these animals are sheltered for the productivity of the agroecosystem and water quality regulation; (3) supporting services that include the foundational processes necessary for the production of other services, including soil formation, nutrient cycling, and photosynthesis (primary production), buffering of floods and droughts; control of pests and diseases; remediation of pollution; and (4) cultural services that provide recreational, touristic, aesthetic, spiritual, and other non-material services. Some of these processes can belong to two categories of services since services that play the role of supporting could in the process regulate some other factors. Thus, agroecosystem contributes services including soil retention, food production and aesthetics; receive beneficial services from natural ecosystems (Example: pollination from outside agroecosystem) and other services that are obtained from adjacent systems and processes.

Future agroecosystem assessments should look into possibilities of applying the new concept of energy/eccentric values (Fengjiao et al., 2014) with its merits and description of how such values flow in agroecosystem. Based on this approach, these authors showed how the method offers a number of advantages including bridging economic and ecological systems; quantifying and valuing non-market inputs into a system; using a common unit that allows for a comparison of all resources. It is shown to offer a more holistic alternative to many existing methods of decision-making. The method is based on the principles of thermodynamics and can be used in future assessments to translate different inputs and outputs of an agroecosystem into the same solar emjoule (sej) unit using solar energy as the base energy. This estimates the ecocentric value rather than the anthropocentric value in contrast to the economic view. Since the values of agrobiodiversity span the biological, ecological and social capitals and are the backbones of livelihoods based on agriculture, the new concept is praised to objectively estimate the ecocentric values. For efficient management of agrobiodiversity in a stable and productive farming system, harmonization with the agroecological processes under sustainable agriculture is considered essential.

6.3 Status, trends and future dynamics of agrobiodiversity

Beginning with a brief recapitulation of the key concepts of the chapter (agroecosystem and agrobiodiversity), this subchapter focuses more on the descriptions of the farming systems and agricultural systems described since a long time ago by generations of researchers. The systems took shape in the country over millennia as described by these researchers. The further development of these concepts/terminologies gradually evolved to agroecosystem, which are discussed in detail including by identifying the crops cultivated, the livestock reared and the areas wherein each is found in the country. The major crops of each agroecosystem including the landrace diversity maintained by farming communities have been elaborated to show nature's contributions to people.

6.3.1 Historical account of agroecosystem in Ethiopia

An agroecosystem is a spatially and functionally coherent unit where agricultural activity is operated, which includes the living and non-living components involved in that unit as well as their interactions (Anon, 1996). The core of an agroecosystem lies in the human activity of agriculture. However, it is not restricted to the immediate site of agricultural activity (the farm), but rather includes the region that is impacted by this activity, usually by changes to the complexity of species assemblages and energy flows, as well as to the net nutrient balance (van de Fliert et al., 1999). Agroecosystem is an important part of the earth's ecosystems, and about 40% of the earth's land is used for agricultural purposes (Chavas et al., 2012). Agroecosystem services help support livelihoods everywhere, especially in developing countries where the agricultural sector constitutes a large part of the economy.

Agrobiodiversity and integrated farming systems are often associated with sustainable agroecosystem (Torquebiau, 1992; Dalsgaard et al., 1995; Altieri, 1995; Swift et al., 2004), because diversity and integration enable the realization of complementarities between different products and activities and may improve resource use efficiency. Agricultural biodiversity has significant role in food security, environmental protection, income stability and reduction of risks of resource-poor households (Neher, 1992; Abebe et al., 2006). This is largely attributed to the rich biophysical and cultural diversity of the country and the farmers' sustained efforts in the domestication and breeding of different crop species.

Ethiopia is a country of great geographical diversity with high and rugged mountains, flat-topped plateau, deep gorges, river valleys, and rolling plains. The topography coupled with its wide range of altitudes (110 m. below sea level to 4620 m.a.s.l.) has led to the development of diverse climatic zones. Although the whole country lies within the tropical latitudes, the climate is cool in the highlands, but actual temperatures vary significantly with altitude. In the highlands, the mean daily temperature during the growing season is 21.3^0C and it drops by 0.6^0C for every 100 meters increase in altitude (Goebel and Odenyo, 1983).

Ethiopia is predominantly an agrarian country in which in 2013, 72.5% of the population is engaged in agriculture and related activities, and the agriculture sector contributes to 32.7% of the 2019/20's GDP (PDC, 2020). This geographical diversity has led to the development of different agroclimatic zones that range from desert to alpine zones, and inhabited by peoples of different cultures. Traditionally, Ethiopians recognize five major agroclimatic zones namely; *Bereha, Kolla, Woina Dega, Dega* and *Wurch* (Table 4). The two extremes, *Bereha* and *Wurch*, are mostly unsuitable for crop cultivation due to high and low temperatures, respectively. The *Kolla* areas are dominated by pastoral and agropastoral livelihoods, but dryland crops such as rain-fed sorghum, finger millet, sesame, cowpea and groundnut, as well as irrigated commercial crops such as sugarcane, cotton, and fruits, are also grown. The *Woina Dega* areas are most suitable for cultivation of diverse species of crops, and the *Dega* agroclimatic zones are the next most suitable. Each climatic zone has a set of preferred species where it flourishes well, and this shows the role of climate in determining composition of agroecosystem. However, it is human beings who shape agroecosystem, based on their preferred components and management practices. Accordingly, cereal- based systems, known as the 'seed farming complex' (Simmonds, 1958) exist in *Kolla*, *Woina Dega* and *Dega* areas but their composition varies due to differences in the climate. On the other hand, different agroecosystem sub-types exist in a similar agroclimatic zone, indicating human preferences.

Table 4. Traditional agroclimatic zones of Ethiopia

Traditional zone	**Altitude (m.a.s.l)**	**Average annual Temperature (^{0}C)**	**Average annual rainfall (mm)**
Bereha (Hot lowlands)	< 500	>27.5	< 300
Kolla (Lowlands)	500 -1500	20.0 - 27.5	300-800
Woina Dega (Midlands)	1500-2300	16.0 -20.0	800-2400
Dega (Highlands)	2300-3200	11.5 – 16.0	800-2000
Wurch (Cold highlands)	> 3200	< 11.5	800-1000

Source: Compiled from FAO, 1986; MoA, 1998; Berhanu et al., 2014

The types of crops cultivated in each locality are determined by the agroclimatic condition of the place, but also cultural preferences of the people living in the area. Accordingly, the Ethiopian farmers have been actively engaging in crop domestication and breeding efforts to suit their taste and adapt to the local climate, for thousands of years. The landraces of various crop plant species and their wild relatives have potential value as sources of important traits for crop improvement programs, especially in the extant time of climate change, to mitigate the problems of increasing drought and pest incidence. In the face of climate change, agricultural diversity is recognized as a strategy in the struggle for greater resilience and adaptability (Bioversity International, 2017). Cultivation of diverse crop species and varieties, mixed crop-animal production and mosaics of land use systems have long been part of the farmers' game plan to reduce vulnerability to drought, flooding, crop pests, and diseases (Oakland Institute, 2015).

In the north and central highlands of the country, where crop cultivation has been practiced for millennia, field crops (cereals, pulses and oil crops) that are commonly grown by farmers show great diversity of farmers' varieties. Vavilov (1951) has reported that the diversity expresses itself under ecological conditions which are rather uniform. The variation in biophysical conditions (altitude, rainfall, temperature, topography, etc.) of the sites and socioeconomic and cultural background of the people, and individual preferences of farmers have resulted in high intra-specific diversity of field crops through millennia of natural and human selection pressures, isolation, migration, and farmer exchange. Consequently, very high landrace diversity of barley, wheat, *Teff*, sorghum and other crops have been reported by many authors (Assefa et al., 1999; Teshome et al., 1997; Hailu et al., 2006; Tanto et al., 2009; Adugna, 2012; Tsehaye et al., 2012; Asmamaw et al., 2019) and many others.

On the other hand, agriculture in the highlands of the South and Southwestern parts of Ethiopia is dominated by *Enset*-based polyculture systems. In the midlands of this region, *Enset* is integrated with coffee, native shade trees including nitrogen fixers, fruit trees, and a multitude of cereals, vegetables, root and tuber crops, spices and condiments as well as livestock. These systems are the most diverse in crop species and varieties. In addition to the diversity in species of crops, the major crops, *Enset* and coffee, are reported to show a high diversity of cultivars or landraces.

An interesting feature of these agroecosystem sub-types is the presence of several under-utilized crop species, with huge potential to improve food security and resilience of agroecosystem. These crops include, among others, yam (*Dioscorea* sp.), taro (*Colocasia esculenta*), Ethiopian potato (*Plectranthus edulis*) and Amochi (*Arisaema schimperanum*). These crops are known to have traits of drought tolerance, disease resistance and high yielding but their cultivation is restricted to some localities in southern Ethiopia. Hence, their potential to mitigate the effects of climate change and their contributions to food security need to be realized elsewhere in the world.

Johns et al. (2013) argue that the capacity to retain traditions and traditional knowledge appears to go hand in hand with the practice of agricultural diversification: Communities, cultures and countries that maintain their own traditional food systems better conserve crop species and varieties as well as animal species and breeds underpinning local specialties. This could explain why Ethiopians were able to conserve a large variety of crop species and cultivars. To summarize, Ethiopia's rich diversity of crop species and cultivars is making contributions to the welfare of the people in the world, and this is attributed to the efforts of Ethiopian farmers in selection, domestication, hybridization and preservation of these invaluable resources in different agroclimatic and socio-cultural settings.

6.3.2 Types of agroecosystem in Ethiopia

Agroecosystem develops as a result of human interaction with nature. For an agroecosystem to exist in a certain area, the climatic and soil condition should be suitable, but the composition of the system and its management depend on the cultural background and socio-economic conditions of the farmers. Based on these factors a diversity of agroecosystem sub-types exists in Ethiopia. Indeed, the term 'Agroecosystem' is rarely used in the literatures, but terms such as 'Farming systems', 'Land use systems' and 'Agricultural systems' have been used to describe it. Accordingly, a nation-wide classification of the major Ethiopian agroecosystem sub-types was made by some authors namely, Westphal (1975), ICRAF (1990), and Amede et al. (2017). In the following, these classification schemes are highlighted.

Westphal (1975) distinguished four major agroecosystem sub-types in Ethiopia namely, the Seed farming complex, the *Enset* planting complex, Shifting cultivation and the Pastoral complex.

a) The ***Seed-farming complex*****:** refers to the cereal-based farm landscapes in the north, central, eastern and parts of southern Ethiopia, where different cereal crops such as maize, *Teff*, wheat, barley, sorghum, millet, as well as pulses and oil crops are managed in integration with livestock. This system has very large geographical coverage, and includes the different cereal-based systems in the lowlands, midlands, and highlands. Westphal (1975) has identified five sub-systems under the seed-farming complex. These are;

    - The grain-plough complex of the central and northern Ethiopian Highlands,
    - The barley-hoe complex in connection with pastoralism,
    - The grain-plough complex of Arsi and Bale,
    - The sorghum-plough complex of the highlands of Hararge, and
    - The sorghum-hoe-terrace complex of the Konso cluster.

b) The ***Enset planting complex*****:** refers to the perennial crop-based systems in the South and southwestern parts of Ethiopia, where *Enset* is managed in integration with different perennial crops, cereals, vegetables, root and tuber crops as well as livestock. In the *Woina Dega*, *Enset* is associated with another native and dominant crop, coffee; and different root and tuber crops, pulses and vegetables and livestock. In the *Dega* barley, pulses and oil crops are managed along with *Enset.* Wesphal (1975), based on the relative importance of *Enset* as a food crop in the different localities, has distinguished four sub-systems of the *Enset* Planting complex. These are;

- *Enset* as staple food,
- *Enset* as co-staple, with cereals and tuber crops,
- *Enset* not as co-staple, with tuber crops dominant and cereals of secondary importance, and
- *Enset* not as co-staple, with cereals dominant and tuber crops of secondary importance.

c) ***Shifting cultivation***: This system occurred in the western and south-western fringes of the Ethiopian highlands and in the lowlands, where population density is low and the natural vegetation is dominated by deciduous woodland and extensive bamboo stands. In the traditional shifting cultivation, the natural vegetation is cleared, burnt and crops are grown for 2-3 years, after which the land is abandoned due to a decline in soil fertility. Then, the cultivators have to clear and burn another patch of natural vegetation to grow crops. A fallow period of 10-20 years is required for the land to rest and regain its fertility. The practice of Shifting Cultivation might be applied in areas where there is abundant land and a very small population, but not in areas with increasing population. Accordingly, shifting cultivation is not widely practiced in the areas at present, mainly due to the increased population, and establishment of some permanent investments (small-scale farms, irrigated large scale farms, dams, etc.).

d) ***Pastoralism*:** Pastoralism refers to systems where livelihoods are primarily based on livestock rearing, but it should be known that livestock are integral components of the crop-based agroecosystem sub-type as well. The major pastoral areas are located in the lower and drier parts of the country, especially in southern Ethiopia (lowlands of Oromia/South Omo (the form 'South Omo' already has been in use for long); Eastern Ethiopia (Afar and Somali regions) as well as some parts of central and northern Ethiopia. Large herds of cattle, sheep, goats and camels (in the driest areas) are kept by the pastoral communities. The pastoralists are mostly transhumant or semi-nomadic, who seasonally move with their livestock in search of grazing land and water. At present, most of the pastoral systems are changing into agropastoral ones, mostly with a government initiative to settle pastoralists, especially in areas with water access. Large irrigated farms are also expanding in areas such as the Awash basin. The expansion of crop cultivation has decreased the migrations considerably.

The comprehensive and detailed description of the Ethiopian agricultural systems by Westphal (1975) helps to understand the agricultural practices about five decades ago, and to compare it to the present situation to determine what elements of the agricultural systems have changed, why, and how. The population of Ethiopia has tripled over the last five decades and this exerts heavy pressure on the agricultural resources (land, water, vegetation, etc.) and leads to changes in agricultural practices.

The other report on Ethiopian agroecosystem was produced by the **International Council for Research in Agroforestry (ICRAF)**, currently named the World Agroforestry Centre (ICRAF, 1990). The study aimed to determine Ethiopian land- use systems with a view to identify problems and potentials of land users, and explore their potential roles for agroforestry. The study focused on the highlands that lie at altitude of above 1500 m.a.s.l., and this was because the highlands accounted for over 90% of the regularly cropped areas. Earlier, the Ethiopian Highland Reclamation Study (EHRS) had classified the Ethiopian highlands into three major agro-ecological zones based on their productivity and the nature of major crops as; High Potential Perennial (HPP) crop zone, High Potential Cereal (HPC) zone and Low Potential Cereal (LPC) zone (FAO, 1986), Table 5.

ICRAF (1990) adopted the classifications of Ethiopian highlands made by EHRS, and identified 13 distinct land use systems in the highland zones. Each of the land-use system was characterized in terms of its climate, soils, components (crops, livestock and trees), constraints, and potentials for agroforestry interventions. Altitude, topography and intensity of cultivation were considered as major criteria to delineate the 13 land use systems.

Table 5. Major agro-ecological zones of the Ethiopian highlands

Zone	Climate	Length of growing Period	Major farming System	Tillage	Area of highlands (%)
High Potential perennial Zone (HPP)	Warmer and more humid	Mainly >240 days	Perennial crops (Coffee, *Enset* etc.)	Hand hoe and Ox Plow	32.9
High Potential Cereal Zone (HPC)	Intermediate	Usually >180 days	Cereals and livestock	Ox plow	31.7
Low Potential Cereal Zone (LPC)	High rainfall variability, Occasional drought	Mainly 90-150 days	Cereals and livestock	Ox plow	35.4

Source: FAO (1986)

The land-use systems (agroecosystem) of Ethiopian highlands identified by ICRAF (1990) are described in the following:

High Potential Perennial (HPP) zone

- *Enset*-coffee-cereals-livestock system at 1500-2500 m.a.s.l.: Hilly intensive *(e.g.,* Sidama, Gedeo, Wolaita),
- *Enset*-coffee-cereals-livestock system at 1500-2500 m.a.s.l.: Hilly extensive *(Wolk*ite - Jimma),
- Forest coffee-*Enset*-livestock system at 1500-2500m a.s.l.: Hilly extensive (Jimma – Agaro – *Be*dele - Gore), znd
- *Enset*-barley-livestock system at 2500-3000m .a.s.l.: Hilly, extensive *(Gura*ge and Gofa highlands).

High Potential Cereal (HPC) Zone

- Mixed cereal – livestock system (1500-2500 m a.s.l.: Flat, intensive (Rift Valley floor, parts of Arsi/Bale, parts of central plateau),
- Mixed cereal – livestock system (1500-2500 m.a.s.l.: Flat, extensive (parts of Hararge highlands, and parts of central plateau, Bahir Dar – Motta),
- Barley - livestock system at 2500 – 3000 m.a.s.l.: Flat, intensive (part of Arsi/Bale, South of Asella),
- Barley - livestock system at 2500 – 3000 m.a.s.l.: Flat, extensive (part of central plateau, Addis – Debre Berhan),

- Barley - livestock system at 2500 – 3000 m.a.s.l.: Hilly, intensive (Arjo in Wollega, Debre Berhan – Debre Sina), and
- Barley - livestock system at 2500 – 3000 m.a.s.l.: Hilly, extensive (Mertulemariam in Gojjam).

Low Potential Cereal (LPC) Zone

- Mixed – cereal – livestock system (1500 – 2500 m a.s.l.): Flat, intensive (Parts of Tigray plateau),
- Mixed – cereal – livestock system (1500 – 2500 m.a.s.l.): Hilly, intensive (North Wollo), and
- Barley – livestock system at 2500 – 3000 m.a.s.l: Hilly, intensive (Semein Mountains, North Gonder, Western Wollo).

The report of ICRAF (1990) demonstrates the major agroecosystem sub-types in the highlands of Ethiopia, along with their constraints and potentials. Classification of the sub-types is based on productivity (high potential or low potential), topography (flat or hilly) and management intensity (intensive or extensive). Although the study was conducted to determine agroforestry potentials and the research needs of the different systems, the constraints and potentials identified in the report are relevant to any form of agricultural development. The limitation with ICRAF's classification is that it focuses only on the highlands, leaving out the lowlands, which are increasingly becoming important not only in livestock production but also in the production of irrigated and rain-fed horticultural and field crops.

A recent comprehensive study on Ethiopian farming systems was conducted by a research team from Ethiopia and international organizations and published by the Australian Centre for International Agricultural Research (ACIAR) under the title, 'A farming systems framework for investment planning and priority setting in Ethiopia (Amede et al., 2017). The study highlights the diversity of farming systems in Ethiopia and their significance as a basis for planning agriculture-led development interventions. The classification of farming systems is based on the available natural resource bases and the dominant pattern of farm activities and household livelihoods. The report identifies 16 distinct farming systems along with the locations where they are found. The report of Amede et al. (2017) has been used as a major resource to determine the

Ethiopian agroecosystem stated in this document. This is because the study is; a) comprehensive (considers all agroecological zones of the country from hot arid lowlands to afro-alpine zones) and b) recent (captures the land-use changes that have been taking place until three years ago). However, some modifications have been made to the classifications made by Amede et al. (2017). These modifications are;

- Amede et al. (2017) have distinguished two types of pastoral systems. The first one which they called the "Pastoral farming system" is found in the lowlands of eastern and southern Ethiopia (Afar, Somali, Oromia and SNNPR regions) and covers about one-third of the country's total area. The second one, what they called "arid pastoral and oasis farming system", is a specialized system that occurs in small areas in the arid low lowlands of Afar. Since we are dealing with the 'major agroecosystem of Ethiopia', we merged the second system with the first one (Pastoral agroecosystem), because it is small in terms of area coverage and the population it accommodates,
- Two fish-based agroecosystem sub-types were identified by Amede et al. (2017), namely 'Rift-valley fish-based system' and 'Lake Tana fish-based system'. However, the livelihoods of the people living in these areas are not primarily based on fisheries, but on the crops and livestock, they manage. The narratives that describe the systems (Amede et al., 2017) also emphasize the crops and mention fisheries as one of the economic activities. So, their designation as fish-based systems does not seem to be appropriate. Due to this reason, the fish-based systems were combined with their neighboring agroecosystem sub-types since they are similar in terms of crop and livestock production systems. Accordingly, the 'Rift Valley fish-based farming system' was combined with 'Eastern highland maize mixed farming system', under the name 'Eastern highland maize mixed agroecosystem'. Likewise, the 'Lake Tana fish-based farming system' was merged with 'Highland *Teff* mixed farming system' taking the name of the latter as 'Highland *Teff* mixed agroecosystem'.
- One of the agroecosystem sub-types described by Amede et al. (2017), the 'Highland perennial farming system', covers large areas with distinct farming systems, that differ in terms of diversity and composition of cultivated species and management intensity, and needed to be treated separately. Therefore, the 'Highland perennial farming system' identified by Amede et al. (2017) is divided into two systems following ICRAF (1990)

as: i) ‘Enset-coffee-cereals mixed agroecosystem sub-type’ and ii) ‘Enset-barley mixed agroecosystem sub-type’.

The term ‘agroecosystem’ is used uniformly throughout the document replacing the terms ‘farming system’, ‘Land use system’ and ‘Agricultural system’ that is described in the different literature sources. Accordingly, a total of 14 distinct agroecosystem sub-types are distinguished in Ethiopia that can be grouped into three categories as livestock-based, cereal crop-based, and perennial crop-based systems. In the following, the different agroecosystem sub-types of Ethiopia are presented and their basic features are discussed. The primary source document for the description of the systems is Amede et al. (2017), supplemented by other literature. The list of agroecosystem sub-types is shown in Table 6.

Table 6. Major sub-types the Ethiopian agroecosystem

Category	***Major sub-types***
Pastoral/Agropastoral	1) Pastoral agroecosystem
	2) Agropastoral agroecosystem
Cereal crop-based	3) Lowland sesame mixed agroecosystem
	4) Western lowland maize mixed agroecosystem
	5) Sorghum mixed agroecosystem
	6) Sorghum-*Chat* mixed agroecosystem
	7) Eastern highland maize mixed agroecosystem
	8) Western highland maize agroecosystem
	9) Highland livestock maize mixed agroecosystem
	10) Highland *Teff* mixed agroecosystem
	11) Highland wheat mixed farming agroecosystem
	12) Highland barley-livestock agroecosystem
Perennial crop-based	13) *Enset*-coffee-cereals mixed agroecosystem
	14) *Enset*-barley mixed agroecosystem

Source: Modified after ICRAF (1990) and Amede et al. (2017)

1. Pastoral agroecosystem sub-type

The pastoral agroecosytem sub-type covers large area of about 36 million ha in Ethiopia (Amede et al., 2017), extending from the south Omo zone (SNNPR) through the southern part of Borena (Oromia), to the wider parts of Somali and Afar regions. It provides livelihoods for an estimated population of over four million people. The pastoral communities keep livestock including cattle, camels, small animals, and equines. The number of animals per household has significantly decreased over the last few decades due to recurrent drought and limitations to mobility. Recently, crop production is being introduced in these systems, mostly on best grazing lands, involving high resource use trade-offs.

Annual rainfall is about 200-600 mm (USAID, 2005), and the daytime temperature reaches about 40°C during much of the year. The landscape is generally flat and soil quality varies in relation to the location of rivers and streams. Calcisols of various types are predominant in the Somali zones, while Lithic Leptosols dominate in the Afar region. The lower Omo landscapes are primarily characterized by Cambisols.

Pastoralists lead a nomadic life organized around clan settlements located in areas with abundant natural pastures. When feed resources are scarce, the livestock are moved in groups by men in search of feed and water, leaving a few milking cows and the rest of the family at the settlement. Milk, as well as live sheep, goats and cattle are brought to local town markets for sale. Due to the arid and semi-arid climate and low erratic rainfall, these pastoral communities are mostly food insecure and vulnerable to shocks. They face a range of problems such as drought, animal diseases, water shortages, and conflict relating to common property resources like rangelands.

Over the recent years, the government of Ethiopia has been exerting efforts for the development of pastoral areas and communities by delegating a ministry of Federal Affairs to coordinate the development efforts. This has resulted in numerous activities aimed at enhancing the resilience of these fragile but economically and culturally significant land management systems. With the introduction of farming technologies and market linkages, pastoralists have engaged in some forms of crop cultivation, as a diversification strategy to assure household food consumption needs. For instance, the Fentale irrigation scheme developed around the Awash river has attracted the interest of pastoralists in Afar region to grow food, fodder and horticultural crops. Development efforts have also led to the establishment of decentralized water points/boreholes. The government has also made efforts to settle pastoralists in areas where water is available, for instance in the Afar region along the Awash River, and in the Somali region along the Genale and Shebele rivers. In these locations, the government encourages the production of vegetables (onion, tomato, pepper), maize, rice and groundnut while livestock are kept outside of these areas. This has been done in parallel with the promotion of education, road development, and investment in health extension for people as well as veterinary services for livestock. There has also been irrigated sugarcane plantation development for settling pastoralists in out-grower schemes.

In addition to the above-mentioned pastoral agroecosystem sub-type which covers about a third of the country's land area, Amede et al. (2017) have identified another distinct sub-type called '*Arid pastoral and Oasis farming system'*. It occurs in a small area, in the arid lowlands of northeastern Ethiopia in Afar region, mainly in the Elidar district bordering Eritrea and Djibouti. Livelihoods are derived mainly from cattle, small ruminants, date palms, and salt mining. The average length of the growing period is less than 30 days. Irrigated crops are grown in some parts of the river banks to provide food supply, although the livelihoods are heavily dependent on livestock. The annual average rainfall is about 100 mm (USAID, 2005), and varies greatly from year to year, resulting in frequent water shortages and severe droughts in some years. The landscape is volcanic and rocky, and soils are characterized by Lithic Leptosols consisting of hard volcanic ashes and sandy soils. Chronic water shortages, recurrent drought and livestock diseases are the main challenges in this system.

2. Agropastoral agroecosystem sub-type

The agropastoral agroecosystem sub-type, which is basically a sedentary form of farming, covers large areas that extend from Moyale through the southern part of the Guji zone to Jijiga zone of the Somali region. It also includes part of the Chefa valley, through Bati to Raya in the north. It covers about 12.67 million ha and features a combination of pastoral and crop production activities at varying levels depending on the availability and reliability of soil moisture for crop production (Amede et al., 2017). In favorable climates, cropping activities tend to dominate the mix in terms of income, whereas the livestock component acts as a source of income security, draft power, and livelihood diversification.

The proportion of farm-based livestock feed is usually used as a basis for demarcation between pastoral and agropastoral systems: In the agropastoral system around 30% of animal feed comes from crop residues of farmers' fields, and 70% is sourced from communal grazing areas (Amede et al., 2017). Herds are generally small and often, when feed and water resources are scarce, farmers bring their stock together for short distance movement to grazing areas. In this lowland farming system, the terrain is mostly flat and soils are generally poor. Luvisols dominate the soil landscape. Rainfall is bimodal in the northern agropastoral region while it is unimodal in the southern area. Water availability is relatively limited but the valley bottoms have more soil water than the hillsides.

Agropastoral systems are mostly low-intensity, low input, and low-output systems. However, the use of fertilizers is increasing to address soil nutrient deficiencies, especially in areas with maize and beans. The average holding size is around one hectare, but this varies depending on soil type (Amede et al., 2017). The main crops grown in the agropastoral system are sorghum, millets and beans. Maize, *Chaat*, and to a lesser extent *Teff* and vegetables are grown for home consumption, usually around the household compound and on irrigable farms. Livestock production includes mostly cattle with some sheep and goats.

Over the past three decades, the area dedicated to sedentary agriculture is increasing at the expense of grazing areas, partly due to population growth and settlement programs of the government. At present, there are an increasing number of irrigation schemes, including large sugar estates and cotton farms, which are providing options for growing high-value crops and diversifying livelihood options.

3. Lowland sesame mixed agroecosystem sub-type

The lowland sesame mixed agroecosystem sub-type sub type sub-type is found in the northwestern part of Ethiopia, extending from Humera to Metekel and Assosa. The agroecosystem sub-type is characterized by warm semi-arid agroclimatic conditions and low population density. It covers about 3.78 million ha of land (Amede et al., 2017). The area under cultivation is small, but there is an increasing trend of crop production on small farmers' fields, communal lands and commercial farms. The main crops grown in the system are sesame, sorghum, cotton, banana, mungbeans (*Vigna radiata*), and rice.

Frankincense from the *Boswellia papyrifera* tree is an economically important component of the system since the incense extracted from the tree has a good market value in the local and international markets. Livestock production comprises cattle, goats, sheep and chicken, including the regionally unique *Gumuz* sheep, a breed of lowland sheep carrying the name of the ethnic group that keeps them. It is the only thin-tailed sheep in Ethiopia and is confined to the western lowlands bordering Sudan. The region is sparsely populated and relatively high returns for investment in sesame production create attractive opportunities. The region has thus become an area of resettlement and attracts a large number of seasonal workers.

The landscape is dominated by extensive plains; where fertile cracking clay Vertisols that shrink and swell with changes in moisture content are common. Eutric Cambisols and Chromic Luvisols are also important soil types in this farming system (Amede et al., 2017). The region has distinctly unimodal and relatively high rainfall that is received from June to September. The rest of the year is dry and hot, leading to semi-arid conditions.

Two main types of farms coexist in this agroecosystem sub-type, almost in equal proportion: smallholder farms ranging in size from 2 to 20 ha and large commercial landholdings of 20 to 2,000 ha. Production is mechanized, but traditional farming practices such as broadcasting of seeds, low reliance on improved sesame varieties, low level of input use, etc. imply that the system has high development potential (Amede et al., 2017). Sesame is grown as a cash crop and hence the system is market-oriented. The area has emerged as a zone of thriving agricultural development in the past ten years, focused on sesame production, which is a national development priority. As it is the case for many areas in Ethiopia, the lowland sesame agroecosystem sub-type is supported by government investment in market development. The region is connected by all-weather roads. Sesame, the main agricultural product, is exported both through the central market in Addis Ababa and across the border to the Sudan.

4. Western lowland maize mixed agroecosystem sub-type

This agroecosystem sub-type extends from Bench Maji through Agnuak to Assosa zones of western Ethiopia. Important crops in this farming system include maize as both a staple and cash crop, sorghum as a staple crop, and other cash crops such as soybean, cotton, sesame, and rice. Vegetables include okra, irrigated tomato, capsicum, and onions (Amede et al., 2017). This agroecosystem sub-type is rather extensive and largely relies on shifting cultivation. There are state-owned sugar plantations and several large-scale private investments in rice production. The system also produces fruit tree crops, mango and papaya.

Livestock production focuses on cattle for both milk and beef, goats for meat, sheep, donkeys and chicken. Apiculture, bamboo production and sale, and hunting provide off-farm household income. The natural vegetation is characterized by scattered Acacia and different tropical trees, including bamboo forests, and grasslands. Eutric Vertisols and Leptosols are the dominant soil types. The western lowland maize mixed farming system consists of large landholdings, due to more abundant land and low market orientation. The environment is relatively wet and humid and the area was traditionally under an agropastoral system, which is still practiced in the southwest. The area is vulnerable to tsetse fly infestations that spread trypanosomiasis and cause livestock death.

Farm households in the system have limited access to services and education. At present, the region is given higher priority by the Ministry of Federal Affairs as an ‘emerging’ region and is receiving greater public investment. Two hydropower stations (Abay and Omo) under construction augment water supply, allowing irrigation water for state-owned sugar plantations, while a major new road to Sudan will expand markets. These government projects and settlement programs are attracting people to the region.

5. Sorghum mixed agroecosystem sub-type

The sorghum mixed farming system is found in the semi-arid areas of Ethiopia, extending from eastern Hararge through Shewa Robit, North Wollo to Kobbo, Alamata and Raya valley at low and intermediate elevations (Amede et al., 2017). The main crops grown are sorghum, millet, *Teff*, maize and pulses. Several species of fruit trees are common, including mango, guava and citrus (orange and limes). The incidence of striga weed is a major challenge for sorghum production. Rainfall is low and erratic. Alluvial soils as well as Cambisols, Fluvisols and Vertisols are found in the northern and eastern zones of the system.

The system is subsistence-oriented, and sorghum, which is the primary staple food, gives a low yield. Livestock is marketed to generate income to buy maize and other goods for the household. During the last three decades, the rainfall is becoming erratic and some catastrophic drought periods have occurred, indicating that this system has not been self-sufficient in food for about three years out of five, and on three occasions there has been mass famine (Amede et al., 2017). Thus, the system has often relied on food relief and a number of safety net projects such as soil and water conservation.

6. Sorghum-Chaat mixed agroecosystem sub-type

This agroecosystem sub-type occurs in the eastern highlands of Ethiopia, extending from the northwestern to the eastern Hararge highlands. The sorghum–*Chaat* farming system is distinguished by the *Chaat* economy. *Chaat* (*Catha edulis*) is a perennial evergreen shrub, the fresh leaves of which are chewed as a mild stimulant. Hararge is one of the major centers of

Chaat cultivation in Ethiopia, mainly due to its good market access to the surrounding cities and export traders. The market for *Chaat*, in addition to Hararge itself, is Somalia and Djibouti.

The dominant crops in the system are sorghum and *Chaat*, the latter being irrigated in the dry season. Other crops include sweet potato, beans and maize, as well as a minor production of groundnuts. The system also includes vegetables (potato, carrot, beetroot, leek, shallot, onion and tomato) on limited irrigated areas, for the local markets in Dire Dawa and for export to Djibouti. Livestock includes cattle, predominantly fattening of young bulls, which are highly valued in the Ethiopian beef market and raised in intensive cut and carry feeding systems. *Chaat* offers opportunities for traders, daily labourers and truck drivers. Increased allocation of land for *Chaat* has reduced availability of animal feed and food crops, and availability of manure. The local vegetation includes highland tree species such as *Juniperus procera* and *Podocarpus falcatus,* as well as plantations of *Eucalyptus* sp. The landscape is hilly with valley bottoms supporting livestock grazing and small scale irrigation schemes. The soils are predominantly Leptosols, which tend to be highly degraded and less fertile.

Due to a high population density, landholdings in the sorghum–*Chaat* farming system are very small, usually less than 0.5 ha. This agricultural system has responded to emerging market opportunities by shifting from subsistence grain-based to a market-oriented, cash crop-based (*Chaat*, coffee, and beef) mixed farming system. The system is extensively linked to markets that generate high income from *Chaat* as well as vegetables, of which the system is the largest producer in the east. This system features a relatively high management intensity involving widespread reliance on inputs and irrigation.

Chaat is a popular crop in the area, because it produces young leaves and twigs even during dry seasons with occasional rain showers, and it has a high market value. Due to these reasons, it has been slowly displacing coffee from homegardens and fertile locations in these systems (Getahun and Krikorian, 1973; Amede et al., 2017). *Chaat* is often planted on contour lines, and it is commonly intercropped with sorghum. Irrigation of *Chaat* in these areas has led to overuse of groundwater, and is linked to drying lakes, for example, Lake Haromaya (Amede et al., 2017).

7. Eastern highland maize mixed agroecosystem sub-type

This agroecosystem sub-type is primarily concentrated in the plateaus of the Rift Valley, extending from Derashe to Butajira in the western part and from Guji to Eastern Hararge in the eastern part. It also includes the agricultural systems that are found in the lake shores of Rift Valley lakes namely, Koka, Ziway, Langano, Abijata, Shala, Hawassa, Abaya and Chamo. The dominant crops are maize and haricot bean and secondary crops include wheat, *Teff*, potato and sweet potato. On the shores of the Rift Valley lakes, particularly Koka and Ziway, there is intensive production of vegetables (onion, tomato, irrigated snap beans, rain-fed pepper) mainly for the Addis Ababa market. Moreover, fruit crops such as papaya and strawberry as well as greenhouse flower production are carried out for domestic and international markets. The production of mango, banana and cotton has also increased in the southern Rift Valley in recent years. Irrigation is practiced only in areas where water quality and supply are suitable. The systems found around Koka and Ziway lakes are evolving as commercial agriculture. Around Lake Abaya (near Arba Minch), numerous irrigated banana plantations are established that sell their produce to different parts of Ethiopia. The presence of good road infrastructure has facilitated marketing of these perishable crops (vegetables and fruits). Large sugar plantations have become the dominant land use activity in the Wonji and Metehara areas.

The main livestock types are oxen, used for plowing, cows for milk, goats for sale and donkeys for transportation of goods and chicken. Fishing is another important economic activity, especially around Chamo, Hawassa and Ziway lakes. There are also a number of intensive commercial livestock fattening feedlots and chicken farms in the system. For off-farm income, farmers are involved in commercial flower farms, charcoal production, petty trade, and casual labour both on other farms and outside agriculture. Acacia woodlands make up the most common vegetation type. Soils in the system include Andosols, Vertisols, and Fluvisols.

The system is characterized by high management intensity, a high level of market linkages, and crop commercialization. The system has undergone significant transformation in recent years. Horticulture has been a focus of investments and vegetable production (onion, tomato) has increased around lakes. There is increasing investment in commercial flower farming, employing thousands of young people all year round. The area of maize cultivation has also recently increased around Awash and Ziway.

8. Western highland maize agroecosystem sub-type

This system stretches from East Wollega to East Metekel and Awi zones, including areas surrounding Lake Tana in West Gojjam and South Gonder zones. The key crops in the western system include maize, *Teff*, finger millet, niger seed (oil crop, Niger Seed, *Noog*), wheat and barley, as well as vegetables (capsicum, potato, and tomato), all of which are both home-consumed and marketed. Common tree crops are mango, papaya and coffee south of the Blue Nile. The Awi subsystem, in the central northern area, is focused on potato, barley, and trees (eucalypts, acacias, and bamboo). Since the early 2000s, fertilizer is increasingly being used on maize, with maize yield reaching 7 tons ha^{-1} in farmers' fields, exceeding the national average (Amede et al., 2017).

Cattle, sheep, goats, chicken, horses, mules and donkeys are the main livestock types. Livestock are fed both on crop residues around the household compound and on communal grazing areas. Rainfall is high, exceeding 1,400 mm per annum, and unimodal. Water availability is not limiting for agriculture. Various soil types (Nitosols, Vertisols, Acrisols, Alisols) prevail according to the area. Soil acidity and associated phosphorus deficiency are becoming prevalent. The western highland maize mixed farming system is one of Ethiopia's high potential productivity zones. Management intensity is high with extensive reliance on improved varieties, fertilizers, compost, herbicides and pesticides. There are medium to large-scale irrigation schemes in the area, such as the Koga dam, and the Dedessa and Fincha hydropower dams which are used for irrigation of large sugar plantations as well as smallholder crops (Amede et al., 2017).

9. Highland livestock-maize mixed agroecosystem sub-type

The highland livestock–maize mixed agroecosystem sub-type is found in western Ethiopia, particularly in Kelem Wollega and Illuababor zones. The dominant commodity of the system is livestock, raised for meat, milk and draft power. The main livestock components are cattle and sheep with less emphasis on goats. The production relies on communal grazing. Some crops, such as maize, sesame and sorghum, are raised around household compounds and supplement household consumption needs. *Anchote* (*Coccinia abyssinica*), an endemic plant grown for its edible tuberous root with high calcium content, is a food that is culturally and economically important crop for the farming communities. Tree crops include coffee, mango and banana. The landscape comprises mid-altitude rolling hills, with soils predominantly characterized as Chromic Vertisols. Annual rainfall is high, and when associated with denuded vegetation, it creates soil and water erosion problems. Farmers mostly rely on rainfall for crop production, but small scale irrigation is also practiced. The level of system commercialization and market orientation is in the range of low to medium, with coffee and maize being the main marketable outputs. There is severe erosion hazard owing to poor agricultural practices and limited engagement in soil and water conservation.

***10. Highland Teff mixed* agroecosystem sub-type**

The Highland *Teff* mixed agroecosystem sub-type extends from the Central Rift Valley through East and North Shewa, South Wollo, Gojjam, including the surroundings of lake Tana, to Central Tigray. The system is considered the breadbasket of highland systems because of its high agricultural productivity, fertile soils and adequate and well-distributed rainfall. This is also where small-scale farmers produce most of the vegetables and fruits using small scale irrigation system. The major crops produced in this system are *Teff*, maize, wheat, faba bean, chickpea, grass pea and lentils. *Teff* is grown by many farmers in Ethiopia, and accounts for 24% of all cultivated land (CSA, 2018). The system also has a strong livestock component where cattle dominate, followed by sheep, goats, and equines, respectively. This system is found around urban areas and along major roads, where the market opportunity is very high.

This agroecosystem sub-type is found in areas with an altitude of 1,700 to 2,200 m, receive an annual rainfall of 600–1,300 mm, and it has a growing season of 100–180 days (Amede et al., 2017). The soils are fertile. The dominant soils are Vertisols, along with Luvisols, Eutric Leptosols and Eutric Cambisols. *Eucalyptus, Croton* and *Cordia* spp. are common tree species in the system. The population density in the highland *Teff* mixed farming system is high, and the average landholding of a household is about 1.0 ha. In general, this farming system is complex and characterized by a high diversity of crops, ranging from 4 up to 14 (Amede et al., 2017). In addition to crop species diversity, intraspecific diversity of the major cereals such as *Teff* and wheat is reported (Assefa et al., 1999; Asmamaw et al., 2019).

In the eastern part of Lake Tana wetlands, rice-based system is dominant, and pulses, mainly chickpea and grass pea, are produced on residual moisture (Amede et al., 2017). Vegetables such as onion and tomato are also grown for market, using residual moisture and supplementary irrigation. In the past, people in the wetlands of Lake Tana depended on a local cattle breed called *Fogera*. But, rice cultivation has expanded on the grazing lands in the last forty years and affected feed availability, threatening the existence of the *Fogera* cattle breed (Amede et al., 2017). Fishing and sale of fish are important economic activities around lake Tana.

There is already a strong diversification and intensification trend in favor of market crops, particularly around towns and cities. Application of chemical fertilizer to maize and *Teff*, and introduction of improved varieties and technologies is also increasing. Given the increasing global interest in *Teff* as a health food, strategies are needed to increase productivity and value addition, develop markets, and brand *Teff* as a unique Ethiopian crop (Amede et al., 2017).

11. Highland wheat mixed agroecosystem sub-type

This system is dominant in Oromia and Amhara regions, extending from East, West and North Shewa to South Wollo, Gojjam, South Gonder and southern Tigray. It occupies the mid sub-humid highlands, where wheat is the major food and cash crop, along with pulses and livestock. Area-wise, wheat is the fourth most important crop countrywide following maize, *Teff* and sorghum. However, the country turned from a net exporting country to a net importing country due to increasing urbanization and food aid (Amede et al., 2017). A large diversity of crops is found in the highland wheat mixed agroecosystem sub-type. In order of importance, crops grown in the system are wheat, maize, barley, faba beans, oats, potato, peas, lentils, *Noog* (niger seed) and flax. The diversity of wheat landraces is high in the areas (Hailu et al., 2006; Asmamaw et al., 2019).

Cattle are the dominant livestock type. Other livestock include donkeys, horses, sheep and chicken. The system includes areas located around towns and major roads, where the market opportunity is very high. The system is found in areas with an altitude of 2,200– 3,000 m asl, receives bimodal rainfall that ranges from 800 to 1,600 mm per annum, and the growing period is 120–180 days. Like the *Teff*-based system, the dominant soils are Vertisols along with Luvisols, Eutric Leptosols and Eutric Cambisols. *Eucalyptus*, *Croton* and *Cordia* spp. are common trees associated with the system.

Wheat yield lags behind other cereals, partly due to market disincentives but also due to attacks by wheat rust. During the long growing season (*Meher*) wheat becomes the principal cereal crop, often covering most of the area allotted to cereals, whereas in the short season (*Belg*) other crops (mainly barley) predominate. There is an increasing trend in using tractors and combine harvesters in wheat belts, particularly in Arsi and Bale highlands, usually through short-term contractual agreements. Crop rotation is rarely practiced in the mechanized major wheat production systems of the Arsi and Bale highlands, while farmers using draft power rotate wheat with legumes once every two to three years. Farms in this system are intensively managed and they are well connected to markets.

12. Highland barley – livestock agroecosystem sub-type

The highland barley–livestock farming system occupies the highest range of the Central Ethiopian Highlands, from Chilalo Highlands to the Semien Mountains. Due to the cool, sub-humid to semi-arid climate, barley and potato are the two dominant crops followed by oats and pulses, especially faba beans and lentils. In Ethiopia barley is ranked fifth of all cereals, and is mostly grown in this system. It is used mainly as food, and to make the traditional beer (*Tella*) for household consumption during festive seasons and for generating cash at other times. The diversity in barley landraces is very high (Tanto et al., 2009; Bantayehu and Esmael, 2011; Tsehaye et al., 2012). Crop residues, including straw, are fed to livestock. Potato is grown either as a relay crop or mixed with barley. Potato production during the short rains is constrained by a high prevalence of late blight disease. The application of chemical fertilizers is generally low in the areas. Sheep are the dominant livestock type, with one or two cattle for milk production and equines for transportation of goods across the mountainous terrain. Livestock is kept throughout the year on natural pasture, rangelands and stubble.

The system is dominant in the cool highlands with altitudes of over 2800 m a.s.l. The natural vegetation is characterized by *J. procera* and *H. abyssinica* –based alpine plant formations. The soils vary between locations and include Leptosols, Glyic Cambisols, Vertic Cambisols and Eutric Regosols (Amede et al., 2017). Soils tend to be hard and marginal with acidity problems. Annual rainfall is high, between 800 and 1,800 mm. Temperature ranges from below freezing to a maximum of 20°C, with a high probability of frost at night, particularly in October and November.

Farm plots are generally small, about 0.25 ha on average, but farmers have multiple plots and the average landholding of a household is around 2 ha (Amede et al., 2017). Livestock, particularly small ruminants, play a very important role across this system as a source of cash to buy food during bad years, but also for purchasing agricultural inputs and other basic household necessities. Manure serves as a major source of fuel and organic fertilizer. The highland barley–livestock farming system has a strong subsistence orientation and is characterized by low productivity. Frost, land degradation and erosion are major production challenges. This system is one of the most food-insecure systems, aggravated by the challenging terrain, the lack of market opportunities, and limited off-farm income opportunities. Crop failure in this system is commonly compensated by food purchase from selling sheep and goats or through food aid. However, this is slowly changing as more farmers are getting access to agricultural inputs. Given the hilly terrain and fragility of these systems, there is a need to strengthen efforts in watershed management

13. Enset-coffee-cereals mixed agroecosystem sub-type

This system is common at altitudes of 1500-2500 m.a.s.l. in the south and southwestern highlands of Ethiopia. It extends from Sidama to Borena Guji Zones, Kambata Tembaro, Wolaita, to Dawro and Kaffa, Sheka Zones in the SNNPR, and Jimma to Gore in Oromia Region. In these systems, the two native perennial crops, *Enset* and coffee are grown in intimate association with cereals (mainly maize), pulses (mainly haricot bean), root and tuber crops (yam, taro, Irish potato, sweet potato, and Ethiopian potato), fruit crops (avocado, mango, banana, papaya, guava, white sapote/*Kasmir (Casimiroa edulis*) and others), vegetables (kale, cabbage, pepper, carrot, etc.), spices and condiments, sugarcane and different types of trees and livestock (Asfaw, 2003; Abebe 2005; Negash 2007; Mellisse et al., 2018a). The dominant soils are Nitosols and Orthic Acrisols on moderate slopes, which merge to Luvisols in the steeper slopes and Fluvisols in the lower lands around lake Hawassa (ICRAF, 1990). The soils are highly weathered and characterized by high phosphorus fixing capacity.

These systems are also called *Enset*-coffee agroforestry homegardens because of the integration of different species of crops and useful trees as well as livestock close to homesteads (Abebe et al., 2006). The diversity of crop species of different forms and growth periods enables households to harvest food products during most of the year. The presence of different species of trees in the systems contributes to households' energy and timber needs, feed and fodder to livestock and income generation. Most importantly, the trees help in sustaining agricultural production due to their positive effects in nutrient cycling, erosion control, and microclimate amelioration. These systems can therefore be considered sustainable, both in ecological and socio-economic aspects.

Livestock include cattle, donkeys, sheep, goats and chickens. Cattle are kept for milk, manure, savings and social security. A cut-and-carry system of feeding is used, where livestock is kept in barns and fed with forage sourced from the vicinity of the farm. In some areas, limited private or communal grazing areas are also present. Animal manure is widely used to fertilize soils in homesteads where *Enset* and vegetables are grown.

Native trees such as *Cordia africana, Milletia ferruginea, Croton macrostachyus, Albizia* sp., *Acacia* sp. *Podocarpus falcatus* and *Ficus* spp. are found scattered in the farms. Among the exotics, *Grevillea robusta, Eucalyptus camaldulensis* and *Cupressus lusitanica* are grown as boundary or block plantations.

The *Enset*-coffee-cereal mixed agroecosystem sub-types are the most diverse in crop species and varieties. For instance, in Sidama, Abebe et al. (2010) reported cultivation of up to 78 crop species at the community level with an average of 16 species per farm. Results of similar studies undertaken in the region are summarized in Table 7. In addition to the diversity in species of crops, the major crops, *Enset* and coffee, are reported to show a high diversity of cultivars or landraces (Negash, 2001; Tsegaye, 2002; Tesfaye, 2002; Abebe, 2005; Woldeyes, 2011; Maryo, 2013; Yemataw, 2018).

Table 7. Species richness of cultivated plants in the Enset-coffee-cereal mixed agroecosystem sub-types of South and southwest Ethiopia

Study area	**No. of crop species**	**Mean number of crop species/farm**	**No. of tree/ shrub species**	**Total no. of cultivated plant species**	**Source**
Wolaita & Gurage	60	14.4	-	-	Asfaw and Woldu (1997)
Sidama	78	16	120	198	Abebe (2005)
Basketo	-	-	-	149	Woldeyes (2011)
Kaffa	-	-	-	192	Woldeyes (2011)
Kambata Tembaro	92	17.4	186	278	Maryo et al. (2018)
Southern Ethiopia	86	-	-	-	Gebre (2015)
Gamo highlands	41	19	-	-	Oakland Institute (2015)

The diversity of *Enset* landraces reported from studies in different parts of south/southwest Ethiopia are summarized in Table 8.

Table 8. Diversity of Enset landraces in the Enset-coffee based agroecosystem sub-types of South and Southwestern Ethiopia

Study area	Number of *Enset* landraces	Mean number of *Enset* landrace/ farm	Source
Kaffa	76	-	Negash (2001)
Kaffa	70	-	Woldeyes (2011)
Sidama	86	-	Tesfaye (2002)
Sidama	52	-	Tsegaye (2002)
Sidama	42	6	Abebe (2005)
Wolaita	55	-	Tsegaye (2002)
Hadiya	59	-	Tsegaye (2002)
Basketo	26		Woldeyes (2011)
Kambata Tembaro	111	7.2	Maryo et al. (2018)
Southern Ethiopia	312	1-28	Yemataw (2018)

These agroecosystem sub-types are also called Agroforestry systems due to the intimate association that exists between crops, trees and livestock in the same land units. These integrated agroecosystem sub-types, provide various ecosystem services including, carbon sequestration, microclimate amelioration, soil and water conservation, nutrient cycling and maintenance of soil fertility. Studies conducted in some agroforestry systems in Ethiopia reveal that agroforestry practices have the potential to store a very large amount of carbon in the soil (Table 9).

Table 9. Carbon stock in agroforestry and other land use systems in Ethiopia

Site	Land use system	Soil Carbon, Mg ha^{-1}	Reference
Gedeo	Agroforest + soil Carbon	95.78	Fikrey (2011)
	Agroforest + soil Carbon	78-115	Negash (2013)
Jimma	Native coffee forest	230	Mohammed (2011)
	Coffee-based Agroforest	150	
	Annual crop fields soil Carbon	65	
Sidama	Natural patch forest	334.86	Abiot (2012)
	Coffee-Enset based agroforestry	242.02	
Kaffa	Natural forest	393.91	Solomon (2013)
	Semi-natural forest with coffee	446.08	
	Homegaden	218.84	
Dollo Menna, Bale	Natural forest	170.11	Mengistu and Asfaw (2019)
	Coffee with shade trees	127.96	
	Homegardens	107.62	
	Annual crops	97.56	

Two distinct sub-types of the *Enset*-Coffee-Cereal mixed agroecosystem sub-types can be distinguished, based on the intensity of management: intensively managed and extensively managed.

i. ***Intensively managed***

This sub-type occurs in Gedeo, Sidama, Wolaita, parts of Kambata and Tembaro, and Hadiya, where land-holding is small (average of 0.5 hectares per household), and where the farms are intensively managed and the diversity of crops is very high. In Gedeo and Sidama, *Enset* is a staple food, while it is a co-staple food in the others. Coffee is the main cash crop, but *Chaat* is increasingly becoming a very important cash crop, especially in some districts of Sidama. *Enset* and coffee, along with associated cultivated plants are grown in homesteads, while cereals are often grown in the outer fields surrounding the *Enset*-coffee complex.

Although *Enset* is widely grown in the region, the area it covers varies across locations. For instance, in Sidama, where *Enset* is the staple food it covers 22% of the farmlands on average (Abebe, 2005) while in Kambata Tembaro its mean area coverage is 9% of the farms (Maryo, 2013). The *Enset* fields are fertilized with animal manure, crop residues and household refuse, but animal manure is increasingly becoming scarce as the number of livestock in the systems decreases. The highest rural population density in Ethiopia is found in this agroecosystem sub-type.

The most famous coffee brands in the world are produced in this system, including Yirgachefe and Sidama. Coffee, tropical fruits and other produce from this system present good opportunities for export-focused marketing. The processing of fruits and spices on the spot would reduce transport costs and increase product value. In this respect, the recently established agro-processing industry at Yirgalem, Sidama provides a good opportunity for socio-economic development.

Recent trends

The intensively managed *Enset*-coffee-cereal mixed agroecosystem sub-types are highly productive and sustainable systems that carry a very dense population of 500-800 persons per square kilometers. However, land use change is taking place since three decades ago, and that could threaten the integrity and productivity of the system. These changes are taking in two forms:

a) In the first case, the change takes place from the complex *Enset*-coffee agroforestry systems to monoculture plots of maize, and this is associated with increased fragmentation of land. *Enset* reaches maturity in 3-5 years after transplanting, or 5-7 years after sucker development. Farmers who do not have mature *Enset* that can be harvested in a year or two do not invest in *Enset* planting. They rather tend to grow maize or root crops that can be harvested in a few months to feed the family (Abebe, 2018). The change in land use could jeopardize the ecological benefits that are derived from the complex and integrated nature of the system. When land is too small to make a living for the family, the landless youth migrate to towns resulting in a stoppage of schooling and lifting up the population of unemployed urban dwellers.

b) In the second case, the change takes place from the *Enset*-coffee agroforestry systems to monoculture plots of *Chaat*, and this is driven by the gain from the market. *Chaat* is the most profitable of all crops as it generates the highest income per unit area of land given that only production of young shoots in a few months are required to merchandize the produce unlike other crops that need to complete a long life cycle before harvesting. The high premium and increasing demand have motivated many farmers to expand *Chaat* production at the deteriment of coffee and *Enset* (Abebe et al., 2010; Mellisse et al., 2018a). In the midlands of the Sidama Zone that are close to towns and major roads, it is common to see monoculture fields of *Chaat* that is developed on previously complex *Enset*-coffee based systems. The expansion of *Chaat* monoculture in this system has several drawbacks. First, it reduces the households' self-sufficiency in production of diverse and nutritious food plants. Secondly, the dependence on one cash crop (*Chaat*) is prone to production or market- linked risks and any failure could expose the famers to food insecurity. Thirdly, the high species diversity and integrated perennial nature of the systems, which are responsible for the sustainability of the agroecosystem sub-types, will be lost and the system will be vulnerable to climatic shocks.

In general, conversion of the intensively managed *Enset*-coffee based system to monoculture plots of maize or *Chaat* is likely to affect the integrity and long term sustainability of the agroecosystem sub-types. Hence, attempts should be made to integrate the new crops into the systems with minimal effects on the diversity and perennial nature of the agroecosystem sub-types.

ii. ***Extensively managed***

This sub-type is found in the highlands located between Jimma to Gore in Oromia and Kaffa and Sheka zones in SNNPR (ICRAF, 1990; Amede et al., 2017). Landholding in these areas is relatively large, and the farms are not managed intensively. Coffee and *Enset* are dominant crops, but other cereals, vegetables, root and tuber crops, fruits and several species of native trees and livestock are managed although the species diversity is lower than the intensively managed systems. Annual rainfall ranges from 1000 to 2200 mm, and the dry season is about three months (FAO, 1986; Berhanu et al., 2014). The long rainy season allows year-round cultivation of different crops, and hence there is a big potential to increase food production in these areas. The presence of forest coffee in some pocket areas (Kaffa, Sheka, Illubabbor) is a unique feature of this system. The original forest habitat of wild coffee is internationally recognized for its high plant diversity and a large number of endemic species (Gil et al., 2004). The land is managed extensively since population density is low. *Enset* and the associated garden crops are cultivated near homesteads, while cereals are grown on crop fields away from home.

In the past, the major means of livelihood of the communities living in Kaffa and Sheka areas were, shifting cultivation, cattle rearing, hunting and wild honey collection. At present, sedentary lifestyle and agriculture is dominant, and the local people use integrated homegarden crop production to produce food for their family (Kassa et al., 2016). They discussed that the conversion of natural forests to agroforestry has few environmental effect. The top soil fertility of agroforestry was similar to that of the natural forest, and the number of cultivated plant species in agroforestry was 30% higher than the natural forests due to introduction of new crops (Kassa et al., 2018).

In Kaffa and Sheka the expansion of cereal cropping, grazing land and monoculture coffee and tea farms are taking place at the expense of closed and dense forests (Kassa et al., 2016). The expansion of cereal monocultures could lead to land degradation and loss of productive capacity of these agroecosystem sub-type. Integrating cereals and other annual crops into the traditionally accepted agroforestry production systems should be taken as viable alternative to reduce deforestation and land degradation and sustain agricultural productivity.

Hoe cultivation is a common practice in the areas. The most important cereal crops grown in these systems are maize, sorghum, *Teff* and millet. The other commonly grown crops include spices and condiments (Ethiopian cardamom, ginger, coriander, hot pepper, and black cumin), root and tuber crops (*Enset*, yam and taro), pulses (haricot bean, faba bean, field pea), oil crops (niger seed, linseed and rapeseed), vegetables (cabbage, tomato, garlic, onion) (ICRAF, 1990; Kassa et al., 2016; Amede at al., 2017). However, the production system is less intensive in spite of the huge agricultural potential the sites have. Spices and condiments that are largely produced in this sub-type play very important social and economic roles in the livelihoods of the local peoples and the country at large. Woldeyes (2011) has reported that there are 24 species of spice yielding plants in the Kaffa Zone, where spices and other Non-Timber Forest Products (NTFPs) serve as the important cash crops (Mohammed and Wensum, 2011; Kassa et al., 2016). Besides their role in the diets of the people, spices contribute in generating foreign currency. For instance, the foreign currency Ethiopia earned from exports of spices and condiments in 2010 was USD 18.6 Million. Out of the total export earnings, 65% (USD 12 million) was obtained from ginger which is mainly produced in these agroecosystem sub-types (ITC, 2010). Woldeyes (2011) recommends valorization of spices and other products from homegardens to secure attractive benefits to farmers, and maintain integrity and continuity of the agroecosystem sub-types.

Apiculture, for honey and wax production, also plays important role in the economy of the local farmers in these systems and other highland agroecosystem sub-types as well. The honey is used in the preparation of the local drink, *Tej* (mead), and also in the local economy through foreign exchange earnings. However, honey production in the traditional method is very low, but there is scope for wider use of improved beekeeping methods, and boost the benefit to farmers and the country at large.

14. Enset-barley mixed agroecosystem sub-types

The *Enset*-barley mixed agroecosystem sub-type is common in the highlands (*Dega*) of southern Ethiopia at altitudes of 2500-3000m a.s.l, especially in the highlands of Gurage, Gamo Gofa and Sidama in the SNNPRS and the highlands of West Arsi (Oromia), around Kofele. It is a mixed system, where the homegarden is allocated for *Enset*, vegetables, and maize, purposefully for manuring, accessibility and closer guarding (ICRAF, 1990). Barley and other field crops are grown in open fields away from the homegarden. This system is generally devoid of cash crops since coffee, *Chaat* and fruits that are primarily produced as cash crops in the *Woina Dega* do not thrive well in this high altitude. *Enset* is the most important crop in terms of area coverage (ICRAF, 1990) and volume of food production. Other important food crops include cereals (mainly barley and wheat), pulses (faba bean and field peas), cabbage and some oil crops. The diversity of crops is low as compared to the *Enset*-coffee-cereal mixed agroecosystem sub-type, because of low temperature, and relatively low soil fertility. Plowing is largely done by hoes and digging sticks. Fallowing and crop rotation of cereals and legumes are practiced.

Livestock in the system include cattle, sheep, goats, equines and chicken. Among the cattle, cows are dominant but oxen are few in number since ox plowing is not widely practiced. Livestock holding is generally lower than the *Enset*-coffee cereal mixed system mainly due to a shortage of feed. Grass, *Enset* leaves, crop residues, tree leaves and herbaceous plants are among the feeds served to cattle.

At this high altitude, the growth of trees is slow and wood consumption is higher since it is used for cooking, construction and heating. As a result, the natural vegetation is largely removed, and only scattered trees of *J. procera, Olea europaea* ssp. *cuspidata*, *H. abyssinica* and clumps of *Arundinaria alpina* are left. In some of these areas *Eucalyptus globulus* is planted on boundaries or as woodlots. Due to the low stock of wood in these high altitudes, the wood shortage is a problem, except in the areas where *E. globulus* is planted.

6.4 Drivers of change in biodiversity and ecosystem services in agroecosystem

The drivers of change can be categorized as direct and indirect drivers that cause negative changes on the status of biodiversity, ecosystem functions and services are examined to acquire insight on the pressures and threats on agroecosystem. A driver is any natural or human-induced factor that directly or indirectly causes a change in biodiversity, ecosystem functions and ecosystem services. A direct driver unequivocally influences ecosystem processes whereas an indirect driver operates more diffusely, by altering one or more direct drivers (MEA, 2005). Direct drivers explicitly influence ecosystem processes, while indirect drivers change the rate at which one or more of the direct drivers affect ecosystem processes. The natural and anthropogenic drivers of changes, the patterns and trends of changes on biodiversity, ecosystem functions and services as well as their impacts on human wellbeing were assessed.

6.4.1 Direct drivers of change

The direct drives of change in agroecosystem, ecosystem functions and ecosystem services are also categorized into natural and anthropogenic or called human- induced factors. Anthropogenic factors are those drivers resulting from the influence of human beings on nature while the natural drivers are those drivers which are beyond human control.

6.4.1.1 Natural drivers

Natural drivers are those that are not the result of human activities and are beyond human control. These include earthquakes, volcanic eruptions, extreme weather such as prolonged drought or cold periods, tropical cyclones and floods, the El Niño/La Niña and extreme tidal events (Bustamante et al. ,2018; Lindenmayer et al., 2009). The types of disturbances could be the natural drivers of change that may be everything ranging from single tree-falls (Brokaw, 1985) to ecological catastrophes (Hughes, 1994). Natural disturbances are caused by natural climatic, geologic, and biological fluctuations. Large, severe disturbances are often considered natural disasters, because they can threaten human life and have striking short-term effects on plant and animal populations (Lindenmayer et al., 2009). They are often event-triggered by natural hazards that overwhelm local response capacity and seriously affect the social and economic development of a region. Natural hazards are classified as geophysical such as earthquakes and volcanoes; meteorological such as short-lived to large scale atmospheric processes e.g. storms; hydrological such as flood; climatological events such as long-lived processes including extreme temperature, drought, wildfire; or biological including epidemic diseases, insect infestation, animal stampede (Guha et al., 2014).

Agroecosystem and agricultural production are often seriously affected by natural disasters. For example, a study of post-disaster needs assessments covering 74 medium-to large-scale disasters in 53 developing countries between 2006 and 2016 showed that agriculture accounted for 23% of all losses and damage incurred (FAO, 2018b). Among the natural disasters encountered, agriculture absorbed 83% of the economic impact due to drought. The crop sector was the most affected (49% of all damage~~s~~ and losses), followed by the livestock sector (36%). The most damaging types of natural disasters both in the crop and livestock sectors of the mountainous countries and those countries which practiced a rain-fed agriculture were found to be drought followed by floods, while in the fisheries sector floods and storms are important (FAO, 2018b). Natural disasters were reported to have had a significant effect on biodiversity for food and agriculture and/or on ecosystem services in Ethiopia include recurrent drought, floods, acidification, heat waves, wildfires and heavy rainfall and hailstorms (FAO, 2019).

Drought is caused due to extended periods of precipitation shortage, normally for a season or more resulting in water deficiency for human activities or environmental sustainability. Human activities such as farming, irrigation, or domestic uses of water are normally highly impacted during droughts. Ethiopia has been experiencing many drought seasons that caused hunger since 1974. In the recent past the 2016, El Niño-induced drought due to below average autumn rains in the southern and southeastern parts of the country, have led to a new drought in lowland pastoralist areas, as well as in pocket areas across the country. As a result, some 5.6 million people required emergency food assistance, 9.2 million people needed support to access safe drinking water, 1.9 million households needed livestock support, and 300,000 children between 6-59 months old were targeted for the treatment for severe acute malnutrition (OCHA, 2017). The main impacts of droughts include crop damage, loss of pasture and water sources, loss of animals, hunger, disease outbreaks, asset depletion, malnutrition, and migration. Droughts can result in sharp reductions in agricultural output and related productive activity and employment, with multiplier effects on the GDP. A study conducted in Yabelo, Borana Zone indicated that households have experienced a severe reduction in their assets, with an average reduction of 80 percent of livestock holdings from their peak holdings over ten years (2004-2014) by climate change, especially of drought (Stark et al., 2011). Additional study indicated that the decline in cattle, goats, sheep and donkey kept by pastoralists of Moyale and Dillo areas was significant in which most of the animals were reported to have died during severe droughts, which occurred in 2005 and 2008 (Zelalem et al., 2009).

Floods are caused by an excess of water entering a lake or river bed from rain. It can overflow the banks, and expand either upslope or across a floodplain. Flooding also destroys crops, animals and can wipe away trees and other important structures on agricultural land. For example, hundreds of thousands of people were affected by flooding in Afar (Awsi), Oromia (Arsi, East Shewa, East and West Hararge zones), SNNPR (South Omo) and Somali (7 zones), as it was reported by (OCHA, 2017). Both riverine and flash floods regularly cause crop loss, infrastructure damage, farmland degradation, and loss of life in Ethiopia.

Acidification is a natural process that usually occurs because of nitrate leaching. Soils in areas with large amounts of rainfall tend to be acidic because the water leaches basic cations calcium, magnesium, sodium, and potassium out of the soil profile, and these cations are then replaced by acidic cations-hydrogen and aluminium. In Ethiopia, vast areas of land in the western, southern and even the central highlands of the country, which receive high rainfall, are affected by soil acidity (MoARD, World Bank, 2007). Soil acidity can lead to elemental toxicities for plants by aluminium, iron, manganese, and zinc due to the increased solubility of these elements at low pH values. Soil acidity can cause limited availability of some macronutrients and micronutrients such as phosphorus, which binds to iron and aluminium oxides in acidic soils and most plant nutrients are available at slightly acidic pH of 5.8 to 6.5 (SMART, 2019). In acidic soils, with low pH levels, metals such as aluminium, Iron and Manganese might be released into the soil solution at high concentrations which may be toxic to many plants that may influence root growth and nutrient and water uptake, and induce a change in microbial populations and activities (Marschner, 2012; Abdenna et al., 2013). Some soil bacteria are responsible for many reactions in the soil, such as decomposition of organic matter (contributes nitrogen and phosphorus) and the nitrification process. Those processes are significantly slowed down in acidic soils, and therefore limit nitrogen and other nutrients availability (SMART, 2019). In Ethiopia, acidification occurs simultaneously with other conditions including eroded topsoil and depleted organic matter, depleted nutrients, and alternating drought stress and high rainfall (Eyasu, 2016). Its severity is extremely variable due to the effects of parent materials, land form, vegetation and climate pattern (Achalu et al., 2012).

6.4.1.2 Anthropogenic drivers

The major anthropogenic direct drivers in agroecosystem include land use change (expansion, abandonment and intensification), over-exploitation (soil, water and biological resources), invasive alien species and diseases, pollution, and climate change (Nelson et al., 2006; Herrero et al., 2012; Garbach, 2014). Drivers interact across spatial, temporal, and organizational scales. For example, global trends such as climate change or globalization can influence regional contexts of local agroecosystem management through different time scales. The major anthropogenic direct drivers are discussed below.

Climate variability and change

Earth's climate system has changed since the preindustrial era, in part because of human activities, and this change is projected to continue throughout the 21st century (Nelson et al., 2006). For example, during the last 100 years, the mean global surface temperature has increased by about 0.6°C and precipitation decreased over much of the subtropical land areas at a rate of about 0.3% per decade. Carbon dioxide (CO_2) is the most important greenhouse gas, with methane and nitrous oxides as other contributors. Precipitation patterns are projected to change, with most arid and semi-arid areas becoming drier and with an increase in heavy precipitation events, leading to an increased incidence of floods and drought.

Climate change is among the major environmental issues facing Ethiopia today. Climate change has occurred across much of Ethiopia, particularly since the 1970s, at a rate that is variable but broadly consistent with wider African and global trends (EFCCC, 2017). The same sources revealed that both maximum and minimum temperature extremes showed a significant increasing trend in more than 60% of the weather stations in Ethiopia. Therefore, Ethiopia has been getting warmer over the last 30 years with an increasing trend of extreme warming indicators in most parts of the country. Rainfall amount on the other hand has remained stable over Ethiopia in the past 60 years, with only a statistically non-significant slight decrease (EFCCC, 2017). Seasonal analysis of the rainfall trend by EPCC (2015) indicated that *Belg* (Feb-May) rains exhibited a decrease by -150 to -50 mm across the south-central and eastern parts of the country, while the *Kiremt* (June-Sept) rains exhibited a decrease by -150 to -50 mm across the western and southern parts of Ethiopia. The two seasons together showed a total loss of more than 150 mm of rainfall per year. Station based rainfall anomaly trend analysis confirmed that there is no significant trend in annual rainfall amount (EPCC, 2015). However, Asaminew (2013) analyzed seasonal rainfall trend from 1975 to 2010 and estimated 15-20% decreases in both *Belg* and *Kiremt*. The collective-mean annual precipitation for all representative concentration pathways (RCPs) shows an increase by 4% to 12% by 2100 compared to the 1975-2005 baseline (EPCC, 2015) while, the mean annual surface temperature increase by 3.5% to 8.5% (0.5^0C to 6^0C).

These changes will negatively affect both crop and livestock production and productivity. This is due to shortened growing period, increased water stress, increased loss of soils and plant nutrients, increased scarcity of livestock feed and water, increased 'heat load' on livestock; flood and drought damages on crops and livestock, decreased grazing and browsing resources in some areas (EFCCC, 2017). Moreover, reduction in the length of growing seasons of some crop varieties that have resulted in the loss of many long duration varieties alters the underlying agroecosystem leading to changes in crop pests and spread of disease (EBI, 2015). It also influences the spread of vector-borne diseases by favouring the distribution and growth rate of vectors and shortening the life cycle (Holly and David, 2001). Regarding economic-wide impacts, World Bank (2011) reported that climate change could reduce Ethiopia's GDP by 0.5-10% from what was projected to be achieved in the 2040-2049 decade with climate change impacts.

Chemical fertilizer application to agricultural lands

Plant nutrients are essential for food production, but current methods of fertilizer use contribute to environmental problems such as greenhouse gas emissions and eutrophication. Nitrogen and phosphorus applied on farm fields to help crops grow are carried out beyond the limits of the field to which they are applied, potentially affecting ecosystems off site (Cassman et al., 2003). A substantial portion of the nitrogen applied is not used by plants and is carried off the field in runoff and such losses of reactive N can damage ecosystem services in the receiving ecosystems (Nelson et al., 2006). Much of the impetus to increase fertilizer application in developing countries like Ethiopia is aimed to feed a growing population as a response measure, for low food security and to enhance productivity. Ethiopia is working hard to increase productivity through investment in intensive use of improved technologies such as fertilizers and seed. The quantities of chemical fertilizer have shown an increasing trend. For example, the amount of total fertilizer used had increased by 38% in 2012 compared to 2008. Similarly, the chemical fertilizer used in 2016 is about 76% higher than the one used in 2012 (EFCCC, 2017). In terms of application rate per hectare of cultivated land, wheat accounted for the largest share (57 kg/ha), followed by teff and maize respectively (Kefyalew, 2011). These statistics indicate that the national level intensity of fertilizer use is still lower than the recommended rate of 200 kg per ha (100 kg of DAP and 100 kg of Urea) (Fufa and Hassen, 2005). However, there is a limitation in using the proper mix of DAP and Urea, and is not complemented with proper conservation measures. The simple descriptive evidence from the 2004 survey shows that only 46% of the respondents are involved in soil conservation practices (Kefyalew, 2011). Thus, the increased fertilizer use coupled with expansion of irrigated farms, inadequate provision of drainage system, and poor water management practices have increased the areas of salt affected and acidic soils. The semi-arid and arid lowlands and valleys particularly in the middle Awash area in Ethiopia have major problems of salinity and alkalinity. Therefore, currently about 9% of the Ethiopian population lives in the areas affected by salinity, whereas 36% of the country's total land area (about 44 million ha) is potentially susceptible to salinity problems (EFCCC, 2017). It is estimated that acidic soils are covering more than 40% of cultivated lands in Ethiopia (IFPRI, 2010). Acidification as well as neutralization of the soil may be very harmful to microbes, which often depend on a sole enzyme and enzymes are active only in a very specific pH. Changes in pH slow down enzyme reaction and microbes have to enter into rest, encysting, or die from hunger (Dharmendra et al., 2013). Thus, decomposition, transformation of plant and animal residues and nutrient recycling actions are hampered. This change of enzymatic activities in the soil negatively affects physical, chemical, and biological nature of soils.

Over exploitation of natural resources

Over extraction of biomass from agriculture, forestry, fishery, hunting, honey bee production and extraction of resins nearly doubled over the last five decades, while that of construction materials increased four times.. The largest increases in the extraction of biomass were observed for the extraction of food which is doubled, reaching today an extraction of 8 million tons per year. Feed extraction was quite similar to that of food extraction (WU, 2015). The cascading effects due to natural resource extraction are manifested by biodiversity loss and accelerated climate change (Butchart et al., 2010). Extraction often results in land use changes, which in turn triggers soil erosion and degradation, and also releases CO_2 into the atmosphere. Extraction of biological resources beyond sustainable limits has deep consequences on species population, population dynamics and ecosystem function (Tick tin, 2004).

In Ethiopia, organic matter and nutrient depletion due to overexploitation often occur together in the same area. These days, most farmers in Ethiopia do not return animal dung and crop residues to the farm (Zeleke et al., 2010). Organic matter depletion is driven by competing uses of crop residues and manure as livestock feed and fuel, respectively. Burning of dung cake and crop residues is common in Ethiopia due to a lack of affordable fuel wood and dung cake that account for about 50% of households' fuel supply, particularly in the north and central highland cereal zones. The use of dung as fuel instead of fertilizer is estimated to reduce Ethiopia's agricultural GDP by 7% and in some cases; manure is used as a source of supplementary cash income (Gebreegziabher, 2007). According to Sileshi and Bediye (1989), 63% of cereal straws are used for feed, while 20, 10 and 7%, respectively are used for fuel, construction, and bedding. Similarly, for crop residues, some estimates suggest that the nutrient contents of crop residues used as feed are higher than the quantities applied as fertilizers.

In addition, other studies have found that tenure insecurity leads to lower long-term investments (Ali and Deininger, 2013a, b) since less secure households may mine the soil in order to extract what they can from the land while they have it. Thus, while the government's formal land titling programme has shown some evidence of being successful (Holden et al., 2009), the programme should be scaled up and the laws behind it strengthened to ensure smallholders' land rights. This will incentivize smallholder farmers to make long term investments that improve soil fertility, make use of inorganic fertilizer more effective, and boost staple crop yields and income.

Anthropogenic soil erosion and acidification

Soils are critical for the functioning of terrestrial and aquatic ecosystems. Soils, as a natural resource, perform a number of key environmental, social and economic functions that could be destroyed by soil degradation processes (Blum, 2005). Soil erosion causes, soil nutrient loss (Lal, 2014) and reduction of agricultural productivity, leading to environmental problems such as flooding, water pollution and reservoir sedimentation (Munodawafa, 2007; Rickson, 2014). Acidification is a natural process, but human activities can accelerate the natural process of soil acidification. Enhanced soil acidification is associated with atmospheric deposition of strong acids (acid rain), as a result of emissions of sulfur dioxide and nitrogen oxides. Agricultural crop harvesting can increase soil acidification and lead to substantial loss of cation resources from naturally base poor soils (Likens et al., 1998). Repeated harvesting of forest or crop biomass, particularly under short rotation (for example, for biomass energy use), can severely acidify soils. Agricultural production systems can accelerate soil acidification via reactions associated with amendments of nitrogen, phosphorus, or sulfur. Ethiopia faces a wide set of issues in soil fertility, the major constraints include topsoil erosion with the rates estimated at 10-13 mm per annum on average and that significantly depleted organic matter due to widespread use of biomass and dung as fuel (Okigbo, 1986); depleted macro and micro-nutrients, and; depletion of soil physical properties and salinity.

In Ethiopia, soil erosion and declining fertility are posing serious challenges to agricultural productivity and economic growth (Lemenih, 2004). Several studies have shown that extensive areas of the highlands have been under serious erosion. In the mid-1980s, it was estimated that around 4% of the highland part of the country (about 2 million ha) had been so much eroded that it could not support cultivation, while 52% of the highlands suffered moderate or serious degradation (Kassie et al., 2008). Average soil loss from cultivated land varied from 21 to 42 tons per hectare/year (Hurni, 1988). The magnitude of soil loss in Ethiopian highlands (Table 10) from different categories of land use is estimated to be 1863.6 mt/year (Hurni, 1988).

Table 10. Land use type and corresponding soil loss in Ethiopia

S. No	Land use type	Area (t/km^2)	Rate of loss t/ha/year	Total loss Mt/year
1	Crop land	104.4	42	438.4
2	Perennial crop land	104.4	8	8.3
3	Pasture land	200.00	5	100.0
4	Waste land	171.3	70	1199.1
5	Uncultivable land	110.1	5	55.0
6	Forest land	127.2	1	12.7
7	Wood land	100.2	5	50.1
	Total	823.6	-	1863.6

Source: Sonneveld (2002)

Of this enormous soil loss, about 90% is deposited in valleys whereas the remaining 10% is transported with water to neighbouring countries. The degradation of agricultural land in high mountains is a serious risk to food production in Ethiopia (Bekele, 2001). It is estimated that Ethiopia loses more than 1.5 billion tons of fertile soil each year through heavy rain and flooding; this lost soil could have increased the country's crop production by an estimated 1.5 million tons (Tamene and Vlek, 2008).

Acidification occurs with other conditions including eroded topsoil and depleted organic matter, depleted nutrients, alternating drought stress and high rainfall. In moisture-stressed areas, acidification can also be caused by continuous application of acid-forming fertilizers. Approximately 80% of acidic soils are expected to derive from Nitisols (Eyasu, 2009). A study by Schlede (1989) found that 41% of land in Ethiopia is likely to be affected by soil acidity: 13 percent is strongly acidic (pH < 4.5) and 28% is moderate to weakly acidic (pH 4.5-5.5). Areas well-known to be severely affected by soil acidity include Ghimbi, Nedjo, Hossana, Sodo, Chencha, Hagere-Mariam, Endibir and Awi zones of the Amahara Regional State (MoARD, World Bank, 2007). Agricultural intensification, if it refers to the use of non-renewable, purchased inputs, such as pesticides and fertilizers, the substitution of mechanization and fossil fuels for human labour and expansion of agriculture to monocultures in an area, adversely impacts the biodiversity on- and off-farm, thereby promoting declining of soil structure and productivity for long (IPBES, 2018).

Fire hazard

Farmers and pastoralists usually use fires for different agricultural activities such as clearing farmlands, to get rid of wild animals from a particular locality, induce new re-growth of grasses for pasture and controlling disease vectors both for humans and animals, to control heavy weed infestation and, for traditional honey harvesting. Most of the fires are attended, managed and controlled by the community members who set them. However, there have been times when fires have broken out on a large scale and brought about serious economic, political, social and environmental shocks and devastation in Ethiopia (Wolde Selassie, 1998). Among the cyclic fire hazards encountered, the forest fires that broke out in 2000 were concentrated in the highlands and high forest areas that posed a serious disaster due to both the scale and type of land it affected (UN-EUE, 2001). Apart from the forest, fires also burned food and cash crops like coffee and killed livestock. Farmers, who are economically dependent on their crops and livestock, suffer extraordinarily when their agricultural production is reduced. Moreover, fire affects the environment in which it burns and may alter the ecosystem, which may have both negative and positive impacts on the land. The negative environmental impact of forest fires is caused by the release of carbon dioxide and the consumption of atmospheric oxygen, the disruption of energy flow and the cycling of nutrients upsetting the ecosystem functions, and the pollution of the atmosphere and water bodies contributing to the impaired health of organisms. Forest fires also affect soils physically, biologically and chemically and radically change an ecosystem and its biodiversity. For example, in Michata *Wereda* of West Hararge zone, lowland areas were flooded and crops washed away after the watershed lost its vegetation cover due to heavy fire-induced degradation of vegetation from Chaffe Anani watershed (UN-EUE, 2001).

The same report also indicated that Ethiopia's forest fire that erupted in 2000 had burnt 151,500 ha of forests and 130,000 beehives, the fire also damaged food and cash crops like coffee and killed many livestock species which incurs a total loss of 331,179,405 Birr.

Water depletion

Water resources are unevenly distributed across the planet. Water withdrawals have increased and caused the depletion of water resources. Excessive water extraction threatens water, alters hydrological regimes and food security (Arroita et al., 2017). Water stress due to depleted aquifers has been identified as a plausible driver of regional insecurity (Richey et al., 2015). Erosion of top soils due to a combination of cultivation of slopes with poor management, high rainfall and inappropriate drainage (water erosion), and significant loss of vegetation cover due to deforestation, overstocking, overgrazing leads to the reduced water-holding capacity of the soil, making it more susceptible to extreme conditions, e.g. drought and limited crop emergence, growth, yield and rooting depth, which in turn contributes to a vicious cycle of an increased rate of loss of organic matter (IFPRI, 2010). This leads to both losses of agricultural production and increased risks of flooding, siltation and sedimentation (Birhanu, 2014). In Ethiopia, the soil and water conservation programme started in 1970. However, it achieved limited success due to its failure in addressing the problems of local people (Worku and Tripathi, 2015). The prominent reasons mentioned were lack of community participation, ignoring indigenous knowledge, adopting a top-down approach and poor institutional collaboration. The present government taking lessons from the past, started community-based integrated watershed management programmes and is trying to avoid the shortcomings through the new policy instruments for improved livelihood and living conditions of rural communities.

Development of irrigation for a country like Ethiopia with ample land and water potential is of paramount importance to increase land and labour productivity; reduce reliance on rainfall, thereby mitigating vulnerability to variability in rainfall; reduce degradation of natural resources; increase exports, and increase job opportunities, and promote a dynamic economic growth via rural entrepreneurship (NASAC, 2014). Despite the country's potential for irrigation, however, by 2015 only 6.2 percent of the potential have been developed. For those already established, reservoir sedimentation caused by the off-site impact of soil erosion which is aggravated by land degradation and deforestation poses a threat to their storage functions. Two very important challenges affecting the sustainability of irrigation schemes include irrigation-induced soil salinization and waterlogging. These are caused either due to inadequate design of the drainage systems that takes soil formation or low irrigation water use efficiency (Abebe et al., 2015). Some of the human pressures that are responsible for the degradation of water resources of the country include catchment degradation, nonpoint source fertilizer uses and pesticide pollution; degradation of wetlands and open access to aquatic resources (Yirefu, 2017). Improved water management practices are being developed and successful cases involving smallholder farmers, have received considerable attention in recent years. Improved agricultural practices and better water management are instrumental in dealing with water stress.

Invasive alien species

Introductions of alien species (IAS) can be beneficial to feed man and his domestic animals. However, biological invasions are a global phenomenon affecting ecosystems in most biomes (Mack et al., 2000). Even though this biological invasion is a natural process, the recent accelerated rate of invasions is clearly an anthropogenic phenomenon and constitutes one of the most important effects that humans have created on the earth (Sharma et al., 2005). The threats that biological invasions pose to biodiversity and to agroecosystem-level processes translate directly into economic consequences such as losses in crops, fisheries, agroforestry, and forage species of a grazing land (Mack et al., 2000). Apart from their threats to biodiversity and ecosystem services, invasive species have significant socio-economic impacts. The weed can affect crop production, animal husbandry, human health and biodiversity (Evans, 1997). In Ethiopia, invasive species are posing negative impacts on native species, agricultural lands, rangelands, national parks, waterways, lakes, rivers, power dams, roadsides, and urban green spaces with great economic and social consequences. Among the 35 so far identified invasive alien species (Tamiru, 2017) in Ethiopia, the major socio-economically important ones include water hyacinth (*E. crassipes*), prosopis (*P. juliflora),* and parthenium weed (*P. hysterophorus*) lantana weed (*L. camara).*

The water hyacinth appeared in Ethiopia in 1965 at the Koka Reservoir and in the Awash River (Admas, 2017). Other infestations in the country include the Awash River Basin (Koka Dam), Abbay River Basin (Lake Tana, Blue Nile), Baro-Akobo River Basin (Sobate, Baro, Gillo and Pibor rivers) and Rift Valley Basins System (Lake Ellen, Lake Abaya, Lake Elltoke), and this has created serious problems for the use of the water as a resource (Stroud, 1994; Fisehaye, 2005; Tessema et al., 2009). The areas where the weed was observed are mostly river mouths and lakeshores where the nutrient condition is relatively better loaded and the water quality has deteriorated (Goshu and Aynalem, 2017). Comprehensive estimates of economic impacts of water hyacinth in the affected areas of the Ethiopian water bodies have not been done, except for the Wonji-Shoa Sugar Estate which incurred about US$ 100,000 in total from 2000 to 2013 for the control of this weed (Yirefu et al., 2014). However, the major impacts of the weed include destroying the fishery industry, irrigation, livestock watering and reduction of biodiversity, creating obstacles to navigation and ecotourism, clogging canals of hydroelectric power plants and will generally create serious environmental imbalance (Tessema et al., 2009). Attempts to combat the threat of IAS in Ethiopia have followed an unintegrated approach and have focused mainly on struggling to address the major invaders.

Prosopis was intentionally introduced as an agroforestry species in the Awash Basin, but now threatens agricultural land and protected areas in the Awash National Park. It is aggressively invading pastoral areas in the Middle and Upper Awash Valley, Borana and Eastern Hararge, displacing native trees, forming impenetrable thickets, and reducing grazing of rangeland potential. Prosopis invasion is taking over prime grazing and irrigable land in Afar Region alone. For example, *Prosopis* has adversely invaded most of the pastoral and agro-pastoral areas of Afar Regional State and Dire Dawa Administration. In Ethiopia, around one million hectares of land already are covered by *Prosopis* (Ryan, 2011), of which about 700,000 ha are located in the Afar Region (Mueller-mahn et al., 2010). In the Middle Awash, about 30,000 ha of grassland, rangelands, water points and croplands are estimated to be occupied by *Prosopis* (Mehari, 2008). *Prosopis* is now causing concern in Ethiopia. Within the last 35 years after its introduction, Prosopis alone has invaded approximately 1.17 million ha at different cover levels in the Afar Region which is 12.3% of the surface of the region (Shiferaw, 2019).

Parthenium was first reported in 1968 from Dire-Dawa in Hararge and it was introduced to the area during the Ethio-Somalia war by army vehicles (Tana and Milberg, 2000). Its infestation was also reported from Wollo, North-East and West Ethiopia (Fite et al., 2017). Since then, its area coverage is enormously increasing across agroclimatic zones of the country. Parthenium is spreading at an alarming rate in Eastern Ethiopia; the central Rift Valley, and neighbouring localities of Afar Region, East Shewa, Arsi, and Bale and in Southern Ethiopia (Bufabo, 2018).

In the Amhara region, it is estimated that about 37,105 hectares of land is infested with parthenium (Bezabih and Araya, 2002). The same source indicated that it is abundantly found in Gojjam, in the south and north Gonder with the potential to spread to agricultural districts of Metama and Setit Humera. It is also well established in many districts of south, north, and central Tigray. In one district alone, Alamata, about 10,000 hectares of the land have been infested with parthenium.

Parthenium weed has many adverse impacts on agriculture including grazing land, cereal-based agriculture and other crop lands (Tana and Milberg, 2000). This is due to the invasive capacity, allelopathic effects, strong competitiveness and health hazards to humans and animals (Tana and Milberg, 2000; Wakjira, 2009). It was reported that Parthenium causes a yield reduction up to 40-97% in sorghum if left uncontrolled throughout the season (Tana and Milberg, 2000) and this goes up to 90% in the case of forage production in grasslands (Angiras and Saini, 1997). Its invasion of Ethiopia has not only had a devastating effect on crop production but also results in grazing shortages, since the weed is unpalatable to livestock; if it is mixed with fodder, it taints the meat and milk (GISP, 2004).

Witch weeds (*Striga* spp.) are endemic parasitic weeds of sub-Saharan Africa including Ethiopia. The genus *Striga* includes over 40 species, of which 11 species are considered parasitic on agricultural crops (Teresa, 2019). The vast tropical savannah between the Semien Mountains of Ethiopia and the Nubian hills of Sudan has the greatest biodiversity of sorghum and pearl millet, the two crops that Striga readily infests. This area is recognized as the centre of origin for sorghum and pearl millet and may also be the home of the two species of *Striga* affecting cereals, namely *Striga hermonthica*, and *S. asiatica* (Teressa, 2019). It is steadily increasing their geographic domain and level of infestation, and thereby greatly reducing crop yield. It is one of the major biotic factors affecting sorghum production in several tropical and subtropical regions of sub-Saharan Africa/SSA including Ethiopia. The parasite also attacks other crops including rice, millet, and maize (Ejeta, 2007). Moreover, Badu and Akin (2011) reported that Striga could cause yield losses ranging from 20 to 80%. Yield loss of sorghum production ranging between 65 and 100% has been reported in Ethiopia and Sudan (Ejeta et al., 2002). In Ethiopia, Striga is a major production constraint in most sorghum producing areas. The weed limits the productivity of the crop by allelopathy, competition for nutrients and limiting the expression of the full genetic potential of sorghum plants (Teressa, 2019). The same source indicated that annual sorghum production loss in Ethiopia attributed to *Striga* is 25% which is estimated to be $75 million. The annual loss of all cereals due to *Striga* is $7 billion in SSA. Recent research conducted by Mesfin (2016) in the northwestern parts of Ethiopia, which represents one of Ethiopia's sorghum growing belts indicated that Striga is the number one constraint in sorghum followed by low soil fertility and drought.

Lantana weed is one of the worst invasive alien species in the world. Even though *L. camara* is spreading in other places within Ethiopia, Bishoftu, Dire Dawa, Harar and the Ethiopian Somali Region are hotspot areas for the weed (Bekele, 2018). The various colours of *L. camara* flowers helped it to be cultivated for its ornamental purpose (Tamiru, 2017) in Ethiopia, which helps the plant to spread faster than other weed plants. Furthermore, its utilization for fencing also contributed to its dispersal within the country. Loss of biodiversity and potential agricultural land; human and animal health problems and infestation of the national parks are the major identified threats the weed is posing within the country. In Ethiopian grasslands dominated by *L. camara*, native plant species composition and abundance were found to be reduced (Reda and Tewolde, 2017). Thus, under the current situation of reduction of grazing lands due to heavy grazing, the weed is capable of excluding useful forage plants and can become dominant resulting in decreased pasture productivity, carrying capacity and land values. Experimental results on major agricultural crops revealed that keeping the weed together with wheat, maize, *Teff* and haricoat bean can affect the root and shoot growth as well as on the biomass production may reduce the quantity and quality of production (Dessei, 2014).

6.4.2 Indirect drivers

Indirect natural drivers of change that affect agroecosystem and associated biodiversity as well as ecosystem services are not reported so far. The main indirect drivers, on the other hand, are of anthropogenic nature. The anthropogenic indirect drivers of change in agroecosystem include demographic (fertility, mortality, and migration), economic, socio-political, scientific and technological, cultural and religious factors. The major drivers prevailing in the Ethiopian situation are discussed in detail.

Demographic change (migration and urbanization)

The rapid change in demography, particularly population growth that causes the changes in food demand; conversion to modern and high-input agriculture; land use changes; and the globalization of agricultural markets have caused rapid loss of agricultural biodiversity, and of biodiversity in the surrounding wild land ecosystems. The population number in Ethiopia has been increasing and is more than double for the last 25 years between 1994 and 2017. The general trend of the population indicates that the annual population growth rate in Ethiopia is in a slightly declining trend (Figures 2 & 3) following the launching and implementation of the national population policy of Ethiopia in 1993 (EFCCC, 2017). The same source indicated that the declining trend in annual population growth rate and total fertility rates recorded is not significant enough to stop the rapid increase of the population, due to the hidden momentum of an already large population to grow further despite policy intervention. It is a fact that rapid population growth, especially the increase in rural population density (RPD) is still one major challenge to Ethiopia's socio-economic development including agroecosystem sustainability.

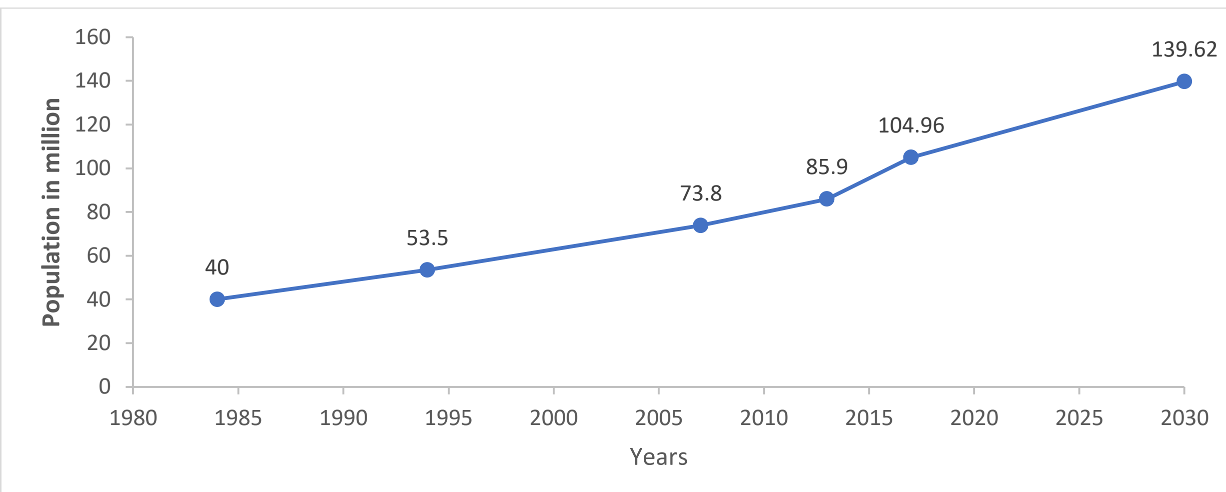


Figure 2. Ethiopian population increase (1950-2030) Source: analyzed from CSA (2007 Census) and 2012 Annual Statistical Abstract

Thus, Ethiopian subsistence agriculture has not only suffered from continuous decline of cultivated land but also from farm fragmentation which is associated with decreasing farm income on a per hectare basis, even under increasing fertilizer use (Anna, et al., 2017). Diminishing farm size leads to a reduction of sustainable land management practices such as shortening of fallow cycles and rotation, with a consequence of declining soil fertility. The decrease in soil fertility resulting from continuous cultivation and declining fallow periods caused by higher RPD incur an additional cost of fertilizer for enhancing productivity which will be the cause for further decline of farm income.

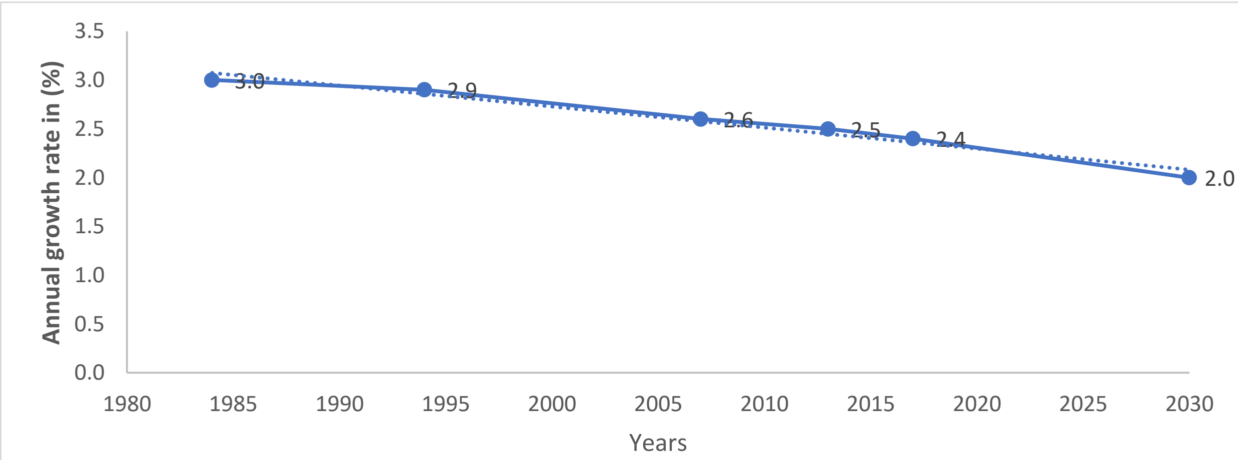


Figure 3. Ethiopian population growth rate ***Source:*** *analyzed from CSA (2007 Census) and 2012 Annual Statistical Abstract*

The increasing human population, not only influences agricultural farm size but also tremendously affects the number of livestock in the country. The number of Tropical Livestock Unit (TLU) per hectare has shown a tremendous increase in 2013 compared to 2007 (398%) (Figure 4). The increased number and concentration of livestock in a given grazing land has also induced a decline in the capacity and quality of rangelands and compromised their ability to support livestock grazing sustainably. Long years of overgrazing reduce plant cover, eliminating the most desirable forage species. This opens up the land to undesirable weeds, bushes, and trees and leads to increased soil erosion and lower soil fertility. Thus, the land becomes less and less productive.

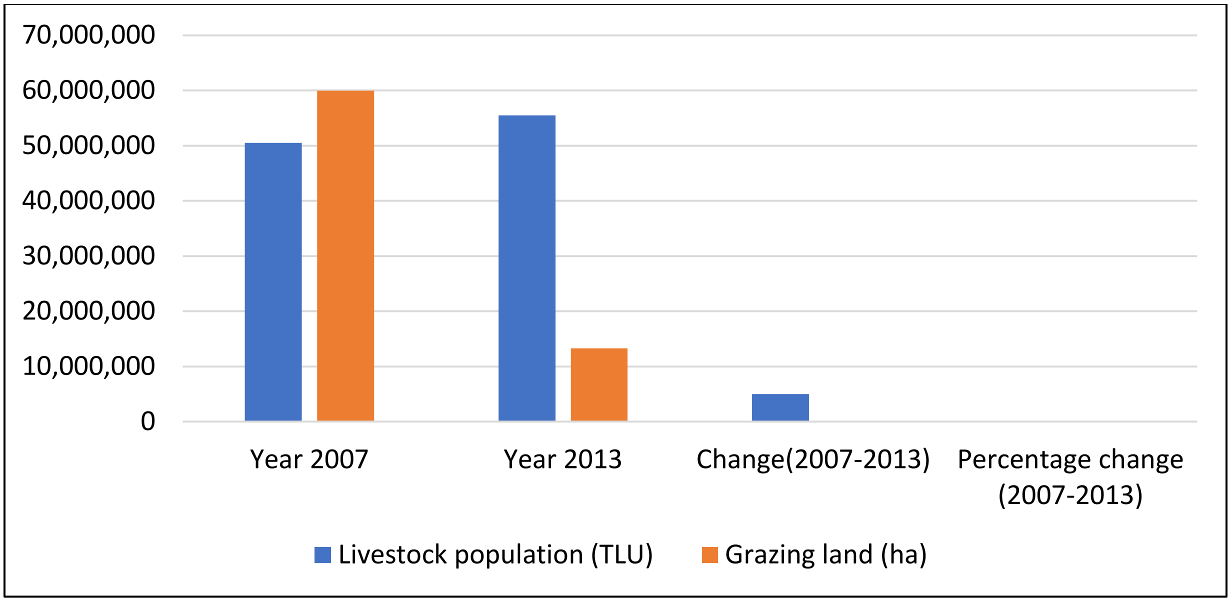


Figure 4. Change in livestock size and grazing land over years: Source: CSA (2007, 2013)

Education and rural extension

Human capital is a significant component of development, judged by many to be the largest share of the total wealth of a nation (Lange et al., 2018). More generally, the levels and types of education and extension within a nation influence economic developments and are linked to the intensity and scale of natural resource extraction , which has immense effects on biodiversity and ecosystem services. The agricultural extension ensures the dissemination and communication of important and relevant information on improved agricultural technologies and good practices to farmers with the main objective to improve their agricultural production and productivity helping farmers to reach their goals through advice, organizing farmers to collectively act, educating farmers, bringing food security, conservation of biodiversity, dissemination and sharing of useful information and promote sustainable agriculture. These become a reality through farmer participation and empowering them for better application of their indigenous knowledge.

Governments of developing countries are confronting new extension challenges: on the one hand, there is a need to increase production to provide food for all citizens, raising the income of the rural population and reducing poverty; on the other hand, there is a need to manage the natural resources including biodiversity and its ecosystem services in a sustainable way in a rapidly changing world with new technologies developed all the time (Rivera et al., 2001).

According to Albore (2018), the major challenges of agricultural extension service delivery in Ethiopia, include:

- unclear extension approach,
- gender biased service,
- suitable technology packages are not made available to the local conditions,
- frequent restructuring of the extension institutions,
- high turnover of staff,
- limitation in the quality of field and technical staff,
- inadequate budget for the implementation of the extension system,
- lack of efficient monitoring and evaluation of the extension system,
- insufficient agricultural inputs supply (seeds, fertilizer, credit, subsidies, etc.) and distribution,
- extension agents involvement on duties other than the intended responsibility,
- weak market linkage and information system,
- weak linkage of research-extension and farmer,
- absence of public private partnership in extension service delivery, and
- indigenous knowledge of the local people is overlooked.

Through agricultural education and rural extension services in Ethiopia have been implemented to bring improvements in the agricultural production and productivity through conservation of natural resources, the outcome remained so limited in some localities and restricted to few crop Varieties. The farmers are still at the subsistence level of production and sometimes the application of the agricultural extension services results in the degradation of the natural ecosystems and loss of local landraces and breeds of animals through indiscriminate cross-breeding and replacement.

Indigenous and Local Knowledge

Indigenous and local knowledge is increasingly seen as relevant for sustainable resource use, not only for indigenous people and local communities (IPLCs) but also to the wider community at large. While there are differences between indigenous and contemporary knowledge with respect to history and characteristics, still they share quite a substantial overlap, as seen today in the convergence around agroforestry and multiple tree-cropping systems of smallholder farmers within many regions (Agrawal, 2014). Even in the formal systems, there are cases in which traditional knowledge and formal education were successfully integrated using local language and culture informal education, motivating traditional knowledge transmission (Ruiz-Mallen, et al., 2013). ILK systems are highly diversified, productive and complex. For example, in many developing regions of the world including Ethiopia, the principle of crop rotation in agriculture is well known and contributes to landscape heterogeneity. The land is periodically fallowed or "rested", and often planted with species that help restore soil fertility. Throughout arid and semi-arid regions of Africa, traditional herders followed migratory cycles, rotating grazing land seasonally and in some cases, also rotating adjacent grazing areas in the same season (Gadgil et al., 1993). Farmers have in place indigenous knowledge-based contingencies, which have proven to be successful over time, to deal with eventualities such as endemic diseases of livestock.

Cassini et al. (2008) observed in Ethiopia that livestock farmers reduced the use of modern veterinary vaccinations when they were required to pay for the full cost of the drugs, by reverting to the use of traditional medicines for their livestock treatment. A similar observation made by Dixon (2001), while working in Ethiopia, identified that farmers have in-depth knowledge about managing wetlands that included extending crop growing seasons and maintaining soil fertility. Studies on indigenous knowledge and practices of forest conservation among forest-dependent Manja and Malla communities in Tocha District of Southern Ethiopia revealed that members of the community are highly attached to their forest because of religious and cultural affairs, their beliefs, rituals and sacrifices took place under certain bigger trees such as *Prunus africana*, *Olea capensis*, *P. falcatus* and *Acacia sieberiana.* Indigenous soil conservation mechanisms of the Konso farmers include terracing, contour ploughing, crop rotation, fallowing, surface mulching, fertilization, agroforestry and crop field/farm boundaries are witnesses of hundreds of years of persistent human struggle to harness the hard, dry and rocky environment (Mulat, 2013). However, in many communities, indigenous knowledge and practices are declining (Forest Peoples Programme, 2016). Changes in both values and knowledge of people can be driven by schooling and other learning mechanisms that facilitate exchange and interaction. Formal education can remove children from the everyday lives of families from opportunities of learning traditional knowledge and experiencing the local practices during periods of formal education that usually takes place away from homes (Reyes-García, et al., 2020), the transmission of which relies on observation, participation and imitation in families and wider local communities.

The Gedeo agroforestry system has many unique features. Its uniqueness emanates from its exclusive reliance on indigenous knowledge (Sileshi, 2016). It is not a supplementary production system in which only fruit and vegetables are grown to supplement field-grown staple crops. Instead, it is a principal livelihood system in which all forms of crops, including staples, cash, and supplementary crops grow together. The system also supports a population of close to 900 persons/km^2. The main component of crops, *Enset* (*Ensete ventricosum*) and coffee (*Coffea arabica*), are the pillars of food security in the system. Negash (2013) mentioned that the Gedeo agroforestry system can host diversity as high as 50 woody plant species belonging to 35 families in each plot of 100 m^2. Thus, it allows the perpetuation of both production and protection functions. However, the wrong perceptions on the productivity of the system, as well as the expansion of monocrops driven by market forces have challenged its survival. If these are not quickly and properly addressed, Ethiopia will lose the indigenous Gedeo agroforestry system, leading eventually to a great loss of agrobiodiversity and socio-ecological benefits (Sileshi,2016).

Most of the ILK in Africa is transmitted orally and it is not well studied, documented, and disseminated for wider access. It is also not institutionalized (albeit the existence of some indigenous institutions) and mainstreamed to different development agendas (Jagawe, 2007; Mulat, 2013). Therefore, it is difficult to obtain the knowledge in order to incorporate it in the educational curriculum for formal transmission from one generation to the next. In this way, even the development and subsequent improvement of the knowledge can be difficult. Moreover, the development sectors geared by western science miss the local embeddedness of indigenous knowledge and practices and try to use the scientific knowledge in a top-down approach without contextualization (Jagawe, 2007; Mulat, 2013).

On the other hand, since the introduction of courses in ethnobiology/ethnobotany to Ethiopian universities starting 1997 (Asfaw and Wondimu, 2007), a considerable amount of graduate and staff research has been focusing on systematizing indigenous biological and ecological knowledge gathered from the field (Adal, 2017) that is gradually bringing the ILK to the formal system and this trend must move on. However, there are ethical issues that need to be considered when indigenous knowledge is used in research and development that is being taught in ethnobotany/ethnobiology courses and practiced in corresponding research utilization of the outcomes as per the access and benefit sharing law of the country. The ownership of most of the research conducted sometimes remains with the researcher who patents the findings. The indigenous people are used only to generate data and have no knowledge of the outcome of the data they have produced. In addition, researchers who are working on ILK have no formal training on IK system epistemology which is how to gain knowledge, barriers, knowledge network systems, methods, use, etc. and the future direction needs to improve such drawbacks (personal communication). This renders its preservation and further application difficult (Jagawe, 2007). Understanding the situation, the Ethiopian government put in place "Access to Genetic Resources and Community knowledge, and Community Rights Proclamation, No. 482/2006" which has been playing a pivotal role in protecting the rights of the community and helping them to benefit from the use of genetic resources which they have cultivated and maintained over a generation.

6.4.3 Interactions among direct and indirect drivers of change and their impacts on agroecosystem

Agroecosystem delivers diversified consumptive values, including food, agriculture, medicine, industry. They have also aesthetic and recreational values. Increasing human demand for food, water, and energy caused by increases in population, per capita Gross Domestic Product and international trade have negative consequences on nature and its material, and none material benefits to people (Bustamante, 2018). Population growth, for example, leads to expanding human settlements and increasing demand for food, fuel and building materials. These in turn can cause overexploitation of resources. This has been manifested in Ethiopia where, decades of Ethiopia's demographic change, with a high proportion of young adults, rapid urban population growth; diminishing levels of per capita cropland and rapid migration have contributed to over-farming and deforestation, which have degraded biodiversity and undermined development (Sahlu, 2004). Land shortage and poverty, taken together, lead to non-sustainable land management practices. For example, without firewood, many resorts to burning animal dung, instead of using it to fertilize the deteriorated soils; without trees to help hold the soil in place; the soil erodes from the steep highlands. As a result, many previously habitable areas have now been transformed into drylands and deserts. Ethiopia's unsustainable population growth contributes not only to its dire economic and social situation but also to the country's environmental degradation, especially in the densely populated highlands. When accompanied by rapid economic and technological advances, population growth can actually contribute to national development (Birdsall et al., 2001). However, Ethiopia's population growth compromises its ability to achieve the productivity gains necessary to break the cycle and eradicate extreme poverty and hunger. Moreover, the limited success achieved to transform Ethiopia's agriculture through modernization of agriculture not only affected the envisaged economic transformation, but also threatens valuable local crop species and animal breeds. Although the government has invested huge sums of public money in setting up the institutional framework for the national agricultural research, education, and extension systems, there seem to be no strong functional linkages among them (Zeleke et al., 2006). Moreover, poor coordination among research, extension and education has affected formal technology development and transfer of technologies from researchers to local level experts and communities, particularly the farmers. Thus, the major factors that drive indirect drivers that also accelerate the impacts of direct drivers include lack of awareness of the people to control the increasing population size, lack of better health coverage, relatively better economic growth, top-down planning of the extension approach, weak linkages among various disciplines, lack of effective implementation of policy and legislation, incomplete technology packages and lack of full participation in resource management (Gebretsadik, 2016).

Agricultural systems have been managed, above all, for the production of food and fibre. More than these, however, agricultural landscapes can provide a wide range of goods and services to society. As both major providers and major beneficiaries of ecosystem services, agricultural landscapes and the people within are at the centre of the paradigm shift due to the relationship between humans and ecosystems in this managed ecosystem (Daily, 1997; Kremen, 2005). Factors that drive the direct drivers come from varying mixes of economic, institutional, technological, cultural, and demographic factors underlying the direct causes of the degradation of the agroecosystem. These are simply the indirect drivers of change that aggravate the effects of direct pressures. For example, the conventional agricultural intensification usually occurred through substantial use of purchased inputs, especially fertilizer, in combination with new plant varieties that respond well to the increased inputs. When it is coupled with the development of markets and transportation infrastructure, as well as changes in credit and price policies can help to boost food production. However, these in turn can be the causes of habitat degradation, acidification, soil erosion and loss of agrobiodiversity. Similarly, population and income growth interacting under excessive use of advanced technology that led to observed changes in climate, especially warmer temperatures, have an effect on biological systems such as changes in species distributions, population sizes, and the timing of reproduction or migration events, as well as an increase in the frequency of pest and disease outbreaks (Nelson et al., 2006). Changes in precipitation patterns are projected to change most arid and semi-arid areas becoming drier and whereas with an increase in heavy precipitation events, leading to an increased incidence in floods and drought. The land has been under state ownership in Ethiopia since the 1975 national land reform, and there have been many redistributions and readjustments since then. Many researchers believed that the frequent land reallocation has been a source of tenure insecurity and a disincentive for the farmers to invest in conservation agriculture (Ahmed et al., 2002).

6.4.4 Drivers of change focused on agroecosystem thematic areas

6.4.4.1 Drivers of change on land-use

Humans change land use through expansion, fragmentation, and intensification to alter the mix of ecosystem services provided by that land. Sometimes the land conversion effort is intentional, such as changing grasslands to agricultural land. In other cases, land conversion is a consequence of other activities. For example, salinization is the unintended consequence of irrigation that does not have adequate drainage. Dryland degradation, also called desertification, has affected parts of Africa, for one or two centuries. Grasslands and rangelands are important repositories of biodiversity (Wilson et al., 2012), and play an important role within the global carbon cycle, as their accumulation rates are high, and the decomposition of organic material is slow (Gibson, 2009). Deforestation and overgrazing have severely degraded these lands endangering ecosystem services and functions (Gang et al., 2014).

The development and diffusion of scientific knowledge and technologies have profound implications for ecological systems and human well-being. For example, due to the emergence of agricultural technologies like Mendelian genetics, the green revolution, application of excess external inputs and the development of pest resistant crop varieties as well as the development of genetically modified organisms that brought important changes in agricultural development linked to new opportunities as well as risks (IPBES, 2018). For example, agricultural intensification that refers to the use of non-renewable, purchased inputs, such as pesticides and fertilizers, the substitution of mechanization and fossil fuels for human labour, and high capital invested per unit of land and expansion of agriculture in an area adversely impacts the biodiversity on- and off-farm, thereby promoting species extinction in managed and constricted wild land habitats (Jackson et al., 2005). Moreover, due to agricultural intensification and a shift to monocultures, there is an enormous increase in pesticide and fertilizer use which causes a significant decline in the cultivation of native varieties of crop and animal genetic resources in many regions of the world, especially developing countries. Studies showed that more intensive land use leads to progressive change in ecosystem functions, in some cases leading to irreversible changes accompanied with land abandonment (IPBES, 2018).

In Ethiopia, unsustainable and inappropriate land management is the main cause of physical, chemical, and biological degradation of cultivated land, grazing lands, and forestland. Vulnerability to degradation can arise from the number of ploughing times (3-6) during field preparation depending on the crop type; the absence of contour plough, terracing or perennial crops which grow throughout the year and the lack of use of manure or crop residue to increase soil fertility through organic cycling (EFCCC, 2017). Cross ploughing is practiced because the traditional plough in Ethiopia, called *Maresha*, cannot be efficiently used over the same line of ploughing in consecutive tillage operations (Gashaw et al., 2014). Moreover, Lemenih (2004) argued that land degradation is a biophysical process driven by socio-economic and political causes in which subsistence agriculture, poverty, and illiteracy are important causes of land and environmental degradation in Ethiopia. Nonetheless, Gebreyesus and Kirubel (2009) reported that the heavy reliance of some 85 percent of Ethiopia's growing population on an exploitative kind of subsistence agriculture is a major reason behind the current state of land degradation. Similarly, studies conducted by Gashaw et al. (2014) in Dera District, Ethiopia, exemplified the increase of land degradation which is mainly caused by the growing population of the area. Fitsum et al. (1999) also illustrated that there are multiple interacting forces that have caused and are causing land degradation in Ethiopia. Moreover, pastoralists in semi-arid areas are also losing their livelihoods as their grazing areas are being used for other purposes like irrigated cropping, rain-fed farming, nature reserves, and wildlife parks (Philipson et al., 2011).

Loss of soil fertility and increased moisture stress result in low crop yields and high levels of poverty. There is inadequate knowledge on watershed management and other related sustainable land management practices to allow informed decision- making at all levels. All these intertwined factors represent constraints for making progress in reducing land degradation and enhancing agroecosystem services through the proper execution of sustainable land management (SLM). Land shortage and poverty, taken together, promoted non-sustainable land management practices. Subsistence farmers are led to clear forests, cultivate steep slopes, overgraze rangelands, and exercise irregular fertilizer applications. Farmers become reluctant in their commitment to land resources conservation if their future rights to use these resources are not secure (Ali and Deininger,2013b). Enforcing the land use policy and solving the land tenure issue should be included as a component in sustainable land development efforts.

6.4.4.2 Drivers of change on agrobiodiversity

It is important to analyze pressures that cause changes in agroecosystem functions and services delivered focusing on major agrobiodiversity thematic areas such as field crop and horticulture, livestock, agroforestry and pollination facets of the agroecosystem.

Drivers of change on field crop and horticulture diversity

Ethiopia is one of the Vavilovian centres of origin and diversity for over 20 cultivated crops (Vavilov, 1951; Westphal, 1975). The farming communities are engaged over the millennia in the domestication and hybridization of crops that suit different agroecosystem sub-types and local tastes. Many crop wild relatives are found growing like weeds on marginal fields, traditionally managed agricultural lands and in disturbed habitats such as roadsides. Both natural and managed agroecosystem delivers important agroecosystem services such as the production of food and fibre, the capacity to store carbon and to recycle nitrogen, and the ability to change in response to climate and other disturbances. Nevertheless, changes in the structure and function of agroecosystem resulting from biodiversity alterations and loss can reduce the availability of vital services and affect the aesthetic, ethical and cultural values of human societies. Ethiopia is in a state of rapid environmental, social, and economic changes and the pace of these changes will accelerate during the next decades with an increasing trend of the human population. To meet this increasing demand for food, production systems are expected to rely progressively on heavy inputs of fertilizers, pesticides, water and the so-called improved varieties. These have been the causes of the dwindling of crop species, varieties, and other horticultural categories. Displacement by the improved varieties is one of the causes for the gradual loss of landraces of both plants and indigenous livestock breeds. The natural populations of many species of crop wild relatives are increasingly threatened due to degradation, fragmentation and finally to loss of habitat. Climate change is also posing significant impacts on species distributions by reducing suitable habitat and increasing the rate of habitat fragmentation (EFCCC, 2017). Climate change is also becoming the cause for risks of frost damage as it has been observed in Gedeo and Sidama zones by 2017. Climate change affects the production and productivity of the crop sector by decreasing soil fertility, increasing pests and crop diseases, and aggravating the lack of access to inputs and improved seeds. Moreover, it affects by creating frequent drought, floods, and poverty (Mahmud et al., 2008).

In Tigray region, for example, farmers' varieties of wheat (locally called *Shehan*, *Gerey* and *Gomad*), barley (D*emhay* and *Gunaza*) and sorghum (*Gedalit*) have been locally lost due to wider use of improved varieties (EBI, 2015). According to this source, about 77% of durum wheat diversity is replaced by improved varieties in Eastern Shewa, mainly due to displacement by bread wheat varieties, which took place gradually in a time of three decades (EBI, 2015). This gradually led to the loss of agricultural biodiversity resulting in loss of ecological, economic, nutritional, and cultural benefits, and increased vulnerability to climate change and food insecurity. A case study made in the Tigray region showed that 133 (91.10%) crop varieties were reported to be lost mainly because of replacement by improved varieties (Reda and Mesfin, 2017).

In addition to the provision of service-providing organisms, such as pollinators and natural enemies of crop pests (Macfadyen et al., 2015; Ricketts et al., 2008), the natural or semi-natural habitats in agroecosystem could also be sources of disservice-providing organisms like weeds, pathogens, and pests (Zhang et al., 2007; Lemessa et al., 2013). Agricultural management practices such as the large-scale intensification of farmland, including larger field sizes, removal of non-cropped areas and high agrochemical input have caused a major decline in farmland biodiversity (Tscharntke et al., 2005). The decline in biodiversity affects humanity in many ways. For example, the decline in service providing organisms, such as pollinators, has raised concern about food security and stability of food production, since many crops are pollinator-dependent (Klein et al., 2007; Potts et al., 2010). According to Rehima et al. (2013), diversification of crop varieties in the Ethiopian situation are dependent on gender, education, trade experience, membership in cooperatives, resource ownership, features of the land owned, and access to extension services. Based on these findings promotion of female participation , investment on formal and informal education of farmers, and improving the extension system can help in the diversification of crop varieties.

Crop pests, including seedeaters, herbivores, frugivores, and pathogens (e.g. Insects, fungi, bacteria, and viruses), can result in reduced productivity, or total crop loss in the worst-case scenarios (Zhang et al., 2007). Weeds and other non-crop plants can reduce agricultural productivity through competition for resources. At the field scale, weeds compete with crops for sunlight, water, and soil nutrients and may limit crop growth and productivity by limiting access to the critical requirements (Welbank, 1963). This situation is highly aggravated in the face of climate change. Within fields, plants may exhibit allelopathy (biochemical inhibition of competitors), such as the toxins exuded by some plant roots that can decrease crop growth (Weston and Duke, 2003). As in all tropical countries, insect pests are major problems in Ethiopia, often causing considerable crop loss. Thus, a checklist of about 70 insects that are major, minor, or sporadic pests of cereals are registered as economically important species in the country (Hein, 1989) whereas Stroud and Parker (1989) listed 107 major economically important weed species of Ethiopia. For example, Duressa (2018) identified the maize, mango and ginger producing Western Oromia zone is becoming at risk due to the recently introduced pests such as Maize Lethal Necrotic Virus Diseases (MLN), Leaf and Fruit Spot of citrus (*Pseudocercospora angolensis*), Bacterial wilt (*Pseudomonas solanacearum*) of ginger, Tomato leaf miner of tomato (*Tuta absoluta*) and White Mango scale insect (*Aulacaspis tubercularis*). Because of these pests' severe damage, up to 95% loss of mangos and a serious yield loss on maize was observed that in turn causes food insecurity of many smallholder farmers. Resource competition that potentially weakens agricultural yields can also take place at larger scales. Competition for pollination from flowering weeds and other non- crop plants beyond agricultural fields can reduce crop yields (Free, 1993). Water used by other plants, such as trees that reduce aquifer recharge, can reduce water available to support agricultural production by diminishing an important source of irrigation water (Zhang et al., 2007). Food safety concerns related to pathogen outbreaks are other potential detractors from agricultural productivity. Since the 1990s these concerns have gained some prominence in highly productive areas of the world, which experienced *Escherichia* *coli* contamination of leafy greens. The unfortunate consequence has been broad-scale removal of riparian habitats to minimize wildlife intrusion into crop fields. Wildlife was posited to spread harmful bacteria, although whether it constitutes a significant food safety risk remains unclear (Gennet et al., 2013). This habitat removal may result in degradation or loss of the ecosystem services typically provided by riparian areas to agroecosystem.

It is important to note that disservices from agriculture can also affect the productivity and environmental impacts of farming systems through multiple feedbacks. For instance, when the habitat for natural enemies is removed, pest outbreaks can result in crop damage or loss, resulting in reduced productivity and potentially increased use of pesticides, which may be accompanied by further detrimental effects (Herrero et al., 2012). Similarly, when riparian habitat is degraded or removed, the hydrologic services of water flow regulation and water purification services can be diminished or lost. Swinton et al. (2006) suggest that incentivizing a system approach to agricultural management rather than a problem response approach could support sustainable production as well as ecosystem services such as climate regulation, wildlife conservation, biological pest control and pollinator management.

Drivers of change on livestock diversity

Ethiopia is rich in livestock genetic resources, both in diversity and population. It is the home of diverse animal genetic resources due to its diversified agroecological zones, topography and its proximity to the gate of Asia which was the potential origin of most domesticated farm animals of Africa. Livestock, especially, the indigenous breeds have diverse functions ranging from the provision of food and income to society and support many social and cultural functions. Livestock have many ecological roles. Nutrient recycling is an essential component of any sustainable farming system and thus the integration of livestock and crop allows for efficient nutrient recycling. For example, animals use crop residues, such as cereal straws, as well as maize and sorghum stovers as feed. The manure produced from the livestock can in turn be recycled directly as fertilizer. Moreover, indigenous cattle breeds of Ethiopia have adaptive traits to drought, ticks and tick-borne diseases, like trypanosomiasis in case of Sheko breed; and adaptation to thrive in waterlogged areas in case of Fogera breed. However, human population growth and the subsequent high demand of livestock products are influencing Ethiopia’s livestock system that necessitates an increase in the productivity of animals. Improving the genetic potential of the country's livestock is one of the key measures taken by the government policy using quick win genetic-based technologies including artificial insemination (AI) and oestrous synchronization that have significant contributions to transform value chains of cattle, small ruminants and poultry. The genetic distinctiveness among most Ethiopian local livestock breeds is largely unknown while the identified ones are under severe threat due to crossbreeding, change in the production system, inbreeding, and lack of institutional capacities that support the improvement and sustainable use of indigenous livestock resources. There is also a limited awareness about the importance of conservation and sustainable use of animal genetic resources (AnGR) among decision-makers and major stakeholders in the livestock sector (FAO, 2006).

Information on the identification and characterization of the livestock resources of Ethiopia is not exhaustive. As a result, breed level data is far from complete and not up-to-date for most of the breeds and making the determination of the status and trends becomes more difficult. There are, however, some indigenous breeds are found at different threat levels. For example, Sheko, the only taurine breed in East Africa; and Fogera cattle appear to be highly threatened because of interbreeding with other local breeds and changes in the production systems in their specific agroecosystem. In addition, Begait, Irob, Ogaden, Afar, and Borena cattle breeds; Sinnar donkey, and Afar, Menz, and Gumuz sheep breeds are also facing various degrees of threats (EBI, 2015).

The paradigm shifts in the production system and land fragmentation situation forced the transformation of transhumance way of cattle management to sedentary farming which is the cause for the decline in population size at the household level, increased admixture and replacement of recognized breeds. The decline in population size and deterioration in its genetic merit of Fogera cattle breed in the Lake Tana belt is due to a paradigm shift in the production system mainly from transhumance livestock dominant crop-livestock production to crop dominant crop - livestock production (Kebede et al. 2014). Sheko cattle breed is also endangered (Hanotte et al., 2000; Taye, 2005). Molecular genetic evidence showed that about 90% of the sampled Sheko bulls have had their specific *taurine* allele replaced by *indicine* allele confirming an alarming introgression of Zebu genes (Hanotte et al., 2000). Moreover, the heterozygosity level observed in Sheko cattle was lower than expected, indicating the problem of inbreeding, and the total number of alleles found in Sheko cattle was the least compared to other contemporary Ethiopian breeds (Dadi et al., 2008).

Increasing demand for the export market of cattle, goats, sheep, and camels seems to threaten the animal genetic resources (AnGR). Generally, the domestic AnGRs are threatened by feed shortage, overgrazing, encroachment of invasive species; and expansion of crop cultivation into grazing lands and into marginal areas. Moreover, the high prevalence of Trypanosomiasis due to climate change has shown its impacts on livestock fertility in the lowland areas of Ethiopia (IFAD, 2009). Additional threats emanate from crossbreeding, interbreeding, diseases and parasites, shortage of water, and poor housing. Particularly, the gene pool of indigenous chicken breeds is under pressure from replacement by pure exotics and their hybrids (IBC, 2012). Furthermore, vegetation loss, diseases and pests, predators, and pesticide and herbicides (IBC, 2005, 2012) threaten honeybee species in the country.

Drivers of change on agroforestry system

Successful small to medium-scale agroforestry projects have already proven that agroforestry can restore degraded lands and improve food security in southern Ethiopia, Tigray, Oromia and Amhara, among other parts of Ethiopia (Hassan et al., 2015). In contrast to monocultures in conventional agriculture, the combination of crops with trees in agroforestry systems provides an array of positive effects, especially in regard to soil protection, erosion prevention and biodiversity conservation. These systems proved to provide farmers with yields from ample sources whilst maintaining the land with a sustainable practice (Hügel., 2017). All forms of agroforestry are ultimately inspired by natural ecosystems. They endorse the combined cultivation of mixed species to broaden the spectrum of products and increase the resilience of the system against an increasingly changing climate, pests and erosion. However, agroforestry comes with a number of challenges, mainly due to its strong difference from conventional agriculture both from an ecological and legal point of view.

From an ecological point of view, agroforestry is a much more complicated system as compared to the conventional, simplistic monoculture system. Agroforestry involves the concurrence of trees and crops or pasture, each of which competes for nutrients and water. This phenomenon according to Jose et al. (2000) causes water and nutrient stresses on the alley crops and this in turn needs to apply some management practices such as digging a trench and choosing appropriate tree and crop species mixes (Newman et al., 1997). Additional methods for managing trees, like trimming the branches and cutting the roots of adjacent crops will be needed as well. Furthermore, as the range of products gets extended by tree crops, biomass, timber, etc., the management of harvesting, processing and marketing will increase in complexity as compared to a simpler monoculture practice. Moreover, the impacts of wild animals on the harvest of crops are other factors that need careful management in this system.

From the legal framework point of view, a regulatory framework concerning either agriculture or forestry is not simple to adjust to deal with agroforestry systems. The mandate of agroforestry currently spreads across various ministries and departments at the national, state, and local levels of the Ethiopian government. For example, it is established as a directorate in Environment, Forest, and Climate Change Commission (currently, it is named as Environment Protection Authority/EPA) and as well as in the Ethiopian Environment and Forest Research Institute (recently moved to the Ministry of Agriculture). However, there is no coordinated implementation framework, no harmonized single National Agroforestry Policy, no real vision, and no specific scheme to promote the practice among the country’s farmers (Hassan, 2011). Additionally, the farmers’ right to adopt various agricultural approaches and the issue of awareness raising of farmers, extension agents and local level decision-makers are important factors that need to be considered in order to assist this system to function properly.

Even though the comparison of conventional farming and agroforestry in terms of productivity cannot be concluded, agroforestry effectively mitigates several pressing global environmental issues , including soil erosion, climate change, biodiversity decline, food insecurity, water depletion and pesticide contamination, all of which are at least partly a direct consequence of conventional modern farming techniques (Hügel, 2017).

Drivers of change on pollination services

Many flowering plants cannot set seeds or fruits without fertilization. Similarly, fertilization cannot occur before the pollen comes into contact with the stigma. Many factors such as the flower physiology and morphology, pollinator characteristics, as well as effects of weather, influence the success of pollination. The area of pollinator-dependent crops has increased disproportionately compared to other crops and the trend is more pronounced in the developing countries compared to the developed world (Aizen et al., 2008). Therefore, pollination is an important input in crop production to improve crop quantity and quality.

Animal pollination is affected by many different species ranging from vertebrates, including bats to invertebrates such as insects. Insects provide more than 86% of the animal pollination in crops, of which bees are the main pollinators worldwide (Ollerton et al., 2011), but only about 15% of the world's crops are pollinated by a few managed bee species, while the rest are pollinated by unmanaged solitary bees and other wildlife (Alemberhe and Gebremeskel, 2016). However, there are reports of declining bee populations, both domesticated honeybees and wild bees (Potts et al., 2010). Global loss of pollination services resulted in a $302 billion reduction in the value of production across all sectors and regions representing a 0.39% decrease from the 2004 baseline (Bauer and Wing, 2011 Many natural and human made challenges cause a decline of many groups of pollinators. This was mainly due to human-induced impacts such as habitat destruction and fragmentation, land-use change, non-targeted use of pesticide~~s~~ and herbicide~~s~~ chemicals, climate change, and invasive alien species (Kearns et al., 1998). Human activities including changing diversification to monocultures, overgrazing, land clearing, irrigation that modify their habitat in the area of agriculture affect the population of bees and other animal species and their abundance (Richards and Kevan, 2002). There are also natural factors that reduce bee population such as drought, flooding, pests, fire and other diseases through the negative effects on bee forage, nests and on individuals, or a mixture of these (Alemberhe and Gebremeskel, 2016).

Moreover, studies carried out in East Gojjam Zone revealed that farmers have very little knowledge on the ecological and economic value of insect pollinators, whereas they (77% of 131 interviewed farmers) perceived that insects destroy their crop, leading to loss of productivity which has a negative implication for pollination and insect pollinators (Misganaw et al., 2017). The increased demand for pesticide uses in the agriculture and flower farms is creating grievances by beekeepers. For example, a study conducted by Desalegn (2015), in three districts of the Amhara region (Guangua, Dangila and Mecha) revealed that a total of 5209, 12109 and 5669 bee colonies were recorded died, absconded and dwindled respectively by the effects of pesticides and herbicides used in the areas. This when calculated based on average colonies per district in Ethiopia, having 10 million colonies of honeybees, about 28.65%, 66.6% and 31.2% of the colonies respectively were lost in that particular year. Subsequent analysis of financial loss incurred due to the dead, absconded and dwindled honeybee colonies was estimated to a total of about 819291.4 USD (Desalegn, 2015).

6.5 Level of awareness and knowledge about nature's benefits, the status and management of biodiversity and ecosystem services

Nature's benefit to people is described by the human-nature interactions of biodiversity and ecosystem service. Understanding the level of awareness and knowledge about this interaction will provide an evidence on the benefits and cost of reducing nature's benefit. Following Agrobiodiversity Knowledge Framework (Zimmerer et al., 2019), the level of awareness and knowledge is synthesised on (1) ecology and evolution; (2) management and governance; (3) food, diet, nutrition, and health; and (4) global environmental and socio-economic challenges.

6.5.1 Ecology and evolution

The level of awareness and knowledge on the biological, ecosystem, and evolutionary values (and associated economic purposes) that range from genetic resources to agroecosystem goods and services is well established in the earlier works on crop and livestock evolution, plant geography and genetic resources. Ecological and evolutionary research has reflected Ethiopia's agricultural landscape as the centre of origin as well as the center of diversity for many crops, evolved through a series of human domestication and hybridization to suit local tastes and cope with the effects of changing environmental conditions. This diversity is embodied in the wisdom and experience of the hundreds of generations of farmers who have selected and managed crop populations since the Neolithic Revolution, some 5000 to 8000 years ago (EPCC, 2015).

Knowledge on agrobiodiversity occurrence, biogeographic patterns, and population genetics is developed through designing *ex-situ* conservation in genebanks at the national scale and *in-situ* conservation through the continuation of on-farm production, local and regional consumption, and agroecosystem functioning. Both *in-situ* and *ex-situ* conservation sites have been established by EBI and a significant amount of crop and animal genetic resources is maintained in the facilities/sites. Through the *in situ* approach, it has become possible to conserve 64 varieties of 34 species of crop and horticulture genetic resources in 27 sites. Similarly, 13 breeds of domestic animal resources are conserved in 13 sites. Genetic resources in the form of seeds, semen, and microbial species have been conserved *ex-situ* in cold rooms while more than 6200 accessions of life plant species, including Arabica Coffee are conserved in field gene banks (EFCCC, 2018).

Knowledge is also developed through the characterization, estimation, and monitoring of the status and levels of agrobiodiversity at key spatial scales. For example, state of knowledge for 28 breeds of cattle, 9 breeds of sheep, 8 breeds of goat, 7 breeds of camel, 6 breeds of the donkey, 8 breeds of horse, 2 breeds of the mule, 7 ecotypes of chicken and 5 geographical races of honeybees has been established so far. Most of these genetic resources are indigenous breeds where few exotic cattle, sheep, goats and chicken breeds have been introduced by different institutions in the last four decades (EBI, 2015). However, little is known on the indigenous farm animal genetic resources and associated indigenous knowledge, innovations and practices relevant to the conservation of the genetic resources and sustainable use of their components. In addition, data on breeds' phenotypic characteristics are often lacking, constraining their use in breeding programmes.

Genetic and genomic marker technologies are supplying new advances to establish knowledge on genetic diversity thereby enabling breeders to utilize the germplasm collection to improve existing commercial cultivars. Research on this used genotyping by sequencing (GBS) to identify single-nucleotide polymorphisms (SNPs) and estimate the level of genetic diversity, population structure, and phylogenetic relationships. Further phylogenetic tree and principal-coordinate analysis (PCoA) and genome-wide association (GWAS) mapping analysis are increasingly employed to detect genetic markers in crop biodiversity (Solomon et al., 2019). Similar methods are employed to establish animal diversity (Gizaw et al., 2007; Zerabruk et al., 2011).

Research on agrobiodiversity demonstrated the essential values of biodiversity to ecological, evolutionary, and environmental services in a diversified farming system. For example, diversity is considered as a form of 'biological insurance' that helps to assure ecosystem performance, including providing ecosystem services. As diversity increases, the chances that one or more species will be able to perform critical functions, there by stability in the agricultural system. Maintaining a larger number of barley varieties in Tigray (northern Ethiopia) supports productivity and reduces the risk of crop failure; thus, conserving landraces in the field provides important productive services and allows farmers to mitigate some of the negative effects of harsh weather and agro-ecological conditions (Di Falco and Chavas, 2009). Similarly, Ethiopia is a center of diversity for durum wheat and farmers manage complex variety mixtures on multiple plots, where variety richness strongly increases expected revenue from wheat and can reduce the cost of risk, especially for high levels of diversity (Di Falco et al., 2007).

6.5.2 Management and governance

Agricultural ecosystems are actively managed and governed by humans to optimize the provision of food, fibre, and fuel. Agriculture also receives ecosystem dis-services that reduce productivity or increase production costs. The flows of these services and dis-services directly depend on how agricultural ecosystems are managed and upon the diversity, composition, and functioning of remaining natural ecosystems in the landscape. Managing agricultural landscapes to provide sufficient supporting and regulating ecosystem services and fewer dis-services requires management options that are participatory, policy-relevant, and multidisciplinary (Zhang et al., 2017).

The governance of biodiversity and ecosystem services in agroecosystem refers to the government policies, strategies and institutional frameworks put in place to manage agrobiodiversity. The major governing instrument that formally employed in recent days is the National Biodiversity Strategy and Action Plan (NBSAP) developed for the conservation and sustainable use of its biodiversity and to mainstream conservation into relevant sectoral and cross-sectoral plans. The EBI is a mandated institute to conserve and promote sustainable utilization of the plant and animal genetic resources in the country.

Seed system is also a typical governance mechanism for the generation and distribution of agrobiodiversity through the market and non-market practices, as well as combined traditional and new cultural practices (Zimmerer et al., 2019). The seed exchange is vital for agrobiodiversity conservation and smallholder resilience in the southern highlands of Ethiopia (Samberg et al., 2013). The role of Community Seed Banking (CSB) in enhancing diversity while providing productivity incentives is well established (Bezabih, 2008). Awareness and research on diverse seed system have shown the complementarity between formal and informal seed systems (MoA, 2019).

There is a significant amount of indigenous knowledge accumulated through time in managing and governing agroecosystem that involved varied knowledge practices stemming from cultural, linguistic, and landscape variation. These are considered as the biological dimensions of governance that integrate the broadly biological and cultural dimensions of human- environment systems, guiding the expansion of many local and community-based initiatives for the conservation of agrobiodiversity (Zimmerer et al., 2019). Awareness and research on Community-based breeding programmes (CBBPs), which focus on indigenous livestock and consider farmers' needs, views, decisions and active participation has been established (Haile et al., 2019)

Farmers and pastoralists employed indigenous knowledge and practices to manage the agricultural ecosystems and sustain the provision of goods and services to society. The Konso cultural landscape management in the southern part of the country contributed for the biodiversity conservation and sustainable utilization of land and water resources in the landscape. Similarly, 'Qero' system of traditional grassland management systems used by the Menz people in the Amhara region, and the agroforestry management systems of Gedeo in Southern Ethiopia are worth mentioning. The southern Rift Valley in Southwestern Ethiopia is also known as one of the hotspots of biocultural diversity and indigenous knowledge associated with the use and conservation of biodiversity through homegardens, agroforestry practices, and sacred forests.

Awareness and knowledge on market and livelihood-based approaches are currently a mainstay of attempts at biodiversity governance. These approaches include the support of organic food value chains involving indigenous and smallholder producers, retailing and wholesale outlets for agrobiodiversity across urban spaces, and international markets (Reiks and Edwards, 2007). Integrating community indigenous knowledge and practices for the conservation and sustainable use of biodiversity and ecosystem services is challenged by underdeveloped organic markets that limit the incentive and benefit-sharing mechanisms. There are few progresses to pay for ecosystem services including for water-related ecosystem services in different parts of the country and designing marketing strategies for selected indigenous crop genetic resources such as *Enset*.

6.5.3 Food, diet, nutrition and health

The level of awareness and knowledge on nature's benefit to people through the provision of material goods: food, fuel, fibre and other harvestable goods is well established. For example, the harvest of grain production increased by more than 200 %, and milk production by more than 300 % since 1990. The agricultural value grew by 40% over the past 5 years to USD 27.5 from

19.6 billion. This had a significant impact on rural poverty where the Poverty headcount ratio recorded a 22 percentage points decline from 47.5 % in 1995 to 25.6 % in 2015.

The provision of these material goods has come at the high cost of unprecedented declines in natural resources degradation and biodiversity loss that affect the integrity of ecosystems and the distinctness of local ecological communities. Such changes reduce vital benefits that people receive from nature and threaten the quality of life of future generations (Diaz et al., 2019). Thus, nature's capacity to provide beneficial regulation of environmental processes-such as building healthy soils, pollinating crops, pest control, modulating air and water quality, sequestering carbon, and cultural and inspirational services. The historical losses of extent and condition as well as rapid ongoing declines of these services is established but lack the data. In general, the level of awareness and knowledge of these services is limited at all levels revealing the services are subject to degradation in the process of agricultural production thereby affecting the provision of services from the ecosystem.

Soil processes in agroecosystems are subject to removal of nutrient-rich biomass during harvest, elevated decomposition rates that increase with frequency of tillage and irrigation, plus the loss of organic matter with the burning of soil (Garbach et al., 2014). In the central highlands of Ethiopia, soil burning (Guie) is practiced to increase phosphorus and other micronutrients but reduces soil organic matter (Amare et al., 2013). Similarly, the agricultural extension programme promotes for repeated tillage which contribute for nutrient losses in the agroecosystem while conservation tillage with minimal soil disturbance provides approximately matching output (Tsegaye et al., 2016).

Pollination is the other important service where 60-90% of all plant species are pollinator-dependent (Klein et al., 2007). Both agricultural management and landscape configuration are important in determining the availability and distribution of pollination services, but have not received the required attention following the limited awareness and knowledge about the service. For example, farmers in Amhara region have limited knowledge about pollination and the importance of insect pollinators for agricultural productivity and maintenance of ecosystem integrity. Farmers rather perceived other insect pollinators as crop pests. In the meantime, farmers also perceived that the diversity of these insect pollinators is decreasing due to the increasing use of herbicides and insecticides applied to control crop diseases and pests (Misaganaw et al., 2017).

Nature's benefits through pest control services to agriculture are appreciated today more than ever before following the dramatic increases in pesticide application with significant ecological degradation including the disturbance of the predator ecology. Increased use of pesticides is also a burden to the economy where a huge amount of foreign exchange is required for the importation and disposal of expired chemicals. The level of awareness and knowledge at all levels about the pest control service is limited to adopt an integrated pest management approach in which natural pest predators are promoted, and pesticide use can be restricted only after damage exceeds the critical economic threshold (MoANR, 2016).

Agricultural production relies on a host of water-related ecosystem services, influencing the hydrologic cycle, including local climate, water use by plants, and modification of ground surfaces that alter infiltration and flow pattern (Braumann et al., 2007). The awareness and knowledge of this services are relatively better understood at policymakers, agricultural practitioners and farmers levels. For more than two decades, massive sustainable land management programmes are implemented on farming plots and beyond, which positively contributed to the amount of water stored in watersheds, or discharged above and below ground, influencing the water supply and availability to downstream users.

The other important ecosystem service from agriculture is carbon sequestration. Improved agricultural practices can help mitigate climate change by reducing emissions from agriculture and other sources, and by storing carbon in plant biomass and soils. In addition, there are farmers' practices that reduce agricultural emissions and sequester carbon while helping to improve the livelihoods of farmers. The carbon emissions due to land use and land cover changes between 1986 and 2016 in the country revealed that change of cropland with vegetation cover contributed themost to the total carbon storage gain of 82%, with the total amount of carbon storage reaching 179.85 Mt CO2e (WLRC, 2019). Similarly, the watershed development programme increased the carbon sequestration from the natural regeneration of plants and the enrichment plantations made in nine selected micro watersheds recorded a total average yearly sequestrated CO2 of 182,860.1 tCO2e in 2019 compared to 133,168.16 tCO2e in 2015 (MoA, 2019). There are well formulated national policies, strategies, programmes (action plans) and enacted proclamations, which contribute to soil carbon sequestration. In the meantime, the level of awareness at the farmers level is limited given the payback period is way beyond the planning perspective of smallholder farmers.

Additional services provided by agricultural landscapes include cultural benefits whose valuation can be especially difficult. These include open-space, rural viewscapes, and the cultural heritage of rural lifestyles. The relationship of agriculture to other cultural services is linked where the farming communities and herders in the country have maintained diversified crops, livestock, and associated biodiversity through their community knowledge and innovations (EFCCC, 2018).

Under the provisional service of nature to people is the role of agrobiodiversity in addressing diet, nutrition and health, which received much awareness and knowledge base these days. Research has focused on food diversity for diverse diets, nutrition transition and health revealed that food biodiversity – the diversity of plants, animals and other organisms used for food, both cultivated and from the wild is a critical element in response to malnutrition, and it supports sustainable food systems (Kenndy et al., 2017). Pieces of evidence indicated that farm diversity is the major factor affecting diets where the relationship between increasing production diversity and diet diversity is smaller compared with the effect of improving market access (Sibhatu et al., 2015). There is also increasing evidence on the role of wild edible species as a source of food (Bharucha and Pretty, 2010).

6.5.4 Global environmental and socioeconomic challenges

The impacts of global environmental and socio-economic challenges on agrobiodiversity have received more significant focus these days than ever before. Global climate change and its role in both undermining agrobiodiversity and strengthening its usefulness is a key knowledge infrastructure. Similarly, research on urbanization and migration, associated changes in land use and land cover has been documented for its impact on biodiversity and ecosystem services.

Climate change projections indicate that Ethiopia will experience increasing temperatures and levels of precipitation in the coming decades; mean annual temperature will increase in the range of 0.9-1.1°C by 2030, 1.7-2.1°C by 2050 and 2.7-3.4°C by 2080 for the IPCC mid-range emission scenario compared to the baseline 1961-1990 level (NMA, 2007). Considerable awareness and knowledge are developed on the anticipated impacts of climate change on the Ethiopian economy as compared to a situation without climate change (MoWE, 2015), biodiversity and associated key ecosystem services (Sintayehu, 2018) and social problems (Eshetu et al., 2014). One potentially common adaptive response to climate change is the introduction of Climate Smart Agricultural practices where the evidence on its potential impact to lift the national GDP and assistance to move people above the national poverty line is documented (Komarek et al., 2019).

Land-use and land-cover (LULC) dynamics have been among the most important socio-economic challenges that have taken place everywhere in the Ethiopian landscape. Research mapped the LULC for Ethiopia revealing a massive change in settlements followed by wetlands, cultivated land, and woodlands, respectively (WLRC, 2019). Location specific researches developed evidence on the impact of LULC changes on ecosystem health including degradation of nature reserves and agrobiodiversity.

Awareness on the negative impact of the green revolution approach on agrobiodiversity is also acknowledged in Ethiopia (Järnberg et al., 2018). The Green Revolution and its successors globally have incurred impacts on agrobiodiversity that now include newer programs of crop and livestock "improvement," comparative-advantage and export agriculture, and agricultural intensification in the Global South, buffering the earlier projections of a cataclysmic "genetic wipeout" (Zimmerer et al., 2019).

6.6 Policies and institutional arrangements for biodiversity conservation and ecosystem services in agroecosystems

The status of the agroecosystems in Ethiopia was examined from the point of view of policy and institutional setups responsible for mainstreaming and monitoring actions as well as evaluation of the dynamics and responses. Policy and strategy reviews further examined the assessment criteria along with the prescribed action plans and executions pathways. The analysis proceeds further to the identification of challenges and gaps in policy, organizational setups, and administrative procedures.

6.6.1 Policy and planning framework

The protection of the environment, biodiversity, or ecosystem services is explicitly stated in Article 92.4 in the constitutions of Ethiopia (FDRE, 1995), which indicated that Government and citizens shall have the duty to protect the environment. However, this does not automatically mean that agroecosystem is always understood as an integral part of biodiversity and ecosystem service protection in the laws and bylaws elaborated on upon the basis of the constitution. In the meantime, Ethiopia has put in place a number of policies and planning frameworks to support the conservation and sustainable management of biodiversity and ecosystem services in agroecosystems (Figure 5).

Some of the frameworks are instruments to ratify and implement international conventions and multilateral agreements on the conservation of biodiversity, its sustainable use and access to genetic resources; and also communicate achievements and good practices. In addition, there are relevant frameworks on nature protection, agriculture and rural development, seeds and planting materials, registration of (also traditional or protected) varieties and breeds, animal breeding that directly or indirectly support Biodiversity Conservation and the Ecosystem Services in Agroecosystem.

National Biodiversity Strategy and Action Plan (NBSAP) 2015-2020

The programme of NBSAP from 2015-2020 and its 18 targets explicitly consider biodiversity conservation and ecosystem services. The rationale is that biodiversity is directly related to the livelihoods and economic well-being of most of the population by affecting all aspects of their livelihoods, including agricultural productivity, food security, building materials, water resources and aesthetic values. As a recognized overarching framework on biodiversity for all stakeholders, the NBSAP is not intended to be limited to environmental goals and institutions, but also to other sectors, including agriculture. In light of the growing threats to and values of biodiversity and ecosystem to the country’s economic development and environmental sustainability, NBSAP targeted to enhance the awareness of the general public and policy makers on biodiversity and ecosystem services, value biodiversity and ecosystem services, reduce the pressures on biodiversity and ecosystems, improve the status of biodiversity and ecosystem services, and ensure access to genetic resources and fair and equitable sharing of benefits arising from their use. In addition, NBSAP offers a major opportunity for mainstreaming biodiversity and ecosystem services into the agriculture sector.

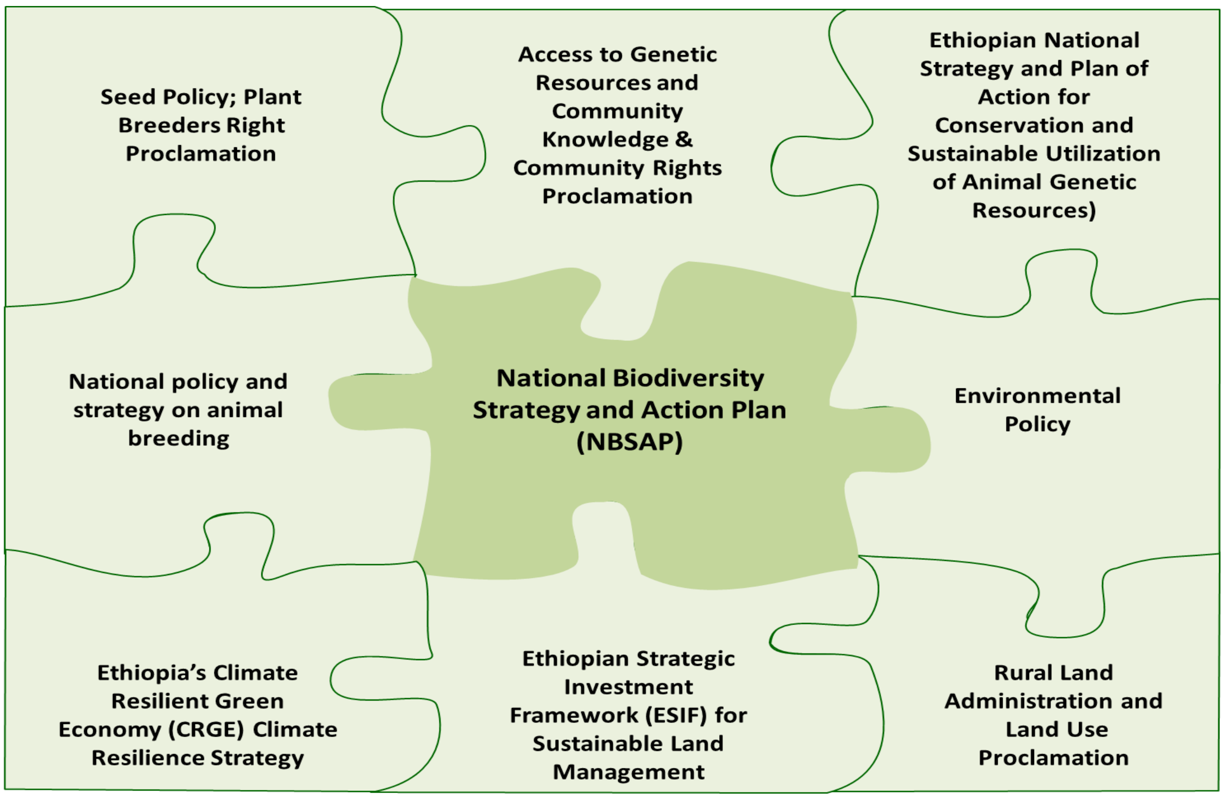


Figure 5. Agroecosystem policy and planning framework

Environmental Policy (1997)

The Environmental Policy of Ethiopia has an overall goal to improve the health and quality of the life of all Ethiopians, and promote sustainable social and economic development by adopting environmental management principles. The policy includes important requirements for environmental impact assessment (EIA) such as recognition of the need for EIA to address environmental, socio-economic, political and cultural impacts, in addition to physical and biological impacts; incorporation of impact containment measures within the design process, and for mitigation measures and contingency plans to be incorporated within environmental impact statements; creation of a legal framework for the EIA process, including a coordinated institutional framework for the execution and approval of EIAs and environmental audits; development of detailed technical sectoral guidelines for EIA and environmental auditing; and EIA and auditing capacity and capabilities within the Environment, Forest and Climate Change Commission (the then EPA), sectoral ministries and agencies, as well as in the regions. The Proclamation on Environmental Impact Assessment (No. 299/2002) is enacted to undertake EIA as a mandatory for specified categories of activities undertaken either by the public or private sectors.

Access to Genetic Resources and Community Knowledge, and Community Rights Proclamation No. 482/2006

The proclamation provides access to genetic resources and community knowledge and community right for the benefit and development of its people. It protects the knowledge of Ethiopian communities generated and accumulated with respect to the conservation and utilization of genetic resources and promotes the wider application of such knowledge with the approval and sharing benefits by such communities. It is an instrument for the implementation of international and regional agreements and conventions on biological diversity (CBD). Ethiopia is a part of the CBD and the Convention requires the enactment of access legislation and also has agreed to the African Model Law on Community, Farmers' and Plant Breeders' Righst and Access to Biological Resources.

Plant Breeders Right (Proclamation No. 1068/2017)

The proclamation deals, *inter alia*, with the protection of the community knowledge that is relevant to the plant genetic resources, obtaining an equitable share of benefits from the use of plant genetic resources, exchanging and selling farm saved seed or propagating material of the farmers' varieties; as well as the new plant varieties protecting under breeders' rights, and to collectively save, use, multiply and process farm-saved seed of protected varieties. Plant Breeders Right (PBR) was one of the significant developments for the conservation and sustainable utilization of the country's plant genetic resources.

National Seed Policy 2020

The policy is designed to ensure the conservation and sustainable use of plant genetic resources for food and agriculture (PGRFA) that promotes diverse seed systems, protects community knowledge and farmers' and pastoralists' rights align with international agreements. The policy requires the participation of farmers and pastoralists in the identification, registration, conservation, and sustainable utilization of traditional varieties as well as the development of new plant varieties. It asserts national sovereignty over genetic resources and stresses the need to ensure benefit sharing from these resources for the stewards. The policy also aims to establish a traceability mechanism for the identification of PGRFA used in new plant varieties that plant breeders wish to protect.

Ethiopian National Strategy and Plan of Action for Conservation and Sustainable Utilization of Animal Genetic Resources (2016)

The strategy directly relates to animal biodiversity and aimed to characterize, make an inventory and monitor breeds of farm animal genetic resources and assess their status and associated risks, thereby promote sustainable use and development of farm animal genetic resources for food security, sustainable agriculture and human well-being. It ensures the conservation of farm animal genetic resources diversity for present and future generations and halts loss and erosion of these crucial resources, and put in place effective policies, institutions and capacity to ensure use sustainable development and conservation of animal genetic resources for food and agriculture.

National policy and strategy on animal breeding (2017)

This national livestock breeding policy and strategy is designed to guide the conservation, improvement and utilization of animal genetic resources and avoid threats that emerge from the different drivers. The breeding policy is prepared to improve meat, milk, pig, rabbit and equine animals; fish, bee and other species (Ostrich, duck, Gunea fowel, crocodile and civet cat) of economic importance. It explicitly relates to the conservation and proper utilization of animal breed/s and germplasm by carrying-out *in situ* and *ex situ* conservation of indigenous animal germplasm for future utilization; establishing gene bank to conserve animal species and germplams; and undertaking inventory and periodical livestock population census in order to know the status of breeds

Rural Land Administration and Land Use Proclamation (Proclamation No. 456/2005)

The proclamation is necessary to sustainably conserve and develop natural resources and pass them over to the coming generation through the development and implementation of a sustainable rural land use planning based on the different agro-ecological zones of the country. This put in place legal conditions for rural land administration, which are conducive to enhance and strengthen the land use right of farmers to encourage them take the necessary conservation measures in areas where mixed farming of crop and animal production is prevalent and where there is a threat of soil erosion and forest degradation.

The proclamation is being revised to improve the rural land administration system; guarantee land use rights; establish a modern land information system, and bring about change in natural resource use by strengthening tenure security. The revison is expected to protect existing land use rights (rights of current farmers to farm and pass on farms to children, and grazing rights for pastoralists), and facilitate exchanges (e.g., leasing and other mechanisms which would promote consolidation/aggregation of farms into larger units).

Ethiopia's Climate Resilient Green Economy (CRGE) Strategy

The CRGE strategy also considered biodiversity and ecosystem services while setting the foundations for the implementation of climate-resilient activities. The strategy aimed at combatting the negative impacts of climate change and building resilient economic growth including agricultural growth and transformation. Improving biodiversity conservation and rehabilitation, and promoting biodiversity in agriculture are among the 41 adaption options identified in the CRGE's Agriculture and Forestry Strategy. In addition, conservation and protection of biodiversity is the main criteria employed to appraise the 41 adaption options. The stratgy's national adaptation plan also identified 18 major adaptation options where improving ecosystem resilience through conserving biodiversity is the key. This adaptation option indicated the need for the implementation of agro-diversity conservation and management in different agro-climatic to enhance natural resilience to the adverse impacts of climate change by enhancing healthy and well-functioning ecosystems.

Ethiopian Strategic Investment Framework (ESIF) for Sustainable Land Management

ESIF provided a holistic and integrated strategic planning framework under which government and civil society stakeholders can work together to remove the barriers, and overcome the bottle-necks, to promote and scale up sustainable land management (SLM). The ESIF provided an alternative approach based on multi-sectoral partnerships in which the different stakeholders seek to harmonize and align their investments in a collaborative manner with the aim of alleviating rural poverty through restoring, sustaining and enhancing the productive capacity, protective functions and biodiversity of Ethiopia's natural ecosystem resources. The SLM programme of the framework targeted biodiversity conservation as one of the indicators for its environmental goal of rebuilding the country's natural capital assets by overcoming the causes, and mitigating the negative impacts of land degradation on the structure and functional integrity of the country's ecosystem services. Despite a significant contribution of ESIF for SLM in watershed restoration, the integration of biodiversity and ecosystem services in ESIF requires more efforrts to implement a landscape approach through holistic planning at the landscape level, improved legal land rights administration and tenure rights, and planting of exotic trees.

Development, Management and Utilization of Community Watersheds Proclamation (Proclamation No.1223/2020)

This proclamation is expected to ensure the active participation of watershed users in watershed management; provide a regulatory framework for sustainable natural resource use; and establish the right of watersheds users' associations (WsUAs) to manage and utilize these resources. In particular, the Proclamation provides the regulatory basis for the creation of WsUAs, the development of watershed management plans, and their implementation, thereby ensuring land resources are used and managed in a way that enhances absorptive and adaptive capacity to climate change, promoting resilience at the landscape level. The establishment of WsUAs also provides a mechanism to initiate payment for ecosystem services (PES) in Ethiopian watersheds by mobilizing additional resources for sustainable land management. This provides ESIF to attract private sector interest to promote PES approach.

6.6.2 Institutional arrangements for the delivery of agroecosystem services

The Ethiopian Government is committed to conserving biodiversity and ecosystem services in agroecosystem through better institutional capacity building and funding. The funding comes from the government treasury as well as donor partners. There exist few institutions that are involved in the management and conservation of biodiversity and ecosystem services in the agroecosystem. The Ethiopia Institute of Biodiversity is the primary actor while the Ministry of Agriculture and the affiliated institutions, and Environment Protection authority are also responsible to manage and conserve biodiversity and ecosystem services in agroecosystem (Figure 6). There are also international development partners that support the institutional arrangement for the delivery and facilitation of better agroecosystem services in Ethiopia.

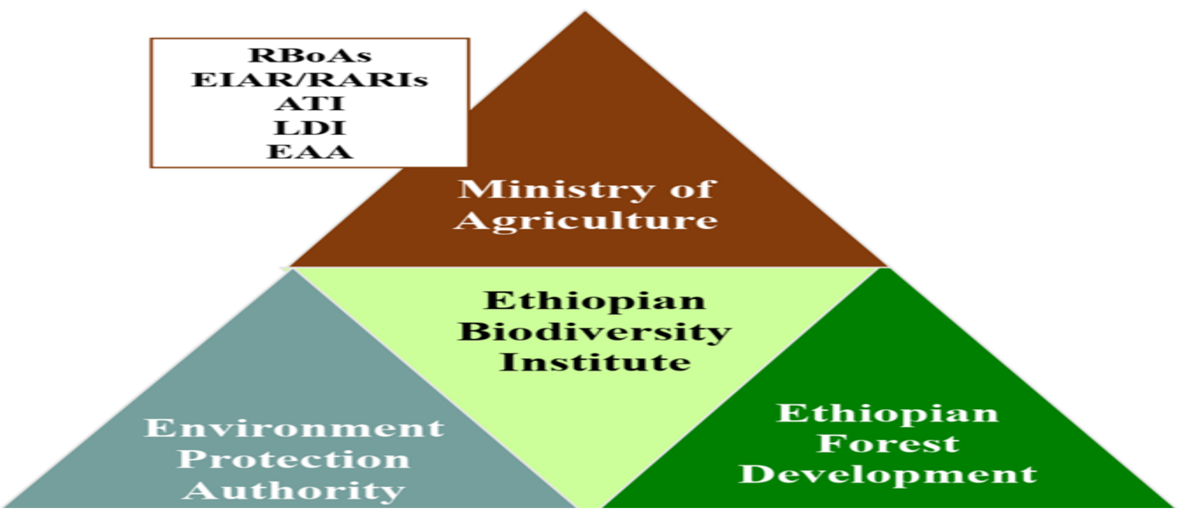


Figure 6. Institutional arrangments for agroecosystem

Ethiopian Biodiversity Institute

Ethiopian Biodiversity Institute **(**EBI) has the power and duties, among others, to initiate policy and legislative proposals for the conservation of biodiversity; explore and survey the diversity and distribution of the country's biodiversity resources; ensure the conservation of the country's biodiversity using *in situ* and *ex situ* methods; develop strategy for the conservation of species threatened by extinction; develop systems and technical standards for the conservation of the country's biodiversity; and issue directives on the collection, import and export of any biological specimen and permits for access to genetic resources and sharing benefits from genetic resources.

The institute has not been in a position to discharge its duties and responsibilities in the conservation of biodiversity optimally due, mainly, to budgetary constraints and inadequacies in infrastructure and logistics. This deficiency and the priority given to other computing national interests resulted in inefficient mainstream of biodiversity and ecosystem services into different sectors.

Environment Protection Authority

The Environment Protection Authority (EPA) was established through Proclamation No. 1263/2021 as an autonomous federal government body having its own legal personality. Its roles are limited exclusively to regulatory functions pertaining to the overall environment of the country without any limitations in the national jurisdiction; and its powers, duties and organizational setup shall be determined by the Council of Ministers Regulation, which currently is under development.

Practically speaking, the Environment Protection Authority has emerged from the three sub-sectors (Forest, Environment, Biodiversity and Climate change) of the former Environment, Forest, and Climate Change Commission (EFCCC). The EFCCC was mandated for managing the Environment of Ethiopia, and was responsible to ensure the realization of the environmental rights, goals, objectives and basic principles enshrined in the Constitution as well as the Environment Policy of Ethiopia through coordinating appropriate measures, establishing systems, developing programmes and mechanisms for the welfare of humans and the safety of the environment. It was responsible to initiate, and coordinate as appropriate, the formulation of policies, strategies, laws and standards as well as procedures. It was also in charge of monitoring and enforcing implementations of the legislative measures, upon approval, across multiple actors; and thus its mandate used to transcend multiple sectors

The EFCCC has evolved through institutional restructuring in response to redefinition of organization, power and duties of the executive organs in the country. The former Environmental Protection Authority, the Ministry of Environment and Forest, and the Ministry of Environment, Forest and Climate Change were institutional entities that came into being in less than three decades; and the intensity of institutional restructuring has not been taken positively, mainly by scholars and practitioners working in the area, for the concern that the dynamism will exert a negative impact on the sector's role in accomplishing climate change regulation, biodiversity conservation and environmental protection related objectives.

Ministry of Agriculture

Ministry of Agriculture (MoA) is mandated to increase the production and productivity of crops and livestock while managing the natural resources base. The Ministry is also the leading institution coordinating the sustainable natural resource management in agricultural landscapes implemented to reduce land degradation for improved agricultural productivity of smallholder farmers and pastoralists. MoA is explicitly engaged in animal genetic resource conservation by ensuring appropriate livestock breeding programme that is implemented in the country. The Ministry also implements the CRGE strategy in agriculture through mainstreaming climate-smart agricultural practices that improve biodiversity at farm and community level and support improved ecosystem services such as water and nutrient cycling.

Natural resource managmnet in agricultural landscapes is approached as a means of counteracting land degradation, where its contribution to the conservation of biodiversity and ecosystem services that would enhance agricultural productivity over time is considered as of secondary importance. The Ministry's policy and strategies are often characterized by conventional intensification and commercialization that are strongly focus on agriculture as an engine of economic growth narrative. This growth trajectory is limited by a discourse that largely decouples social and ecological domains, in contrast with the more integrated perspective that sustainable intensification rests on (Järnberg et al., 2018). The policy that promotes large-scale commercial agricultural investment, though it recognizes the contribution of protecting the environment for achieving sustainability in all dimensions, implementations on the ground may have actual and potential threats of deforestation and ecosystem degradation (Bekele et al., 2015). Among the different factors contributing to the stated drawbacks, is often related to the weak policy and regulatory implementation capacity at Federal and Regional levels to enforce existing EIA procedures in large-scale land investment, which is considered to be "weak or non-existent" (Rahmeto, 2011).

Ethiopia is structured in a framework of a federal parliamentary republic, which comprises the Federal Government and the member states. The governance of the agriculture sector is organized in tandem with Ethiopia's federal structure. Along with the Federal Ministry, there are regional bureaus, accountable to the regional states. The Federal Ministry is responsible for providing oversight and policy guidelines for the country as a whole, while the regional bureaus are responsible for the individual regions. There are also autonomous federal institutions that report to the Ministry vis-a-vis the Agricultural Transformation Agency (ATA), Federal Cooperative Promotion Agency; Ethiopian Institute of Agricultural Research (EIAR), Ethiopia Agricultural Research Council Secretariat, Ethiopia Soil Research Institute (ESRI), Coffee Development and Marketing Agency, National Animal Health Diagnostic and Analysis Centre (NAHDAC), Ethiopian Veterinary Drug and Feed Administration (EVDFA), National Tsetse and Trypanosomiasis Investigation and Control Center (NTTICC), National Animal Genetic Improvement Institute (NAGII), and National Veterinary Institute (NVI). Limited collaboration and lack of a clear accountability mechanism among the regional and federal institutions hindered the effective implementation of policies and strategies for the intended purpose.

Research institutions and development initiatives

The Ethiopian Institute of Agricultural Research (EIAR) is a Federal Agricultural Research Institute responsible for the running of federal research centers, and Regional Research Institutes are administered by the Regional governments. In addition to conducting research at its federal centers, EIAR is charged with the responsibility for providing the overall coordination of agricultural research countrywide, and advising the Government on agricultural research policy formulation. Its main objective is to generate, develop and adapt agricultural technologies that focus on the needs of the overall agricultural development and its beneficiaries. The research system of often mentioned not designed to support research on the sustainable use of local cultivars/breeds and wild biodiversity for food and nutrition.

National Animal Genetic Improvement Institution (NAGII) is established with the main objective of improving livestock breeds and ensuring a sustainable supply of improved animal genotypes for increased production and productivity of livestock thereby increasing livestock keepers' income and economic transformation of the country. It is mandated to lead the development of national breeding policy, programme and strategy as well as support their implementation in the regions. Livestock breed improvement research, study and technology transfer is one of the main powers and duties of the Institute.

Agricultural Transformation Agency (ATA) is mandated to address systemic constraints of agricultural transformation, through conducting studies, recommending solutions, and implementing support in order to ensure sustainability and structural transformation. It also leads the design and implementation specific projects aimed at improving production and productivity such as Agricultural Commercialization Clusters (ACC) through strong implementation support programs. ATA's role to promote sustainable agriculture is evolved through an inclusive and sustianble approach, and there is a major emphasis on Green Revolution technologies and commercialization, strengthening agriculture as an engine for growth policy narrative of the Government.

6.7 Conclusion

Ethiopia's agroecosystems are places where rich and unique agrobiodiversity elements reside. These elements are the key resources that the people of Ethiopia depend upon for their livelihoods and for improvingthe quality of their lives. In addition, the agrobiodiversity produced and maintained within the Ethiopian agroecosystem under continued innovation of local farming communities also contributes to the global biodiversity resources. Thus, the protection of these resources and the local and indigenous knowledge of the diverse ethnolinguistic communities are important biodiversity and knowledge assets.

Agriculture has been practiced in Ethiopia for thousands of years, and traditional farming practices dominate in modern Ethiopia as well. Over 95% of the regularly cultivated areas occur in the highlands, where mixed crop-livestock systems are managed by smallholder farmers. On the other hand, the lowlands are dominated by pastoral and agropastoral livelihood systems and a very small area of irrigated commercial farms. The country has diverse agroclimatic zones and people of different cultures, and this has resulted in the development of different agroecosystem sub-types, agricultural practices and food systems.

In the north, central and eastern parts of the country, mixed cereal-livestock production systems are practiced both in high-potential and low-potential areas. Although the diversity of crop species varies across farms depending on the productivity of the sites and individual preferences, cereals, pulses, and oil crops are grown by almost all farmers as the traditional household economy is constructed on a ‘self-contained’ system. There is a high diversity of farmers’ varieties of cereal crops such as barley, *Teff*, wheat, sorghum and finger millet, and this is mainly due to the active role of farmers in the selection, domestication, hybridization and preservation of local varieties that serve different purposes. The major challenges of the cereal-livestock systems are soil fertility depletion, shortage of wood for fuel and household uses and shortage of feed. On top of these, severe soil and water erosion, the poor water-holding capacity of soils and lack of vegetation cover are critical problems on hilly areas of the cereal-livestock systems. Sustainable intensification in these areas should therefore aim at integrated soil and water conservation and land management practices, application of proper agronomic practices and integration of multipurpose trees and shrubs. Multipurpose trees and shrubs in these systems have several contributions that include a) reduction of soil and water erosion, b) soil fertility improvement, c) amelioration of the microclimate, d) provision of food and medicine for people and feed and medicine for livestock and e) provision of wood for fuel, construction and income generation. If there is sufficient wood or another alternative source of fuel for household energy supply, farmers can use livestock manure and crop residue for soil fertility improvement instead of as fuel. In general, integrating and managing woody perennials, application of appropriate land management practices, exploitation of the positive interactions between farm components, including nutrient cycling processes, and linking farmers with markets could play important roles in improving and sustaining livelihoods in the cereal-livestock systems.

In the south and south-western parts of Ethiopia, perennial-crop-based polyculture systems with abundant *Enset* and coffee in the agroecosystem with diverse assemblages of perennial and annual crops integrated with livestock and different species of trees are widely practiced. These systems produce more food and plant biomass per unit area of land and hence the rural population density, especially in the intensively managed areas, is very high. These integrated systems largely use internal resources and exploit the positive interactions between components to maintain regular production. The high diversity of cultivated species and local varieties and the perennial basis of these systems are believed to reduce risks of farmers by stabilizing yield in the face of crop or market failure. The major constraint facing the intensively managed systems such as the Gedeo, Wolayita and Sidama zones is the increasing fragmentation of land that is in some cases leading to expansion of monoculture plots replacing the integrated polyculture systems. Another developing trend in some parts of Sidama Zone is the expansion of *Chaat* replacing the polyculture systems. The future of these systems lies in the maintenance of biodiversity and perennial components of the systems. Hence, any attempts to improve the systems should aim at integrating high-value species without affecting the diversity and perennial nature of the systems.

In general, the agrobiodiversity of most of the Ethiopian agroecosystem is high, thanks to the Ethiopian farmers who conserved and made available these invaluable resources to the present generation of Ethiopians and the world at large. However, agricultural productivity is generally low and hence research efforts should be strengthened to develop suitable intensification models that are appropriate to the different biophysical and socioeconomic settings of the agroecosystem.

Agrobiodiversity and associated services are affected by a variety of interacting drivers of change: the indirect drivers such as rapid demographic change, low level of education and the likes that give rise to the direct drivers such as a change in land use, climate change, overexploitation of resources, soil erosion and land degradation, water depletion, replacement of farmers' varieties and breeds and the proliferation of invasive species. While there are many potential means of addressing immediate threats through the adoption of various sustainable management practices and implementation of conservation measures, improved commitment of decision-makers rooted in a strengthened science-policy interface is desired in order to combat the drivers of unwanted change. It is essential to build on the opportunities that are emerging as a result of growing consumer demands for biodiversity friendly products such as organic products produced through agroecological practices. Agroecological farming has the explicit goal of strengthening the sustainability of all parts of the food system, from the seed and the soil, to the dining table, including ecological knowledge, economic viability and social justice.

Much of the awareness and knowledge on agroecosystem is focused and optimized on the provisioning service of food, fibre and fuel that are linked to a wide variety of supporting and regulating services, such as diversity of genetic resources, soil structure and fertility enhancement, nutrient recycling, water provision, pollination, and pest control. The level of awareness and knowledge on the latter is limited by policy makers and many land users. In the meantime, efforts to enhance the awareness at all levels and the use of a wide range of management practices and approaches are reportedly increasing and regarded favorable to sustainable use and conservation of agrobiodiversity and agroecosystem.

More efforts are required to enhance the awareness of communities, policy makers, development partners and private sectors on the importance of agrobiodiversity and agroecosystem services by adopting more multidisciplinary, more participatory and more focus on interactions between the different components.

The main policy discourses supporting the country's agrobiodiversity and agroecosystem services are the Strategic Investment Framework for SLM and the Environmental Policy of 1997, the Climate Resilient Green Economy Strategy of 2011 and the Biodiversity Strategy of 2015-2020. These policies and strategies create enabling environment to further improve conservation and management of agrobiodiversity and agroecosystem services. However, the formulation of policies and promulgation of laws are not the only conditions for transforming the state of agrobiodiversity in Ethiopia. Among the crucial factors are commitment and determination to invest in implementation. Policy implementation and translating laws to action require organizational capacity, work force, financial and material resources; willingness to comply, enforce and cooperate among concerned individuals and institutions with accountability.

The quest for more sustainable cropping and farming systems that can meet food needs while conserving agrobiodiversity and ensuring agroecosystem services require policies, strategies and institutional arrangements that are socially, economically and environmentally sound. More practical policies and strategies such as landscape approaches are required to provide tools and concepts for allocating and managing land to achieve social, economic and environmental objectives in areas where agriculture and other land uses compete with agrobiodiversity negatively impacting agroecosystem services. Thus, food production goals of agriculture are expected to be met in ways that alleviate poverty, improve nutrition and conserve the environment, emphasizing priorities in the integration of agriculture, agrobiodiversity and agroecosystem services by applying a people-centered approach at landscape scales where universal development of biophilia is promoted. The proper implementation of such programmes and projects requires regular monitoring and evaluation of the sustainability and service provision capacities of the agroecosystem. These activities must be regulated by farmers, research and development partners and government bodies including policy-makers. Therefore, enabling situations must be created to implement the following:

1) Target the low potential cereal crop zone for immediate environmental restoration and rehabilitation through integrated watershed management and reforestation by undertaking soil and water conservation, enforcing laws that forbid annual crop cultivation on lands higher than a given slope, reforestation, and area closure by adopting science-informed land use system,

2) Strengthen agricultural extension system to raise farmer adoption of technologies with due attention to major constraints (soil erosion, waterlogging, shortage of livestock feed and wood), including by enforcing policies that prohibit annual crop cultivation on lands higher than a given slope determined on the basis of erosion vulnerability modelling to ensure sustainability in agrobiodiversity and agroecosystem,

3) Ensure that agricultural landscapes have rich plant cover with continued diversification of species, crops, varieties and livestock breeds, increasing productivity with continuous enrichment and effective use and management of underutilized species and orphan crops. Develop and implement a special strategic framework for the promotion of underutilized species/varieties. Expand and develop homegardens and agroforests particularly in degraded and degrading agroecosystem with restoration and rehabilitation to stock and enhance agrobiodiversity through intensification in spatial and temporal scales being backed by proactive policy frames, enhance ongoing institutionalization of community seedbanks and botanical gardens in collaboration with national and international partners,

4) Research and development must focus on designing suitable models of intensifications that fit with specific local needs and priorities including by providing new policy directives to absorb the increasing young population into other sectors, such as agriculture-based industries akin to the Agricultural Development Led Industrialization (ADLI) macroeconomic policy of the country; redesign agroecosystem in ways that maximize agrobiodiversity and stimulate interactions between crops, livestock and wildlife as part of holistic strategies to build long term fertility, healthy agroecosystem and secure livelihoods through monitoring and evaluation schemes,

5) Motivate effective practice of ILK, innovations and practices by working with farmers and especially by engaging farmer conservators,

6) Ensure security in food, nutrition and economy of households and reduce poverty by developing effective action plans that effectively engage farmers, researchers and development partners,

7) Mount strong awareness raising action programmes that target all stakeholders with a science-informed understanding of impacts of drivers of change and addressing those that undermine the sustainability of agroecosystem, its functions and services. Forge active collaboration and involvement of stakeholders that include investors, investment office, academia and the relevant line ministries, complementing it by a strong drive to produce a huge contingent of graduates trained with a comprehensive agroecosystem science at agriculture and biology departments and colleges with world standard curricular packages,

8) Strategies and action plans must be agroecosystem-based to be more relevant and impactful,

9) Improve the monitoring and control of recognized threats or strengthen efforts to reduce them or mitigate the effects of land degradation and soil erosion, water depletion, replacement and extinction of farmers' varieties, breeds and pollinators, inappropriate use of agricultural inputs, overexploitation of resources, pests, diseases and invasive alien species,

10) Strategize and promote the use of technologies and management practices such as crop rotations, multiple cropping, agroforestry systems, minimum tillage in the dry areas, use of cover cropping, animal integration, effective soil and water conservation practices, etc. that will have positive effects on agroecosystem and supply of ecosystem services,

11) Support agroforestry practice through proper policy framework to well integrate into planning and financing mechanism,

12) Endeavour to develop agrobiodiversity indices to help policy-makers and the private sector assess dimensions of agrobiodiversity in order to guide interventions and investments for sustainable food systems; strengthening tree-growing initiatives,

13) Promote the use of adapted and better producing indigenous resources to address drivers that negatively affect production systems and the supply of ecosystem services keeping climate change adaptation and mitigation high on the agenda. The Ministry of Agriculture needs to make a paradigm shift in using adaptable and climate-resilient indigenous breeds and local farmers' varieties, the EBI needs to promote the use and conservation of indigenous breeds and local farmers' varieties and the national agricultural research system (NARS) and higher learning institutions focus on production problem-solving technologies that are rooted in indigenous and local genetic resources and knowledge. Strengthen participatory approaches and ensure strong cooperation among ministries, research institutes, education system, farming communities and farmer conservators, and

14) Implement policies that help to protect the agroecosystem and associated biodiversity from the effects of negative drivers and support its sustainable use. Such policy directions must include limiting excess population growth, promotion of agroforestry and agroecological practices, proper use of inorganic fertilizers, policy directions that helps to return crop residues and animal dung to the farm and encouraging and facilitating the use of organic fertilizers while removing policies that may encourage excessive use of inorganic fertilizers and incentivizing of heavy-duty machinery imports.

6.8 References

Abdenna, D., Bikila, B., Hirpa, L., (2013). Evaluation of Soil Cations in Agricultural Soils of East Wollega Zone in South Western Ethiopia. Sciences, Technology and Arts Research Journal. 2(1): 10-17.

Abebe, F. Alamirew, T., Abegaz, F., (2015). Appraisal and mapping of soil salinity problem in Ambara Irrigation farm, Middle Awash, Ethiopia. International Journal of Innovation and Scientific Research 13 (1): International Journal of Innovation and Scientific Research. 13 (1), 298-314.

Abebe, T. et al., (2006). Diversity and dynamics in homegardens of Southern Ethiopia. In: Kumar BM and Nair PKR (eds). Tropical homegardens: A time-tested example of sustainable agroforestry. Springer Science, Dordrecht, The Netherlands. pp. 87-103.

Abebe, T., (2005). Diversity in homegardem agroforestry systems of Southern Ethiopia. PhD dissertation, Wageningen University, Netherlands.

Abebe, T., (2018). Land-use changes in the Enset-based agroforestry systems of Sidama, Southern Ethiopia and its implications to Agricultural sustainability. Ethiopian Journal of Biological Sciences. 17, 121-132.

Abebe, T., Wiersum, K.F., Bongers, F., (2010). Spatial and temporal variation in crop diversity in agroforestry homegardens of Southern Ethiopia. Agroforestry systems. 78, 309-322.

Abiot, M., (2012). Woody species diversity and carbon stock under patch natural forests and adjacent enset-coffee based agroforestry in midland of Sidama zone, Ethiopia. MSc thesis Hawassa University, Wondo Genet College of Forestry and Natural Resources, Hawassa, Ethiopia.

Achalu, C., Heluf, G., Kibebew, K., Abi, T., (2012). Effects of Liming on Acidity-Related Chemical Properties of Soils of Different Land Use Systems in Western Oromia, Ethiopia. World Journal of Agricultural Sciences. 8 (6): 560-567.

Adal, H., (2017). Biocultural Values in Borena Sayint National Park, North-Eastern Ethiopia: Contributions of Ethnobotany for Ecotourism Diversification. Abyss. J. Sci. Technol. 2(1): 40-55.

Admas, A. et al., (2017). Controlling Water Hyacinth in Lake Tana Using Biological Method at Green House and Pond Level. European Journal of Experimental Biology. 7 (1), PP. 5-29. doi: 10.21767/2248-9215.100029.

Adugna, A., (2012). Analysis of in situ diversity and population structure in Ethiopian cultivated Sorghum bicolor (L.) landraces using phenotypic traits and SSR markers. Springer Plus. 3, 212 (2014). https://doi.org/10.1186/2193-1801-3-212.

Agrawal, A., (2014). Indigenous and scientific knowledge: some critical comments. IK Monitor 3(3). Available at: http://www.nuffic.nl/ciran/ikdm/3-3/articles/agrawal.html.

Ahmed, M. et al., (2002). Measurement and Sources of Technical Efficiency of Land Tenure Contracts in Ethiopia. Environment and Development Economics. 7(3), PP. 507-527. DOI: https://doi.org/10.1017/S1355770X0.

Aizen, M.A. et al., (2008). Long-term global trends in crop yield and production reveal no current pollination shortage but increasing pollinator dependency. Current Biology, 18(20): PP. 1572-1575. doi: 10.1016/j.cub.2008.

Albore, A., (2018). Review on Role and Challenges of Agricultural Extension Service on Farm Productivity in Ethiopia. International Journal of Agricultural Education and Extension. 4(1), PP. 093-100.

Alemberhe, K., Gebremeskel, K., (2016). A Review on: Role of Honey Bee Pollination in Improving Crop Productivity and Seed Quality in Northern Ethiopia. Food Science and Quality Management. 47, ISSN 2224-6088.

Ali, D.A., Deininger, K., (2013a). Is there an Inverse Farm Size–Productivity Relationship in African Agriculture? Evidence from Rwanda. Draft paper. The World Bank, Washington, DC.

Ali, D.A., Deininger, K., (2013b). Costs and Benefits of Land Fragmentation. Draft paper. The World Bank, Washington, DC.

Altieri, M.A et al., (2015). Agroecology and the design of climate change-resilient farming systems. Agronomy for Sustainable Development, Springer Verlag/EDP Sciences/INRA. 35 (3): 869-890. 10.1007/s13593-015-0285-2hal-01309778.

Altieri, M.A., (1995). Agroecology: The Science of Sustainable Agriculture (2nd ed). Westview Press.

Altieri, M.A., (2002). Agroecology: the science of natural resource management for poor farmers in marginal environments. Agriculture, Ecosystems and Environment. 93:1–24.

Altieri, M.A., (2015). Agroecology: Key concepts, principles and practices. Third World Network.

Altieri, M.A., Funes-Monzote, F.R., Petersen, P., (2012). Agroecologically efficient agricultural systems for smallholder farmers: contributions to food sovereignty. Agron. Sustain. Dev. 32:1–13.

Altieri, M.A., Nicholls, C.I., (2013). The adaptation and mitigation potential of traditional agriculture in a changing climate. Climatic Change. 140: 33-45.

Amare, T., Yitaferu, B., Hurni, H., (2013). Effects of" Guie" on Soil Organic Carbon and Other Soil Properties: A Traditional Soil Fertility Management Practice in the Central Highlands of Ethiopia. Journal of Agricultural Science. 5(7), E-ISSN 1916-9760.

Amede, T. et al., (2017). A farming system framework for investment planning and priority setting in Ethiopia. ACIAR Technical Reports Series No. 90. Australian Centre for International Agricultural Research: Canberra. 52 pp .

Anna, L.J., Jacob, R.G., Florax, J.G.M., (2017). How does population density influence agricultural intensification and productivity? Evidence from Ethiopia.: ELSEVEIR. 48, 142-152. www.elsevier.com/ locate/foodpol.

Anon, (1996). Agroecosystem health. Agroecosystem System Health Project. University of Guelph, Guelph, Canada.

Arroita, M. et al., (2017). Water abstraction impacts stream ecosystem functioning via wetted-channel contraction. *Freshwater Biology*, 62(2): 243–257. https://doi.org/10.1111/fwb.12864.

Asaminew, E., (2013). Climate Change, Growth, and Poverty in Ethiopia. Climate Change and African Political Stability. Working Paper No. 3. The Robert S. Strauss Center.

Asfaw, Z., (1997). Survey of Indigenous Food Crops, their Preparations and Homegardens in Ethiopia. Indigenous African Food Crops and Useful Plants. Bede N. Okigbo (ed.), United Nations University/Institute for Natural Resources in Africa. Assessment Series No. B6. ICIPE Science Press, Nairobi, Kenya.

Asfaw, Z., (2000). The Barleys of Ethiopia. In: S.B. Brush (ed.), Genes in the Field: On-Farm-Conservation of Crop Diversity, IPGRI/IDRC, LEWIS PUBLISHERS, N.Y. pp. 77-107.

Asfaw, Z., (2003). Tree species diversity, topsoil conditions and arbuscular mycorrhizal association in the Sidama traditional agroforestry land use, Southern Ethiopia. Doctoral Thesis, Swedish University of Agricultural Sciences, Uppsala. Silvestria, 263. 69.

Asfaw, Z., Chekol, H., (2018). Baseline household level questionnaire-based survey report of Wonch District, Central Ethiopia. Reseasrch report submitted to the project “Regional Capacity Building for Sustainable Natural Resource Management and Agricultural Productivity under the Changing Climate (CAPSNAC)”, 35 pages.

Asfaw, Z., Nigatu, A., (1995). Homegardens in Ethiopia: characteristics and plant diversity. SINET: *Ethiopian Journal of Science* **18**: 235-266.

Asfaw, Z., Woldu, Z., (1997). Crop Associations of homegardens in Wolayita and Gurage in Southern Ethiopia. SINET: Ethiopian Journal of Science. 20: 73-90.

Asfaw, Z., Wondimu, T., (2007). Introduction to Ethnobiology. People and the Biota. Department of Biology, Addis Ababa, University.

Asfaw, Z.; Linger, E. and , Zewudie, S., (2015). Plant Species Richness and Structure of Homegarden Agroforestry in Jabithenan District, North-Western Ethiopia. *International Journal of Environmental Sciences* **4 (2)**: 52-58.

Asmamaw, M., Keneni, G., Tesfaye, K., (2019). Genetic Diversity of Ethiopian Durum Wheat (Triticum durum Desf.) Landrace Collections as Reveled by SSR Markers. Advances in Crop Science and Technology. 7(1): 413.

Assefa, K. et al., (1999). Diversity among germplasm lines of the Ethiopian cereal tef [Eragrostis tef (Zucc.) Trotter]. Euphytica. 106(1):87-97.

Badu, A. B. and Akin, W, R. O., (2011). Cultivar evaluation and trait analysis of tropical early maturing maize under Striga infested and Striga free environments. Field Crops Research.

Bantayehu, M., Esmael, J., (2011). Achievements in food barley breeding research in the early production systems of northwest Ethiopia. In: Bayeh Mulatu and Stefania Grando (eds.) Barley Research and Development in Ethiopia. Proceedings of the 2nd National Barley Research and Development Review Workshop Holetta Agricultural Research Centre, Ethiopia 28–30 November 2006. EIAR. Addis Ababa.

Bauer, D.M.; Wing, I.S., (2011). The Macroeconomic Cost of Catastrophic Pollinator Declines. Department of Geography and Environment, Boston University, USA, p.13.

Bekele, A., (2001). Status and Dynamics of Natural Resources in Ethiopia. In: Food Security through Sustainable Land Use: Population, Environment and Rural Development Issues for Sustainable Livelihoods in Ethiopia. 2(6), pp. 165-184.

Bekele, F., (2018). Invasive Lantana camara L. Shrub in Ethiopia: Ecology, Threat, and Suggested Management Strategies. Journal of Agricultural Science. 10 (7). ISSN 1916-9752 E-ISSN 1916-9760.

Bekele, M. et al., (2015). The context of REDD+ in Ethiopia: Drivers, agents and institutions. Occasional Paper 127. Bogor, Indonesia: CIFOR.

Berhanu, B., Seleshi Y., Melesse, A., (2014). Surface Water and Groundwater Resources of Ethiopia: Potentials and Challenges of Water Resources Development. In: Melesse A.M ed). Nile River Basin, DOI 10.1007/978-3-319-02720-3_6, 97 © Springer International Publishing, Switzerland.

Bezabih, F., Araya, T., (2002). Spread and status of parthenium in Tigray Regional State at Woreda level. Tigray Bureau of Agriculture and Natural Resources.

Bezabih, M., (2008). Agrobiodiversity conservation under an imperfect seed system: the role of community seed banking schemes. Agricultural Economics. 38(1), pp.77-87.

Bharucha, Z., Pretty, J., (2010). The roles and values of wild foods in agricultural systems. Philosophical Transactions of the Royal Society of Biological Sciences, 365(1554). pp.2913-2926.

Bioversity International. (2016). Mainstreaming Agrobiodiversity in Sustainable Food Systems: Scientific Foundations of an Agrobiodiversity Index – Summary, Bioversity International, Rome, Italy. pp 32.

Bioversity International. (2017). Mainstreaming agrobiodiversity in sustainable food systems. Bioversity International, Rome, Italy 180p.

Birdsall, N., Allen, C.K., Steven, W.S., (2001). Population matters: Demographic change, economic growth, and poverty in the developing world. New York: Oxford University Press.

Birhanu, A., (2014). Environmental Degradation and Management in Ethiopian Highlands: Review of Lessons Learned. Journal of Environmental Protection and Policy. 2(1), pp. 24-34.

Birmeta, G., Bakeeva, A., & Passoth, V., (2018). Yeasts and bacteria associated with kocho, an Ethiopian fermented food produced from enset (*Ensete ventricosum*). *Antonie Van Leeuwenhoek*, 112(4), 651–659. https ://doi.org/10.1007/s10482-018-1192-8.

Blum, W. E. H., (2005). Functions of soil for society and the environment. Reviews in Environmental Science and Biotechnology. https://doi.org/10.1007/s11157-005-2236.

Borrell, J. S, et al., (2020). Enset-based agricultural systems in Ethiopia: A systematic review of production trends, agronomy, processing and the wider food security applications of a neglected banana relative. Plants, People, Planet 2(2): 12–28. h t t p s://doi. org/10.1002/ppp3.10084.

Brandt, S.A., et al., (1997). The "Tree against Hunger": Enset-Based Agricultural Systems in Ethiopia. American Association for the Advancement of Science with Awassa Agricultural Research Center, Kyoto University, Center for African Area Studies and University of Florida, Washington, DC.

Brauman, K.A et al., (2007). The nature and value of ecosystem services: an overview, highlighting hydrologic services. Annu. Rev. Environ. Resour. 32, pp.67-98.

Brokaw, N.V., (1985). Gap phase regeneration in a tropical forest. Ecology. 66(3), PP. 682-687.

Brookfield, H., Padoch, C., (1994). Appreciating agrodiversity: a look at the dynamism and diversity of indigenous farming practices. Environment: Science and Policy for Sustainable Development. 36 (5): 6-45.

Brush, S.B., (1991). A farmer-based approach to conserving crop germplasm. Economic Botany. 45: pp. 153-65.

Bustamante, M., (2018). Direct and indirect drivers of change in biodiversity and nature's contributions to people. In IPBES (2018): The IPBES regional assessment report on biodiversity and ecosystem services for the Americas. Rice, J., et al. (eds.). Secretariat of the Intergove.

Butchart, S. H. M., et al., (2010). Global Biodiversity: Indicators of Recent Declines. *Science*, 328(5982).

Cassini, R., et al., (2008). Traditional systems and development interventions in LVIA experience in Moyale, pastoral area of Southern Ethiopia. Journal of Agriculture and Environment for International Development. 102 (1-2), pp. 7-33.

Cassman, K. G. et al., (2003). Meeting cereal demand while protecting natural resources and improving environmental quality. Annual Review of Environment and Resources. 28 (3): pp. 315-358.

CEM (Commission on Ecosystem Management). (2017). A Quarterly Newsletter from IUCN-CEM Agroecosystems Specialist Group. Vol (01) Issue (01).

Chavas, J., Salvatore, Di. F., (2012). On the Productive Value of Crop Biodiversity: Evidence from the Highlands of Ethiopia. Land Economics. 88 (1): 58–74.

Collins, W.W., Hawtin, G.C., (1999). Conserving and using crop plant biodiversity in agroecosystems. In: Biodiversity in Agroecosystems. Collins, W.W and Qualset, C.O., (eds). CRC, Boca Raton, FL, pp.267-282.

Costanza, R., (1997). The value of the world's ecosystem services and natural capital. Nature. 387: pp. 253-260.

Cromwell, E., (1999). Agriculture, biodiversity and livelihoods: issues and entry points, Final Report. 69 pp.

CSA. (2012). The Federal Democratic Republic of Ethiopia, Central Statistical Agency, Statistical Report on the 2012 urban employment-unemployment survey, pp. 243.

CSA. (2007). Agricultural sample survey 2007/2008, volume II Report on Livestock and livestock characteristics (private peasant holdings). Addis Ababa: Central Statistical Agency.

CSA. (2011). Agricultural sample survey 2011/2012, volume II: Report on Livestock and livestock characteristics (private peasant holdings). Addis Ababa. Central Statistical Agency.

CSA. (2013). Population Projection of Ethiopia for All Regions at Wereda Level from 2014 – 2017, Addis Ababa, Ethiopia, Central Statistical Agency.

CSA. (2017). Agricultural sample survey 2016/17, report on livestock and livestock characteristics (private peasant holdings). Federal Democratic Republic of Ethiopia: Addis Ababa. Central Statistics Agency.

CSA. (2018). Agricultural Sample Survey 2017/18 (2018) Volume I: Report on area and production of major crops. Addis Ababa. Central Statistical Agency.

Dadi, H. et al., (2008). Microsatellite analysis reveals high genetic diversity but low genetic structure in Ethiopian indigenous cattle populations. International Society for Animal Genetics, Animal Genetics. 39: pp. 425–431.

Daily, G.C., (1997). Nature's Services: Societal Dependence on Natural Ecosystems. Washington, DC: Island Press.

Demissew, S., Friis, I., (2018). Review of the history, taxonomy and nomenclature of Ensete and the objectives and expectations of the international workshop on Ensete ventricosum (Welw.) Cheesman. Ethiopian Journal of Biological Sciences. 17: pp.1-23.

Desalegn, B., (2015). Assessment of Pesticides Use and its Economic Impact on the Apiculture Subsector in Selected Districts of Amhara Region, Ethiopia. J Environ Anal Toxicol. 5 (2): 267. doi:10.4172/2161-0525.1000267.

Dessei, T., (2014). Allelopathic Effects of Lantana (Lantana camara L.) Leaf Extracts on Germination and Early Growth of three Agricultural Crops in Ethiopia. Momona Ethiopian Journal of Science. 6 (1), pp.111-119.

Dharmendra, S., J., Parul, G., Abhishek, Rajeev, N., (2013). Soil Diversity: A Key for Natural Management of Biological and Chemical Constitute to Maintain Soil Health & Fertility. International Journal of Bio- Science and Bio-Technology, 5(1).

Di Falco, S., Chavas, J.P., (2009). On crop biodiversity, risk exposure, and food security in the highlands of Ethiopia. American Journal of Agricultural Economics. 91 (3), pp. 599-611.

Di Falco, S., Chavas, J.P., Smale, M., (2007). Farmer management of production risk on degraded lands: the role of wheat variety diversity in the Tigray region, Ethiopia. Agricultural Economics. 36 (2), pp.147-156.

Dí'az, S. et al., (2019). Pervasive human-driven decline of life on Earth points to the need for transformative change. Science. 366 (6471).

Dí'az, S., et al., (2015). The IPBES Conceptual Framework - connecting nature and people. Current Opinion in Environmental Sustainability. 14:1–16. Retrieved from https://doi.org/10.1016/j.cosust.2014.11.002 28.

Dixon, A., (2001). Indigenous hydrological knowledge in south-west Ethiopia. Indigenous Knowledge and Development Monitor. 1 (3), pp. 3-5.

Duressa, T.F., (2018). Newly Emerging Insect Pests and Diseases as a Challenge for Growth and Development of Ethiopia: The Case ofWestern Oromiya. J Agri Sci Food Res. 9: 20.

EAS. (2013). The State of Agricultural Science and Technology in Ethiopia. Proceedings of the Workshop held at the International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia from 28-30 November 2011, Edited by Brhane Gebrekidan, Sime Debela, Solomon Bekure, Taye Bezuneh, Solomon Hailemariam and Gete Zeleke.

EAS. (2015). First Assessment Report, Working Group II Agriculture and Food Security. Ethiopian Panel on Climate Change. The Ethiopian Academy of Sciences.

EAS. (2017). The state of the environment: Land. The Ethiopian Academy of Sciences.

EBI. (2014). Ethiopia's Fifth National Report to the Convention on Biological Diversity, Ethiopian Biodiversity Institute (EBI). Addis Ababa.

EBI. (2015). Ethiopia's National Biodiversity Strategy and Action Plan (NBSAP) 2015-2020. Ethiopian Biodiversity Institute (EBI). Addis Ababa.

EFCCC. (2017). The state and outlook of the environment. Environment for sustainable development. Prepared in collaboration with Ethiopian Academy of Sciences. Environment, Forest and Climate Change Commission. Addis Ababa.

EFCCC. (2018). Ethiopia State and Outlook of the Environment. Environment for Sustainable Development. Addis Ababa. Environment, Forest, and Climate Change Commission.

EIAR. (2011). New agroecological map of Ethiopia. Coordination of National Agricultural Research System. EIAR, Addis Ababa.

Ejeta, G., (2007). Breeding for Striga resistance in sorghum: exploitation of an intricate host parasite Biology. Crop Science. 47, pp. 216-227.

Ejeta, G., Babiker, A.G.T., Butler, L., (2002). New approaches to the control of Striga, a training workshop on Striga resistance. Melkassa, May 14-17, (2002). Nazareth, Ethiopia.

EPCC. (2015). First Assessment Report, Working Group I, Physical Science Basis. Ethiopian Panel on Climate Change (EPCC). Ethiopian Academy of Sciences.

EPCC. (2015). First Assessment Report. An Assessment of Ethiopia's Policy and Institutional Frameworks for Addressing Climate Change. Ethiopian Academy of Sciences.

Eshetu, Z. et al., (2014). Climate finance in Ethiopia. Overseas Development Institute, London and Climate Science Centre, Addis Ababa.

Evans, H.C., (1997). Parthenium hysterophorus L. Review of its weed status and the possibility of Biological control. Biocontrol News and Information: 8: pp. 7-30.

Eyasu, E., (2009). Approaches for Integrated Soil Fertility Management in Ethiopia: A review, Addis Ababa, Ethiopia, unpublished.

Eyasu, E., (2016). Soil of Ethiopian Highlands: Geomorphology and properties. CASCAPE Project, ALTERA, Wageningen University and Research Centre (Wageningen UR). The Netherlands. pp 385.

FAO. (1986). Ethiopian Highlands Reclamation Study (EHRS) Report. Food and Agricultural Organization of the United Nations, AG: UTF/ETH/O37/ETH Final Report, FAO, Rome. 354 pp.

FAO. (2006). Exchange, use and conservation of animal genetic resources: Policy and regulatory options," Centre for Genetic Resources, the Netherlands (CGN) Report, Rome, Italy.

FAO. (2008). Agricultural Biodiversity in FAO: How agriculture benefits biodiversity and how biodiversity benefits agriculture. Food and Agriculture Organization of the United Nations, Rome. www.fao.org/biodiversity, 46pp.

FAO. (2013). The state of Ethiopia's biodiversity for food and agriculture. Food and Agriculture Organization of the United Nations, Rome. 2015.

FAO. (2015). FAO statistical pocketbook world food and agriculture. Food and Agriculture Organization of the United Nations, Rome. 2015.

FAO. (2018a). The 10 elements of agroecology: Guiding the transition to sustainable food and agricultural systems. Published on Tuesday, May 8th, 2018 Accessed online April 24, 2019.

FAO. (2018b). The impact of disasters and crises on agriculture and food security. Rome. (available at http://www.fao.org/3/I8656EN/i8656en.pdf).

FAO. (2019). The State of the World's Biodiversity for Food and Agriculture, J. Bélanger & D. Pilling (eds.). FAO Commission on Genetic Resources for Food and Agriculture Assessments. Rome. 572pp.

FDRE. (1995). Proclamation of the Constitution of the Federal Democratic Republic of Ethiopia Negarit Gazeta No. 25 (Proclamation No. 1/1995), pp. 1–38. Addis Ababa.

FDRE. (2011). Ethiopia's Climate Resilient Green Economy: Green Economy Strategy. Federal Democratic Republic of Ethiopia. Addis Ababa.

Fengjiao, M.A., Eneji, A., Egrinya, A., Liu, J., (2014). Sustainability. 6: pp. 8700-8719; doi:10.3390/su6128700).

Fikrey, T. (2011). Woody species diversity, management and carbon stock along an elevation gradient in coffee-based Agroforestry in Yirgacheffe, Ethiopia. Hawassa University, Wondo Genet College of Forestry and Natural Resources, Hawassa, Ethiopia

Fisehaye, R., (2005). Water hyacinth (Eichhornia crassipes): A review of its weed status in Ethiopia. Arem, 6: 105-111.

Fite, T., Hirpa, L., Alembrihan, M., (2017). Distribution and Spread of Parthenium Weed (Parthenium hysterophorus L.) Infestation in Western Oromiya, Ethiopia.

Fitsum, H., Pender, J., Nega, G., (1999). Land degradation in the highlands of Tigray and strategies for sustainable land management: Socio economics and Policy Research Working Paper 25. International Livestock Research Institute.

Foley, J.A. et al., (2011). Solutions for a cultivated landscape. Nature. 478: pp. 337-342.

Forest Peoples Programme. (2016). Annual Review of the Forest Peoples Programme 2016, 40 pp.

Free J.B. (1993). Insect pollination of crops, Academic Press; London, UK.

Fresco, L.U. and Westphal, E., (1988). A Hierarchical classification of farm systems. Experimental Agriculture. Vol. 24: 99. 399-419.

Fufa, B., and Hassan, R.M., (2005). Stochastic Technology and Crop Production Risk: The Case of Small-Scale Farmers in East Hararghe Zone of Oromia Regional State in Ethiopia, Strategies and Analysis for Growth and Access. Ethiopia.

Gadgil, M., Berkes, F., Folke, C., (1993). Indigenous knowledge for biodiversity conservation. Ambio, 22(2/3), 151-156.

Galluzzi, G., Eyzaguirre, P., Negri, V., (2010). Homegardens: neglected hotspots of agrobiodiversity and cultural diversity. Biodiversity and Conservation. 19: pp. 3635-3654.

Gang, C. et al., (2014). Quantitative assessment of the contributions of climate change and human activities on global grassland degradation. Environmental Earth Sciences. 72 (11): 4273–4282.

Garbach, K. et al., (2014). Biodiversity and ecosystem services in agroecosystems. Encyclopedia of Agriculture and Food Systems, 2: 21-40. doi:10.1016/B978-0-444-52512-3.00013-9 21.

Gashaw, T., Amare, B., Hagos, G.S., (2014). Land Degradation in Ethiopia: Causes, Impacts and Rehabilitation Techniques. Journal of Environment and Earth Science. 4 (9). ISSN 2224-321.

Gebre, T., (2015). Plant species diversity across Enset based agroecosystems of Ethiopia: Effects of landscape level factors. PhD Thesis, Addis Ababa University, 245 pp.

Gebreegziabher, Z., (2007). Household fuel and resource use in rural-urban Ethiopia. Wageningen University, The Netherlands.

Gebretsadik, T., (2016). Causes for Biodiversity Loss in Ethiopia: A Review from Conservation Perspective.

Gebreyesus, B., Kirubel, M., (2009). Estimating Soil Loss Using Universal Soil Loss Equation (USLE) for Soil Conservation planning at Medego Watershed, Northern Ethiopia. Journal of American Science. 5 (1): pp.58-69.

Gennet, S., Howard, J., Langholz, J., (2013). Farm practices for food safety: an emerging threat to floodplain and riparian ecosystems. Front Ecol Environ. 11 (5): 236–42. doi:10.1890/120243.

Getahun, A., Krikorian, A.D., (1973). Chaat: Coffee's rival from Harar, Ethiopia. Botany, cultivation and use. Economic Botany. 27: 353–377.

Gibson, D. J., (2009). Grasses and grassland ecology. Oxford University Press. PP. 320. ISBN: 9780198529194.

Gil, P.R. et al., (2004). Hotspots revisited. CEMEX, Mexico City.

GISP (Global invasive Species Programme). (2004). Africa Invaded: The Growing Danger of Invasive Alien Species. Global invasive Species Programme, Cape Town. http://www.gisp.org/downloadpubs/gisp%20africa%202.pdf.

Gizaw, S. et al., (2007). Population structure, genetic variation and morphological diversity in indigenous sheep of Ethiopia. Animal Genetics. 38(6), pp.621-628.

Goebel, W., Odenyo, A., (1983). Agroclimatic resources for land-use planning. GOE/FAO Project. ETH/82/010/. FAO Assistance to Land use planning in Africa. Addis Ababa.

Gorfu, D., Ahmed, E., (2013). Crops and agro-ecological zones of Ethiopia. Ethiopian Institute of Agricultural Research, Addis Ababa.

Goshu, G., Aynalem, S., (2017). Problem Overview of the Lake Tana Basin. K. Stave et al. (eds.), Social and Ecological System Dynamics, AESS Interdisciplinary Environmental Studies and Sciences Series, DOI 10.1007/978-3-319-45755-0_2.

Guha-Sapir, D. et al., (2014). Annual disaster statistical review 2013: the numbers and trends. Brussels. Centre for Research on the Epidemiology of Disasters.

Haile, A. et al., (2019). Community-based breeding programmes are a viable solution for Ethiopian small ruminant genetic improvement but require public and private investments. Journal of Animal Breeding and Genetics. 136(5), pp.319-328.

Hailu, F. et al., (2006). Multivariate analysis of diversity of tetraploid wheat germplasm from Ethiopia. Genetic Resources and Crop Evolution. 53: pp.1089–1098.

Hanotte, O. et al., (2000). Geographic distribution and frequency of a taurine Bos taurus and an indicine Bos indicus Y specific allele amongst sub–Saharan African cattle breeds. Molecular Ecology. 9: pp. 387–3.

Harlan, J. R., (1969). Ethiopia: A centre of diversity. Economic Botany. 23: pp. 305–314.

Hassan, M. et al., (2015). Agroforestry in Ethiopia: using trees on farms to boost crop productivity and strengthen food security. Policy Brief No.30.

Hassan, M., U., (2011). Analyzing Governance Reforms in Irrigation: Central, South and West Asian Experience. Irrigation and Drainage. 60 (2): pp.151-162.

Hein, B., (1989). Insect Pests of Cereals in Ethiopia. identification and control methods, FAO/UNDP Project ETH/86/029 Crop Protection Phase II, Addis Ababa.

Herrero, M. et al., (2012). Drivers of change in crop–livestock systems and their potential impacts on agro-ecosystems services and human wellbeing to 2030: A study commissioned by the CGIAR Systemwide Livestock Programme. Nairobi, Kenya: ILRI.

Hill, R. et al., (2019). Working with indigenous, local and scientific knowledge in assessments of nature and nature's linkages with people. Current Issues in Environmental Sustainability. 43: pp. 8–20.

Hillbrand, A., (2013). Indigenous Agroforestry systems under pressure - the case of Gedeo Agro-forestry and its value to farmers' livelihoods, southern Ethiopia. MSc Thesis, Bangor University, UK.

Holden, S.T., Deininger, K., Ghebru, H., (2009). Impacts of low-cost land certification on investment and productivity. Am. J. Agric. Econ. 91 (2): pp. 359–373.

Holly, S. and David, P., (2001). Reducing child poverty in Britain: an assessment of government policy 1997-2001. *The Economic Journal*, 111 (469). F85-F101. ISSN 0013-0133.

Hufnagel, H.P., (1961). Agriculture in Ethiopia. Food and Agriculture Organization of the United Nations, Rome.

Hügel, S., (2017). A Review of Agroforestry Practices with an Introduction to the Arba Minch Slope Farming Project in R Schaldach & R Otterpohl (eds), RUVIVAL Publication Series, vol.1, Hamburg, pp. 6 - 13, <http://nbn-resolving.de/urn:nbn:de:gbv:830-88216892.

Hughes, T. P., (1994). Catastrophes, phases hifts, and large-scale degradation of a Caribbean coral reef. Science. 265(5178), pp. 1547-1551. https://doi.org/10.1126/.

Hurni, H., (1988). Degradation and Conservation of the Resources in the Ethiopian Highlands. Mountain Research and Development. 8: pp.123-130.

Hurni, H., (1998). Agroecological Belts of Ethiopia. Soil Conservation Research Programme, Ethiopia (Research Report).

Husen, A. et al., (2012). Biodiversity status in Ethiopia and challenges. In: Environmental Pollution and Biodiversity, K. P. Bharati; A. Chauhan and P. Kumar, Pvt Ltd. Publishing House, New Delhi, India. DOI: 10.13140/RG.2.1.1788.9121.

Hussain, S., Miller, D., (2013). The Economics of Ecosystems and biodiversity (TEEB) for agriculture and food (Concept Note).

IBC. (2012). The Sate of Forest Genetic Resource of Ethiopia. Country Report Submitted to FAO. Ethiopian Biodiversity Institute, Addis Ababa, Ethiopia.

ICRAF. (1990). Agroforestry Potentials for the Ethiopian Highlands. Working paper no. 21, International Centre for research in Agroforestry (ICRAF), Nairobi, Kenya.

IFAD. (2009). Federal Democratic Republic of Ethiopia, Document for Country program evaluation. International Fund for Agricultural Development. Report No. 2045-ET.

IFPRI. (International Food Policy Research Institute), (2010). Fertilizer and Soil Fertility Potential in Ethiopia. Constraints and opportunities for enhancing the system. Technical report. DOI: 10.13140/RG.2.1.3632.5846.

IGAD. (2011). The Contribution of Livestock to the Ethiopian Economy – Part III GAD LPI Working Paper No. 02 – 11.

Iinstituet of Biodiversity Conservation (IBC). (2005). National Biodiversity Strategy and Action Plan. Ethiopian Biodiversity Institute, Addis Ababa, Ethiopia.

IPBES (2018). Summary for policymakers of the regional assessment report on biodiversity and ecosystem services for Asia and the Pacific of the Intergovernmental Science-Policy

Platform on Biodiversity and Ecosystem Services. (Karki, M. et al, Eds.). Bonn, 8824 Germany: IPBES secretariat. 49pp.

ITC (International Trade Center). (2010). Spice sub-sector strategy for Ethiopia. Spice sub-sector strategy committee. International Trade Center, Division of country program. http://www.intracen.org.

Jackson, L., et al., (2005). Agrobiodiversity: A new science agenda for biodiversity in support of sustainable agroecosystems. DIVERSITAS Report N°4. 40 pp.

Jacobsen, ven-Erik., (2015). Using our agrobiodiversity: plant-based solutions to feed the world. Agron. Sustain. Dev. 35: pp. 1217–1235.

Jagawe, M., (2007). Challenges and opportunities in the protection and preservation of indigenous knowledge in Africa. In International Review of Information Ethics. 7, pp. 344-348.

Järnberg, L. et al., (2018). Green niche actors navigating an opaque opportunity context: Prospects for a sustainable transformation of Ethiopian agriculture. Land Use Policy. 71: pp. 409-421.

Jarvis, D. I., Hodgkin, T., (1999). Wild relatives and crop cultivars: detecting natural introgression and farmer selection of new genetic combinations in agroecosystems. Molecular Ecology. 8: pp. 159–173.

Jarvis, D.I., Padoch, C., Cooper, H.D., (2007). Managing Biodiversity in Agricultural Ecosystems. Columbia University, New York. 105 pp.

Jifar, H. et al., (2018). Agro-Morphological Traits Diversity in Tef [Eragrostis Tef (Zucc.) Trotter] Genotypes from Various Sources. Ethiop. J. Agric. Sci. 28 (3): pp. 131-148.

Johns, T. et al., (2013). Agricultural biodiversity as a link between traditional food systems and contemporary development, social integrity and ecological health. J. Sci. Food Agric. 93: pp. 3433–3442.

Jose, S. et al., (2000). Defining competition vectors in a emperate alley cropping system in the midwestern USA: 2. Competition for water', Agroforestry Systems. 48: pp. 41–59.

Kassa, H. et al., (2016). Transition from forest-to cereal-based agricultural systems: A review of the drivers of land use change and degradation in Southwest Ethiopia. Land degradation and development. https://doi.org/10.1002/ldr.2575.

Kassa, H. et al., (2018). Agroecological implications of forest and agroforestry system conversion to cereal based farming systems in the White Nile basin, Ethiopia. Agroecology and Sustainable food systems. 42 (2): pp. 149-168.

Kassa, H., Bekele, M., Campbell, B.M., (2011). Reading the landscape past-update: explaining the lack of on-farm tree planting in Ethiopia. Environment and History. 17 (3): pp. 461-479. ISSN: 0967-3407.

Kassie, M. et al., (2008). Economics of Soil Conservation Adoption in High-Rainfall Areas of the Ethiopian Highlands. Environment for Development, discussion Paper series.

Kearns, C.A, Inouye D.W., Waser, N.M., (1998). Endangered Mutualism: The Conservation of Plant-pollinator Interaction. Annul Rev Ecol. 29: pp. 83-112.

Kebede, A. et al., (2014). "Impact of farming system shift and land fragmentation on livestock production: The case of Fogera district. In:" Proceedings of the international workshop on-farm size dynamics in the east and southern Africa, Bahir Dar, Ethiopia, Jun 3-5, 2014.

Kefyalew, E., (2011). Fertilizer Consumption and Agricultural Productivity in Ethiopia. Working Papers 003, Ethiopian Development Research Institute.

Kelbessa, E., Demissew, S., (2014). Diversity of the vascular plant taxa of the Flora of Ethiopia and Eritrea. Ethiop. J. Biol. Sci. 13 (supp.): pp.37-45.

Kennedy, G. et al., (2017). Food biodiversity for healthy, diverse diets. Bioversity International. ISBN 13: 978-92-9255-070-7.

Ketema, S., (1993). Tcff {Eragrostis tef): breeding, genetic resources, agronomy, utilizaton and role in Ethiopian agriculture. Institute of Agricultural Research, Addis Abeba.

Kippie, T., (2002). Five Thousand Years of Sustainability? A case study of Gedeo Land Use (Southern Ethiopia). PhD. Dissertation, Wageningen University, The Netherlands.

Klein, A.M. et al., (2007). Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B-Biological Sciences. 274: pp. 303-313.

Koehler, J., (2017). Where the wild coffee grows. Bloomsbury, New York, USA, 269pp.

Komarek, A.M. et al., (2019). Economywide effects of climate-smart agriculture in Ethiopia. Agricultural Economics. 50(6), pp.765-778.

Kremen, C., (2005). Managing ecosystem services: What do we need to know about their ecology. Ecology Letters. 8: pp. 468–479.

Lakew, B. and Assefa, A., (2011). Advances and experiences in barley landrace improvement in Ethiopia. pp 31-46 in Barley Research and Development in Ethiopia Edited by Bayeh Mulatu and Stefania Grando, EIAR and ICARDA. Proceedings of the 2nd National Barley Research and Development Review Workshop. 28-30 November 2006, HARC, Holetta, Ethiopia. ICARDA, Aleppo, Syria.

Lal, R., (2014). Soil conservation and ecosystem services. International Soil and Water Conservation Research. https://doi.org/10.1016/S2095-6339(15)30021-6.

Lange, G.M, Wodon, Q., Carey, K., (2018). The Changing Wealth of Nations. In Building a Sustainable Future. Washington, DC: World Bank. © World Bank. https://openknowledge.worldbank.org/handle/10986/29001.

Lemenih, M., (2004). Effects of Land Use Changes on Soil Quality and Native Flora Degradation and Restoration in the Highlands of Ethiopia. Acta Universitatis Agriculturae Sueciae Silvestria.

Lemessa, D. Hylander, K., Hambäck, P., (2013). Composition of crops and land-use types in relation to crop raiding pattern at different distances from forests. Agriculture Ecosystems & Environment. 167: pp. 71-78.

Lenne, J. M., Wood, D., (1997). The conservation of agrobiodiversity on-farm: questioning the emerging paradigm. Biodiversity and Conservation 6: pp. 109-129.

Likens, G. E. et al., (1998). The biogeochemistry of calcium at Hubbard Brook. Biogeochemistry, 41: 89–173.

Lindenmayer, D. B., Likens, G. E., (2009). Adaptive monitoring: a new paradigm for long-term research and monitoring. Trends in Ecology & Evolution. 24 (9): pp. 482-486.

Lulekal, E., Asfaw, Z., Kelbessa, E., Damme, P.V., (2011). Wild edible plants in Ethiopia: A review on their potential to combat food insecurity. Afrika Focus. pp. 24 (2): pp. 71-121.

Macfadyen, S. et al., (2015). Early-season movement dynamics of phytophagous pest and natural enemies across a native vegetation-crop ecotone. Agriculture Ecosystems & Environment. 200: pp. 110-118.

Mack, R.N. et al., (2000). Biotic invasions: causes, epidemiology, global consequences, and control. Ecological Applications. 10: pp. 689-710.

Mahmud, Y. et al., (2008). The Impact of Climate Change and Adaptation on Food Production in Low-Income Countries: Evidence from the Nile Basin, Ethiopia, International Food

Policy Research Institute, Environment and Production Technology Division, Washington Dc.

Marschner, P., (2012). Mineral Nutrition of Higher Plants (3rd eds.) Acadamic Press Elsevier Ltd., United States of America. 668p.

Maryo, M. (2013). Enset-based agrobiodiversity in the agricultural landscape of Kambata Tembaro, Southern Ethiopia. PhD dissertation, Addis Ababa University, Ethiopia. 267 pp.

Maryo, M., Nemomissa, S., and Bekele, T., (2018). Diversity, challenges and management of enset (Ensete ventricosum (Welw.) Cheesman) by Kembatta people, southern Ethiopia *Journal of the Biological Society of Ethiopia.* **17** (Supplementary)**:** 133-161.

MEA (Millenium Ecosystem Assessment). (2005). Ecosystems and human well-being. Synthesis. Millenium Ecosystem Assessment.Washington, DC, U.S.A.: Island Press. 313.

Mehari, Z., (2008). Invasion of Prosopis (SW.) DC and rural livelihoods. The case of Afar pastoralists at Middle Awash Area of Ethiopia. MSc. thesis, 3. Oslo: Norwegian University of Life Science.

Mellisse, B.T. et al., (2018a). Home garden system dynamics in Southern Ethiopia. Agroforestry System. 92: 1579-1595.

Mellisse, B.T. et al., (2018b). Are traditional homegardens in Southern Ethiopia heading for extinction: Implications for productivity, species richness and food security. Agriculture, Ecosystems and Environment. 252: pp. 1-13.

Mengistu, B. and Asfaw Z., (2019). Carbon Sequestration in Agroforestry Practices with relation to other Land Uses around Dallo Mena Districts of Bale Zone, Southeastern Ethiopia. Academic Research Journal of Agricultural Science and Research. Vol. 7(5), pp. 218-226.

Mesfin, A., (2016). Assessment of Striga infestation and Evaluation of sorghum landraces for Resistance/Tolerance to [Striga hermonthica (Del.) Benth] in North-Western Ethiopia. pp. 2082 –2090. DOI 10.1002/ps.4426.

Misganaw, M., Mengesha, G., Awas, T., (2017). Perception of Farmers on Importance of Insect Pollinators in Gozamin District of Amhara Region, Ethiopia. Biodiversity Int J. 1(5): 00029. DOI: 10.15406/bij.2017.01.00029.

MoA (Ministry of Agriculture). (1998). AgroEcological Zones of Ethiopia. Natural Resources Management and Regulatory Department, Ministry of Agriculture (MoA), with support of German Agency for Technical Cooperation (GTZ), Addis Ababa.

MoA. (2000). Agroecological Zonations of Ethiopia. Ministry of Agriculture, Addis Ababa.

MoA. (2019). Productive Safety Net Program (PSNP)- Public Works Impact Assessment, Phase IV. SuDCA Development Consultants. Ministry of Agriculture (MoA), Addis Ababa.

MoA. (2019). Transforming the Ethiopian seed sector: Issues and Strategies. Ethiopia: Ministry of Agriculture (MoA).

MoANR (Ministry of Agriculture and Natural Resources). (2016). Pest Management Support Services Strategy for Ethiopia. Addis Ababa, Ministry of Agriculture and Natural Resources, Addis Ababa.

MoARD, World Bank. (2007). Thematic Papers on Land Degradation in Ethiopia. Ministry of Agriculture and Rural Development and World Bank, Addis Ababa, Ethiopia.

MoARD. (2005). Major Agro-ecological Zones of Ethiopia. Forestry, Land Use and Soil Conservation Department, Ministry of Agriculture and Rural Development, Addis Ababa.

MoFED (Ministry of Finance and Economic Development. (2010). Federal Democratic Republic of Ethiopia, Growth and Transformation Plan, 2010/11-2014/15, Volume I, Addis Ababa.

Mohammed, A., (2011). Carbon Under Native Forest and Adjacent Land Use Systems at Gera, Jimma Zone, South-West Ethiopia. MSc thesis, Hawassa University, Wondo Genet College of Forestry and Natural Resources, Hawassa, Ethiopia

Mohammed, C., Wiersum, K.F., (2011). The role of non-timber forest products for livelihood diversification in Southwest Ethiopia. Ethiopian e-Journal for Research and Innovation Foresight. 3 (1): pp. 44-59.

MoWE (Ministry of Water and Engery). (2015). Ethiopia’s Climate-Resilient Green Economy Climate Resilience Strategy: Water and Energy. Ministry of Water and Engery (MoWE). Federal Democratic Republic of Ethiopia, Addis Ababa.

Mueller-mahn, D., Getachew, G., Rettberg, S., (2010). Pathways and dead ends of pastoral development among the Afar Karrayu in Ethiopia.: European Journal for Development Research. 22: pp. 660-677.

Mulat, Y., (2013). Indigenous Knowledge Practices in Soil Conservation at Konso People, South western Ethiopia. Journal of Agriculture and Environmental Sciences. 2(2). www.aripd.org/jaes.

Munodawafa, A., (2007). Assessing nutrient losses with soil erosion under different tillage systems and their implications on water quality. Physics and Chemistry of the Earth. https://doi.org/10.1016/j.pce.2007.07.033.

Munzara, A., (2007). AgroBiodiversity and Food Security, Community Technology Development Trust, Harare, Zimbabwe.

NASAC. (2014). Challenge of Water security in Africa: Network of African Science, Academies, Recommendations for Policy Makers.

Negash, A., (2001). Diversity and conservation of enset (Ensete ventricosum Welw. Cheesman) and its relation to household food and livelihood security in South-western Ethiopia. PhD dissertation, Wageningen University, the Netherlands.

Negash, M., (2007). Tree management and livelihoods in Gedeo agroforests, Southern Ethiopia. Forests, Trees and Livelihoods. 17: 157-168.

Negash, M., (2013). The indigenous agroforestry systems of the south-eastern Rift Valley escarpment, Ethiopia: their biodiversity, carbon stocks, and litterfall. PhD thesis. University of Helsinki, Helsinki, Finland. Tropical Forestry Reports 44.

Negash, M., Achalu, N., (2008). History of Indigenous Agro-Forestry in Gedeo, Southern Ethiopia based on local community interviews: vegetation diversity and structure in the Land-use systems @ AGRIS RECORDS http://agris.fao.org/aos/records/ET2009000185.

Neher, D., (1992). Ecological sustainability in agricultural systems: definition and measurement. Journal of Sustainable Agriculture. 2: pp.51-61.

Nelson, G.C. et al., (2006). Anthropogenic Drivers of Ecosystem Change: An Overview. Ecology and Society. 11 (2): 29: http://www.ecologyandsociety.org/vol11/iss2/art29/.

Newman, S.M., Bennett, K., Wu, Y., (1997). Performance of maize, beans and ginger as intercrops in Paulownia plantations in China', Agroforestry Systems. 39 (1): pp. 23–30.

NMA (National Meteorological Agency). (2007). Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia, National Meteorological Agency (NMA), Addis Ababa.

Oakland Institute. (2015). Protecting Biodiversity and Traditional Agro-Systems in Ethiopia. Agroecology Case studies. Alliance for Food Security in Africa. www.afsafrica.org.

OCHA (Office for the coordination of Humanitarian Affairs). (2017). The Mission of the United Nations Office for the coordination of Humanitarian Affairs. A product of the Disaster Risk Management Technical Working Group (DRMTWG). Drought Response Situation Report No. 09 (28 February 2017). https://reliefweb.int/report/ethiopia/ethiopia-drought-response-situation-report-no-09-28-february-2017.

Okigbo, P.N.C., (1986). Theoretical and Methodological Issues Relating to Unemployment in Nigeria: In annual Conference Proceedings of the Nigeria Economic Society, Kaduna, May 13-17.

Ollerton, J., Winfree, R., Tarrant, S., (2011). How many flowering plants are pollinated by animals? Forum. 120: pp. 321–326. https://doi.org/10.1111/j.1600-0706.2010.18644.x.

Ossendorf, G. et al., (2019). Middle Stone Age foragers resided in high elevations of the glaciated Bale Mountains, Ethiopia. Science. 365: pp. 583–587.

Philipsson, J. E. et al., (2011). “Sustainable breeding programmes for tropical farming systems,” in Animal Genetics Training Resource, J. M. Ojango, B. Malmfors, and A. M. Okeyo, Eds. International Livestock Research Institute and Swedish University of Agricultural Sciences, Uppsala, Sweden.

Poncet, A. et al., (2009). Useful plants in the Flora of Ethiopia and Eritrea area. In: Flora of Ethiopia and Eritrea volume 8, Inga Hedberg, Ib Friis and Eva Persson (Eds). 1-7, 40-95.

Potts, S.G., Biesmeijer, J.C., Kremen, C., Neumann, P., Schweiger, O., & Kunin, W.E., (2010). Global pollinator declines: trends, impacts and drivers. Trends in Ecology & Evolution. 25: pp. 345-353.

Rahmato, D., (2011). Land to investors: Large scale land transfers in Ethiopia. Forum for Social Studies Policy Debates Series. Forum for Social Studies, Addis Ababa.

Reda, A., Mesfin, M., (2017). Assessment of the Current State of Genetic Erosion of Field Cro Species in Tigrai, Ethiopis: A Survey Report. African Journal of Basic and Applied Sciences. 9 (5): pp. 259-271.

Reda, A., Tewelde, F., (2017). Impact of Invasive Alien Plants on Biodiversity and Livelihood of Local Communities in Tigray, Ethiopia. World Applied Sciences Journal. 35 (11): pp. 2364-2378. https://doi.org/ 10.5829/idosi.wasj.2017.2364.2378.

Rehima, M. et al., (2013). Factors affecting farmers' crops diversification: Evidence from SNNPR, Ethiopia. International Journal of Agricultural Sciences. 3 (6): 558-565.

Reiks, H., Edward, S., (2007). Organic chain development in Ethiopia. Proceedining of the Participatory Networking Workshop Addis Ababa, Ethiopia, 24-25 May 2007. Addis Ababa.

Reyes-García, V. et al., (2020). Protocol for the Collection of Cross-cultural Comparative Data on Local Indicators of Climate Change Impacts, ICTA, Barcelona pp. 126 .

Richards, K.W., Kevan, P.G., (2002). Aspects of bee biodiversity, crop pollination, and conservation in Canada. In: Kevan, P. and Imperatriz, F. VL (eds) Pollinating Bees the Conservation Link between Agriculture and Nature Ministry of Environment/Brasilia, pp. 77-94.

Richey, P.S. et al., (2015). Quantifying renewable groundwater stress with GRACE, Quantifying renewable groundwater, *Water Resour. Res.*, **51**: 5217–5238 doi:10.1002/2015WR017349 https://doi.org/10.1002/2015WR017349.

Ricketts, T.H. et al., (2008). Landscape effects on crop pollination services: are there general patterns? Ecology Letters. 11: pp.1121-1121.

Rickson, R. J., (2014). Can control of soil erosion mitigate water pollution by sediments? Science of the Total Environment. https://doi.org/10.1016/j.scitotenv.2013.05.057.

Rivera, W. M., Qamar, M. K., Crowder, L.V., (2001). Agriculture and Rural Extension World Wide: Options for Institutional Reform in the Developing Countries. FAO, Extension, Education and Communication Service; Research, Extension and Training Division, Rome.

Rudebjer, P. et al., (2011). Teaching agrobiodiversity: a curriculum guide for higher education. Bioversity International, Rome. 97pp.

Ruelle, M.L. et al., (2019). Biocultural diversity and food sovereignty: a case study of human-plant relations in northwestern Ethiopia. Food Security. 10 (53): pp. 1-17.

Ruiz-Mallén, I., (2013). Children's use of time and traditional ecological learning. A case study in two Amazonian indigenous societies. Learning and Individual Differences. https://doi.org/10.1016/j.lindif.2012.12.012.

Ryan, F., (2011). US Forest Service Technical Assistance Trip to Ethiopia: Invasive Species Management.

Sahlu, H., (2004). Population and development in Ethiopia. Paper presented at the National Symposium on the Occasion of the 10th Anniversary of the Launching of the National Population Policy of Ethiopia, Addis Ababa.

Samberg, L.H., Shennan, C., Zavaleta, E., (2013). Farmer seed exchange and crop diversity in a changing agricultural landscape in the southern highlands of Ethiopia. Human Ecology. 41(3), pp.477-485.

Schlede, H., (1989). Distribution of acid soils and liming materials in Ethiopia. Note No. 326. Ethiopian Institute of Geological Survey, Addis Ababa.

Shaner, W.W., Philipp, P.F. and Schmehl, W., (1982). Farming systems research and development: Guidelines for developing countries, Boulder, Colorado, 17 Westview Press.

Shapiro, B.I., Gebru, G., Desta, S., Negassa, A., Nigussie, K., Aboset G. and Mechale. H., (2017). *Ethiopia livestock sector analysis*. Project Report, Nairobi, Kenya: International Livestock Research Institute (ILRI).

Sharma, G. P., Raghubanshi, A. S. and Singh, J. S., (2005). Lantana invasion: An overview. Weed Biology and Management. 5, pp. 157-165.https://doi.org/10.1111/j.1445-6664.2005.00178.x.

Shiferaw, H. et al., (2019). Modelling the current fractional cover of an invasive alien plant and drivers of its invasion in a dryland ecosystem. Scientific Reports, DOI:10.1038/s41598-018-36587-7.

Sibhatu, K.T., Krishna, V.V, Qaim, M., (2015) Production diversity and dietary diversity in smallholder farm households. Proceedings of the National Academy of Sciences of the United States of America 112(34): pp. 10657–62.

Sileshi, D., (2016). Home garden agroforestry practices in the Gedeo zone, Ethiopia: a sustainable land management system for socio-ecological benefits. UNU-IAS & IR3S/UTIAS 2016, Socio-ecological production landscapes and seascapes (SEPLS) in Africa. United Nations University Institute for the Advanced Study of Sustainability, Tokyo, pp. 28-36.

Sileshi, Z., Bediye, S., (1989). Utilization of feed resources and feeding system in the central zone of Ethiopia. pp. 129-132. Proceeding of the 3rd national livestock conference, IAR, Addis Ababa, Ethiopia.

Simmonds, N.W., (1958). Ensete cultivation in the southern highlands of Ethiopia: a Review.Trop. Agric.Trin. The Enset planting culture of Eastern Sidamo, Ethiopia. Acta Geographica. 13 (4). pp. 35:302-307.

Sintayehu, D.W., (2018). Impact of climate change on biodiversity and associated key ecosystem services in Africa: a systematic review. Ecosystem Health and Sustainability. 4(9), pp.225-239.

SMART. (2019). Smart Fertilizer Management. Innovative software for optimizing fertilization and yields! https://www.smart-fertilizer.com/articles/soil-acidity.

Snir, A.D. et al., (2015). The origin of cultivation and proto-weeds, long before Neolithic farming, PLOS One 10 (7): 1-12.

SOCLA. (Undated). Agroecology: Concepts, principles and applications. Contributions by the Sociedad Cientifica Latino Americana de Agroecologia (SOCLA) to FAO's International Symposium on Agroecology for Food Security and Nutrition. www.agroeco.org/socla.

Solomon, A.M. et al., (2019). Genetic diversity and population structure of Ethiopian Capsicum germplasms. PLoS ONE 14(5). e0216886. https://doi.org/10.1371/journal.pone.0216886.

Solomon, E., (2013) Comparative study on plant diversity and carbon stocks in forest, semi-forest and garden Coffee systems in Gimbo Woreda, Southwest Ethiopia. MSc thesis Hawassa University, Wondo-Genet College of Forestry and Natural Resources, Wondo-Genet, Hawassa, Ethiopia.

Sonneveld, B.G., (2002). Land under Pressure: The Impact of Water Erosion on Food Production in Ethiopia. Shaker. PhD Thesis - Research VU, graduation VU.

Stark, J., Terasawa, K., Ejigu, M., (2011). Climate Change and Conflict in Pastoralist Regions of Ethiopia: Mounting Challenges, Emerging Responses. CMM Discussion Paper No. 4. 1-54p.

Steffen, W. et al., (2015). Planetary boundaries: guiding human development on a changing planet. *Science* **347**, 6223.

Sthapit, B.D. et al., (2017). Agrobiodiversity Index to measure agricultural biodiversity for effectively managing it. Conservation and Utilization of Agricultural Plant Genetic Resources in Nepal (BK Joshi, HB KC and AK Acharya, eds). Pages 170-175 in Proceedings of 2nd National Workshop 22-23 May 2017, Dhulikhel.

Stroud, A., (1994). Water hyacinth (Eichhornia crassipes [Mart.] Solms) in Ethiopia. In: Rezene, F. (Ed.), Proc. 9th Ann. Conf. EWSC 9-10 April 1991, Addis Ababa, Ethiopia, Addis Ababa, pp.7-16.

Stroud, A., Parker, C., (1989). A weed identification guide for Ethiopia. Food and Agriculture Organization, Rome, Italy. Amharic language, 278 pp.

Swift, M.J., Izac, A.M.N., van Noordwijk, M., (2004). Biodiversity and ecosystem services in agricultural landscapes—are we asking the right questions? Agriculture, Ecosystems and Environment. 104: pp. 113-134.

Swinton, S. et al., (2006). Ecosystem services from agriculture: looking beyond the usual suspects. American Journal of Agricultural Economics. 88: pp. 1160–1166.

Tadesse, M., (2017). Ethiopia: Home of Arabica Coffee, CreateSpace Independent Publishing Platform, North Charleton, USA, 94pp.

Tamene, L., Vlek, P.L., (2008). Soil erosion studies in Northern Ethiopia. Land use and soil resources. Netherlands: Springer Science.

Tamiru, G., (2017). Invasive Alien Weed Species Distribution, Impacts on Agriculture, Challenge and Reaction in Ethiopia: A Review. Journal of Biology, Agriculture, and Healthcare. 7(7). ISSN 2224-3208 (Paper) ISSN 2225-093X.

Tana, T., Milberg, P., (2000). Weed flora in arable fields of Eastern Ethiopia with emphasis on the occurrence of Parthenium hysterophorus L. Journal of Weed Research. 40: pp. 507-521.

Tanto, T. et al., (2009). Genetic diversity of barley (Hordeum vulgare L.) landraces from the central highlands of Ethiopia. Genetic Resources and Crop Evolution. 56 (8): pp. 1131-1148.

Taye, T., (2005). On farm phenotypic characterization of Sheko breed of cattle and their habitat in Bench Maji zone, Ethiopia. MSc Thesis, Alemaya University, Alemaya, Ethiopia.

Teressa, T., (2019). "Review on Striga Distribution, Infestation and Genetic Potential in Ethiopian Sorghum (Sorghum Bicolor (L.) Moench)" International Journal of Research Studies in Agricultural Sciences. 5 (2): 23-31, http://dx.doi.org/10.20431/2454-6224.0502004.

Tesfaye, B., (2002). Studies on landrace diversity, in vivo and in vitro regeneration of enset (Enset ventricosum Welw.). PhD dissertation, Humboldt University, Berlin, Germany.

Teshome, A. et al., (1997). Sorghum (Sorghum bicolor (L.) Moench) landraces variation and classification in north Shewa and south Welo, Ethiopia. Euphytica. 97: pp. 255–263.

Tessema, A.B., Birnie, A. and Tenqnas, B., (1993). *Useful Trees and Shrubs for Ethiopia. Regional Soil Conservation Unit*. Technical Handbook No.5. Swedish International Development Authority (SIDA). 472 pp.

Tessema, A.B., Birnie, A. and Tenqnas, B., (2007). Useful Trees and Shrubs for Ethiopia: identification, Propagation and Management for Agricultural and Pastoral Communities. SIDA‘s Regional Soil Conservation Unit, 486 pp.

Tessema, T. et al., (2009). Review invasive weed research in Ethiopia. In: Abraham T. (ed.) Increasing crop production through improved plant protection: Plant Protection Society of Ethiopia, Addis Ababa, Ethiopia. 2. pp. 381-407.

Thrupp, L.A., (1998). Cultivating diversity: agrobiodiversity and food security World Resources Institute, Washington, DC.

Ticktin, T., (2004). The ecological implications of harvesting non-timber forest products. Journal of Applied Ecology. https://doi.org/10.1111/j.1365-2664.2004.00859.

Torquebiau, E., (1992). Are tropical agroforestry homegardens sustainable? Agriculture, Ecosystems and Environment. 41: 189-207.

Tscharntke, T. et al., (2005). Landscape perspectives on agricultural intensification and biodiversity–ecosystem service management. Ecology Letters. 8: pp. 857-874.

Tsegaye, A., (2002). On indigenous production, genetic diversity and crop ecology of enset (Enset ventricosum (Welw.) Cheesman). PhD dissertation, Wageningen University, Wageningen, the Netherlands.

Tsegaye, B., (2003). Local Community Participating in Reversing Trends of Genetic Erosion: A Community Seed Bank Approach from Ethiopia. Paper Prepared for the CAPRI-IPGRI International Workshop on Property Rights, Collective Action and Local Conservation of Genetic Resources, Rome, 21 pp.

Tsegaye, W., LaRovere, R., Mwabu, G. and Kassie, G.T., (2016). Adoption and farm-level impact of conservation agriculture in Central Ethiopia. Environment, Development and Sustainability, 19 (6): 2517-2533.

Tsehaye, A. Bjornstad, A., Abay, F., (2012). Phenotypic and genotypic variation in flowering time in Ethiopian Barleys. Euphytica. 188 (3): pp. 309-323.

Tsiafouli, M.A. et al., (2017). Optimizing the Delivery of Multiple Ecosystem Goods and Services in Agricultural Systems: open access e-book. Frontiers Media S.A., Lausanne. http://dx.doi.org/10.3389/978-2-88945-296-5.

UNCED. (1992). Convention on Biological Diversity. The Earth's Summit on the Issue of Biological Diversity. Rio de Jenero.

UN-EUE. (2001). Forest fires in Ethiopia: Reflections on socio-economic and environmental effects of the fires in 2000. UNDP Emergencies Unit for Ethiopia. Available from Relief web. www.telecom.net.et/~undp-eue/, viewed 4 march 2019.

Unruh, J. D., (2001). The Dilemma of African Agrobiodiversity: Ethiopia and the Role of Food Insecurity in Conservation, paper presented at the conference "Managing Biodiversity in Agricultural Ecosystems" 8-10 November 2001, Montreal, Canada.

USAID. (2005). An Atlas of Ethiopian Livelihoods. Disaster Risk Management and Food Security Sector, MOARD, Addis Ababa.

van de Fliert, E., Braun, A.R., (1999). Farmer Field School for Integrated Crop Management of Sweet potato. Field guides and Technical Manual. Bogor, Indonesia: International Potato Center. ISBN 92-9060-216-3.

Vandermeer, J.H., (2011). The Ecology of Agroecosystems. Jones and Bartlett Publishers International, London.

Vavilov, N.L., (1951). The origin, variation, immunity and breeding of cultivated plants. Chronica bot. 13 (1-6): pp. 1-364.

Wakjira, M., (2009). Allelopathic effects of Parthenium hysterophorus L. on onion germination and growth. Allelopathy Journal. 24: pp. 351-362.

Water and Land Resource Centre (WLRC). (2019). Estimating Above -ground Carbon Stock for the Entire Ethiopia: A Remote Sensing Approach. Water and Land Resource Centre, Addis Ababa, Ethiopia.

Welbank, P.J., (1963). A comparison of competitive effects of some common weed species. Annals of Applied Biology. An international Journal of the qqb. https://doi.org/10.1111/j.1744-7348.1963.tb03679.x.

Weston, L.A., Duke, S.O., (2003). Weed and Crop Allelopathy. Critical Reviews in Plant Sciences. 22: pp. 367-389. http://dx.doi.org/10.1080/713610861.

Westphal, E., (1975). Agricultural Systems in Ethiopia. Wageningen: Centre for Agricultural Publication and Documentation, The Netherlands.

Wiggering, H., Weißhuhn, P., Burkhard, B., (2016). Agrosystem services: An additional terminology to better understand ecosystem services delivered by agriculture. Landscape Online. 49: pp. 1-15, DOI 10.3097/LO.201649.

Wilson, E.O., (1984). Biophilia: the human bond with other species.

Wilson, J. B. et al., (2012). Plant species richness: the world records. Journal of Vegetation Science. 23 (4): pp. 796–802.

Wolde Selassie, G., (1998). The Forest Resources of Ethiopia; Past and Present, Walia - Journal of the Ethiopian Wildlife and Natural History Society. 19: pp.10 - 28.

Woldeyes, F. et al., (2016). Homegardens (Aal-oos-gad) of the Basket People of Southwestern Ethiopia: Sustainable agro-ecosystems characterizing a traditional Landscape. Ethnobotany Research & Applications. 14: pp. 549-563.

Woldeyes, F., (2011). Homegardens and spices of Basketo and Kafa (Southwest Ethiopia): Plant diversity, Product valorization and implications to biodiversity conservation. PhD Thesis, Addis Ababa University. 222 pp.

Wolff, F., (2004). Legal factors driving agrobiodiversity loss. Environmental Law Network International 1: pp.1-11.

Worede, M., (1991). An Ethiopian perspective on conservation and utilization of plant genetic resources. In: Plant Genetic Resources of Ethiopia (Engels, J.M.M., Hawkes, J.G. and Melaku Worede, eds). Cambridge University Press, New York. 306 pp.

Worede, M., Tesemma, T., Feyissa, R., (2000). Keeping Diversity alive: an Ethiopian perspective. In: S.B. Brush (ed.), Genes in the Field: On-Farm-Conservation of Crop Diversity, IPGRI/IDRC, LEWIS PUBLISHERS, N.Y. pp.143-163

Worku, T., Tripathi, S.K., (2015). Watershed Management in Highlands of Ethiopia: A Review. Open Access Library Journal. 2: 1481pp. http://dx.doi.org/10.4236/oalib.1101481

World Bank. (2011). World Development Report 2011: Conflict, Security, and Development, World Bank Publications, 2011 M05 26 pp384.

WU. (2015). Global Material Flow Database. 2015 Version., (March), 1–37. Avaialable from http://www.materialflows.net.

Yemataw, Z., (2018). Agromorphological and molecular characterization of Enset (Ensete ventricosum (Welw.) Cheesman landraces from Ethiopia. PhD Thesis, Addis Ababa University. 251 pp.

Yirefu, F. et al., (2014). Water hyacinth in the Rift Valley water bodies of Ethiopia: Its distribution, socio-economic importance and management. International Journal of Current Agriculture Research. 3: pp. 67-75.

Yirefu, F., (2017). Management of water hyacinth (Eichhornia crassipes [Mart.] Solms) using bioagents in the Rift Valley of Ethiopia. PhD thesis, Wageningen University, Wageningen, the Netherlands. DOI http://dx.doi.org/10.18174/401611.

Zelalem, Y., Aynalem, H., Emmanuelle, G., (2009). Effect of climate change on livestock production and livelihood of pastoralists in selected pastoral areas of Borana, Ethiopia. In Climate change, livestock and people: Challenges, opportunities, and the way forward. Zelalem Yilma and Aynalem Haile (eds). Proceedings of the 17th annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia.

Zeleke, G. et al., (2010). Fertilizer and Soil Fertility Potential in Ethiopia: Constraints and opportunities for enhancing the system. International Food Policy Research Institute (IFPRI), Ethiopia.

Zeleke, G. M., Kassie, J. P., Yesuf, M., (2006). Stakeholder Analysis for SLM in Ethiopia: Assessment of Opportunities, Strategic Constraints, Information Needs and Knowledge gaps. EDRI/EEPFE. Addis Ababa, Ethiopia.

Zerabruk, M. et al., (2011). Genetic diversity and admixture of indigenous cattle from North Ethiopia: implications of historical introgressions in the gateway region to Africa. *Animal genetics.* 43(3), pp.257-266.

Zhang, W. et al., (2007). Ecosystem services and dis-services to agriculture. Ecological Economics. 64: pp. 253-260.

Zimmerer, K.S. et al., (2019). The biodiversity of food and agriculture (Agrobiodiversity) in the anthropocene: Research advances and conceptual framework. Anthropocene. 25: pp. 1-16.

7. Conclusions and Recommendations

7.1 Conclusions

The National Ecosystem Assessment (NEA) of Ethiopia has been undertaken based on the IPBES principles and processes at the national scale to assess the current state of knowledge on biodiversity and ecosystem services, and contributions to human wellbeing. Accordingly, the assessment aims at understanding the biodiversity and ecosystem services with respect to the benefits to people and quality of life, status and trends, direct and indirect drivers of change, level of awareness and knowledge, and impacts of policies and institutions as well as governance structures. The assessment focused on five broad ecosystems, viz., Mountain, Forest and Woodland, Aquatic and Wetland, Rangeland and Agricultural ecosystems. These ecosystems are sources of plant, animal and microbial biodiversity and provide diverse ecosystem services. Thus, the evidence synthesized from this NEA is expected to strengthen the knowledge base on biodiversity and also the interface between science and policy.

The Mountain ecosystem maintains high biodiversity since it is comprised of rich assemblages of species in a dense ecological community and acts as a refuge or sanctuary for plants and animals that became locally extinct in significantly transformed lower altitude surrounding areas. The Ethiopian highlands exhibit high diversity and endemicity of wildlife resources because of their large spatial extent and isolation within the Afro-tropical region.

The Forest and Woodland Ecosystem, which also harbors a rich biodiversity resource, contributes to human wellbeing through income generation and regulating ecosystem services. Sustainable utilization of forest resources has a big contribution to the development of the nation and its people. However, the current system of forest and woodland utilization is almost near open access, and thus unsustainable.

The Aquatic and Wetland ecosystem, that encompasses unique habitats and assemblages of organisms, is an important source of ecosystem services that include provision of food; including fish resources, water for household use and irrigation, reeds for thatching and craft making, dry season grazing, regulation of hydrological systems, filtration of water flow and sediment trapping, flood and pollutant control, provision of medicinal plants, and site for recreation and cultural practices.

The Rangeland Ecosystem, which is mainly associated with livestock production that generates significant economic benefits, plays important role in the maintenance of plant and animal biodiversity. The ecosystem serves as a source of food and herbal medicines; plays important role in carbon sequestration and climate regulation, associated with cultural identity and diversity; a place for exercising cultural and spiritual practices; and serves as a site for tourism and archeological and socio-anthropological studies.

Ethiopia's Agroecosystems contain rich and unique agrobiodiversity elements, key resources on which people depend for their livelihoods. The agrobiodiversity also contributes to global biodiversity resources. Over 95% of the regularly cultivated areas of the country occur in the highlands where mixed crop-livestock systems predominate, whereas the lowlands are dominated by pastoral and agropastoral livelihood systems. The country has diverse agroclimatic zones and people of different cultures, which resulted in the development of different agroecosystems, agricultural practices and food systems.

The conditions and functions of the different ecosystems are changing over time because of increasing anthropogenic and natural pressures. Accordingly, the ecosystems' functions and biodiversity have been degrading over time due to various socio-ecological drivers.

The Mountain ecosystem is highly susceptible to soil erosion, habitat fragmentation and biodiversity loss. The changes in land use land cover are negatively affecting biodiversity in this ecosystem. For example, loss of habitats are restricting movement and limiting availability of food for some range restricted species of wildlife thereby exposing the species to population decline, threatening their survival.

The Forest and Woodland ecosystem is also affected by diverse anthropogenic and natural causes including habitat fragmentation, over exploitations of wood and non-wood resources, agricultural expansion, fire and climate change. The degradation in forest and woodland ecosystem has been continuing at unprecedented rate due, mainly, to high human population growth.

The Aquatic and Wetland ecosystem is also under pressure due to causes that originate from natural factors and human activities. Irrespective of its potential to provide diverse benefits, the ecosystem suffers from over-exploitation and lack of proper management. This resulted in degradation and loss of wetlands and water bodies leading to loss of biodiversity and ecosystem services.

Similarly, the Rangeland ecosystem is deteriorating; leading to land degradation. This resulted in a consequent reduction in vegetation cover and palatable plant species and deterioration of soil quality, with an overall impact on restoration of denuded rangelands. Bush encroachment is also prevalent in rangelands where grazing pressure is high. The rangeland ecosystem has been subject to transformation into other land-use types.

The Ethiopian agroecosystem is also affected by both natural and anthropogenic causes including drought, floods, invasive alien species, climate change, over-exploitation, improper use of agro-chemicals and urbanization. These have resulted in soil acidification, loss of soil fertility, soil erosion, genetic erosion of agrobiodiversity and an overall decline in productivity.

The natural and anthropogenic causes exerting impacts on the ecosystems and their services are usually classified into direct drivers of change (e.g., natural fire, climate change, land use land cover change, overexploitation, invasive alien species and pollution) and indirect drivers of change (e.g., population growth, migration, governance systems, land tenure, economic and technological developments, social conflicts and international trade). Indirect drivers of change often result from the complex interactions of social, economic, political, cultural and technological developments, ultimately triggering the direct drivers to set off.

Moreover, undermining the roles of traditional institutions and ILK resources in policy frameworks is one of the key challenges in biodiversity management and conservation. Understanding the level of local people's awareness and knowledge on biodiversity and the interconnectedness among direct drivers of change in both natural and manmade environments would help to look for effective biodiversity management and conservation strategies. Therefore, it is important to enhance the awareness of communities, policy makers, development partners and private sectors on the importance of biodiversity and ecosystem services by adopting multidisciplinary, participatory and more focus on interactions between the different components, and by promoting the use of the indigenous and local knowledge.

Sustainable natural resource management and conservation need effective policies and regulations. Besides 1995 Federal Constitution and the 1997 Environment Policy, the Ethiopian government has issued different policies and strategies with respect to management and utilization of biodiversity and ecosystem services.

At different scales, the legislative development and organizational reforms have played their role in reducing environmental challenges although their impacts to reverse damages are minimal. The major root causes impeding effective outcomes are both legislative and weak institutional capacities that resulted in law enforcement and implementation gaps. The observed limitations are also associated with imperfection in institutional arrangements and issues like mandate overlaps, lack of proper coordination and synergy. Rectifying the deficiency cannot only be achieved through formulation of appropriate polices and promulgation of laws but also creating conducive conditions for policy implementation and and law enforcement through establishing well organized institutional set-up, creating skilled manpower, allotting optimum financial and material resources, ensuring willingness to comply, accountability and cooperation among actors.

7.2 Recommendations

Based on the findings of the National Ecosystem Assessment, the following recommendations are drawn.

- The ecosystems and biodiversity have been severely degrading in Ethiopia due to various indirect and direct drivers such as rapid population growth and agricultural expansion, where, currently, the impacts are highly pronounced in biodiversity-rich but fragile mountain and aquatic and wetland ecosystems. Therefore, the interventions strategies need to be designed and implemented to maintain the ecological functions thereby ensuring the sustainability of the services they provide to human wellbeing.

- The factors causing the loss of habitats and biodiversity are complex and thus compatible conservation approaches such as designing alternative ways of restoration activities, establishment of new and strengthening of existing protected area systems; engaging communities as custodians of environmental resources and introducing incentive schemes that benefit local communities are seemingly vital.

- In light of the rapid deterioration and the consequent loss of biodiversity from across all ecosystems of the country, it is vital to collate sound qualitative and quantitative data on floral, faunal and microbial components of ecosystems as well the associated biophysical and socioeconomic aspects.

- Lack of data management and retrieval system has already proven to be one of the limitations in effective conservation of biodiversity and associated knowledge. It is, therefore, crucial, to establish a national biodiversity database to facilitate access to accurate and up to date information and thereby enhance a nationwide biodiversity monitoring system that enables to tracking of the status and trend of genetic, species, habitats, ecological community diversity and associated knowledge.

- Banning ages-old local resources management practices such as the application of regulated fire by range land communities has been argued to have had negative consequences on the status of ecosystems and the benefits they provide to humans as well as both domestic and wild animals. It is, therefore, important to study and understand well the details before taking restrictive measures on such indigenous resource use and management options. Furthermore, maximizing the use and application of indigenous best practices with scientific support deserves proper attention. Motivating effective practice of ILK, innovations and practices by working with local communities (farmers and pastoralists) is also equally important.

- Lack of sufficient awareness by stakeholders at all levels (ranging from policy makers to implementers on the ground) is recognized to be among the major causes for the witnessed deterioration of ecosystems and the services. It is, therefore, crucial to work towards creating knowledge and awareness of the public on such issues as the importance of ecosystem restoration, the contribution of ecosystems to human existence and development, the importance of minimizing ecological footprints in terms of ensuring a healthy environment, and the need for integrating knowledge systems in conservation and development related undertakings.

- Given that Ethiopia aspires to register development in its all forms and also ensure self-sufficiency, the adoption of technologies and application of extension service with the objective of improving production systems is inevitable. However, such endeavors should take into account the perpetuation and diversity of local living forms (species, varieties, breeds) when integrating high-value improved kinds; should not encourage monocultures that result in ecological simplification; and should prohibit the use of land for activities that either transform ecosystems or make them vulnerable to degradation.

- Research and development should would focus to designing of suitable models of conservation and innovation that fit with specific local needs and priorities and also that stimulate interactions between ecosystem components as part of holistic strategies to build long term fertility, healthy agroecosystems and secure livelihoods through monitoring and evaluation schemes;

- The limitations in achieving effective management and conservation of ecosystems are significantly linked to incompatibilities of policies and law enforcement. Therefore, it is essential to formulate appropriate policies and legal provisions, and also translate these into implementation instruments such as regulations, directives, and guidelines. Such policy frameworks should also give attention to issues like the roles and authorities of customary institutions, cultural and historical aspects, responsible decision-making and effective representation.
- Regulatory frameworks and sector institutions need to be strengthened and the latter needs to be empowered with human, technical, financial and infrastructural capacities.

- The collaborative efforts among stakeholders and operational synergies among relevant institution are the feasible means to achieve the aspired objective of the conservation of ecosystems, biodiversity and the supply of the services, and thus increased commitment of the scientific community, decision-makers, and practitioners by strengthening the science-policy interface.

9. Scenarios of Changes in Biodiversity and Ecosystem Services in Ethiopia

Authors

Mekuria Argaw (PhD)

Woldeamlak Bewket (Professor)

Table of Contents

List of Tables

List of Figures

9. Scenarios of Changes in Biodiversity and Ecosystem Services in Ethiopia

Key messages and findings

Scenario analysis is an important tool for exploring alternative futures in socioeconomic and socio-political pathways, trends in major drivers of change in ecosystems and the consequent long-term impacts on biodiversity, ecosystem services and human wellbeing. Scenarios are useful in synthesizing large amount of data and information into a characteristic archetype so as to capture and assess modeling results, predictions and scientific projections. Scenario analysis is useful in informing policy design and decision-making in the context of uncertain futures. It is useful to outline desired future targets, set policy goals and management objectives, evaluate progress toward long-term goals, and raise awareness of policy and decision makers as well as the general public about possible futures.

In Ethiopia, if socioeconomic development trends over the past few decades continue into the future, biodiversity resources and ecosystem services will continue to decline. Currently, there is insufficient knowledge on the severity of the losses and our understanding of the loss of biodiversity and ecosystem services is limited. In the business as usual scenario, the provisioning services of ecosystems will be reduced along with the per capita availability of agricultural land, fresh water, wood for fuel and other uses, and increased rarity of medicinal organisms. This scenario produces negative effects on all supporting services. Expansion of agriculture to marginal lands continues to drive deforestation and soil degradation in major ecosystems. Despite declined quality of biodiversity and ecosystems, places of spiritual value maintain their social and symbolic values to local communities.

If Ethiopia prioritizes fast economic growth and food self-sufficiency aimed at improving the living standard of its population, the major ecosystems continue to decline in area coverage, biodiversity and ecosystem services. In terms of food and fiber, the provisioning services will increase and food security will be ensured at the national level as well as household level to a large extent. This will be resulted from increased local production and improved access to food through purchases due to increased income of households. Whereas, the regulating services of ecosystems will decline significantly because of the over-riding national priority of economic growth to ensure food security, job creation, poverty elimination and transition to the middle-income status. The supporting services such as nutrient cycling are reduced, while the changes in production of oxygen and soil formation will remain variable. Although the spiritual, heritage and religious services remain stable, the aesthetic and educational/ILK values of ecosystems are reduced.

If Ethiopia strictly implements the green growth policy and follows the green economy pathway, the major ecosystems (mainly mountain, forest and woodland, aquatic and wetlands, rangelands) will be restored, conserved and protected. The current national climate resilient green economy strategy is aimed at achieving net zero emissions through interlinked approaches of reducing emissions of greenhouse gases and enhancing carbon sinks. The scenario envisages that the available environmental laws and policies will be effectively implemented and new policy and legal instruments issued and enforced. Biodiversity conservation is a high priority in the political agenda and ecosystem services are enhanced through human intervention. The provisioning ecosystem services of food, feed, freshwater, energy, and medicinal/ornamental materials will be enhanced. The supporting and regulating services of ecosystems will increase significantly.

Under the on-going socioeconomic and sociopolitical policy reforms, high level of uncertainty reins and rule of law could be compromised. Uncertainty may not bring sustained peace and leads to declining accountability in a compromised implementation of the rule of law. Enforcement of environmental laws, pollution control and regulatory measures become loose. Environmental down-turn may seize in major ecosystems and cause negative impacts on biodiversity resources. Particularly, forest, mountain and wetland ecosystems will suffer the most, hampering the goods and services provided by them. There will be rapid loss of provisioning services as landscapes degrade. In the absence of stable economy, ecosystems and their functions are heavily disturbed due to increased degree of anthropogenic pressure. The regulating services are hampered and there will be an increase in carbon release, deforestation, habitat modifications and increase in changes in micro-climates.

Regional integration is a scenario of rapidly growing and strengthened ties among countries. Regional integration creates high degree of interconnectedness and interdependence built upon a multitude of factors, mainly on sustained peace and security, mutual trust, collective vision and policy harmonization for joint actions and growth. Regional integration brings diverse environmental responses both negative and positive. It triggers ecosystem restoration and/or biodiversity loss. Regional integration opens up opportunities for increased interaction and increased flow of goods and labor among countries. The negative impact is habitat fragmentation in natural ecosystems. Habitats will become more fragmented and degraded due to infrastructure installments. This heavily affects the forest and woodland ecosystem, rangeland ecosystem and agroecosystem. The physical disturbance to surface hydrological systems reduces water flow and decreases the environmental flow. Hence, food, fiber, medicine, and other non-timber products decline.

9.1 Introduction

The preceding chapters presented findings of the assessment on status and trends of biodiversity and ecosystem services in Ethiopia over the past decades. The assessment covered the five major ecosystems of the country: Mountain ecosystem, Forest and woodland ecosystem, Aquatic and wetlands ecosystem, Rangeland ecosystem and Agroecosystem. The estimated area coverage of the five ecosystems is shown in Table 1 below. While the rangeland ecosystem covers about 69% of the total area of the country, the forest and woodland ecosystem and the agroecosystem cover 15-27% and 9.2-22% of the country, respectively.

Table 1. Estimated extent and coverage of the five major ecosystems of Ethiopia

Ecosystem Types	Area (in km^2)	Area (% of country's area)	Descriptive remarks
Mountain	3000-6500	0.27-0.59	Covers all landmass that has risen significantly above sea level and the surrounding areas, forming altitudinal gradient defined vegetation zones of Afro-montane, Ericaceous and Afro-alpine
Forest and Woodland*	173,500 - 300,000	15.7-27	This ecosystem includes all forest lands and woodlands in all landscapes.
Aquatic and Wetland*	9318	0.844	Covers all wetlands and water bodies
Rangeland**	767, 000 (Mengistu et al., 2018)	69	Uncultivated land areas that provide forage and pasture for grazing and browsing animals. They are areas where natural rainfall variability is high, and climatic and other environmental conditions limit crop production
Agroecosystem**	105,974-242,880	9.6-22	Croplands that cover large areas in the highlands and mid-altitude areas, pastoral livelihood systems in the lowlands; are grouped into Cereal/grain crop-based, Perennial crop-based, Pastoral and agro-pastoral systems sub-types.

Note: some of the area coverage figures are taken from the chapters (*) and some are collected from other literature and extrapolated (**).

The findings in the preceding chapters on the status and trends of the ecosystems and the services guided the assumptions of the scenario analysis presented in this chapter. The key finds are summarized as follows.

Mountain ecosystem: As indicated in the first chapter of this report, the mountain ecosystem has declined in *area coverage of important vegetation types*. Most of the *endemic flora and* *fauna* of these isolated mountain ecosystem have been assigned *critically endangered status by the IUCN Red List Criteria*. The direct drivers of this change are *land use and land cover change* and *increased climate variability,* while *population pressure* is the major indirect driver. The steep slopes in the high altitude range are encroached by agricultural cultivation and overgrazing. This ecosystem is highly *vulnerable to the adverse impacts of climate change*. The assessment has also indicated that there is limited research and documentation about the mountain ecosystem of the country.

Forest and woodland ecosystem: this ecosystem is vast and comprises of various vegetation types distributed in agro-climatic gradients stretching from the lowland woodlands to the high mountain tropical forests. Past trends showed that *deforestation and forest degradation have been rampant and threatened biodiversity* in the forests and woodlands. *Protected areas that are largely embedded within this ecosystem* are facing extreme anthropogenic pressure and becoming *more and more vulnerable*. Continuous deterioration in natural habitats and a decline in the number of flora and fauna are very common. The continued *deterioration of ecosystem services* hampered production and *threatened human well-being*. Among the many, *failure to comply with and implement existing policies, laws and regulations has remained the most important factor.* The direct drivers of degradation are driven by the underlying legal and institutional factors. These are absence of *land use policy, institutional instability, low capacity of forestry institutions, poor inter-sectorial coordination and lack of synergy between sectors, inadequacy of the forestry legal framework, weak law enforcement, and unclear forest tenure and user rights*.

Aquatic and wetland ecosystem: the aquatic and wetland ecosystem is a biodiversity hotspot in Ethiopia encompassing at least 10% of the Ethiopian floral diversity, providing habitat for at least 25% avifaunal diversity and hosting several other mega fauna. However, the wetlands and aquatic ecosystem in Ethiopia is *rapidly declining due to degradation caused by excessive human activities*. The direct causes *are excessive water abstraction; habitat changes due to agricultural practices, drainage agriculture, rapid land-use changes, overgrazing, deforestation, urbanization, and climate change whereas population growth constitutes the major indirect driver.* The biodiversity of the aquatic and wetland ecosystem is rapidly declining. As a result, those *associated wildlife and floral diversity are highly likely to decline*. Besides, the traditional wetland related *knowledge systems* and their contribution toward conservation and wise use of resources therein are *vanishing*. The major factors for the degradation and loss of wetlands are population growth, unmanaged urban expansion and encroachment to wetlands, international trade and agricultural investment, and the absence of a national policy that recognizes the values and benefits of wetlands and aquatic resources. Climate change is expected to exacerbate all the direct and indirect drivers.

Rangeland ecosystem: the rangelands in Ethiopia have been *shrinking since the 1960s due to extensive land use changes*. The management systems are also gradually changing due to the expansion of enclosure systems leading to increased degree of private ownership of grazing lands. The expansion of various forms of enclosures and associated *land-use changes curtailed* seasonal mobility between wet and dry season grazing areas, causing *continuous grazing and resulting in loss of vegetation cover and soil erosion*. *Climate change and increased human pressure are aggravating the deterioration of the ecosystem*. This is seen in the increasing rate of soil erosion, loss of palatable grasses, and rapid expansion of *bush encroachment*. The shift towards sedentrization, crop cultivation and privatization of the communal rangelands in pastoral areas is causing serious conflicts among communities. The prevailing policy, governance systems, and institutions emphasize poverty reduction and development efforts focusing on resource extraction aimed at short term gains at the expense of long term biodiversity conservation and sustainability. This has been progressively weakening the customary institutions leading to declines in rangeland biodiversity and ecosystem services.

Agroecosystem: Ethiopia's agroecosystem, agricultural biodiversity and their services to human wellbeing are seriously affected by natural and anthropologic drivers of change (climate change, recurrent droughts, floods, acidification, etc.), resulting in disasters identified to have significant effects on biodiversity for food and agriculture in Ethiopia. The ecosystem is highly vulnerable to climate change and the spread of invasive alien species (IAS), which negatively affect crop and livestock production and productivity as well as human health. The agroecosystem is negatively affected by unsustainable utilization of resources either in the form of overexploitation or excessive use of nutrients with dire consequences of soil erosion, water depletion, acidification and salt accumulation. There is a growing need to increase production and productivity in order to provide food for the growing population and to reduce poverty, while managing agro-biodiversity and agroecosystem services in a sustainable manner to maintain healthy human ecology and socioeconomic wellbeing.

9.2 Scenario analysis

This chapter deals with the analysis of scenarios of future changes in biodiversity and ecosystem services in the country. Scenarios are storylines that describe possible futures. To tell the story, scenarios can include qualitative descriptions of changes (i.e., a narrative) and quantitative representations (i.e., numbers). Scenarios do not forecast or predict the future, as the future development of systems that scenarios address is highly complex and inherently unpredictable. Yet, scenario analysis is useful in informing policy design and decision-making in the context of uncertain futures. More specifically, scenario analysis is a useful tool to outline desired future targets, set policy goals and management objectives, evaluate progress toward long-term goals, and raise awareness of policy and decision makers as well as the general public about possible futures. There are different types of scenarios: exploratory, intervention, and policy evaluation scenarios.

Exploratory scenarios examine a range of plausible futures based on potential trajectories of indirect and direct drivers of change. They are used to explore possible futures with high levels of unpredictability and uncertainty. ‘Exploratory scenarios typically involve the development of coherent, integrated storylines that aim to account for the relationships and dependencies amongst key drivers’ (IPBES, 2018). IPBES (2016) notes that assessments at global, regional and national scales to date have mostly used exploratory scenarios. Exploratory scenarios are also called explorative scenarios or descriptive scenarios. Intervention scenarios are those types that are used to inform policy alternatives and management options through ex-ante evaluations. Evidence shows that intervention scenarios have been mostly used for decision-making at national and local scales (IPBES, 2016). The policy evaluation scenarios are scenarios used for ex-post assessment of outcomes of different policies or actions that have been undertaken. This is suitable for review of policies.

The other common classification of scenarios is that recognizes two categories: participatory and non-participatory scenarios. Participatory scenarios involve relevant stakeholders in the scenario development process; hence, allow for the integration of stakeholder views on key drivers of future developments and enhance the relevance and acceptance of scenario findings. The non-participatory scenarios are expert-driven with little or no involvement of stakeholders, and hence are developed in a top-down approach. After scenario storylines are established for the indirect drivers such as population and economic growth, a variety of models are used to project changes in the direct drivers such as land use change and effects on biodiversity and ecosystem services such as food production (IPBES, 2016). The scenario analysis reported in this chapter is mostly based on information from the assessment itself (the preceding chapters), review of available literature and expert judgment. A total of six experts participated in the process. There was no modeling work done to translate the scenarios into projected changes in biodiversity and ecosystem services; instead, a qualitative interpretation approach was employed.

9.3 Scenarios and storylines for Ethiopia

For this assessment, expert-driven exploratory scenario development approach was adopted. It is suitable for the objective at hand which is to explore how the indirect and direct drivers of change will shape the future biodiversity and ecosystem services in the country. It is a 'what if' assessment of changes in biodiversity and ecosystem services under different possible futures of nature and society interaction. The following focal questions guided the development of scenarios archetypes:

- What will happen to biodiversity and ecosystem services if socioeconomic development trends over the past few decades continue into the future?
- How would biodiversity and ecosystem services be changed in a future where Ethiopia has prioritized fast economic growth aimed at improving the living standard of its population?
- What would biodiversity and ecosystem services look like if Ethiopia follows a green growth path across all sectors of the economy?
- How would the on-going socioeconomic and policy reforms in the country shape the political economy and consequently affect natural ecosystems and biodiversity?
- What happens to ecosystems and biodiversity in national and trans-boundary landscapes in the era of increasing trends towards regional integration?

Guided by the above questions, five distinct *scenario archetypes* or plausible futures were identified and the conceptual framework shown on Figure 1 below was used for the analysis.

Scenario archetypes are groups of general patterns of future developments that help to summarize and harmonize large amount of information in individual sets of scenarios. This approach has been applied at the *global, regional and national scale assessments*.

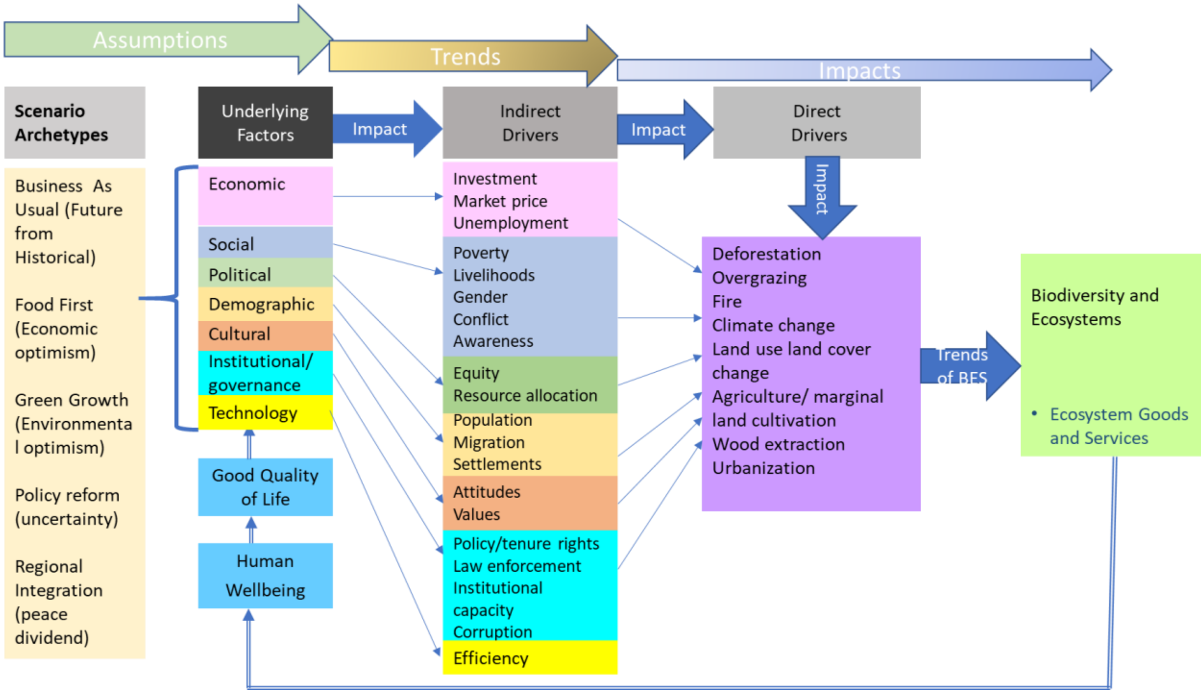


Figure 1. Conceptual framework for the analysis of scenarios (plausible futures) of biodiversity and ecosystem services in Ethiopia. The archetypes are the alternative social and political economy futures that determine the underlying factors with anticipated negative or positive outcomes on the indirect and direct drivers of change in biodiversity and ecosystem services

9.3.1 Business as usual

This is a vision of how society and environment evolve if we continue with the current socioeconomic and environmental policies and development trends. Over the past three decades, Ethiopia's economic policies and strategies have been guided by an overarching framework strategy known as **Agricultural Development Led Industrialization (ADLI**). It identifies agriculture as the lead growth sector that will generate surplus production by achieving maximum utilization of the country's human and natural resources and support industrial development. Successive five-year development plans have subsequently been prepared and implemented in this context. Substantial economic growth and poverty reduction outcomes have been attained as a result. For instance, poverty headcount ratio at the national poverty lines (% of population) has reduced from 29.6% in 2009/10 to 23.5% in 2014/15; it has declined from 30.4% to 25.6% in the rural areas and from 25.7% to 14.8% in urban areas between 2009/10 and 2020

(FDRE/NDC, 2020). Despite, the gain in economic growth, food insecurity is widely prevalent which in times of rainfall shortages and droughts affects a large number of people. **Poverty is still widespread**.

The five-year development plans mostly considered environmental sustainability as a cross-cutting issue with limited emphasis in implementation and evaluation phases. Nonetheless, **significant investments have been made into soil and water conservation activities** by the government as well as many non-governmental organizations over the years. But achievements so far are far from satisfactory compared to the scale of the problem. Hence, **environmental degradation remains a major challenge.**

Recently, the government of Ethiopia has developed a ten-year perspective plan for the period 2021- 2030 (PDC, 2020). The plan aims to build a prosperous country by following a pragmatic **market-based economic system**; registering a fast and sustainable economic growth by ensuring sustainable macroeconomic environment; bringing structural economic transformation by promoting productivity and competitiveness; ensuring access to quality social and physical infrastructure to citizens; and building institutions and systems to promote rule of law and stability in the country. The plan has dedicated a separate chapter to **environment and climate change (climate resilient green economy)**, and the objectives are stated as to identify IAS and, through research, substantially mitigate the damage they cause; collect and preserve biodiversity and genetic resources; **reduce the amount of sectorial greenhouse gas emissions**; and strengthen the development and protection of forests, the ecosystem as well as the wild life. **The Plan is aligned with the SDGs.**

The *Future from Historical* scenario is thus **an outcome of past trends and current development plans**. Under this scenario, **agricultural production as well as industrial outputs increase**, and **urban settlements and infrastructure expand**. The numbers of food insecure people and those living below the poverty line have decreased. Yet, there are a considerable number of **poor and food insecure people**. Sustainable land management and forest protection in parts of the country have increased areas under sustainable land use and forest cover. But there are also areas affected by **accelerated soil erosion** and other forms of land degradation. Although successive development plans have contained environmental and climate change related targets, **environmental sustainability has not been a primary consideration** in implementations across all sectors of society. Local scale sustainable land use and forest management practices are found in many places, **but it has not been implemented at scale**. Hence, **land degradation, biodiversity loss and fragmentation of habitats continue to be pressing environmental problems**. **Climate change impact remains high in agriculture, water**, energy and health sectors.

9.3.2 Food first

This is a scenario of **rapid economic growth targeting food self-sufficiency driven by investments** in all economic sectors by the private sector, public sector investments in infrastructure, and **weak implementation of conservation policies and enforcement of environmental protection laws**. This is a storyline of **unfettered economic growth**, and environmental issues are given **little priority**. Under this scenario, the utilitarian view of nature is dominant. It shares many features of the *Future from Historical* storyline but is different in the extent of focus on **economic growth for food self-sufficiency and job creation**. This storyline prioritizes **self-reliance over other values**, including **long-term environmental sustainability**. **Political stability** has provided an overarching enabling environment for fast economic growth. In the *Food First* scenario, the growing needs for food security, job creation for the youthful population, changing consumption patterns of a growing middle class made a state-level priority to be '**grow first and clean up later'**. There is increased economic liberalization to encourage economic growth. **Population growth**, change in consumption patterns, and market forces play out as the main drivers.

Under this scenario, **agriculture has been expanded to all cultivable areas** and a significant proportion of the total production comes from **large scale commercial agriculture**. The manufacturing sector contributes a large share to **total employment and the national** economy. In overall economic growth, the country has entered into the middle-income category. **Urbanization has** reached an average level of the middle income countries. The prioritization of economic growth means that **biodiversity and ecosystems have become** the losers. **Water and air pollution have become** major problems in urban areas and natural landscape in rural areas is **converted into managed landscape**. Vast areas in the lowlands of the country are under irrigation agriculture and new towns have sprouted consequent to the economic opportunities created. Large areas that are currently rural become more developed. There is high human and economic pressure on nature in both urban and rural areas. Consumption and per capita use of resources has increased and as a result per capita GHGs emission has increased. Exposure to climate change may be increased but adaptive capacity may have increased to reduce overall vulnerability to its adverse impacts.

9.3.4 Green growth

This is a storyline where Ethiopia successfully follows a green growth path such as that outlined in the current national climate resilient green economy (CRGE) strategy (FDRE/EPA, 2011). This strategy is **aimed at achieving net zero emissions**, through interlinked approaches of reducing emissions of greenhouse gases (GHGs) and **enhancing carbon sinks**. For the climate resilience component, climate resilience strategies have been developed and are under implementation for key sectors (e.g., agriculture and forestry, water and energy sectors), and an integrative national adaptation plan has been developed. Complementary to the CRGE, there is a **sustainable land management program**, which has been under implementation since 2007 with funding from the government and development partners. There is also an annual mass mobilization program where rural people contribute some 40 to 60 days of free labour for watershed management activities that are focused on implementation of soil and water conservation structures. Since 2018, the 'green legacy' initiative has contributed to the planting of billions of trees annually across the country. The country is a party to the UNCCD target of land degradation neutrality and aims to adhere to the Bonn challenge of the global goal to bring 150 million hectares of degraded and deforested landscapes into restoration by 2020 and 350 million hectares by 2030.

Ethiopia has several laws and proclamations to govern environmental protection such as environmental impact assessment and pollution control (Proc. No. 300/2002 Environmental pollution control). The *Green growth* scenario has the available environmental laws and policies effectively implemented and new policy and legal instruments issued and enforced. The *Green Growth* storyline is, therefore, a future where sustainable environmental management is achieved including restoration of degraded lands, forests, protected areas and sustainable use of agricultural landscapes. Public awareness about ecosystem services is raised because of continued engagement in ecosystem management activities, in addition to environmental issues being adequately covered in the school curricula. Society recognizes that biodiversity and ecosystems provide irreplaceable services to the existing and future generations. Ecosystem services are produced from nature but the protection, regeneration and continued supply will only be ensured by reinvesting on its protection. Thus, payment for ecosystem services (PES) are becoming important instruments to pool resources and a PES policy is drafted and about to be enacted as a law to be implemented in Ethiopia. Environmental impact assessments and pollution control standards are strictly enforced.

Under this scenario, the population meets its food needs through sustainable intensification of agricultural production and energy needs primarily from renewable energy sources. Widespread use of modern technologies supports the green growth path. In the agriculture sector, for instance, this may include use of biotechnology, cultivation of land races that are already adapted to the changing climate and widespread adoption of soil and water conservation measures. Biodiversity conservation and habitat restoration have boosted tourism and its contribution to the national economy. Climate change impacts are mitigated due to the fact that green growth path provides nature-based solutions. In this scenario, environmental sustainability and conservation of biodiversity and ecosystems are the dominant driving forces or policy goals. The visions presented in the CRGE and current afforestation and tree planting initiatives provided motivation for this storyline.

9.3.5 Policy reform

This scenario explores the pathway in the perspective of **enormous policy reforms** and high level of **uncertainty since** the country is passing through unprecedented national and global challenges. COVID-19 and external interference are the most serious external challenges that impacted the economy (Sanchez-Martin, et. al., 2021). Ethiopia has embarked on **fundamental economic, socio-political and institutional reforms** since 2018. The government has been pursuing **home grown economic reforms and conducted macro-economic changes including major fiscal and monetary policies**. The Growth and Transformation Plan has been replaced with the ten years perspective plan. These reforms helped to negotiate with international lenders on debt restructuring and saved the country from default. Trade laws, electoral laws, penal laws, civil society and terrorism prevention laws have been either revised or replaced. The **massive reform reshaped not only the social and economic landscapes but also the**

political/governance structure. Formation of new regions, gradual transformation of the governing coalition and embracing the emerging regions to the center politics, to ensure inclusiveness, participation and transparency in decision making has changed the political landscape. To the broader mass, **an increased level of economic and political optimism** was created. Nevertheless, the reform did not go without snags. Small differences grew to **violent conflicts. The short-lived war** has caused immediate and long-term impacts on the country's development endeavor.

Significant numbers of people have become Internally Displaced People (IDPs), requiring emergency, resettlement and rehabilitation assistance. Manufacturing industries, the service sector, tourism destinations have received unparalleled damage, leaving tens of thousands out of jobs. Infrastructure, social service facilities and communication systems have collapsed. **Resources and efforts are diverted from capital investment projects towards emergency responses**. The **impacts on the environment will linger for several years to come**. The social strain will grip the productive force of the rural mass and will **diminish the efforts to arrest natural resource degradation**. The rural poor will **resort to natural resources for immediate needs and to sustain livelihoods**. Rehabilitation and reconstruction efforts **will demand use of available natural resources**, **particularly forest resources aggravating negative consequences of land use land cover change**.

This is a scenario in which the reform process may result in **high economic uncertainty** if the country continues passing through episodes of instability and conflicts. The reform trajectory is on-going and may demand **further institutional restructuring, policy changes and designing of new ones**. High level of **uncertainties may have a negative impact on FDI, public spending on infrastructure, export earnings, urban and rural unemployment rate and environmental degradation**. Challenged with the impacts of the COVID-19 pandemic (Sanchez-Martin, et.al., 2021) and the war, **economic growth may remain in a wobbly state and perhaps may stagnate**. With the anticipation of liberalizing the market (financial sector), rising costs of imports and growing demands for goods, **inflation will continue to rise leading to further uncertainty**. **Enforcement of environmental laws, pollution control and regulatory measures may become loose**. **Environmental down-turn may seize in major ecosystems** and cause **negative impacts on biodiversity resources**. Particularly, **forest**

ecosystem, mountain ecosystem and aquatic and wetland ecosystem will suffer the most, hampering the goods and services provided by them.

9.3.6 Regional integration

The breadth and depth of regional integration varies. **The first is cooperation** and this may be the weakest and a particular issue-focused arrangement. Countries may cooperate for a joint development project. They may do so for facilitating exchange of information and best practices. The second is **harmonization**. It is a higher and more formalized degree of cooperation and commitment; hence a more effectively tied arrangement as compared to simple cooperation. It may be best applied to **tax policy, trade policy (tariff and facilitation), legal (business law) and regulatory** framework (standard rules and procedure for licensing, quality control, environmental standards, etc.). This does not necessarily need a joint administration or supra-national entity. **Integration** is the strongest form and implies a higher degree of lock-in and **compromising sovereignty**, applied to broader scope, implying more united markets for goods (Free Trade Area and custom unions), common markets, and a common currency. It requires countries to relinquish some sovereignty to a supra-national agency (e.g., commission, parliament, judiciary, etc.).

This scenario is a plausible future that visions a region with **high degree of interconnectedness and interdependence** built upon a multitude of factors, mainly on **sustained peace and security**, mutual trust, collective vision and policy harmonization for joint actions and growth. Past trends show that regional integration has become a pathway of **collective development through sustainable peace building** across nations and communities (Thobejane and Biniam, 2018). **Regional integration optimizes conservation of natural resources**, promotes human **development by improving access to education, health services, employment and poverty reduction**. Regional integration also promotes **human rights, good governance and advances** the region's role in global matters (Robert, 2004; Thobejane and Biniam, 2018). Despite this, the African continent is far behind in realizing its potential for regional integration (African Union[1], 2019). The East African Community (EAC) is relatively the most integrated sub-region in the continent (World Bank, 2020). The World Bank (2020) pointed out that the COVID-19 pandemic is a reality that showed certain problems are not border limited, and hence, **responses**

[1] Africa Regional Integration Index: AU et al: Africa Regional Integration Index 2019

to cross-border problems should not be dealt in domestic terms/policy. Although there is high interest and political commitment to regional integration, the real challenge is translating commitments into tangible actions (Thobejane and Biniam, 2018).

The Horn of Africa, through its regional organization, the **IGAD, has been promoting regional cooperation in peace and security, economic integration, environmental governance and agricultural development**. Infrastructure development has been the main driver of regional integration. Ethiopia has played a pivotal role in promoting such developments in the region. This is increasingly strengthened through **practical actions on investments in roads and power lines, development corridors (e.g., LAPSSET and Berbera port**) and advocating for free movement of people. IGAD is currently promoting road connectivity that extends up to 5000 km (Thobejane and Biniam, 2018). It facilitates **railway, telecom and energy connectivity in the region**. There are **already several forms of bilateral agreements** (trade, security, joint development, etc.) among the countries. For instance, **the new Ethiopian Ministry of Trade and Regional Integration is tasked with driving the regional integration** agenda and it is **promoting the green legacy initiative at the Horn of Africa (HoA) level**. However, **lack of policy harmonization is a major barrier for regional integration**, resulting in high cost of transaction. Free movement of goods and people is very much limited due to internal conflicts, risks of cross-border crime/terrorism, drug trafficking and illegal trade.

Nowadays, the HoA region is galvanizing the gains so far in regional integration efforts in order to bolster resilience in the region. Now there are several initiatives funded by the **Word Bank and the African Development Bank to support economic corridors, energy trade, digital economy**, disease **surveillance and response to locust crisis**. Both banks are supporting the Isiolo/Mandera corridor through the HoA Gateway Development project (WB, 2020). The **support is promoting harmonized trading frameworks** between Djibouti and Ethiopia, and used to establish the second **Ethiopia-Djibouti Interconnector and Ethiopia-Somalia Interconnector**. The countries in the HoA are moving forward towards a more **interconnected, more integrated and more resilient region**. These actions are strong indicators of sustainable peace for the region in the future.

Increasing regional integration opens up the opportunity for collaborative research and knowledge sharing on key environmental problems such as **droughts, climate change, invasive**

species, ecosystem degradation, particularly across trans-boundary ecosystems. Landscape **restoration and biodiversity conservation will improve nationally and regionall**y by **reducing conflicts, and lifting pressures on the resources**. Due to increased investment, regional integration **may also have negative environmental consequences unless safeguard measures are properly implemented**. Nevertheless, **collaborative management of critical ecosystems** and biodiversity resources will improve along with regional integration.

9.4 Scenarios and trends in drivers of change in biodiversity and ecosystem services

9.4.1 Population

Ethiopia's **population has increased steadily over the years**. The first national census, which was conducted in 1984, reported the total population to be 42.6 million (CSA, 1984). Subsequent censuses were conducted in 1994 and 2007 and reported the population to be 53.5 million and 73.5 million, respectively (CSA, 1994, 2007). This is a 38% increase in just 13 years between 1994 and 2007. An inter-census population survey in 2012 estimated the population at 83.7 million (CSA, 2013). **At the present, Ethiopia's population is estimated at over 114 million, making it the second most populous country in Africa**. The crude birth and death rates are 36.5 and 7.7 per 1000 population (2017 est.), indicating a rate of natural increase of 28.8 per 1000 population which is quite high. The median age is less than 20 years, which is a feature of rapidly growing populations. Over 70 percent of the population is below the age of 30 years. Figure 2 shows trends in total population and growth rate changes between 1955 and 2020. It is shown that the growth rate has shown some decline since the mid-nineties while the total population has continued to grow. This is because of what is known as population momentum; the effect of a large number of women entering childbearing age every year due to past high fertility and continued growth in the number of children despite declining fertility.

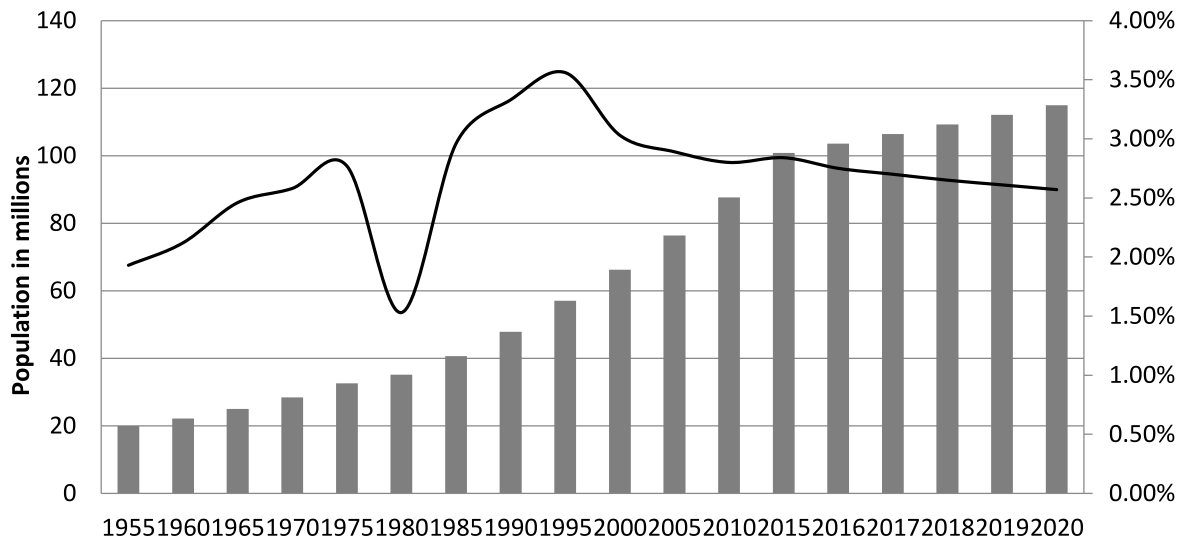


Figure 2. Trends in total population (Bars) and growth rate (line) between 1955 and 2020, Ethiopia. Plotted based on data from https://www.worldometers.info/world-population/ Ethiopia-population/ accessed on 03 Feb 2022

Figure 3 below shows projected population size and growth rate for Ethiopia for the period 2020 to 2050. This **projection shows that total population will be around 160 million by 2035 and to exceed 205 million by 2050**. This is higher than CSA's (2013) medium variant projection of 137 million by 2037, and that of Bekele and Lakew (2014) study that projected the total population to be 133.5 million in 2032 and 171.8 million in 2050 basing their projection on the 2012 inter-census survey. The data shown in figure 3 also shows that the growth rate will continue to decline and reach around 1.5% by 2050, which is less than the natural replacement rate.

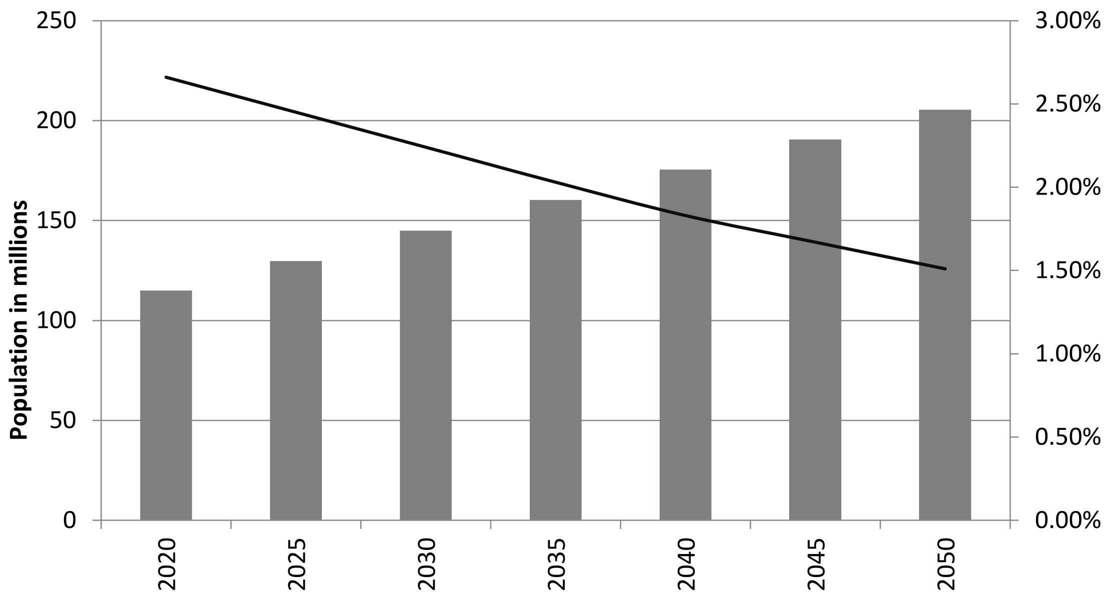


Figure 3. Projected total population and growth rate for Ethiopia, 2020 to 2050. Plotted based on data from https://www.worldometers.info/world-population/ethiopia-population/ accessed on 03 Feb 2022.

Even though population size does not necessarily determine the change in biodiversity and ecosystem services, it is obvious that more people require more resources. Thus, **increase in population size suggests declining trends in per capita availability of arable land, grazing land, potable water**, etc., Forests and other **habitats are disturbed or destroyed to construct homes and settlements including towns, businesses, roads, and for domestic energy** production to accommodate needs of the growing population. As population increases, **more land is used for agricultural activities to grow crops and support livestock**. This, in turn, can decrease species diversity, population size, and geographic ranges and alters the interactions among organisms. Decrease in forest cover increases soil erosion and reduces freshwater storage capacity of catchments. It also causes decline in the number of wild animals and even lead to extinction as human expansion encroaches into their habitats and limits their mobility and geographic spread.

Population increase also **entails increased extraction of freshwater from rivers, lakes, groundwater, and man-made reservoirs for drinking, agriculture, recreation, and industrial processes, negatively affecting availability of water for ecosystems**. Besides the decrease in the per capita quantity, wastes from residential, agricultural, commercial, industrial and transportation activities all contribute to increasing pollution of water resources as well as ambient air, which has serious implications to biodiversity and ecosystem services.

Population increase is an important factor even **in the transmission of diseases and pests as well as the transport of invasive species**. Increase in population numbers **increases settlement density** and makes contacts and interactions easier and more frequent. This creates favorable condition for both animal and plant diseases and pests as well as invasive species to spread easily and quickly within and among populations and into new areas. Densely settled areas often create disturbed environments where **invasive species thrive and reduce native species**. For example, a study has shown that *Prosopis juliflora*, the invasive species which has affected a large area in the Afar region of Ethiopia, thrives around human settlements and along strips of land next to roads and trails (Shiferaw et al. 2019).

Distributional pattern of the population is an important factor in the extent of its impact on biodiversity and ecosystem services across the landscape. Ethiopia is still **predominantly rural, with over 80% of the population living in rural areas** mainly in the central and northeastern highlands (Figure 4). Nearly 80% of Ethiopia's population lives in only 37% of the total area of the country, while the remaining 20% lives in 63% of the country's land area (Selome and Assefa, 2010). The same source states that about 14% of the population lives in areas above 2,400 m.a.s.l in climates similar to the temperate zone; about 75% live between 1,500 and 2,400 m where temperature is moderate and the rest live below 1,500 m where temperatures are high.

Much of the population increase now and in the near future is going to be in the rural areas and in the highlands of the country. Livelihood security of the rural population is directly linked to biodiversity and ecosystem services. Thus, the rapid growth of the **rural population places increasing pressure on biodiversity and ecosystem services, and leads to expanding ecological degradation, loss of biodiversity and ecosystem services** and raising vulnerability to the changing climate.

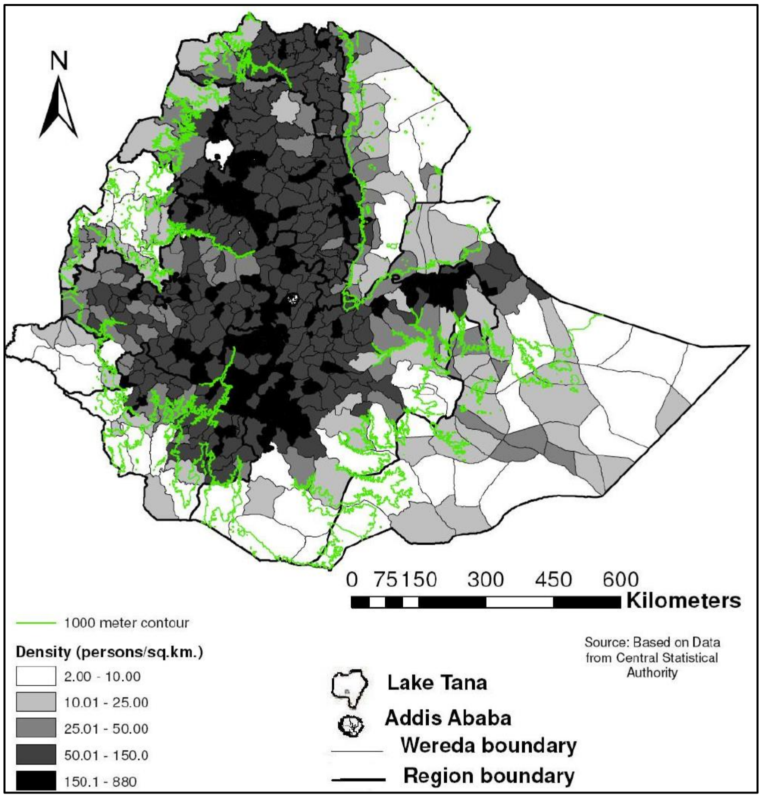


Figure 4. Population density map of Ethiopia

9.4.2 Urbanization

The level of **urbanization of Ethiopia is still low**. The urban population was 6% of the total population in 1960 and this increased to 10.4% in 1980 and it was estimated to reach 17.6% by 2010 (Bekele and Hailemariam, 2010). CSA (2013) **projected the urban population to reach 22.8% of the total population by 2022**. This shows that the country is still one of the least urbanized even compared to countries of sub-Saharan Africa. But, the **rate of urbanization is high in Ethiopia**. The urban population increased from 4.5 million in 1984 to 11.9 million in 2007 and it is projected to reach 42.4 million by 2037 (CSA, 2013). This is a 3.5 times increase in three decades between 2007 and 2037. Mezegebo (2021) noted that **between 1984 and 2021 the total population increased by 158%, while the urban population increased by 414%.**

Temporal change in the proportion of the urban population between 1955 and 2020 is shown in Figure 5 below. This is based on data from the web-based *Worldometer* database (www.worldometers.info/world-population/ethiopia-population/) which tends to show higher figures to both current and projected population sizes than other projections (e.g., CSA, 2013).

According to this estimate, the urban population has increased from accounting for 5.4% of the total population in 1955 to 14.8% in 2000 and 21.3% in 2020. The annual average rate of increase is 4.7%. The same database has projections for up to 2050 (Figure 6). It is estimated that the urban **population would account for 28.4% of the total population in 2035 and 36.3% by 2050**. In terms of headcount, the estimated increase is from 24.5 million in 2020 to 74.5 million in 2050, **which is a threefold increase**. The various estimations also indicate that, despite the rapid urbanization, **Ethiopia will remain primarily rural with close to 70% of its population living in rural areas by 2040.**

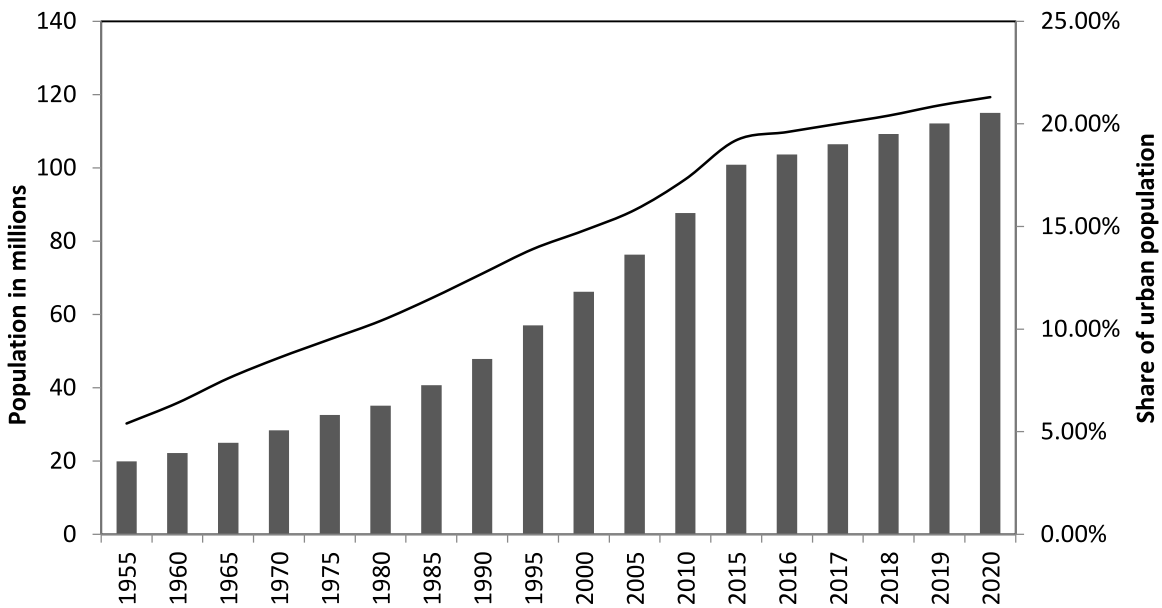


Figure 5. Trend in urban population growth of Ethiopia between 1955 and 2020. Plotted based on data from https://www.worldometers.info/world-population/ethiopia-population/ accessed on 03 Feb 2022.

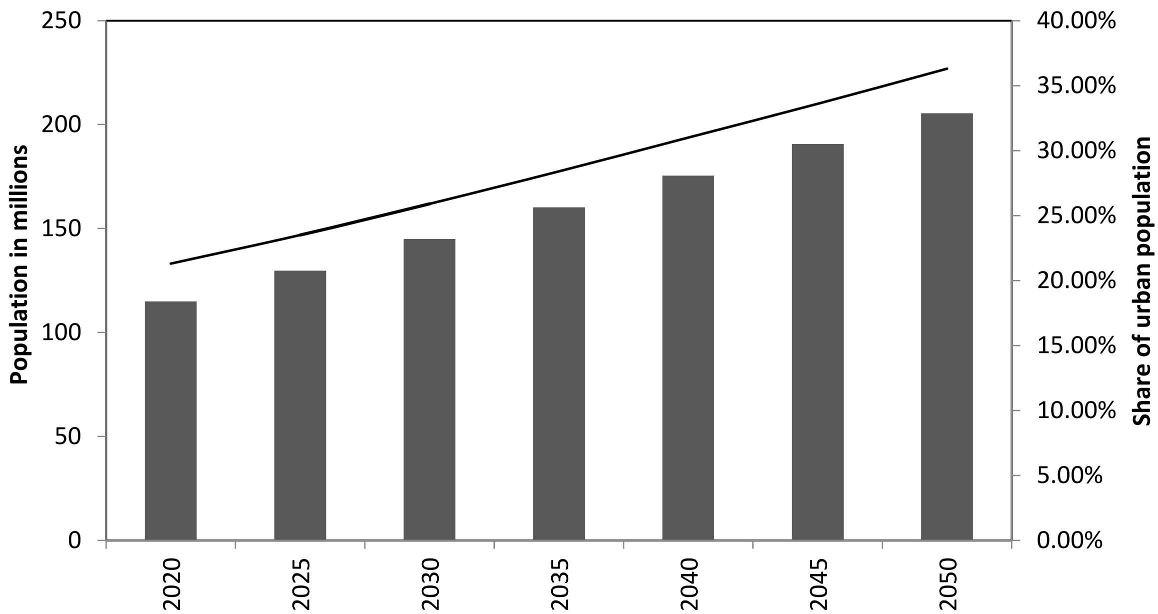


Figure 6. Projected of urban population growth of Ethiopia between 2020 and 2050. Plotted based on data from https://www.worldometers.info/world-population/ethiopia-population/ accessed on 03 Feb 2022.

The drivers of urban population growth include **natural growth, rural to urban migration, and emergence of new towns**. According to Mezegebo (2021), **natural growth** is the highest contributor followed by **rural-urban migration** and reclassification of rural villages to urban centers, i.e., emergence of new towns. In the near future, **rural to urban migration** is likely to exceed the contribution of the natural growth because of the **fast-growing landlessness** of the rural youth and emergence of **large scale industrial projects** which would create new towns. If managed proactively, urban population growth presents a huge opportunity to shift the structure and location of **economic activity from rural agriculture to the larger and more diversified urban industrial** and service sectors. On top of these, job creations in the urban sectors lifts the huge pressure exerted on natural resources, the environment and biodiversity in the rural landscapes. Otherwise, rapid urban population growth poses a demographic challenge as **urban settlements struggle to provide jobs, housing, infrastructure and services.**

The increase in the urban population has expectedly been accompanied by **expansion of areas of urban centers as well as emergence of new towns**. For instance, Terfa et al. (2019) found that between 1987 and 2017, Addis Ababa expanded by 186.7% (from 99 km^2 to 283.9 km^2), Adama expanded by 476.9% (from 8.8 km^2 to 50.6 km^2) and Hawassa expanded by 540.8% (from 6.1

km^2 to 39.1 km^2) (Figure 7). Sinha et al. (2016) also found that built-up area of Adama expanded by 293% between 1984 and 2015.

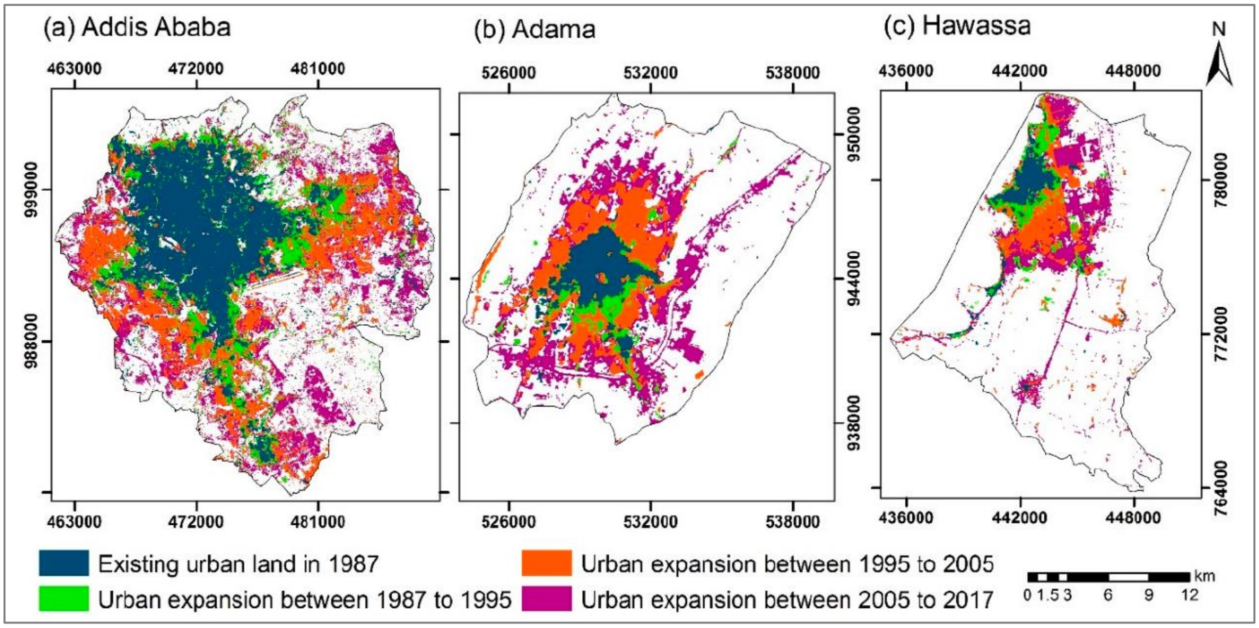


Figure 7. Urban expansion map of (a) Addis Ababa, (b) Adama, and (c) Hawassa from 1987 to 2017. Source: Terfa et al. (2019)

Urbanization impacts biodiversity and ecosystem services both directly and indirectly. Direct impacts primarily consist of habitat loss and degradation, modified land cover and other physical transformations caused by the expansion of urban areas. Indirect impacts include **changes in water and nutrient availability, increases in water and air pollution**, and increases in **competition from non-native species**. The most obvious direct impact of urbanization on biodiversity is **land cover change** due to the growth of urban areas. Construction of buildings and other artificial surfaces contributes to the loss of **sensitive ecosystems, fragmentation of natural habitats** and results in **isolation of species**. Urbanization also threatens endemic species due to increased incidence of introduced species. **With fragmentation and loss of habitat and ecosystems, pollinators, pest regulators and seed dispersers** are threatened or lost. Because urban areas exhibit large artificial surfaces including expansion into agricultural lands, food production, temperature regulation, waste treatment and climate regulation benefits are reduced or lost. These constitute loss of the **provisioning, regulating, cultural and supporting services of ecosystems**.

Perhaps the most evidently **affected ecosystem service is the regulatory hydrological service**. Expanding **urban settlements replace natural vegetation covers** and **increase impermeable surface areas**. This leads to increased volumes of surface runoff, which subsequently **increases vulnerability to flooding of urban residents as well as downstream communities**. As urban populations increase, the number of people affected by floods also increases owing to the concentration of people in small areas. This is in the backdrop of **climate change** that is increasing intensity and frequency of weather extremes. As urban areas are places of high levels of fossil fuel combustion, transportation and industrial activities, contributions to climate change are exacerbated in urban settlements. These activities are also **sources of pollutants and pollution is an important driver of biodiversity and ecosystem change**, with particularly devastating direct effects on freshwater and marine habitats.

Like the general distribution pattern of the population, urban population is concentrated in the highlands of Ethiopia (Figure 8), which are the areas of **high species richness and endemism**. Hence, **urban expansion potentially has significant negative impacts on biodiversity and ecosystem services in the country**. Potential **positive effects of urbanization on biodiversity** and ecosystems services could include increased recreational activities, eco-tourism and nature-based education, thus contributing to increased awareness among residents and visitors about the need to value and conserve biodiversity and ecosystem services.

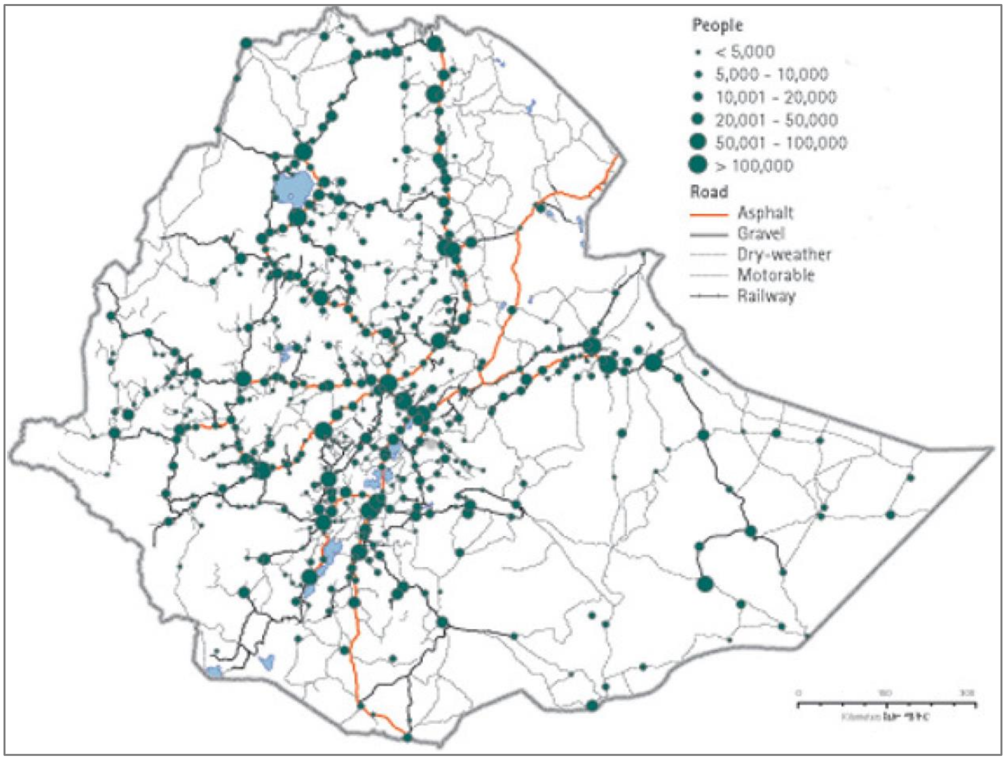


Figure 8. Location of Towns and Roads in Ethiopia in 2004, Source: CSA (2006), Atlas of the Ethiopian Rural Economy. Addis Ababa

9.4.3 Land use and land cover change

The IPBES global report ranked land use land cover change as the greatest **driver of declines in nature and biodiversity** (IPBES, 2018). Land use land cover change affects **biodiversity, the functioning of ecosystems**, and the services they provide. The major form of global land use land cover change is **agricultural expansion for cropping, plantations, and animal rearing** (IPBES, 2018). **Expansion of agriculture is therefore the major driver of loss of biodiversity and declines in ecosystem services**. In general, land use land cover change **alters types and magnitude of ecosystem services provided, as different land use land cover types provide** the different ecosystem services at extremely varied magnitudes. For instance, **forests provide higher services in terms of habitat for species, timber production, carbon stock and water regulation than croplands**. Similarly, wetlands provide higher services of water provision and regulation than croplands and grazing lands. Land use land cover change therefore causes **gains in some ecosystem services and losses in others**. This suggests that **trade-off and synergy** exists between the different ecosystems services associated with land use land cover changes.

Trade-off occurs when the provision of one ecosystem service is reduced as a consequence of increased use of another ecosystem service. For instance, when forest or grassland is converted into farmland, the provision of food will be increased while its capacity for carbon sequestration will be reduced. On the other hand, synergy occurs when two ecosystem services are enhanced. For instance, enhanced hydrological regulation by forests reduces sediment load of runoff, improves dry season water availability, and improves water quality for downstream users; thus increasing hydrological regulation, water supply, soil nutrient retention, and water quality improvement services in synergistic relationships. However, trade-offs are more common than synergies; hence, maximizing one ecosystem service often leads to a sharp decline in other ecosystem services or even causes irreversible losses.

Land use land cover change interacts with climate change to exacerbate the negative effects of one another on biodiversity and ecosystem services. Climate change is expected to result in altitudinal and latitudinal shifts in land use, influencing land use and land cover patterns at large spatial scales. Land use land cover change, in turn, affects local, regional and global climate directly through changes in surface energy budgets and indirectly through the carbon cycle. Land use and land cover change, particularly deforestation, is an immediate cause to land degradation which is strongly related to biodiversity loss. Indeed, biodiversity loss is one of the primary consequences of land degradation. In other words, sustainable land management is essential for the protection of biodiversity and ecosystem services, and biodiversity is in turn fundamental to the services provided by land. Both land degradation and biodiversity loss are results of the same direct and indirect drivers of change. Land degradation, biodiversity loss and climate change accelerate occurrence and **expansion of IAS**. Invasive species contribute to land degradation and biodiversity loss by **replacing native species**, and by unproductive use of water and land.

In Ethiopia, the general pattern of **land use change over the past decades** is **a decrease in forest cover, wetland areas and grazing lands, and increase in cultivated lands and settlements.** MEFCC (2017) estimated an annual **forest loss at 92,000 ha and reforestation rate at 19,000 ha**, which is a net loss of some 73,000 ha per annum. EMA (2013) has published an assessment of land use land cover changes between 2007 and 2013 (Figure 9). The results show increase in cropland area from 13% to 18% of the country between 2007 and 2013, while grassland decreased from 51% to 11%, and uncultivated land declined from 19% to 1.2%. Forest and woodland cover showed some recovery, partly due to the **definitions used in the report to describe these land cover types**. It is reported that forest cover had increased from 3.6% to 14%, and woodland and shrub land increased from 7% to 27%.

A significant increase is shown for the **unproductive land category**; increase from 3.8% in 2007 to 10.6% in 2013, which is an increase by **about 179% in just six years**. This is indicative of the severity of land degradation and loss of land productivity in the country. It is caused by **soil erosion, nutrient depletion, soil compaction, and increased salinization and acidity** occurring at different intensities in different parts of the country. **Soil erosion is arguably** the most serious threat in the highlands where rain fed agriculture is the predominant land use land cover system. As estimated by Hurni et al. (2015), annual net soil loss from cultivated fields in the highlands is 20.2 tons/ha, taking into account erosion/deposition factors. The same study estimated that 77% of rain fed cropland areas in the highlands had slopes steeper than 8%, and only 18% of this area was covered by some sort of soil and water conservation structures. This shows that there is still extensive area that requires protection measures from soil erosion.

Invasive species are also posing negative impacts **on native biodiversity, agricultural lands, rangelands, national parks, lakes, reservoirs, and even urban green spaces**. The most common ones are *Parthenium* weed (*Parthenium hysterophorus*), prosopis (*Prosopis juliflora*), water hyacinth (*Eichhornia crassipes*), and lantana weed (*Lantana camara*). These have inflicted significant damage to rangelands and farmlands, and in particular are threatening pastoral and agro-pastoral livelihoods. *Prosopis* was intentionally introduced as an agroforestry species in the Awash Basin, but has now become a major threat to agricultural land and protected areas in the Awash National Park. It is aggressively invading pastoral areas in the Middle and Upper Awash Valley, Borana and Eastern Hararghe, destroying natural pasture, displacing native trees, forming impenetrable thickets, and reducing grazing potential. *Prosopis* invasion is taking over prime grazing and irrigable land in Afar Region alone. *Parthenium* is also another invasive plant that was introduced accidentally through aid shipments, and it is spreading rapidly, causing up to 90% reduction in forage production. Its impact in natural habitats clearly poses a major threat to rangelands and croplands. Attempts to combat the threat of invasive species in Ethiopia have followed the usual piecemeal approach, which have not been coordinated across sectors, and have focused mainly on **attempting to address the major invaders**. The emphasis is on tackling problems that **threaten agriculture and human activity**, due to insufficient resources and capacity or information to address the threats to biodiversity and ecosystems.

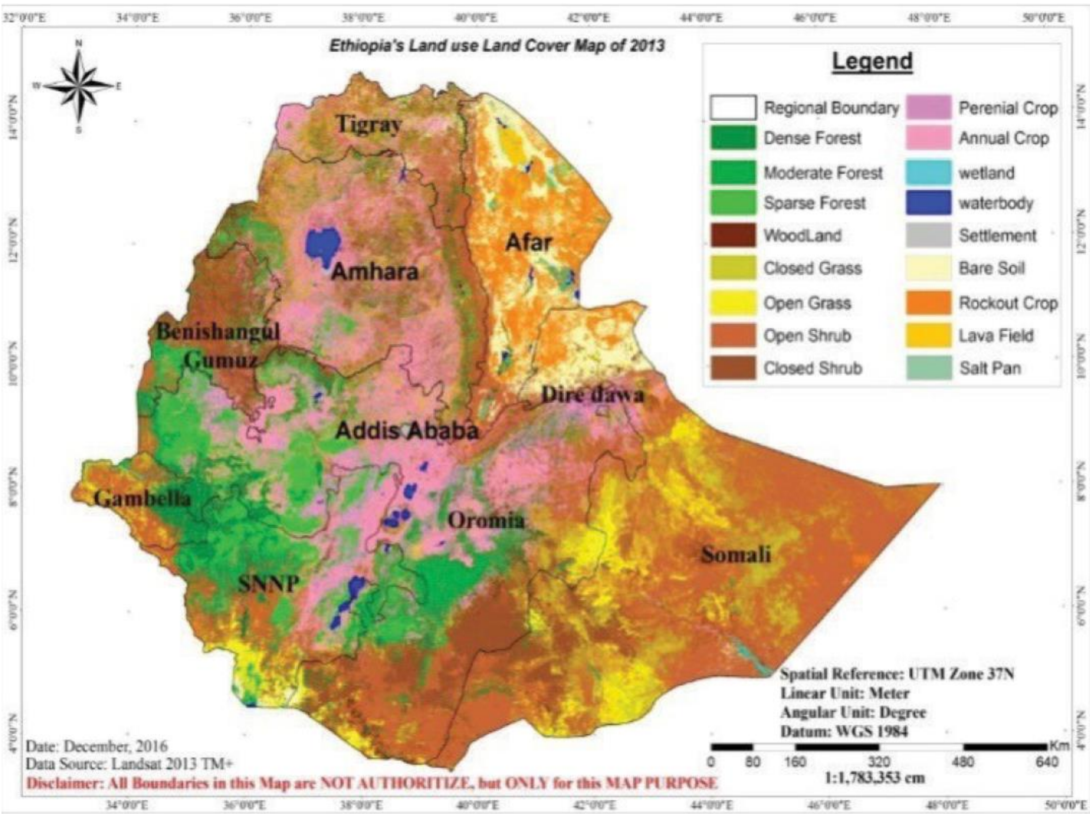


Figure 9. Land use land cover of Ethiopia (Source: Ethiopian Mapping Agency; Landsat 2013 ETM+) (cited in FDRE/EFCCC, 2018)

9.4.4 Economic policies and institutions

The other underlying drivers of change in biodiversity and ecosystem services are economic growth, markets, technology and governance factors, which are often collectively considered as the root causes. **Economic growth generates negative externalities** in the **form of habitat destruction and environmental pollution** and in turn, **degradation of biodiversity and ecosystem services**. Higher rates of economic growth are generally associated with **greater biodiversity decline**. This is so because markets alone do not assign appropriate monetary value to biodiversity. Hence, without policy intervention, market prices do not properly reflect the losses to society as a whole arising from the loss of biodiversity and ecosystem services (Acemoglu etal., (2005). This failure leads individuals, companies and governments to use biodiversity **in an unsustainable manner**.

Market failures can either be of a local nature or on a global scale. The former refers to the inability of markets to capture some of the local or national benefits of biodiversity conservation, or the inability of markets to capture the costs of converting ecologically valuable land to other uses and losing biodiversity and ecosystem services in the process. The latter refers to the fact that biodiversity conservation also yields benefits to the global community, external to where actual conservation work takes place. Policies focusing on economic growth tend to increase exploitation of natural resources for export as well, and this can lead to over-harvesting of biodiversity resources. It also **increases private sector access to biodiversity resources** to meet the demand **for export earnings**, including to service debts and support imports. In other words, trade expansion has the potential to facilitate both legal and illegal exports, as people perceive new opportunities to generate income.

Economic inequality is an important predictor of biodiversity loss. Where income inequality prevails and poverty is pervasive, the number of people directly dependent on biodiversity resources will be large. This leads to unsustainable exploitation, **biodiversity degradation** and **loss of ecosystem services** (Ring et al., 2010).

Governance is also an important factor in biodiversity loss. It is expressed in terms of political will, **the quality of relevant policies and legislation**, and organizational capacities for biodiversity conservation. Biodiversity loss increases where **biodiversity policy goals are unclear, legal frameworks are inadequate, law enforcement activities are weak**, involvement of **stakeholders in biodiversity conservation is absent or inadequate**, and a general lack of commitment to sustainable management exists.

Ethiopia has several policies, legislation, standards and plans that are relevant for biodiversity conservation. The main policy document is the National Biodiversity Strategy and Action Plan (NBSAP) 2015-2020, a subsequent phase of which is already drafted. This is an overarching framework on biodiversity for all stakeholders to value biodiversity and **ecosystem services, reduce pressures on biodiversity and ecosystems, improve the status of biodiversity and ecosystem services, and ensure access to genetic resources and fair and equitable sharing of benefits arising from their use**. Ethiopia's **Climate Resilient Green Economy (CRGE) Strategy, the Green Growth Strategy (GES), the Sustainable Land Management Program**

(SLMP), the Resilient Landscapes and Livelihoods Program (RLLP), the Forest Sector Development Program (FSDP), the National Adaptation Program (NAP), and the Ten-Year Development Plan (2020-2030) have either policy provisions or action plans and activities that contribute to nature conservation, ecological restoration, sustainable use of biodiversity resources and mitigation of climate change impacts, and in so doing address the major drivers of biodiversity loss. The Ten-Year Development Plan (2021-2030), which is a comprehensive development plan to guide the country's development over the coming decade, has 10 pillars. One of the pillars is on climate resilient green economy with a focus on environmental protection, climate change mitigation and renewable energy. In addition, Ethiopia is also a party to a number of multilateral environmental agreements, such as the UNCBD, UNCCD and UNFCCC, which are meant for biodiversity and ecosystem conservation, forest management, land degradation control and the mitigation of climate change.

A major gap in the country's policy arena is the **absence of a national land use policy**. **Lack of a comprehensive land use policy** is an institutional barrier to **effectively tackle the drivers of biodiversity loss**. Assessment of implementation of the available policies and programs, as presented in the preceding chapters, has also shown serious gaps and challenges of implementation. It is reported that **in general the policy and legal instruments of implementation are patchy to protect ecosystems** with unclear and overlapping mandates; their **implementation and enforcement have been irregular, incomplete, and ineffective**. In other words, efforts have been focused on developing policies and strategies while little has been done on strengthening institutional arrangements, implementation at field levels and enforcement of laws. With regard to forests in particular, institutional instability, poor capacity, **poor inter-sectorial coordination and lack of synergy between sectors, inadequacy of the forestry legal framework, weak law enforcement, and unclear tenure and forest user rights** have made the forestry related policies and **activities ineffective**. The assessment also noted that the rangeland ecosystem has **not received the attention it deserves, as for instance there is no dedicated government organization responsible for rangeland development**. This coupled with the absence of a clear policy framework that recognizes and empowers customary institutions and ILK for resource governance, **conflict management and other methods of traditional**

protection applicable to rangelands, has led to the deterioration of biodiversity and ecosystem services of rangelands.

9.4.5 Climate change

Ethiopia's meteorological observations exhibit some evidences of climate change. Mean annual temperature has increased by about 0.28°C per decade over the last 40-50 years (EPCC, 2015). The rate of increase showed spatial variability; it is much higher in already hot and dry parts of the country. In terms of seasons, it is higher in the July-September season. McSweeney et al. (2008) found that the number of 'hot days' and 'hot nights' had increased by 20% and 38%, respectively, between 1960 and 2003, especially from June to August where the increase was as high as 32% and 59%, respectively. The number of 'cold days' and 'cold nights' had decreased by 6% and 11%, respectively. The minimum temperature increase reaches up to 0.4°C per decade in some localities (Keller, 2009).

While research evidence on the increase in temperature is consistent across time and regions, changes in rainfall are unclear and research findings are different for different areas and study periods considered. Many studies show that rainfall has remained more or less stable over the last 50 years when averaged over the country (Keller, 2009), and the drier conditions that characterized the 1980s have shown some recovery from the 1990s (Woldeamlak and Conway, 2007). For sub-national and seasonal scales, studies show mixed patterns of change. For instance, Funk and Rowland (2012) reported Belg and Kiremt rainfall decreased by 15-20% across parts of southern, southwestern, and southeastern Ethiopia between the mid-1970s and late 2000s. In their study of the Awash River basin, Mulugeta et al. (2019) found significant decreasing trend in five of the seven sub-basins, but no trend in the two sub-basins for the June-September rainfall. The high natural spatial and temporal variability of rainfall in the country is a challenge to **the detection of long-term trends** (Bewket and Conway, 2007).

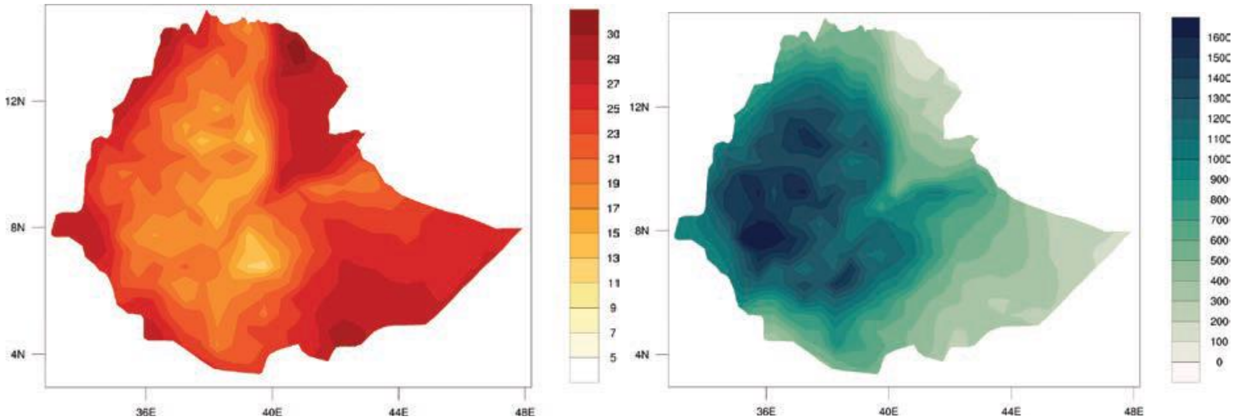


Figure 10. Average annual temperature (left); annual precipitation (right) of Ethiopia, 1901–2020. Source: World Bank, 2021.

Changes in temperature and rainfall increase the frequency and severity of extreme events. The rise in temperature has exacerbated drought impacts particularly in the lowlands, and the increase in the frequency of short, heavy rains in the highlands has increased soil erosion hazard onsite and flooding and sedimentation in downstream and lowland areas.

Regarding **future changes**, studies using different global climate models consistently project increases in temperature. While all models foresee warming, they differ in the rates of warming as well as in parts of the country where the largest increase will happen. On average, temperatures are expected to increase in all **seasons by 1°C by 2030, 2°C by 2050, and 3°C by 2080; but some models project a maximum increase of as high as 5.1°C by the 2090s** (McSweeney et al., 2008). Similarly, most models project increases in the frequency of hot days and nights, with up to 93% of days and 99% of nights considered ‘hot’ in the July-September season by the 2090s (compared to 10% of days and nights in the same season in the 1960s) (McSweeney et al., 2008). Projections of rainfall show increase for some parts of the country and decrease for others; **expected changes range from -25% to +30% by the 2050s** (USAID, 2016). Figure 11 shows projected changes in temperature and rainfall under a high (RCP8.5) emission scenario. It is shown that temperature will increase significantly across the country, while rainfall increase in some parts and decreases in others. Even in those areas of potential increase in rainfall, warmer temperatures will accelerate the rate of evapotranspiration and reduce benefits from the increased rainfall.

Ethiopia is one of the **most vulnerable countries to the adverse impacts of climate change**. By most measures, exposure and **sensitivity are high and adaptive capacity is low** in Ethiopia. The ecological setting and level of socioeconomic development of the country are the main reasons. Ecologically, high natural climate variability, a large highland area with rugged terrain and steep slopes, and a vast lowland area with arid, semi-arid, and dry sub-humid climates characterize Ethiopia. The major areas of concern for Ethiopia are **human health, agriculture, food security, water resources, energy, and infrastructure.** Regarding economy-wide impact, World Bank (2010) projects that climate change could **reduce Ethiopia's GDP by between 0.5 and 10% from what could be achieved in the 2040-49 decade without climate change impacts.**

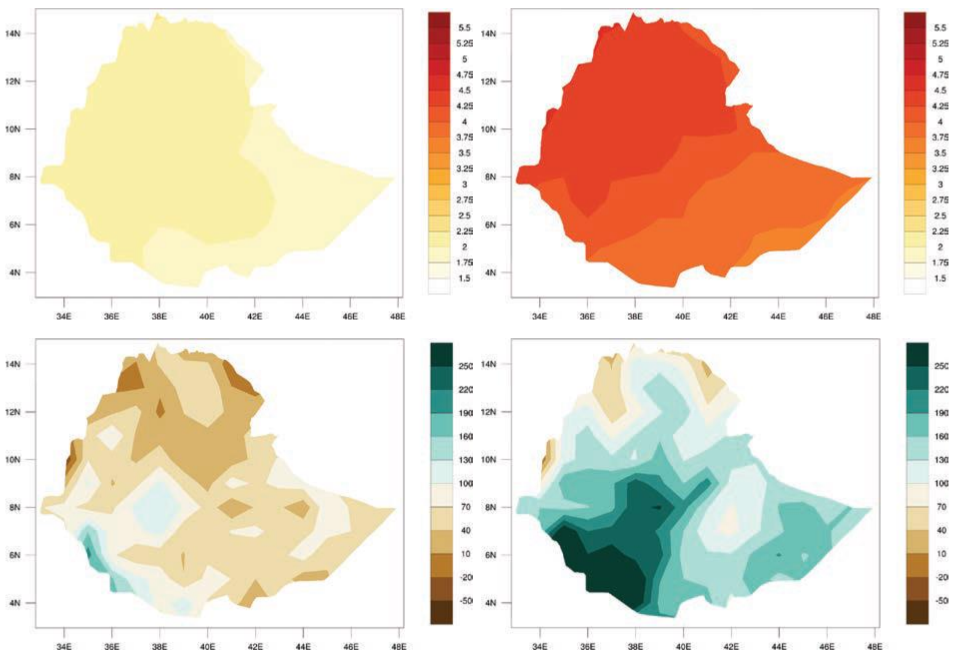


Figure 11. CMIP5 ensemble projected change (32 GCMs) in annual temperature (top) and precipitation (bottom) by 2040–2059 (left) and by 2080–2099 (right), relative to 1986–2005 baseline under RCP8.5. Source: World Bank (2021)

There is limited empirical research **on vulnerability of ecosystems to climate change impacts in Ethiopia**. Based on a review of the limited available studies, EPCC (2015) concluded that climate change is likely to cause significant a**dverse impacts in all five of the major ecosystems in the country**; i.e., (i) Mountain, (ii) Forest and Woodland, (iii) Rangeland, (iv) Aquatic and wetlands and (v) Agricultural ecosystems. The experienced and projected impacts, according to this review, include **shifts in geographical** ranges of some native plants and animals, **changes in timing of life cycle events of some plants** and animals, **spread of invasive**

species and diseases, and **declines in species, populations and genetic resources as well as extinction or loss of biodiversity** resources. The cumulative effect of these multidimensional impacts of climate change is loss of biodiversity and ecosystem services, which are vitally important for human wellbeing.

Projected future changes in the different indirect and direct drivers represented within the exploratory scenarios for Ethiopia are summarized in Table 2 for each scenario archetype.

Table 2. Trends in drivers (indirect and direct) of biodiversity and ecosystem services change under the scenario archetypes

Scenario archetypes	Drivers of Change in BES				
	Population growth	Urbanization (Settlements)	Land Use Land Cover Change	Policies and institutions	Climate change
Business as usual (Future from Historical)	↑	↑	↗	↘	↗
Food first (Economic optimism)	↗	↑	↗	↘	↗
Green Growth (Environmental optimism)	↗	↗	↗	↑	↗
Policy Reform (unstable economy)	↗	↗	↑	↓	↑
Regional Integration	→	↗	→	↗	

↑ = Strong increase ↗ = Increase → = Stable ↘ = Decrease ↓ = Strong decrease

= Positive = Neutral = Negative = Not interpreted In impacts = lack of evidence

9.5 Biodiversity and ecosystem services under the different scenarios

9.5.1 Biodiversity and ecosystems

Business-as-usual: under the *future from historical* scenario, the loss of biodiversity resources and ecosystem services is significant (Table 3). The existing gap in knowledge and research limits our understanding of the severity of the losses. Climate change will intensify current variability and increase intensity and frequency of extreme events affecting fragile ecosystems in the dry lowlands. Population growth will be the main driver of land use cover change and urbanizations. Headcount of vulnerable population is large due to increased total population. Protected areas are affected by encroachment by local communities engendered by the growing shortage of grazing and cultivable lands.

Table 3. Changes in biodiversity and ecosystems under the five scenario archetypes

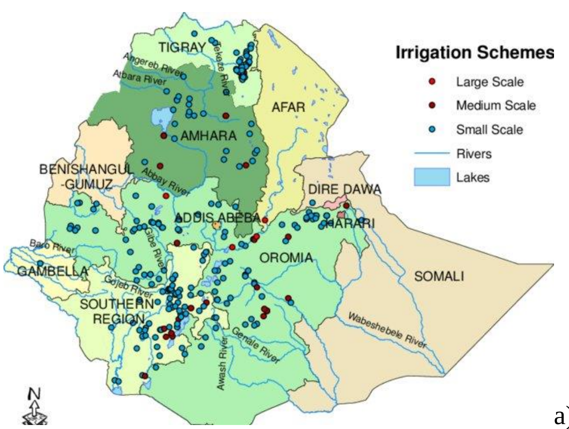
Ecosystems	Scenario Archetypes									
	Business As Usual		Food First		Green Growth		Policy Reform		Regional Integration	
	Biodiversity	Ecosystem services	Biodiversity	Ecosystem services	Biodiversity	Ecosystem services	Biodiversity	Ecosystem services	Biodiversity	Ecosystem services
Mountain	↘	↘	↘	↘	↗	↗	↘	↘		
Forest & Woodland	↘	↘	↘	↘	↗	↗	↘	↘	↕	↕
Aquatic and wetland	↘	↘	↘	↘	→	↗	↘	↘		
Rangeland	↘	↘	↘	↘	→	↗	↘	↘	→	→
Agrocosystem	↘	↘	↕	↕		↗	↘	↘	↕	↕

↗ = Increase ↘ = Decrease → = Stable ↕ = Variable = lack of evidence

Despite the economic progress in the recent past, poverty remains the driving factor for natural resource degradation. Expansion of cultivation to marginal lands continues to drive deforestation and soil degradation in major ecosystems. In the business-as-usual scenario, extreme climate events, declining productivity and IAS further cause loss of biodiversity particularly in agroecosystem, and rangeland and aquatic and wetland ecosystems. The impacts of IAS will extend further to forest and woodland ecosystem in the absence of strong control measures. For instance, *Prosopis juliflora* is thriving in woodlands and lowland rangelands threatening indigenous species. With current trend of the climate trajectory, mountain ecosystem will further shrink due to droughts, habitat loss and encroachment for cultivation and grazing. Changes in moisture and temperature regimes drive species migration.

Food first: the *Food first* scenario is likely to see further expansion of smallholder agriculture into steep lands and commercial irrigated agriculture into grasslands in the lowland areas of the country. The rangeland ecosystem, the biodiversity and the services will diminish while the food and feed supply increases. Irrigated agriculture used to concentrate in the highland agroecosystem covering only a small proportion of potentially irrigable areas (Figure 12) (Bekele and Denekew, 2015). Irrigation is one of the climate-resilient strategies to overcome effects of drought and crop failures from rainfed agriculture (Assefa et al., 2019). Expanding irrigation into the lowland regions is a development priority to increase food production. There is an estimated irrigable area of between 3.7-18 million ha, and there is a great potential for expansion as shown in Figure 12.

The *food first* priority is focused on increasing production per unit area and achieving self-sufficiency from domestic production. This is not only by intensifying the existing production but also highly likely by expanding to new frontiers in the forest and woodlands ecosystem. Expansive agriculture drives habitat loss, soil erosion and water pollution. Rapid urbanization and industrialization increase pollution of air and water, and conversion of land into cultural landscapes. Thus, under this scenario, the major ecosystems continue to decline in area coverage, biodiversity and ecosystem services.



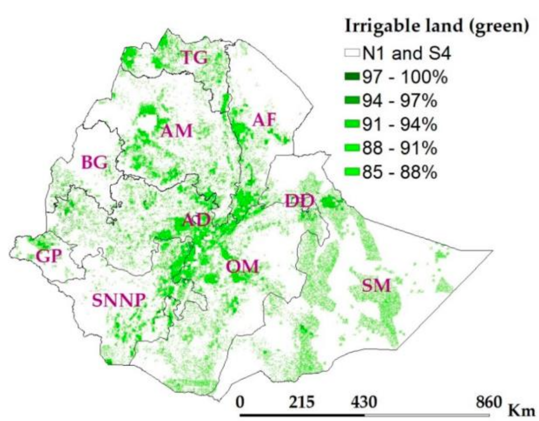


Figure 12. Distribution of existing irrigation schemes (a) and potential irrigable areas and new expansion towards the lowlands (b) in Ethiopia (Bekele and Denekew, 2015)

***Green growth*:** In this scenario, biodiversity conservation is given priority in the political agenda and ecosystem services are enhanced through human intervention. The Green growth prioritizes low carbon pathways and is guided by actions that target GHGs emission reduction and carbon capture. Policies, laws, proclamations, multi-lateral commitments will be implemented.

Environmental governance will be improved at national, regional and local levels. Landscape restoration will be the central goal for local sustainability. For instance, in the country's green growth strategy (CRGE), it is planned to afforest two million ha of pastureland and reforest one million ha of degraded land to achieve a sequestration rate of 10.75 Mt CO_2e/ha/year. In addition, two million ha of high forests and woodlands each will be managed to attain a sequestration rate of 3.24 Mt CO_2e/ha/year. The guiding document for the green growth, the Climate Resilient Green Economy (CRGE) strategy aims "to meet half of its target reduction in carbon emissions by adding five million ha of forests by 2020 and restoring 22 million ha of degraded landscapes by 2030". Restoration recovers biodiversity and enhances ecosystem services in terrestrial and aquatic ecosystems. The growing interest and preference towards indigenous species in restoration planting are reviving local biodiversity (herbs, shrubs, small mammals, birds, soil fauna, etc.). Landscape re-greening connects fragmented habitats in agroecosystem and improves ecological flow thresholds, which is critical for maintaining ecological functions such as nutrient cycling.

Community mobilization, popular participation in conservation works and in seasonal planting campaigns will advance the green growth objectives at scales. Strict implementation of the national green agenda and popular response at grassroots levels reduces GHGs emissions. Green growth succeeds under effective governance, which in turn leads to effective environmental regulation, increasing protected area management, enhanced provision of ecosystem goods and services. Energy substitution by shifting to non-fossil fuel options (e.g., solar, wind, hydropower) and promoting energy-efficient technologies greatly reduces deforestation and improves biomass return to the systems.

Policy reform: high level of uncertainty ensue ineffective policy implementation and a weakened rule of law resulting in ecosystem degradation and biodiversity loss. Policy reform shakes the **economic and political landscape** through sustained institutional reforms to culminate at a targeted socio-economic goal. The economic reforms refurbish economic institutions such as laws, regulations, and policies that regulate the relationships among economic players along with restrictions on economic transactions. The rule of law, policies affecting consumption and production, property rights, and regulatory standards are reformed. This shapes investments on land, scale of production, quality and standards, distribution and value chains. Under stable and smooth transition, economic reforms uphold compatible environmental standards. Nevertheless, the success of the economic reforms are guided and determined by the success of socio-political reforms. The political reforms are transforming institutions that are dealing with organizing the political entity, how power is **controlled, legitimized, constituted, redistributed**, and exercised (Zhao and Madni, 2021). The trajectory of the political reform process bears uncertainties for the socio-economic transformation. Transformational policy reforms may culminate either in legitimate democratic governance that prioritizes environmental protection or in autocratic governance that lacks legitimacy, weakened rule of law and ineffective policy implementation thriving largely on natural resource extraction that neglects the environment (Wang et al., 2020). Under such circumstances and high level of uncertainties, the environment is the loser and the loss of biodiversity increases (Keith et al.2011). With increasing population, land use land cover change, urbanization, coupled with failure to implement policies, laws and regulations will drive biodiversity decline and ecosystem degradation. Absence of investment on land restoration reduces productivity of agroecosystem. Declining production leads to expansive agriculture, aggravating deforestation and conversion in forest and woodland ecosystems (Argaw, 2005). The risk of erosion and sedimentation in wetlands increases. Lowland rangelands shrink due to agricultural expansion and bush encroachments.

***Regional integration*:** regional integration brings diverse environmental responses triggering ecosystem restoration and/or biodiversity loss. Regional integration opens up opportunities for increased interaction and increased flow of goods and labor among countries. Increased level of interdependence paves the way for tolerance and dialogue to solve disagreements and to increase trust. Free flow of goods and movement of people increases trade, creates jobs, and increases investment on infrastructure and social services. Regional integration may reduce or enhance illegal trade. Regional integration tends to have positive and/or negative impacts on ecosystems and biodiversity in the particular region and in the countries involved (Perz et al. 2012). At the level of policy harmonization and regional cooperation, states in regional integration are more likely to constitute a regional arrangement to achieve an integrated environmental regime by setting common environmental standards and laws that govern environmental management across the region. This may advance ecosystem protection and biodiversity conservation. The level of environment protection reflects the level of economic development. In this regard, regional integration has more positive effects on environmental governance (Abbott, 1992).

Regional integration brings physical connectivity, enhances and facilitates movement of people and wildlife. As much as the positive contributions towards coordinated conservation actions, habitats will become more fragmented and degraded due to infrastructure installments (roads, rails, communication lines, pipelines, etc.). This heavily affects the forest and woodland ecosystem, rangeland ecosystem and agroecosystem. Isolated habitats are exposed to more edge effects and tend to rapidly lose their biodiversity. Wildlife, that tends to avoid roads, may become more vulnerable. IAS may find favorable conditions to expand into protected areas and to new habitats. Besides, infrastructure modifies the natural flow and network of streams and cause disconnections on ecological flows. This negatively affects terrestrial and aquatic biodiversity (Perez et al. 2012).

On the other hand, increased physical connectivity improves access to resources and markets in the region. Interaction among communities increases. Rural-urban linkages increase flow of resources and people. This might either increase the pressure on extraction of resources from ecosystems and/or opens up opportunities for alternative livelihoods and reduces pressure on natural ecosystems. Regional integration can enhance socio-ecological resilience and adaptation to shocks. The ecological resilience includes the feedbacks from habitat mosaics, species assemblages and other components of the ecosystems. The social resilience is the capacity of communities and landscapes to adapt to externally induced shocks. The external shocks could be diseases outbreaks, droughts, floods, fluctuating commodity prices and large scale infrastructure. Sensitive ecosystems such as aquatic and wetlands with their biodiversity will be more affected by such shocks.

9.5.2 Ecosystem services

Ecosystems are the sources of freshwater, food and fiber, energy and timber, medicinal organisms and ornamental materials that are vital to human wellbeing. These are material services that nature provides from ecosystems. The state and availability of these services varies under the different scenarios.

9.5.2.1 Provisioning services

***Business-as-usual*:** this scenario is characterized by continued population growth, variable and slow-growing agricultural production, slow growth in industrial production, rapid and unplanned urbanization mainly driven by push factors from rural areas, high exposure and sensitivity to climate change, and weak capacity to coordinate and enforce environmental policies and laws of the country. Poverty and food insecurity remain major socioeconomic challenges. The biodiversity and ecosystem implications are decline in per capita availability of environmental resources, increased total extraction of resources, depleted biodiversity and increased land degradation, increased pollution of fresh water resources, and high vulnerability to the multidimensional impacts of climate change.

The effects of the business-as-usual scenario on the provisioning services of ecosystems are reduced per capita availability of agricultural land, fresh water resource, wood for fuel and other uses, and increased rarity of medicinal organisms. Population growth and climate change are the key drivers causing decline in the provisioning services under this scenario, while poor implementation of policies and laws, or total absence of such policies in some cases (e.g. land use policy) provides important contribution. The rapid population growth will lead to unsustainable exploitation of land and water resources and increased shortage of land, which will become a push factor to increase rural-urban migration. The rural-urban migration leads to rapid urbanization and unplanned expansion of urban settlements, which further negatively affects agricultural land availability, or food production, and increases pollution of water resources, or freshwater supply. The recent and projected reduction in per capita surface water availability because of population growth, assuming a constant supply, is shown in Figure 13. It is shown that annual per capita water availability was well over 2000 m^3 by the beginning of the 1990s, presently around 1200 m^3, and it is projected to decline to less than 1000 m^3 by 2050.

The food production service of the rangelands ecosystem will be highly compromised by climate change, human and livestock population pressure, bush encroachment, and invasion by invasive plant species. The invasive plant species will also cause decline in the water and food provisioning capacity of the aquatic and wetland ecosystem. Climate change projections show inter-annual variability and the incidence of extremes is highly likely to increase. This affects inter-annual stability of food availability, freshwater supply, and energy production from hydropower as well as biomass sources. The trends in each of the provisioning services of ecosystems under the business-as-usual scenario are thus downward (Table 4).

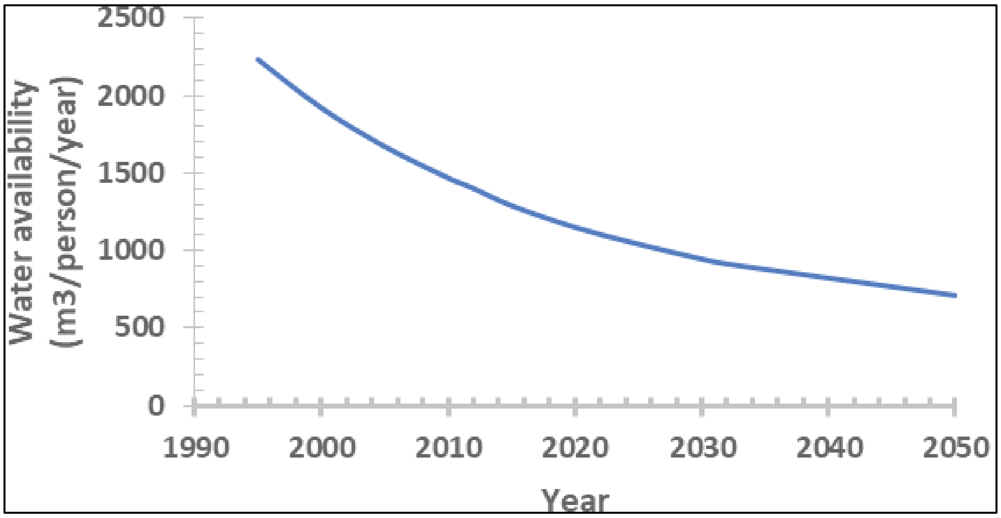


Figure 13. Surface water availability per capita (Source: FDRE/MEFCC, 2018)

***Food first*:** under the *Food First* scenario, food security will be ensured at the national level as well as household level to a large extent. This is a result of increased local production and improved access to food through purchases that is possible because of the increased household incomes. Demand for resources such as water increases as a consequence of more people and a greater demand for water for agricultural, industrial, urban and domestic uses. The rapid economic growth and urbanization causes pollution of water and ambient air. Expansion of large scale irrigated agriculture particularly in the lowlands negatively affects pastoral livelihood systems. Indigenous knowledge and practices become marginalized or even lost. A **'grow first and clean up later'** attitude by the state to environmental sustainability contributes to declines in genetic variety because of increased replacement of indigenous species and land races by improved varieties and monocultures. While change in the ornamental materials provisioning service is indeterminable, availability of medicinal organisms declines because of increased conversion of the natural landscape into a human-managed landscape.

Green growth: In this storyline, environmental sustainability is an important national priority and hence all environment-related policies, strategies and programs are effectively implemented, and policy goals and targets are achieved. The country meets the net zero emissions and land degradation neutrality objectives, and climate change impacts are mitigated through nature-based solutions and other adaptation measures. Increased use of modern technologies such as biotechnology, improved crop varieties, improved animal breeds, improved livestock and feed management practices, local-specific application of fertilizers, and water saving irrigation technologies coupled with widespread adoption of sustainable land management practices enables sustainable intensification of agricultural production and meeting of the increased food demands of the population. Also, energy needs will be fulfilled primarily from the renewable energy sources of hydropower, wind, solar and geothermal sources, as the country's vast potential will have been developed. This *Green growth* path will enhance availability of the provisioning ecosystem services of food, feed, freshwater, energy, and medicinal/ ornamental materials and thus the trend are upward for these and maintains a stable pool of genetic variety (Sala, et al., 2000) (Table 4).

Table 4. Changes in ecosystem goods and services under the five scenarios

Ecosystem goods and service (material, regulating and non-material services)		Scenario archetypes				
		Business as usual	Food First	Green Growth	Policy Reform	Regional Integration
Provisioning services	Food/feed/fiber	↘	↗	↗	↘	↘
	Fresh Water	↘	↘	↗	↘	↘
	Energy/fuel/timber	↘	↘	↗	↘	↘
	Medicine/Ornamental	↘	↘	↗	↘	
	Genetic/ variety	↘	↘	→	↘	↕
Regulating Services	Climate	↘	→	↗	↘	↗
	Air quality	↘	→	↗	↘	→
	Erosion control	↘	↘	↗	↘	
	Water flow	↘	↕	↗	↘	↘
	Natural hazard control	↕	↕	↗		
Supporting services	Material cycle (nutrient, water)	↘	↘	↗	→	
	Soil formation and retention	↘	→	↗	↘	
	Biomass production (NPP)	↘	↗	↗	↘	↗
	Habitat for flora and fauna	↘	↘	↗	↘	↗
	Production of oxygen	↘	↕	↗		
Cultural services	Spiritual/ religious	→	→	↗	→	→
	Aesthetic/ scenic	↘	↘	↗	↘	↗
	Educational/ ILK	↘	↕	↕	↘	
	Heritage/ Historical/ diversity	↘	→	↕	→	↗
	Recreational/ Eco-Tourism	↘	→	↗	↘	↗

↗ = Increase ↘ = Decrease → = Stable ↕ = Variable = lack of evidence

***Policy Reform*:** In this scenario, the loss of provisioning services will be rapid. Uncertainty may not bring sustained peace and leads to declining accountability with compromised implementation of the rule of law. Unmanaged urban expansion, conversion of natural ecosystems into managed landscapes will increase. Species with medicinal values and the wild gene reserves will diminish with the destruction of the natural ecosystems. The future supply of timber and fuel wood will decrease. Shifting to use of crop residue and cow dung for fuel compromises nutrient return and further reduces yield. Economic stagnation reduces investment on sustainable land management and the agroecosystem lose the production potential through increased erosion, nutrient mining and invasive species. Expansive agriculture undermines the role of critical catchments as sources of fresh water.

Regional integration: this scenario brings positive and negative impacts on the goods and services produced from ecosystems. Regional integration fosters geo-physical and social-interconnections along trans-boundary landscapes. This is realized through roads, railways, and energy and communication infrastructures. The negative impact is habitat fragmentation in natural ecosystems. This causes interruptions in the life cycle of flora and fauna of ecosystems by causing disconnections and increasing biological distance. The physical disturbance to surface hydrological systems reduces water flow and decreases the environmental flow. Hence, food, fiber, medicine, and other non-timber products decline. Land degradation happens following road and railways openings, which reduces provisioning services from ecosystems. Policy harmonization facilitates implementation of strict environmental standards and may lead to improved conservation and provision of genetic resources.

9.5.2.2 Regulating services

The regulating services are benefits obtained from ecosystems through the regulatory processes. The major services under this bundle include the regulation of climate, air quality, water flow, soil erosion, natural hazards and pollination functions. The direction and magnitude of change, and future availability condition of these ecosystem services under the five scenarios is presented below.

Business as usual: under this scenario, population growth, dependence on small scale agriculture, urbanization, climate change, and weak enforcement of environmental policies and laws, and limited spatial coverage of sustainable biodiversity and ecosystem management practices reduce the regulating services of ecosystems. Climate change alters the rainfall behavior, making high intensity events more common. High intensity events generate higher surface runoff, compared to low intensity events, and this reduces soil moisture and groundwater recharge while increasing soil erosion rates. Soil erosion is the leading cause of land degradation in Ethiopia, particularly in the highlands where a large majority of the population lives and the bulk of agricultural production is generated.

Soil erosion, deforestation and climate change will interact to alter rainfall partitioning patterns in favor of increased surface runoff and reduced infiltration and groundwater recharge. This will lead to decreased dry season water flows in springs, streams and rivers and depletion of groundwater resources. Increased surface runoff and soil erosion contribute to pollution of water while degraded catchments lose their water purification functions. Land degradation also reduces water storage, drought absorption and flood attenuation capacity of watersheds, hence reducing an important natural hazards regulation service of ecosystems. Similarly, landslides, other forms of hydro-meteorological hazards, also become more frequent phenomenon in degraded hill-slopes. The carbon storage, air quality and climate regulation benefits are reduced, under this scenario, because of land use land cover change, deforestation, expansion of small scale agriculture into marginal areas, cultivation of wetlands and overgrazing in the rangeland ecosystem.

Food first: the decline in the regulating services of ecosystems is significant under the *Food First* scenario, because the over-riding national priority is economic growth to ensure food security, job creation, poverty elimination and transition to the middle-income group. The 'grow now and clean up later' attitude has relegated environmental sustainability issues as secondary to economic growth. Agriculture has expanded into higher elevations at the expense of natural vegetative covers as the increasing temperature shifts temperature limits to crop cultivation. Fertilizer application rates are increased and use of herbicides is common. This change in the highland and agricultural ecosystems reduces the soil erosion, water flow and climate regulation services of ecosystems. Commercial agriculture covers a large area in the lowlands of the country, which is a land use conversion from the rangelands ecosystem. As a result of the land use conversion, total soil carbon storage of the rangelands ecosystem, which is a climate change regulation service, is reduced. The rapid urbanization and industrialization increased pollution of air and water, negatively affecting the air and water quality regulation services of ecosystems. Urbanization and expansion of agriculture and rural settlements in the upstream areas also increases risks of both flash floods in the upstream areas and river floods in the downstream areas; this is reduction in a natural hazard regulation service of ecosystems.

Green Growth: the regulating services of ecosystems improve significantly under the *Green growth* scenario. Areas under forest and tree cover increase, protected areas and rangelands are sustainably managed, sustainable land management is adopted throughout the agroecosystem, and dairy and ranch farming use modern technologies and management practices. Commercial agriculture adheres to strict environmental standards. The guiding principle for agriculture in general is sustainable intensification of production systems. Effective agricultural management enhances carbon sequestration through soil conservation, or by introducing trees as agroforestry systems. Urban centers and infrastructure development are guided by long-term development plans. The overall result is increased regulating ecosystem services, such as climate change adaptation and mitigation benefits, improvement of air and water quality, water flow regulation and erosion control, mitigation of impacts from hydro-meteorological hazards such as floods, landslides and droughts. The aquatic and wetlands ecosystem which includes wetlands, floodplains, lakes, and reservoirs are effectively managed and provide flood attenuation, water flow and water quality regulation and climate change mitigation and adaptation benefits.

Policy reform: in the absence of stable economy, ecosystems and their functions are heavily disturbed due to increased degree of anthropogenic pressure. The regulating services are hampered in this scenario. Carbon release, deforestation and habitat modifications increase GHGs release and induce changes in micro-climates. Biological activities of micro-fauna are interrupted. Hence, the climate regulating role is minimized. The air and water infiltration role of ecosystems is weakened from poor management of liquid and solid wastes. Reduced investment on sustainable land management in upper catchments disrupts water flow and causes downstream flooding.

***Regional integration*:** policy harmonization and multi-lateral agreements on environmental governance and standards contribute to GHGs reduction at national level. However, habitat fragmentation reduces hydrological regulating function due to disruptions to drainage systems. The impacts of climate change may also be better dealt through cross-border cooperation on adaptation actions, landscape restorations and protected areas management. Air quality may deteriorate due to increased infrastructure and industrialization. Nevertheless, air quality may also be improved due to strict control measures and standards set forward by the regional members. Hence, the regulating services may either be enhanced or curtailed in this scenario.

9.5.2.3 Supporting services

The supporting services of ecosystems are the foundations for the production of all the other ecosystem services. The major supporting services include photosynthesis and biomass production, production of atmospheric oxygen, soil formation, nutrient cycling, water cycling, and provisioning of habitat. Obviously, without these supporting services, the provisional, regulating, and cultural services would not exist. The supporting services differ from the other three bundles of services in that their impacts on people are either indirect or occur over a very long time, whereas changes in the other categories have relatively direct short-term impacts on people. It is important to stress that the supporting services maintain the conditions for life on Earth in general.

Business as usual: the *business-as-usual* scenario produces negative effects on all supporting services. Expansion of agriculture to marginal lands continues to drive deforestation and soil degradation in major ecosystems. Land degradation, biodiversity loss, habitat fragmentation and climate change remain major challenges to cause declines in the habitat provisioning, biomass production, soil formation, and nutrient cycling services of ecosystems. The water cycling service is affected by the change in land use land cover of watersheds; surface runoff increases, transpiration and infiltration decrease, and seasonality of stream flows and groundwater levels increase. The production of atmospheric oxygen through photosynthesis, which is an important supporting service, is negatively affected by the reduced forest and tree cover and urban expansion, although its human impact is over an extremely long time and at the global scale.

Food first: the overriding policy priority under the *Food first* scenario is economic growth. As a result, the country is in the group of middle-income countries, food security is ensured at the national level, agricultural production has significantly increased with expansion of cultivated lands into highland as well as lowland areas and use yield-enhancing modern inputs, and the industrial sector has also become a major employer. Urbanization has reached an average level of the middle income countries. As the focus is on economic growth, unsustainable exploitation of environmental resources has prevailed, and caused deterioration in diversity and richness of biodiversity, natural vegetation cover, and water and air quality. In consequence, the different supporting services of ecosystems are affected differently. Biomass production has increased, and habitat provisioning and water and nutrient cycling functions are reduced, while the changes in production of oxygen and soil formation remained variable.

Green Growth: the supporting services are enhanced under the *Green growth* storyline. Policies and plans for environmental sustainability in general and conservation of biodiversity and ecosystems in particular are effectively implemented under this scenario. As a result, significant increase is achieved in area coverage of forests, agroforestry systems, protected areas, and aquatic and wetland ecosystem. Soil and water conservation measures are implemented across cultivated lands and rangelands are effectively managed. Soil health is also enhanced through efficient application of agricultural inputs. The results in terms of the supporting services are that biomass production is increased, soil formation and retention is enhanced, and species diversity and richness has increased. The positive influence of forest and vegetation cover on water cycle is well known; it improves the productive flow of water through ecosystems. The production of oxygen is maximized due to total increase in vegetation covers across all ecosystems including in urban settlements.

Policy reform**:** the supporting services are lost in many of the ecosystems in this scenario. Habitats are lost when vegetation in forests, woodlands and rangelands are degraded or converted to farmlands due to institutional and policy failures. Loss of biomass and organic matter in agroecosystem affects soil micro-organisms and disrupts pedogenesis (the soil formation processes). This reduces net primary production. Soil holding functions are reduced due to increased deforestation, erosion and sedimentation. In Ethiopia, the forestry and agriculture sector governance and laws have been formed and reformed over decades. The results are increased deterioration of protected areas and their ecosystem services.

Regional integration: the most significant impact on the supporting services is habitat fragmentation. One of the basic potential effects of fragmentation is that a decrease in fragment/patch size (area shrinkage), an increase in fragment isolation (disconnection), or both, lead to fragments with fewer species due to both increasing extinction and decreasing immigration rates. That basically affects most forests, woodlands and rangeland ecosystem. In Ethiopia, deforestation and forest degradation driven by anthropogenic factors has resulted in habitat fragmentation, leading to reduced gene flow among populations (MEFCC, 2018).

9.5.2.4 Cultural services

The cultural services of ecosystems to people are the non-material benefits received through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience. All ancient civilizations have invariably left drawings of environmental elements such as animals, plants or landforms, and this indicates the significance of ecosystems in the development of human creativity and cultural advancement. Interaction with ecosystems, or nature, has always been a major inspiration for music, art and architecture. Aesthetic experience or recreation through nature-based tourism has economic values, and also it is increasingly recognized as having positive impacts on physical and mental health of people.

Business as usual: under *business-as-usual* scenario, the spiritual/religious functions of ecosystems remain stable. Despite declined quality of biodiversity and ecosystems, places of spiritual value maintain their social and symbolic values to local communities. The aesthetic, educational and heritage values are reduced with loss of biodiversity and degradation of ecosystems.

Food first: the *Food first* scenario involves large scale modification of the natural landscape and its replacement by a cultural/managed landscape. The focus is on economic growth and use of modern technologies. Indigenous knowledge and practices become marginalized and some are even lost. Environmental sustainability is compromised. Urban expansion lacked appropriate planning, and hence green spaces and public parks cover limited areas. Emotional bonds of people to places are reduced, as they instead followed economic opportunities in their location decisions. The aesthetic and educational/ ILK values of ecosystems are reduced, the spiritual and heritage values remain stable, and recreational use is increased because of improved per capita incomes.

Green Growth: sustainable utilization and management of environmental resources has, under the *Green growth* scenario, enhanced the cultural services of ecosystems. Forests, springs, lakes and wetlands that are considered to be sacred places by local communities in different parts of the country are protected and continue to provide their spiritual and religious functions. Cultural and religious diversity of the country is maintained at a stable state as a result. Effective management of protected areas and public parks in urban settlements has improved biodiversity and ecosystem conditions. This has, in turn, increased local and international tourists visiting natural attractions, making the sector an important source of employment and income generation. Public parks and scenic landscapes provide places of recreation, relaxation and exercise, and contribute to mental and physical well-being of people. These public places are important sites used by the art, music and film industry for their recordings, thus delivering important aesthetic, inspirational, heritage and educational cultural services.

Policy reform: under this scenario, ecosystems continue to provide cultural services to society. Regardless of the severity of degradation, sacred sites and religious heritages will continue to remain sacred. Such services remain stable in the ecosystems they are found. However, the aesthetic and educational services including the indigenous local knowledge will be eroded along with the degradation of the ecosystems. In forest, woodland; and rangeland and aquatic and wetland ecosystems, the ecotourism values will decline under this scenario.

***Regional integration*:** religious and spiritual services of ecosystems will continue to serve society and will remain stable under this scenario. The aesthetic and scenic services of ecosystems will be enhanced through regional integration. Inaccessible and unprotected sites can be reached due to road openings and improved infrastructure including communication. Alongside, the recreational and eco-tourism services are increased. Cultural and heritage sites and services will be better protected through multi-lateral agreements.

9.6 Knowledge gaps and research needs

Scenario archetypes are important policy instruments to guide informed decision making. They are neither predictions nor projections of indicators. They are plausible futures formulated from expert assumptions on the future directions of the drivers of change. Scenario archetypes provide the opportunity to organize and synthesize pool of diverse information from scenarios and modeling studies of future projections on direct and indirect drivers of changes in biodiversity and ecosystems. Scenario archetypes are group of scenarios defined by specific assumptions, storylines and characteristics on drivers that determine plausible future outcomes. Therefore, scenario analysis is very much dependent on existing knowledge in literature. Past studies on scenarios and modeling works are important inputs. However, in our assessment, except for climate projections and land use land cover changes, scenario studies are very much limited. Modeling works on future dynamics of biodiversity and ecosystems are scanty. Even at the local scales, it is only recently that modeling of habitat quality change and ecosystem services change started to appear in the literature (Youhannes et al., 2021).

Except on few of the known species of plants and animals, the impact of the direct and indirect drivers on the flora and fauna of the majority of the ecosystems are lacking. Besides, scenario analysis on the vegetation, climate, population dynamics, land use land cover changes are not quite readily available for most ecosystems. National scale scenario analysis results are rarely found in the literature. This is an important priority for research in academic and research institutions. Expert knowledge on the application of scenario modeling, spatial and multi-temporal projections, and understanding of the global and regional scenario groups is essential for building scenario archetypes. Generally, there is limited knowledge on the future dynamics of ecosystems, on the extent of the loss of biodiversity in most ecosystems, on the future projections of key drivers, on national scale scenario and modeling analysis, availability of reliable sources of data and information on biodiversity and ecosystems.

9.7 Conclusions

Five scenario archetypes, characterizing the national socioeconomic and socio-political plausible futures, were identified to analyze the impacts on biodiversity and ecosystem services. These are *business as usual*, *food first*, *green growth*, *policy reform and regional integration*. The scenario archetypes and the storylines exhibit different assumptions and plausible futures on the drivers of change in biodiversity and ecosystem services. The impacts of the drivers on biodiversity and ecosystem services under the different scenario are summarized using the guiding questions posed for designing the scenario archetypes as follows.

What will happen to biodiversity and ecosystem services if socioeconomic development trends over the past few decades continue into the future?

The *business as usual* scenario is characterized by continued population growth, variable and slow-growing agricultural production, slow growth in industrial production, rapid and unplanned urbanization mainly driven by push factors from rural areas, high exposure and sensitivity to climate change, and weak capacity to coordinate and enforce environmental policies and laws of the country. In this scenario, the loss of biodiversity resources and ecosystem services will continue to decline. There no sufficient knowledge on the severity of the losses. Hence, our understanding of the loss of biodiversity and ecosystem services is limited. The provisioning services of ecosystems will be reduced along with the per capita availability of agricultural land, fresh water resources, wood for fuel and other uses, and increased rarity of medicinal organisms. This scenario produces negative effects on all supporting services. Expansion of agriculture to marginal lands continues to drive deforestation and soil degradation in major ecosystems. However, the spiritual/religious functions of ecosystems remain stable. Despite declined quality of biodiversity and ecosystems, places of spiritual value maintain their social and symbolic values to local communities.

How would biodiversity and ecosystem services be changed in a future where Ethiopia has prioritized fast economic growth aimed at improving the living standard of its population?

The *food first* scenario is characterized by rapid economic growth targeting food self-sufficiency driven by investments in all economic sectors by the private sector, public sector investments in infrastructure, and weak implementation of conservation policies and enforcement of environmental protection laws. The priority is focused on increasing production per unit area and achieving self-sufficiency from domestic production. Under this scenario, the major ecosystems continue to decline in area coverage, biodiversity and ecosystem services. The provisioning services will increase and food security will be ensured at the national level as well as household level to a large extent. This is a result of increased local production and improved access to food through purchases that is possible because of the increased household incomes. Demand for resources such as water increases as a consequence of more people and a greater demand for water for agricultural, industrial, urban and domestic uses. The rapid economic growth and urbanization causes pollution of water and ambient air. Expansion of large scale irrigated agriculture particularly in the lowlands negatively affects pastoral livelihood systems.

However, the regulating services of ecosystems will significantly decline under the food first scenario, because of the over-riding national priority of economic growth to ensure food security, job creation, poverty elimination and transition to the middle-income group. It adopts the notion of 'grow now and clean up later' attitude, neglecting the environmental sustainability issues as secondary to economic growth. Likewise, because of the priority to economic growth, unsustainable exploitation of environmental resources has prevailed, and caused deterioration in diversity and richness of biodiversity, natural vegetation cover, and water and air quality. Thus, the different supporting services of ecosystems are affected differently. Water and nutrient cycling functions are reduced, while the changes in production of oxygen and soil formation remained variable. Although the spiritual, heritage and religious services remain stable, the aesthetic and educational/ILK values of ecosystems are reduced. On the contrary, the recreational services and use will be increased because of improved per capita incomes.

What would biodiversity and ecosystem services look like if Ethiopia follows a green growth path across all sectors of the economy?

The *Green Growth* scenario is a storyline where Ethiopia successfully follows a green growth path such as that outlined in the current national climate resilient green economy strategy, which is aimed at **achieving net zero emissions**, through interlinked approaches of reducing emissions of greenhouse gases and **enhancing carbon sinks.** The scenario envisages that the available environmental laws and policies will be effectively implemented and new policy and legal instruments issued and enforced. Biodiversity conservation is a high priority in the political agenda and ecosystem services are enhanced through human intervention. Environmental governance will be improved at national, regional and local levels. Landscape restoration will be the central goal for local sustainability. The *Green growth* path enhances availability of the provisioning ecosystem services of food, feed, freshwater, energy, and medicinal/ornamental materials. Besides, the regulating services of ecosystems increases significantly under this scenario. The supporting services are enhanced under the *Green growth* storyline. Policies and plans for environmental sustainability in general and conservation of biodiversity and ecosystems in particular are effectively implemented under this scenario. As a result, significant increase is achieved in area coverage of forests, agroforestry systems, protected areas, and aquatic and wetland ecosystems. The cultural services of ecosystems are improved under this scenario. Forests, springs, lakes and wetlands that are considered to be sacred places by local communities in different parts of the country are protected and continue to provide their spiritual and religious functions.

How would the on-going socioeconomic and policy reforms in the country shape the political economy and consequently affect natural ecosystems and biodiversity?

The policy reform scenario explores the pathway in the perspective of enormous policy reforms and high level of uncertainty that emanated from the challenges that the country is passing through. This is a scenario in which the reform process may result in high economic uncertainty if the country continues to experience episodes of instability and conflicts. In this scenario enforcement of environmental laws, pollution control and regulatory measures may become loose. Environmental down-turn may seize in major ecosystems and cause negative impacts on biodiversity resources. Particularly, forest and woodland ecosystem, mountain ecosystem and aquatic and wetland ecosystem will suffer the most, hampering the goods and services provided from them. High level of uncertainty ensue ineffective policy implementation and a weakened rule of law resulting in ecosystem degradation and biodiversity loss. Uncertainty may not bring sustained peace and leads to declining accountability with compromised implementation of the rule of law. The loss of provisioning services will be rapid. In the absence of stable economy, ecosystems and their functions are heavily disturbed due to increased degree of anthropogenic pressure. The regulating services are hampered in this scenario. Carbon release, deforestation, habitat modifications increase GHGs release and induce changes in micro-climates. The supporting services are lost in many of the ecosystems in this scenario. Habitats are lost when vegetation in forests, woodlands and rangelands are degraded or converted to farmlands due to institutional and policy failures. However, ecosystems continue to provide cultural services to society. Regardless of the severity of degradation, sacred sites and religious heritages will continue to remain sacred. Such services remain stable in the ecosystems they are found.

What happens to ecosystems and biodiversity in national and trans-boundary landscapes in the era of increasing trends towards regional integration?

The *regional integration* scenario is a plausible future that visions a region with **high degree of interconnectedness and interdependence** built upon a multitude of factors, mainly on **sustained peace and security**, mutual trust, collective vision and policy harmonization for joint actions and growth. Regional integration brings diverse environmental responses triggering ecosystem restoration and/or biodiversity loss. Regional integration opens up opportunities for increased interaction and increased flow of goods and labor among countries. Increased level of interdependence paves the way for tolerance and dialogue to solve disagreements and to increase trust. Regional integration brings physical connectivity, enhances and facilitates movement of people and wildlife. As much as the positive contributions towards coordinated conservation actions, habitats will become more fragmented and degraded due to infrastructure installments (roads, rails, communication lines, pipelines, etc.). This heavily affects the forest and woodland ecosystem, rangeland ecosystem and agroecosystem. The negative impact is habitat fragmentation in natural ecosystems. This causes interruptions in the life cycle of flora and fauna of ecosystems by causing disconnections and increasing biological distance. The physical disturbance to surface hydrological systems reduces water flow and decreases the environmental flow. Hence, food, fiber, medicine, and other non-timber products decline. Policy harmonization and multi-lateral agreements on environmental governance and standards contribute to GHGs reduction at national level. However, habitat fragmentation reduces hydrological regulating function due to disruptions to drainage systems. A decrease in fragment/patch size (area shrinkage), an increase in fragment isolation (disconnection), or both, lead to fragments with fewer species due to both increasing extinction and decreasing immigration rates. The religious and spiritual services of ecosystems will continue to serve society and will remain stable under this scenario. The aesthetic and scenic services of ecosystems will be enhanced through regional integration.

9.8 References

Abbott, F. M., (1992). Regional Integration and the Environment: The Evolution of Legal Regimes. Chicago-Kent Dedication Symposium, Chicago-Kent Law Review, Volume 68 Issue 1, Article 16.

Acemoglu, D., Johnson, S., & Robinson, J. A., (2005). *Chapter 6 Institutions as a Fundamental Cause of Long-Run Growth. Handbook of Economic Growth, 385–472*. doi:10.1016/s1574-0684(05)01006.

Argaw, M., (2005). Forest Conversion-Soil degradation and farmers' perception nexus: implications for sustainable land use in southwest Ethiopia, Ecology and Development Series, No. 26, Curvillier Verlag Gottingen, ISBN 3-86537-444-1.

Assefa, T., Jha, M., Worqlul, A.W., Reyes, M., and Tilahun, S., (2019). Scaling-Up Conservation Agriculture Production System with Drip Irrigation by Integrating MCE Technique and the APEX Model. Water, 11, 2007; http//www.doi:10.3390/w11102007.

AU. (2019). Africa Regional Integration Index (ARII) 2019.

Bekele, A and Lakew, Y., (2014). Policy Brief: PROJECTING ETHIOPIAN DEMOGRAPHICS FROM 2012–2050 USING THE SPECTRUM SUITE OF MODELS.

Bekele, S. and Denekew, A., (2015). Status quo analysis, Characterization and Assessment of Performance of Irrigation in Ethiopia. IWMI, https://www.researchgate.net/publication/266288453.

CSA (Central Statistical Agency). (1984). *1984 National Population and Housing Census of Ethiopia*. Addis Ababa: CSA.

CSA. (1994). *1994 Census, Vol. 1 and 2*. Addis Ababa: CSA.

CSA. (2006). Atlas of the Ethiopian Rural Economy, Addis Ababa, Ethiopia.

CSA. (2013). Report of the Inter Censal Population Survey, 2012. CSA, Addis Ababa.

EMA (Ethiopian Mapping Agency). (2013). Land use land cover of Ethiopia (Source: Ethiopian Mapping Agency; Landsat 2013 ETM+) (cited in the SOE).

EPA (Environmental Protection Authority). (2011). Federal Democratic Republic of Ethiopia, Ethiopia's ClimateResilient Green Economy strategy, Federal Democratic Republic of Ethiopia, Environmental Protection Authority, Addis Ababa.

Federal Democratic Republic of Ethiopia Planning and Development Commission (GoE). (2020). Ethiopia 2030: *Ten Years Development Plan: A Pathway to Prosperity, 2021-2030*. Addis Ababa, Ethiopia (Now Ministry of Planning and Development).

Funk, C. and Rowland, J., (2012). A Climate Trend Analysis of Ethiopia. FEWSNET/USAID. http://documents.worldbank.org/curated/en/672121619537898959/Eighth-Ethiopia-Economic-Update-Ensuring-Resilient-Recovery-from-COVID-19.

Hurni K, Zeleke G, Kassie M, Tegegne B, Kassawmar T, Teferi E, Moges A, Tadesse D, Ahmed M, Degu Y, Kebebew Z, Hodel E, Amdihun A, Mekuriaw A, Debele B, Deichert G, Hurni H., (2015). Economics of Land Degradation (ELD) Ethiopia Case Study. Soil Degradation and Sustainable Land Management in the Rainfed Agricultural Areas of Ethiopia: An Assessment of the Economic Implications. Report for the Economics of Land Degradation Initiative. 94 pp.

Keith, D. A., Martin, T. G., McDonald-Madden, E. & Walters, C., (2011). *Uncertainty and adaptive management for biodiversity conservation. Biological Conservation, 144(4), 1175–1178.* doi:10.1016/j.biocon.2010.11.02.

Keller, M., (2009). Climate Risks and Development Projects: Assessment Report for a Community-Level Project in Guduru, Oromiya, Ethiopia. Bread for all. https://www.iisd.org/cristaltool/documents/BFA-Ethiopia- Assessment-Report-Eng.pdf. Accessed on 16 February 2022.

MEFCC (Ministry of Environment, Forest and Climate Change). (2017). Ethiopia Forest Sector Review: Focus on Commercial Forestry and Industrialization. Addis Ababa: MEFCC.

Mengistu, A., Kebede, G. and Feyissa, F., (2018). Status of Ethiopian rangelands: with special Reference to Southern Rangelands. Inter J Agri-Biosci, 7(3): 175-181.

Mulugeta, S., Fedler, C. and Ayana, M., (2019). Analysis of Long-Term Trends of Annual and Seasonal Rainfall in the Awash River Basin, Ethiopia. Water 2019, 11, 1498; doi:10.3390/w11071498.

Perez, S.G., Liliana, C., Lucas, A.C., Jorge, C., Rosmery C., Rosa, E.C., Yeni, F.S., Jeffrey, H., Leonor, M.P., Israel, P., Daniel, R. C., Ioav, R. C., Ada˜o, C.S., (2012). Regional integration and local change: road paving, community connectivity, and social–ecological resilience in a tri-national frontier, southwestern Amazonia. Reg Environ Change (2012) 12:35–53, DOI 10.1007/s10113-011-0233-x.

Ring, I., Hansjürgens, B., Elmqvist, T., Wittmer, H., & Sukhdev, P., (2010). *Challenges in framing the economics of ecosystems and biodiversity: the TEEB initiative. Current Opinion in Environmental Sustainability, 2(1-2), 15–26.* doi:10.1016/j.cosust.2010.03.00.

Robert, R., (2004). The Social Dimensions of Regional Integration in ECOWAS. MSc Thesis, International Labour Organization, Geneva, Switzerland.

Sala, O. E., (2000). *Global Biodiversity Scenarios for the Year 2100 Science, 287(5459), 1770–1774.* doi:10.1126/science.287.5459.177.

Sanchez–Martin, M.E, Mulugeta, S., Wieser, C. and Kelbore, Z., (2021). *Eighth Ethiopia Economic Update: Ensuring Resilient Recovery from COVID-19 (English).* Washington,D.C.: World Bank Group.

Sinha, P., Verma, N.K., Ayele, E., (2016). Urban built-up area extraction and change detection of Adama Municipal Area using time-series landsat images. Int. J. Adv. Remote Sens. GIS **2016**, 5, 1886–1895.

Thobejane, T.D and Biniam, Y., (2018). Probing Regional Integration in the Horn of Africa: the case of Intergovernmental Authority on Development (IGAD). The Social Science, vol. 13, (5): 1042-1052.

USAID. (2016). CLIMATE CHANGE RISK IN ETHIOPIA: COUNTRY FACT SHEET 2.

Wang, C., Cardon, P. W., Liu, J. & Madni, G. R., (2020). *Social and economic factors responsible for environmental performance: A global analysis. PLOS ONE, 15(8), e0237597.* doi:10.1371/journal.pone.0237597.

World Bank. (2020). *Supporting Africa's Recovery and Transformation : Regional Integration and Cooperation Assistance Strategy - Update for the Period FY21–FY23 (English).* Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/249911623450779120/Supporting-Africa-s-Recovery-and-Transformation-Regional-Integration-and-Cooperation-Assistance-Strategy-Update-for-the-Period-FY21-FY23 .

World Bank. (2021). Climate Risk Profile: Ethiopia (2021): The World Bank Group.

Youhannes, H., Soromessa, T., Argaw, M. and Diwan, A., (2021). Spatio-temporal changes in habitat quality and linkage with landscape characteristics in the Beressa watershed, Blue Nile basin of Ethiopian highlands. *Journal of Environmental Management*, 281, Issue 1, (2021) 111885. https://doi.org/10.1016/j.jenvman.2020.111885.

Zhao, J., Madni, G.R., (2021). The impact of economic and political reforms on environmental performance in developing countries. PLoS ONE 16(10): e0257631. https://doi.org/10.1371/journal. pone.0257631.

8. Glossary

Afro-alpine the uppermost vegetation belt of a mountain ecosystem above 3500m a.s.l., and is characterized by its landmark plant species, *Lobelia rynchopetalum,* and remarkable diurnal variation of temperature.

Afro-montane vegetation the vegetation or forest in the lowermost zone of the mountain ecosystem stretching between 2500 m and 3200 m.a.s.l.

Agricultural system broadly applied to a system that produces crops used as food, feed, fibre, energy and combinations of these and others along with various livestock types and breeds adapted to the system. The social, economic and political components that are associated with the system are considered parts and parcel of the agricultural system.

Agrobiodiversity also known as agricultural biodiversity refers to the biological diversity that sustains key functions, structures and processes in agricultural ecosystems. It includes the variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels.

Agroecosystem an agricultural ecosystem, which essentially includes the biophysical and human components and interactions where ecological principles govern the system being stirred or guided by farmers' decision-making processes and actions.

Agroecosystem service a collective term for the goods and services that humans obtain from agrobiodiversity in agroecosystem.

Agroforestry a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and animals, in some form of spatial arrangement or temporal sequence.

Climate change variability in climate attributed directly or indirectly to human activities that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

Carbon sequestration the long-term storage of carbon in plants, soils, geologic formations, and the ocean. Carbon sequestration occurs both naturally and as a result of anthropogenic activities and typically refers to the storage of carbon that has the immediate potential to become carbon dioxide gas.

Carbon storage the biological process by which carbon in the form carbon dioxide is taken up from the atmosphere and incorporated through photosynthesis into different compartments of ecosystems, such as biomass, wood, or soil organic carbon.

Deforestation human induced conversion of forested land to non-forested land. Deforestation can be permanent, when this change is definitive or temporary when the change is part of a cycle that includes natural or assisted regeneration.

Degraded land a land exposed to persistent decline or loss of biodiversity and ecosystem functions and services that cannot fully recover unaided.

Drivers of change factors that directly or indirectly, cause changes in nature, anthropogenic assets, nature's contributions to people and a good quality of life. **Direct drivers of change** can be both natural and anthropogenic and have direct physical (mechanical, chemical, noise, light etc.) and behaviour-affecting impacts on nature. They include, inter alia, climate change, pollution, different types of land use change, invasive alien species and zoonoses, and exploitation. **Indirect drivers** are drivers that operate diffusely by altering and influencing direct drivers, as well as other indirect drivers. They do not impact nature directly. Rather, they do it by affecting the level, direction or rate of direct drivers.

Ecosystem a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.

Ecosystem degradation a long-term reduction in an ecosystem's structure, functionality, or capacity to provide benefits to people.

Ecosystem function the flow of energy and materials through the biotic and abiotic components of an ecosystem. It includes many processes such as biomass production, trophic transfer through plants and animals, nutrient cycling, water dynamics and heat transfer.

Ecosystem services the benefits people obtain from ecosystems. In the Millennium Ecosystem Assessment, ecosystem services can be divided into supporting, regulating, provisioning and cultural. This classification, however, is superseded in IPBES assessments by the system used under "nature's contributions to people". This is because IPBES recognizes that many services fit into more than one of the four categories. For example, food is both a provisioning service and also, emphatically, a cultural service, in many cultures.

Ericaceous belt the second vegetation zone of a mountain ecosystem found between 3200-3400m a.s.l., which is dominated by *Erica arborea*.

Farming system a unique and reasonably stable arrangement of farming enterprises that the household manages according to well-defined practices in response to physical, biological and socioeconomic environments and in accordance with the household's goals, preferences and resources; and that farmer households are central to the system. A decision-making unit comprising the farm household, cropping and livestock systems that transform land, capital and labour into useful products that can be consumed or sold. Thus, in the Ethiopian context a farming system is taken as a natural grouping of activities on the landscape that draw on natural features of the land, the socio-environmental and cultural aspects further reflecting the living record of farmers' adaptation strategies that allowed them to overcome long-term climatic and associated changes in vegetation and associated land resources.

Forest land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10% or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.

Forest degradation a reduction in the capacity of a forest to produce ecosystem services such as carbon storage and wood products as a result of anthropogenic and environmental changes.

Grassland type of ecosystem characterized by a more or less closed herbaceous (non-woody) vegetation layer, sometimes with a shrub layer, but – in contrast to savannas – without, or with very few, trees. Different types of grasslands are found under a broad range of climatic conditions.

Habitat the place or type of site where an organism or population naturally occurs. Also used to mean the environmental attributes required by a particular species or its ecological niche.

Indicator a quantitative or qualitative factor or variable that provides a simple, measurable and quantifiable characteristic or attribute responding in a known and communicable way to a changing environmental condition, to a changing ecological process or function, or to a changing element of biodiversity.

Indigenous and local knowledge social and ecological knowledge practices and beliefs pertaining to the relationship of living beings, including people, with one another and with their environments. Such knowledge can provide information, methods, theory and practice for sustainable ecosystem management.

Institutions encompasses all formal and informal interactions among stakeholders and social structures that determine how decisions are taken and implemented, how power is exercised, and how responsibilities are distributed.

Invasive alien species (IAS) any species that successfully invades ecosystems, where it is previously unknown causing biological change, ecological or economic harm in that ecosystem "Alien" refers to the species' having been introduced outside its natural distribution ("exotic", "non-native" and "non-indigenous" are synonyms for "alien"). "Invasive" means "tending to expand into and modify ecosystems to which it has been introduced". Thus, a species may be alien without being invasive, or, in the case of a species native to a region, it may increase and become invasive, without actually being an alien species. Examples of IAS in Ethiopia include *Prosopis juliflora, Opuntia ficus-indica, Argemone mexicana, Lantana camara, Eichornia crassipes*, which are posing negative impacts on native species.

Land degradation the processes that drive the decline or loss in biodiversity, ecosystem functions or their benefits to people and includes the degradation of all terrestrial ecosystems.

Land use the human use of a specific area for a certain purpose (such as residential; agriculture; recreation; industrial, etc.). Influenced by, but not synonymous with, land cover. Land use change refers to a change in the use or management of land by humans, which may lead to a change in land cover.

Land use land cover change the conversion from natural vegetation to farmlands, grazing lands, infrastructure, human settlements and urban centers, which significantly contribute towards loss of biodiversity and disruption of ecosystem functionality. Land cover changes can also be caused by a number of natural driving forces such as climate in addition to human factors.

Mountain a landmass that has risen significantly above sea level and the surrounding area, forming attitudinally defined vegetation zones. Mountains exhibit three distinct zones types of vegetation (Afro-montane, Ericaceous and Afro-alpine) along the altitudinal gradient forming belts around the high rising landmass.

Nature's contribution to people (NCP) all the contributions, both positive and negative, of living nature (i.e. diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to the quality of life for people. Beneficial contributions from nature include such things as food provision, water purification, flood control, and artistic inspiration, whereas detrimental contributions include disease transmission and predation that damages people or their assets. Many NCP may be perceived as benefits or detriments depending on the cultural, temporal or spatial context.

Pastoralism farming system where livelihoods are primarily based on livestock rearing, but it should be known that livestock are integral components of the crop-based agro-ecosystems as well. The pastoralists are mostly transhumant or semi-nomadic, who seasonally move with their livestock in search of grazing land and water.

Peatlands wetlands which accumulate organic plant matter in situ because waterlogging prevents aerobic decomposition and the much slower rate of the resulting anaerobic decay is exceeded by the rate of accumulation.

Plantation forests managed forests in which the trees are planted of the same age and species, and are intended to maximize the production of wood fiber.

Rangelands uncultivated areas of land that provide the necessities of life for grazing and browsing animals. They are areas where moisture is sufficient for growth of grasses and shrubs, but where climatic and other environmental conditions limit the suitability of the land for rain-fed crop production. The major rangeland types of the world are grasslands, desert shrub lands, savanna woodlands, forests, and tundra.

Rangeland condition the state of rangeland health expressed in terms of its ecological status, resistance to soil erosion, and potential for producing forage for sustained optimum livestock production. The state of health and vigor of rangeland vegetation in relation to its full productive potential. It evaluates present range production in proportion to the production potential of the range sites.

Rangeland dynamics the change of vegetation in rangelands over time and space since vegetation changes happen in seasonal, annual, and long-term basis, and also on the different time scale- daily to thousands of years.

Rangeland trend the direction of change in rangeland condition ratings on specific sites through time in relative terms. It refers to the changes in the status of resources at a site detected by monitoring and is usually expressed as improving, declining, or stable. It is carried out by periodic measurements of rangeland (and climatic) attributes at the same location at different points in time.

Wetlands areas that are subject to inundation or soil saturation at a frequency and duration, such that the plant communities present are dominated by species adapted to growing in saturated soil conditions, and/or that the soils of the area are chemically and physically modified due to saturation and indicate a lack of oxygen; such areas are frequently termed peatlands, marshes, swamps, sloughs, fens, bogs, wet meadows, etc.

Woodland a land not classified as 'Forest' spanning more than 0.5 hectares with trees higher than 5 m and a canopy cover of 5-10% or trees able to reach these thresholds; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use.

Supported by:

Federal Ministry
for the Environment, Nature Conservation,
Nuclear Safety and Consumer Protection

based on a decision of
the German Bundestag

In partnership with:

UN environment programme WCMC

NATIONAL ECOSYSTEM ASSESSMENT INITIATIVE

BESNet Biodiversity and Ecosystem Services Network