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Longan fruit farmers' demand for policies aimed at conserving native pollinating bees in Northern Thailand

Manuel Ernesto Narjes *, Christian Lippert

Department of Production Theory and Resource Economics, University of Hohenheim, Schloß-Osthof-Südflügel, D-70593 Stuttgart, Germany

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ABSTRACT

Northern Thailand is orienting its agriculture towards intensive production systems at risk of being subjected to the current worldwide pollinator crisis. Bee-friendly pest management, improving native bee habitats within agro-forest ecosystems and fostering the husbandry of native bee species are three widely recognized strategies to conserve the local pollinating fauna. We attempted at eliciting farmers' valuation of these measures and that of their potential effect on local native bees, by conducting a choice experiment with 198 longan (Dimocarpus longan) farmers. The results of a mixed logit model indicate a significant heterogeneity in farmers' preferences, part of which was explained by the respondents' attitude towards native bees, among other idiosyncratic variables such as gender. We also determined a generally positive willingness to pay for the above mentioned conservation measures, which implemented together were valued at approx. €18.1 by the average household, all else equal. Additionally, avoiding a 50% native bee population decline was valued in average at €40.5 per household. These estimates stand in strong contrast with the comparatively high economic losses such a decline could potentially entail in terms of reduced longan production and the relatively low investment costs to implement a conservation strategy aimed at preventing such losses.

1. Introduction

The international community is showing increasing concerns regarding the continued decline of both wild and managed pollinator populations worldwide (Dias et al., 1999; Ricketts, 2004; Steffan-Dewenter et al., 2005; Kluser and Peduzzi, 2007; FAO, 2008; Gallai et al., 2009; Potts et al., 2010). Agricultural intensification has been recognized as the main driver for the decline of wild bee populations, especially due to the inappropriate use of pesticides and by reducing natural habitats through land-use change (Kremen et al., 2002; Potts et al., 2010).

Thailand is located in a bee diversity hotspot. With the exception of the European honeybee (*Apis mellifera* L.), all other 8 honeybee species of the world are indigenous to Southeast Asia (Hepburn and Radloff, 2011). There is also a great diversity of stingless bees in this subcontinent, with a large number of species recorded in Thailand, particularly in its northern provinces (Rajitparinya et al., 2001; Klakasikorn et al., 2005; Jongjitvimol et al., 2005). The region has therefore historically been a cluster for traditional beekeeping, which is mainly practiced by smallholders with rather rudimentary technologies that have been developed around the culture of the Asian honeybee (*Apis cerana* F.) and that of stingless bees.

Northern Thailand is also rapidly orienting its agriculture to the production of high-value crops under intensive systems that are often characterized by the overuse of synthetic pesticides (Schreinemachers et al., 2011), which in connection with deforestation (Delang, 2002) risk reproducing the case of other regions in the world, where intensive agriculture has driven pollinator populations to substantial declines (Biesmeijer et al., 2006; National Research Council, 2007; Potts et al., 2010). Thailand has also responded to the continuously growing demand for longan (*Dimocarpus longan* L.), a fruit obtained from a bee-pollination dependent crop (Blanche et al., 2006; Pham, 2012), by dramatically expanding its cultivated area and its yields, i.e. from 12,094 ha (corresponding to 45,756 tons per annum) in 1983 to 168,517 ha (i.e. 976,729 tons per annum) in 2014 (Anupunt and Sukhivibul, 2005; Thai Office of Agricultural Economics, 2014). Currently, ~82% of the longan land is cultivated by 206,328 households in Northern Thailand, ~30% thereof by 69,330 households in Chiang Mai province (Thai Office of Agricultural Economics, 2014), rendering this region the leading exporter of longan worldwide and its economy highly dependent on this crop (Anupunt and Sukhivibul, 2005; Menzel and Waite, 2005).

Although there are yet no official reports on a pollinator crisis in Thailand, in June 2011 we collected anecdotal evidence from the

* Corresponding author.
E-mail addresses: manuel.narjes@uni-hohenheim.de (M.E. Narjes), Christian.Lippert@uni-hohenheim.de (C. Lippert).

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eastern Thai province of Chanthaburi that supports the suspicion that a pollinator problem might exist, in at least that region: according to accounts from many local rambutan (*Nephelium lappaceum* L.) farmers, habitat encroachment due to agriculture and pesticide overuse has dramatically reduced the population of wild bees with economically important consequences on their crop yields. In response, a local initiative is correcting such pollination deficiencies by promoting on-farm meliponiculture (i.e. keeping stingless bees).

Against this background, Northern Thailand could benefit from a policy directed at conserving native pollinating bees. Such policy should take into account the perceptions of longan farmers with regards to the benefits of its implementation and the expected yield losses that could arise in the event of an important decline of pollination services. A pollinator conservation policy could consist of following measures: (i) offering farmers bee-friendly alternatives to conventional pesticides (e.g., biological control and integrated pest management), (ii) encouraging the protection and improvement of natural bee habitats within agro-forest ecosystems and (iii) fostering the husbandry of native bee species. Expert interviews and focus group discussions with farmers helped us recognize that, among the recommendations of the Plan of Action of the International Pollinator Initiative (IPI-POA) (Byrne and Fitzpatrick, 2009), these measures potentially have the greatest impact and implementation chances in Thailand's current agricultural and political context.

We conducted a discrete choice experiment (DCE) in Chiang Mai Province in order to understand the preferences of longan farmers with regards to the conservation strategies mentioned above and to hypothetical changes in the local population of native bees. The respondents had to choose between a status quo scenario, associated with an assumed 50% native bee population decline, and a series of alternative hypothetical policy scenarios in which the implementation of different conservation strategy combinations would avoid such declines. The choice decision also involved a single-payment tax hypothetically incurred by the respondents before any conservation policy bundle could be implemented. Our analyses include by this design willingness to pay (WTP) estimates for the individual conservation policy attributes and for the bee population declines assumed in the DCE. Furthermore, we confront the value estimates obtained with the potential costs that would arise if some or all of the ecosystem services provided by local native bees to longan orchards would be lost, as calculated based on the bee-pollination dependence ratios given by Blanche et al. (2006) and Pham (2012) (see Section 2).

2. The economic value of pollination services

In several studies, the economic value of the contribution of pollinators to agricultural production has been estimated using a dependence ratio that accounts for the partial production loss of specific crops, attributed to the complete absence of pollinators (Morse and Calderone, 2000; Losey and Vaughan, 2006; Gallai et al., 2009). Gallai et al. (2009) for instance estimated the total economic value of pollination services worldwide at €153 billion. Building upon this approach and having estimated the demand functions of a variety of insect-pollination dependent crops, the potential welfare losses from increases of food prices that would result from the effect of insect pollination shortages on crop yields can be considered (Kevan and Phillips, 2001). Accordingly, Southwick and Southwick Jr. (1992) estimated the annual value of crop pollination by managed honeybees (*A. mellifera*) in the USA to range between USD1.6 and USD5.7 billion.

Pollination experiments along replicated distance gradients have also been used to estimate the economic value of tropical forest patches that, serving as nesting sites for bees, contribute to the pollination of crops, such as coffee (*Coffea arabica* L. and *Coffea robusta* P.) (Ricketts, 2004; Olschewski et al., 2006). Blanche et al. (2006) conducted similar experiments with longan (*Dimocarpus longan*) orchards in North Queensland, Australia, where they assessed the effect of their proximity to rainforests (as beneficial insect reservoirs) on this crop's pollination. No monetary results were offered by this study, yet it concludes that initial fruit set in longan is substantially enhanced by insect pollination (i.e. 62% contribution), prominently from stingless bees. A similar result obtained by Pham (2012) for four different longan cultivars in Quoc Oai, Vietnam attributes 67% of their yields to floral visits by Asian honeybees (*A. cerana*), amounting to €0.34 per kg of fruit in 2011.

Other studies have measured the economic value of pollination services by directly observing the market prices of existing commercial pollination services that are contracted by farmers to substitute their failing ecosystem service counterpart, such as it occurs in the almond groves of California, USA (Rucker et al., 2012). Another approach consists in calculating the cost of potentially having to replace pollination services with labor or capital (e.g., hand pollination, or pollen dusting, respectively), such as to maintain crop production at the same levels that are attained with pollination services from a healthy natural ecosystem (Allsopp et al., 2008).

More recent studies have integrated the estimation of economic values for pollination services with spatial analyses. Ricketts and Lonsdorf (2013), for instance, calculated (discrete) marginal values for unit changes in pollinator habitats by combining the pollen limitation experiment results for coffee fields in Costa Rica from Ricketts (2004) with a model by Lonsdorf et al. (2009) that predicts the supply of pollinators based on the surrounding land cover's suitability to provide nesting sites and floral resources. On the other hand, Barfield et al. (2015) and Lautenbach et al. (2012) applied the pollination dependence ratio and crop vulnerability ratio approaches to plot economic value estimates at local and global scales, respectively; the former using a farm gate dataset for 55 crops in the US state of Georgia, while the latter combined FAO country-specific data for the years 1993 through 2009 with the global crop distribution maps of Monfreda et al. (2008).

3. Material and methods

3.1. The discrete choice experiment

The studies reported above (Section 2) estimate the so-called use value of pollination services relying upon market price observations of either pollination dependent crops or commercial pollination services. In contrast to such studies, DCEs have been deemed not suitable for the estimation of the economic benefits of pollination services, with the sensible argument that such stated preference methods would require respondents to possess a sound knowledge of the quantitative contribution that pollination delivers to their agricultural production (Mburu et al., 2006), i.e. a lack in ecological knowledge may hinder them from correctly assessing the use value of pollination. We do not dispute such argument, nor do we consider DCEs an alternative to studies that estimate the market value of pollination services. On the contrary, we think both approaches can complement each other: market-based valuation methods are important tools to estimate the use value of pollination, whereas DCEs can be used to assess peoples' current preferences for measures to conserve bees and for avoiding their declines. After all, policy makers should take into account stakeholders' preferences for the implementation and implications of the conservation policies considered in order to ensure some degree of public support. Thus, similar to the studies concerning wild geese conservation by Hanley et al. (2003) and compensatory wetland mitigation by Bauer et al. (2004), we propose approaching the economic valuation of pollination services from a perspective of *public demand for policies* aiming at conserving the native bees that deliver this ecosystem service in agro-forest landscapes. To this effect, the trade-offs that are stimulated in a DCE can capture the economic value of *measures* to conserve native bees. Furthermore, DCEs can also capture the existence value of pollinators and the option value of preserving them, disregarding the awareness that respondents may or may not have about how much pollinating bees contribute to the production of their crops. In this sense, one must be careful when interpreting DCE value estimates for changes in the population of native bees; these encompass several components of the total economic value of pollinating bees, contingent on socio-demographic characteristics of the respondents, and must not necessarily be equivalent to the true use values realized at specific levels of bee abundance.

Hanley et al. (2015) insist in the importance of capturing non-market benefits when estimating the economic value of pollinators and that this may only be approached by means of stated preference methods such as the DCE. To our knowledge, this is the first study to apply the DCE method to obtain economic value estimates for the conservation of pollinating bees.

3.2. Economic theory of discrete choice modeling

According to random utility theory (RUT) (Thurstone, 1927; Marschak, 1960), human choice can be explained by the utility maximizing behavior of individuals when they are confronted with paired or multiple comparisons of discrete choice alternatives. Each alternative potentially yields a certain level of utility that is known to the decision-maker, but unknown to the researcher. From the researcher's perspective, the utility that an individual i derives from a choice alternative j (U_{ij}, $j = 1, \ldots, J$) can be decomposed into a systematic (explainable) component (V) and a stochastic (unexplainable) component (ε) that represents unobservable influences over the decision-maker's choice. This can be formalized as follows:

$$U_{ij} = V_{ij}(X_j) + \varepsilon_{ij} = \beta' X_j + \varepsilon_{ij}, \tag{1}$$

where X_j is a vector of observed variables that relate to the choice alternative and are weighted by parameters β to account for their relative contribution to an individual's utility (i.e. part-worth utilities). The decision-maker i chooses from a given set of J choices the alternative h that maximizes her utility, strictly holding that the utility associated with alternative h is superior to that of any other alternative j. The probability P_{ih} of this choice outcome can be expressed as follows:

$$P_{ih} = P[(U_{ih} > U_{ij})] = P[(V_{ih} - V_{ij}) > (\varepsilon_{ij} - \varepsilon_{ih})] \ \forall j \neq h \tag{2}$$

Assuming independent and identically distributed (IID) extreme value distribution type I error terms ε_{ij}, the choice probabilities can be expressed as the standard logit model (Train, 2009). The mixed (random parameter) logit (ML) model (Hensher and Greene, 2003) is an extension of the standard logit model that allows for taste variation in the utility function with parameters β_i. As the researcher cannot observe individual parameters β_i, the (unconditional) choice probability P_{ih} is the expected value of the standard logit probability over all the possible values of β_i, weighted by the continuous mixing distribution $f(\beta)$, the functional form of which is specified by the researcher. In this study the density of all attribute parameters β is assumed to be normal. As such, the choice probability (2) is given by

$$P_{ih} = \int \frac{e^{\beta' X_h}}{\sum_{j=1}^{J} e^{\beta' X_j}} \varphi(\beta|\theta) d\beta, \tag{3}$$

where θ collectively denotes the moments of the normal density, which are the parameters to be estimated. Normally distributed random parameters enter the model as follows

$$\beta_i = \beta + \delta' w_i + \sigma v_i,\ v_i \sim N(0, 1), \tag{4}$$

where β is the fixed population mean, w_i are (observed) individual-specific characteristics that induce heterogeneity around the mean, v_i is the individual (unobserved) specific heterogeneity and σ is the standard deviation of β_i around β. Some random coefficients may only present unobserved heterogeneity (homogeneous parameter means), in which cases the vector δ is set to zero. The introduction of additional stochastic elements through β_i in the utility function that may be correlated across alternatives and choice situations partially relaxes the restrictive IID assumption (Hensher and Greene, 2003; Hensher et al., 2005).

The integral (3) does not have a closed form and the choice probabilities P_{ih} must therefore be approximated through computational simulation: for different moments θ, values of β are drawn from $f(\beta)$, with which the values behind the integral sign (Eq. (3)) are calculated. This process yields the simulated probability $\check{P}_{ih}$ as a weighted mean of the probabilities calculated from the different draws of β. The parameters of the distribution ϕ are optimized by iteratively inserting (for different parameters of θ) the resulting $\check{P}_{ih}$ into the log-likelihood function, yielding the maximum simulated likelihood estimator (MSLE).

The estimated coefficients β can be used to derive welfare measures, such as the change in the expected consumer surplus $E(CS_i)$, due to changes in the alternatives and/or choice set, as given by

$$\Delta E(CS_i) = -\frac{1}{\beta_c}\left[\ln\left(\sum_{j=1}^{J^1} e^{V_{ij}^1}\right) - \ln\left(\sum_{j=1}^{J^0} e^{V_{ij}^0}\right)\right], \tag{5}$$

where the log sums $\ln(\sum_{j=1}^{J^t} e^{V_{ij}^t})$ express the expected maximum utility at the initial situation $t = 0$ and after the changes at $t = 1$, and their difference is divided by the negative cost coefficient β_c (the marginal disutility of cost). The total change in consumer surplus in the population can be computed as the weighted sum of $\Delta E(CS_i)$, with the weights reflecting the share of individuals in the population who share the same representative utilities as the sampled individual. The $\Delta E(CS_i)$ is consistent with RUT and often referred to as the willingness to pay (WTP) for changes in a choice alternative (McConnell, 1995; Lancsar and Savage, 2004; Train, 2009). Furthermore, it collapses to its simplest form, namely the marginal WTP (implicit price) for an attribute k, given equal changes in such attribute in all alternatives, *ceteris paribus* (*c.p.*):

$$MWTP_k = -\frac{\beta_k}{\beta_c}, \tag{6}$$

where β_k is the estimated coefficient of the attribute of interest. Obtaining economically meaningful WTP estimates becomes complex when it involves analyzing the ratios of two random parameters. When choosing a normal distribution, also the issue arises of how to handle extremely high WTP estimates as β_c approaches zero. To solve this problem, β_c can be fixed in the model and point estimates of a normally distributed WTP obtained with mean $-\frac{\beta_k}{\beta_c}$ and standard deviation $\frac{\sigma_k}{\beta_c}$ (Hensher et al., 2005; Train, 2009).

3.3. Hypotheses underlying this study and experimental design

We aim at explaining the choices made by longan farmers, regarding alternative policy profiles for the conservation of native bees. Accordingly, the alternative hypotheses stated in this study are:

H1: The presence of each of the three proposed bee conservation strategies has a positive contribution *c.p.* to the utility derived from the conservation policy alternatives that contain them. Similarly, an increase in the population of native bees increases *c.p.* the probability that a policy presenting this attribute level will be chosen, while the opposite is true for a decline.

H2: The preference for the attributes constituting the choice alternative profiles varies among the population of longan farmers. This heterogeneity should be reflected in parameter standard deviations that are significantly different from zero and in parameter means that may interact with socio-demographic characteristics of the respondents.

We defined the choice attributes with the assistance of provincial officers from the Thai Ministry of Natural Resources and Environment and from the Department of Agricultural Extension, who helped identifying the IPI-POA recommended conservation measures that could be implemented under the local political infrastructure. Focus group discussions with local longan farmers additionally contributed to formulating and phrasing plausible attribute levels that could be easily comprehended by the DCE participants. Consequently, we defined the attributes and levels (Table 1) as measures that would hypothetically be implemented at the village level and take effect with the support of extension services. With the implementation of a “bee-friendly pest control” program, the farmers would get information on methods (e.g., integrated pest management and spraying during times with low bee activity levels) and products that offer an alternative to conventional agro-chemicals, reducing the risk of bee poisoning. The “improving native bee habitat” measure would consist of the provision of expertize and native tree seedlings to promote local reforestation and habitat management campaigns in public lands and near cropland, aiming at offering nesting sites and food sources for native bees within agro-forest ecosystems. Extension services would also transfer technical knowledge on how to build bee hives to keep native bee species such as the Asian honeybee (*A. cerana* F.) and stingless bee spp. (Heard, 1999; Hepburn and Radloff, 2011) on farm, under the “native bee husbandry” measure. The cost attribute represents a one-time fee that the farming households would pay to the local authorities for the implementation of the chosen policy alternative.

A Bayesian efficient (Chaloner and Verdinelli, 1995) subset of the full factorial design was generated using the Ngene 1.1.1 software. Efficient designs, in contrast with the traditionally preferred orthogonal designs, aim at data results that generate parameter estimates with as small as possible standard errors. Bayesian efficiency is achieved by generating the design around prior parameter estimates that are obtained from a pilot study (ChoiceMetrics Ltd. 2012). The prior parameter estimates used to generate the design for this study were based on a pilot study that we conducted with 27 respondents. Finally, we generated 12 choice sets, one of which is presented below (Fig. 1).

At the beginning of each DCE, we asked the respondents to imagine a hypothetical scenario under which a conservation plan was not instituted, therefore leading the population of native bees to decline to half of its current population. This scenario was presented as the status-quo alternative “No Policy” and it did not entail policy implementation costs. Alternatively, the respondents had the option to choose one of two unlabeled policies (i.e. Policy A or Policy B, whose names are not meaningful sources of utility and which are only distinguishable by their attribute level combinations), containing *at least one* of the three proposed conservation measures, which if implemented could avoid a native bee population decline (0% change from the current population), or even increase it by 50%. Nevertheless, some of the policy implementation profiles also included the 50% native bee population decrease level. The levels describing the changes in abundance of native bees were defined with support of the focus group discussions and after pre-testing the questionnaire. Their three-level specification aims at reducing the respondents' cognitive burden and the design and sample size requirements for their estimation. The implementation of a conservation policy was always bound to a single-payment implementation cost ranging between THB250 and THB750. We randomized choice sets across questionnaires before administering them to the interviewees, in order to avoid biases from order effects.

In addition to the choice questions, the respondents were asked to provide information on their farm, socio-demographic characteristics and on their attitude towards the proposed native bee conservation measures. Previous to each interview, the respondents were informed about the importance of bee-mediated pollination for the fruit-set of longan and about the current trends and consequences of pollinator declines worldwide. This supporting information was complemented with text and illustrations that, similar to the choice cards, were conveyed in colored cards.

Table 1
Choice alternative attributes and corresponding design levels.

Bee conservation policy attribute	*Levels*
Bee-friendly pest control	no [a], yes
Improving native bee habitat	no [a], yes
Native bee husbandry	no [a], yes
Changes in native bee population (%)	−50 [a], 0, +50
Policy implementation costs (THB) [b]	0 [a], 250, 500, 750

[a] Attributes fixed at these levels for the status quo alternative.
[b] €1 = 39.3048 Thai baht (THB), as of June 1, 2013.

3.4. Survey and sampling

The DCE survey was conducted in May–June 2013, in 10 villages of the districts of Chom Thong and Saraphi, which are located along the Upper Ping River Basin, in the lowlands of the Chiang Mai–Lamphun valley (Fig. 2). With 7862 and 5269 longan farming households (5284 ha and 1794 ha cultivated with longan) registered in the Thai Department of Agricultural Extension databases of Chom Thong and Saraphi respectively, these two districts have the greatest extension of land cultivated with longan in Chiang Mai Province (DoAE., 2015). We selected the villages randomly with the sampling technique of probability proportional to size, using the villages' total longan acreage as the allocation criterion. Thereby, six villages were drawn from Chom Thong, while the other four were drawn from Saraphi.

From 899 longan farming households registered under the 10 selected villages (DoAE., 2015), a total of 198 randomly selected individual heads of household (with a total of 187.6 ha cultivated with longan) understood and completed the choice exercise. Each respondent faced twelve choices, resulting in 2376 observations. A selection of variables that describe the sampled population is listed below (Table 2).

4. Results

We analyzed the 2376 choice observations using NLOGIT 5/ LIMDEP 10 econometric software. All attributes were assigned generic coefficients (i.e. the utility specification was the same for

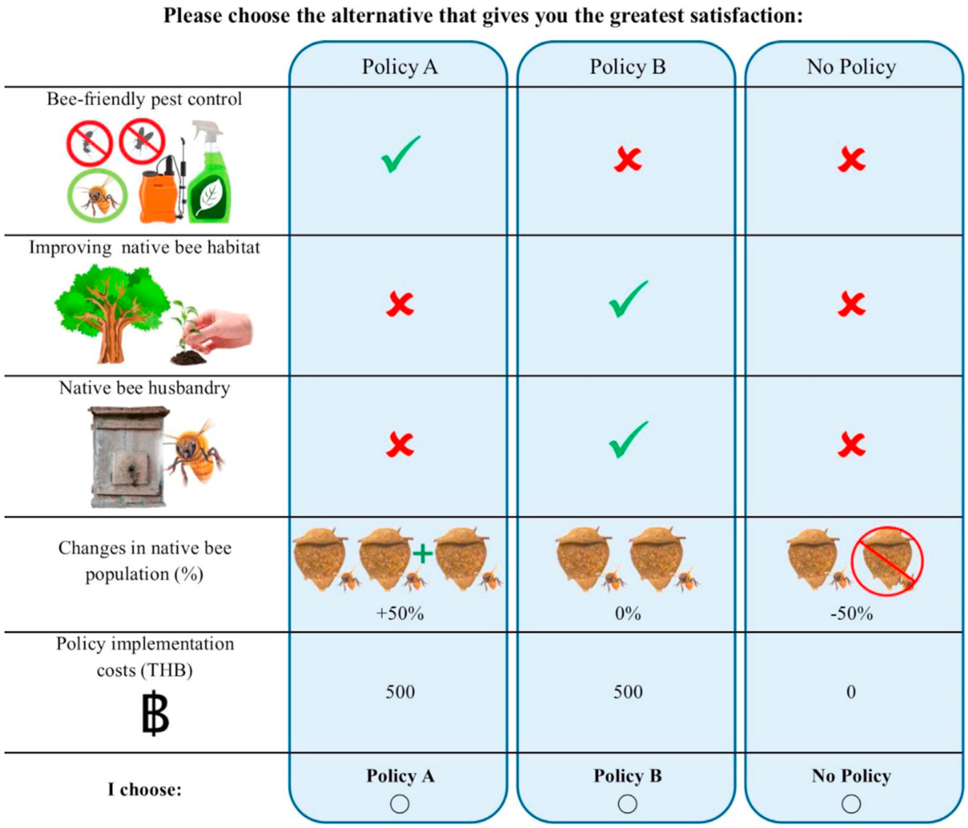

Fig. 1. An example choice set.

the three choice alternatives). The three conservation measures entered the estimated models as dummy variables that take the values zero, if absent, and one if implemented. The cost attribute on the other hand was assigned a continuous variable, the coefficient of which relates changes in the utility to a cost increase of one Thai baht. We coded the native bee population change levels with two dummies representing a 50% increase and a 50% decrease respectively. We did not include alternative specific constants (ASCs) in our models due to the unlabeled nature of the presented policy alternatives. One could arguably regard the status-quo as a label and thus specify a constant term that is common for policy alternatives A and B, capturing possible preferences for any native bee conservation intervention being implemented over doing nothing. Nevertheless, in our study's design we included in each policy alternative *at least one* of the three proposed conservation measures in every choice set; modeling ASCs would thus

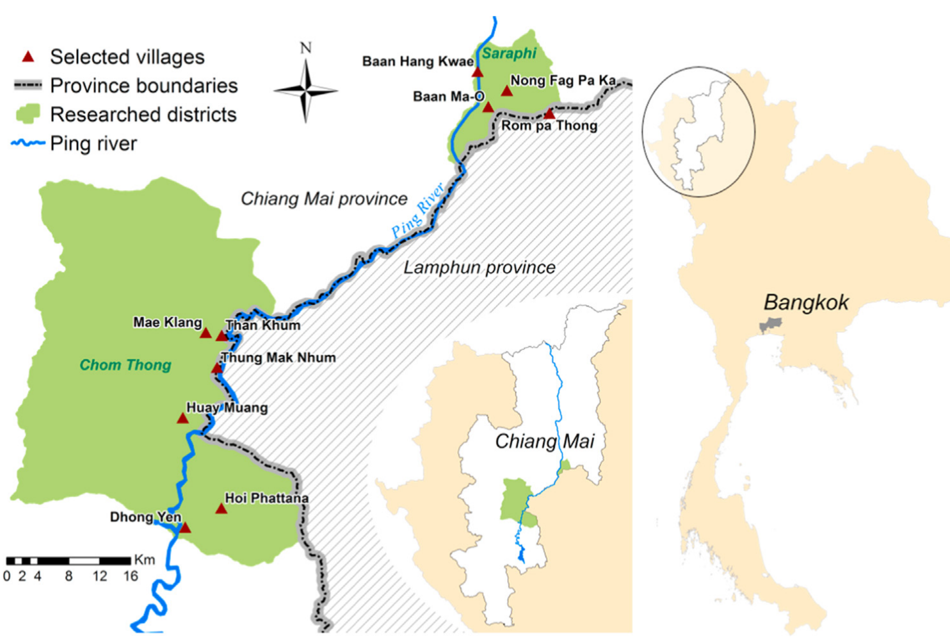

Fig. 2. Research area: 10 villages along the lowlands of the Chiang Mai-Lamphun valley. Source: Own representation using vector data from the DCW and GADM databases (DIVA-GIS, 2014).

Table 2
Descriptive statistics of the sampled population.

Variable	*Mean*		*SD*
Age (years)	55.76		11.98
Total cultivated acreage (rai) [a]	7.15		7.49
Longan cultivated acreage (rai) [a]	5.92		6.09
Annual revenue from longan (THB) [b]	91,119		105,080
Net annual agricultural income (THB) [b]	76,415		96,822
Net total annual income (THB) [b]			
Male (N_{male} = 116)	302,085*		836,880
Female (N_{female} = 82)	188,405*		191,008
	Sample shares (%)		
Regard longan as their main income source	68.18		
Completed six years of primary school only [or less]	71.71 [5.55]		
Self-employed in agriculture	85.35		
Aware of positive effect of native bees on longan yields	87.37		
Engage in at least one of the bee-related activities below:	50.00		
Allowing migratory beekeepers in their farm	28.79		
Beekeeping [c]	17.68		
Honey hunting [d]	20.71		
Individuals favoring [policy alternative]	45.58 [A]	43.52 [B]	10.90 [None]

N=198 respondents = 2376 choice observations. Total longan cultivated area =187.63 ha.

* Statistically significantly different: $F(1, 196)=9.04$, $p=0.003$.
[a] 1 rai=0.16 ha.
[b] €1=39.3048 Thai baht (THB), as of June 1, 2013.
[c] *A. mellifera* or native bees (i.e. *A. cerana* and/or stingless bee spp).
[d] Harvesting honey from wild bees in the forest.
Respondent's per household estimate.

result in their estimates being confounded with the effects of the single attributes.

We calculated two ML models, accounting for panel data structure and an assumed normal distribution for the random parameters: one with the full parameter vector set to be random and, in order to also find economically meaningful WTP estimates, a second model in which only the cost attribute was held fixed (Table 3) (Train, 2009; Hensher et al., 2005). Following a stepwise approach we finally explained part of the heterogeneity in the random parameter means by interacting them with four idiosyncratic covariates; a dummy indicating whether or not the respondent is aware of the positive effect that native bees may have on crop yields interacted with both the bee-friendly pest control and improving native bee habitat attributes. Another dummy indicating whether or not bees (i.e. *A. mellifera* and/or native bees) are kept in the household interacted with the native bee husbandry attribute in the "fixed-cost model" only. The native bee husbandry attribute (in the "all-parameters-random model" only) and the 50% increase in the population of native bees interacted with a third dummy indicative of whether or not the household engages in at least one of three economic activities involving bees, i.e. beekeeping, harvesting honey from wild bees in the forest (honey hunting) and/or charging migratory beekeepers a fee for bringing honeybees (typically *A. mellifera*) to forage longan nectar on their farms. Lastly, a fourth dummy representing the respondent's gender interacted with the cost variable in the "all-parameters-random model" only. The simulations to approximate P_{ih} (Eq. (3)) were done using 100 Halton draw sequences (Train, 2000).

These models (Table 3) are statistically significant and their simulated probabilities correctly predict 66.41% of the observed choices, in the full random parameter vector model, and 66.25% in the model with fixed cost coefficient. Their corresponding AICs and pseudo R^2 indicate a good model fit.

The estimate for the bee-friendly pest control parameter mean came out non-significant in both models. The estimates corresponding to the heterogeneity around the mean (i.e. std. deviation and covariate) of this parameter on the other hand indicate a highly significant large spread in the respondent's value perception for this conservation measure and that being aware of the contribution of native bees to longan production has a significant positive effect on the utility it generates. A similar interpretation can be offered for the coefficients corresponding to the native bee habitat improvement measure in the fixed-cost model, which resulted in a non-significant parameter mean estimate with significant high estimates for the heterogeneity around the mean.

We obtained statistically significant estimates for the remaining parameter means and for the coefficients corresponding to the covariates and standard deviations in both models; the latter resulted smaller than in previous models that were estimated without interaction terms. Observing the assumption of normally distributed random parameters, we standardized the mean estimate $[(\beta + \delta' w_i)/\sigma]$ from the all-parameters-random model to obtain information on the share of respondents placing a positive value on the different attributes. Accordingly, the bee-friendly pest control measure generated a positive utility in 50% of the respondents who did not believe in native bees positively contributing to their crop yields, while this was true for 74% of those thinking otherwise. Similarly, the shares of respondents (presenting the corresponding covariate characteristics) who increased their utility with the improving native bee habitat and native bee husbandry measures and with a 50% increase in the population of native bees were 100%, 80% and 97% respectively. Only 4% of the entire sample expressed a positive preference for a 50% decrease in the population of native bees.

Considering the expected negative sign in the cost coefficient, we used the significant values of the fixed-cost model with confidence to calculate meaningful MWTP mean estimates along with their corresponding heterogeneity (Eq. (6)). The mean MWTP estimates of the attributes with coefficient estimates that resulted not significantly different from zero were calculated at zero Thai baht. Thereby, each respondent's expected $MWTP_{ik}$ was calculated (Eq. (4)) and aggregated over the whole sample, using the representative shares for each covariate (Table 2) as weights, in order to obtain the average longan farming household's MWTP for each attribute k. We aggregated these values over the surveyed sample and the total population of the research area, and added them up to obtain average WTP estimates for a conservation policy bundle with all measures implemented (Table 4).

To compare these WTP estimates with the potential costs of losing a proportion of the pollination services provided by local native bees, we calculated the resulting longan yield reductions (Table 5) using a 60% bee-pollination dependence ratio [slightly conservative as compared to the ratios provided in the literature (Blanche et al. 2006; Pham 2012)], an average production of 5.55 metric tons per hectare per year and a farm gate price of 29 THB per kg of longan in Chiang Mai Province, in 2013 (Thai Office of Agricultural Economics, 2014). Accordingly, the economic value of longan production attributed to bee pollination can be estimated at 17.4 THB per kg (€0.44 per kg) and 96,570 THB per hectare (€2457 per ha) per year.

Our calculations (Table 5) suggest that the actual forgone longan revenues incurred by the average farm from a 5% decline (assuming that natural pollination services are being provided at the ecologically necessary levels for a normal longan production) are much higher than our estimated WTP of an average household for avoiding a 50% native bee population decline and for the implementation of a policy that combines all three conservation measures; we also determined a great (but smaller) divergence between these values when aggregating them at the surveyed

Table 3
Mixed logit coefficients for an all-parameters-random model and for a fixed-cost model with corresponding WTP estimates.

Variable		*All-parameters-random model*		*Fixed-cost model*		
		Coefficient [a]	*(SE)*	*Coefficient* [a]	*(SE)*	*MWTP* [e]
Bee-friendly pest control	*Mean*	0.48746	(0.3737)	−0.23226	(0.3635)	0.0[f]
	SD	1.39573***	(0.2046)	2.15956***	(0.1936)	629.4***
Improving native bee habitat	*Mean*	0.62168*	(0.3100)	0.09699	(0.2901)	0.0[f]
	SD	0.18831	(0.1786)	1.27936***	(0.1664)	372.9***
Native bee husbandry	*Mean*	0.60467***	(0.1798)	0.48032***	(0.1466)	140.0***
	SD	1.26305***	(0.1621)	1.35414***	(0.1475)	394.6***
−50% bee pop. (vs 0%)	*Mean*	−5.67399***	(0.4507)	−5.46216***	(0.4873)	−1591.9***
	SD	3.25209***	(0.3795)	3.19020***	(0.3658)	929.7***
+50% bee pop. (vs 0%)	*Mean*	2.83981***	(0.3304)	2.36089***	(0.2876)	688.1***
	SD	2.30053***	(0.3018)	1.82806***	(0.3603)	532.8***
Costs (THB)	*Mean*	−0.00540***	(0.0005)	−0.00343***	(0.0003)	−1.0
	SD	0.00369***	(0.0003)	Fixed parameter		
Heterogeneity in random parameter mean (Covariate ×Attribute)						
Thinks native bees boost yields (yes)						
	× Bee-friendly pest control	0.90528*	(0.3645)	1.12966**	(0.3530)	329.2**
	× Improving native bee habitat	0.82310**	(0.3096)	0.99251***	(0.2854)	289.3***
Beekeeper (yes)						
	× Native bee husbandry	Fixed at zero		0.60022**	(0.2145)	174.9**
Economic activity bees (yes)						
	× Native bee husbandry	0.43869*	(0.2068)	Fixed at zero		
	× 50% bee pop. increase (vs 0%)	1.37934***	(0.3760)	0.79309*	(0.3247)	231.1*
Male (yes)						
	× Costs	0.00133**	(0.0005)	Fixed at zero		
Log-Likelihood (LL)		−1455.6685		−1513.8718		
AIC/*N* [b]		1.2522		1.2945		
McFadden pseudo R-squared[c]		0.3630		0.3375		
LRT [c,d] χ^2 (*df*)		(30) 1659.0624***		(22) 1542.656***		

[a] Significance levels: *$p<0.05$, **$p<0.01$, ***$p<0.001$.
[b] AIC=Akaike information criterion; N=2376.
[c] Based on the LL function of a restricted model with two constants only, i.e. with choice probabilities set at each alternative's sample shares.
[d] Likelihood ratio test.
[e] Thai baht (THB): €1=39.3048 THB, as of June 1, 2013.
[f] MWTP of attributes with coefficient estimates not significantly different from zero were calculated at zero THB.

Table 4
Average and aggregated consumer surplus change estimates (THB) [a]

Attribute	*Average household*	*Surveyed sample* (*N*=198)	*Total research area* (*N*=13,131) [b]
−50% bee pop. (vs 0%)	−1591.87	−315,190.17	−20,902,876.76
+50% bee pop. (vs 0%)	803.62	159,116.17	6,344,185.19
Bee-friendly pest control	287.66	56,955.77	3,777,201.21
Improving native bee habitat	252.73	50,040.87	3,318,617.97
Native bee husbandry	170.90	33,838.88	2,244,133.58
All measures implemented	711.29	140,835.51	9,339,952.77

Weighted with sample shares of idiosyncratic covariates (Table 2).
[a] €1=39.3048 Thai baht (THB), as of June 1, 2013.
[b] Number of registered households in Chom Thong and Saraphi districts (DoAE, 2015).

sample and the whole research area levels (Table 4). Nevertheless, one must be careful when interpreting the estimated WTP for a 50% native bee population decrease, as the abosulute value of this estimate, i.e. 1591.9 Thai baht, substantially exceeds the range of policy implementation costs that was presented to the respondents during the DCE (Table 1).

Table 5
Estimated longan production losses [a] attributed to declining bee pollination services (THB) [b]

Native bee population loss (%)	*Average farm* (1.144 ha)	*Surveyed sample* (188 ha)	*Total research area* (7078 ha)
100.00	−110,476.08	−18,155,160.00	−683,522,460.00
50.00	−55,238.04	−9,077,580.00	−341,761,230.00
5.00	− 5523.80	−907,758.00	−34,176,123.00

[a] Calculated with a 60% bee-pollination dependence ratio.
[b] €1=39.3048 Thai baht (THB), as of June 1, 2013.

5. Discussion

We could reject the hypothesis of a zero mean preference for all attributes, other than for the bee-friendly pest control (in both models) and the improving native bee habitat (in the fixed-cost model only) measures (Table 3); an indifferent taste perception for these two measures could not be dismissed with confidence in the 12.63% share of the population who did not believe in a positive contribution of native bees to their crop yields (Table 2). Furthermore, the substantial discrepancy between the estimated WTP to avoid a 50% native bee population decline and the actual costs that such loss would imply in terms of forgone longan yield revenues (Tables 4 and 5) hints at the respondents' unawareness of the extent by which bees contribute to their crop production. These results accentuate the importance of education in the formation of value perceptions and thus that informing farmers about their crops dependence on pollination services could be seen as an effective policy measure to have them deploy more of their own resources in conserving this ecosystem service.

As suggested by the relevant interaction term coefficient, engaging farmers in economic activities involving native bees may also sensitize them for native bee population changes by attaching a direct use value to natural bee abundance (Table 3). Besides the obvious relation existing between being a beekeeper and an expected higher preference for participating in a native bee husbandry program, the significant result for this interaction may point out a demand for more sophisticated technologies and skills than those currently available to beekeepers. On-farm native husbandry is indeed considered a more sustainable alternative to honey hunting, as the latter activity (if not carefully carried out) may deplete wild bee colonies and damage their habitat (Partap, 2011). Moreover, on-farm beekeeping has encouraged orchard farmers in Chanthaburi province to use less pesticides on their crops as these would also harm their bees. The significant interaction of gender with costs, which suggests a lower reluctance to spending money *c.p.* by male respondents than by females, may relate to the significant income differences between male and female headed households (Table 2).

The resulting standard deviation estimates indicate a statistically significant preference heterogeneity among the population of longan farmers, leading to the rejection of the hypothesis of homogeneous taste parameters. The variance in the value perceived by the population for the "native bee husbandry" measure could, for instance, be related to the difference in opinions that members of some of the surveyed communities expressed (in the additional comments section of the DCE survey) regarding bee husbandry. Modern beekeeping with the European honeybee (*A. mellifera*) is widely practiced in this region due to the valuable honey that can be obtained from longan nectar. Beekeepers therefore practice migratory beekeeping (i.e. relocating the hives in search for new bee foraging sources). In some villages, the respondents expressed a negative opinion regarding modern bee husbandry, based on their belief that honeybees carry the parasites that serve as vectors for *witches' broom* (*Candidatus* Phytoplasma spp.), a disease that affects longan and lychee (*Litchi chinensis* S.) trees in the region. Some individuals additionally stated believing that bees harm their yields by eating their crop's flowers. On the other hand, these negative opinions contrasted with a general interest in native beekeeping that could be especially determined in individuals from communities that had an already established tradition for this activity.

The parameter means of the "changes in native bee population" attribute suggest that avoiding a 50% *loss* of native bee populations is valued twice as much as an equally sized population *increase*, a result that is consistent with loss aversion behavior; a Wald test for linear restrictions led to the rejection of the hypothesis that the part-worth of these dummies could be captured as a single linear effect [$\chi^2(1)=36.56$, $p=0.000$]. In this regard, and considering the prospects of a local pollinator crisis such as we suspect might have stricken Chanthaburi province, avoiding the losses that could arise from even a small decline in the population of native bees (Table 5) justifies the comparably small investment in its prevention: the cost of implementing a conservation policy that includes all the proposed measures amounts to less than five thousand Thai baht per village, which includes an extension service officer's salary (72% of total costs), contracted farmers' wages, tree seedlings and transportation expenses. Every household interested in native beekeeping could additionally acquire bee boxes at 150 Thai baht each, an investment that can readily be amortized with the sales of honey (THB 80/kg) and other valuable hive products; moreover, distributed among all longan farming households in a village (an average of 1130 in the research area), the costs of implementing the full project would lay far below the sum corresponding to the average household's WTP for such purpose.

Placing the derived WTP estimates in the context of the average income earned by the sampled population of respondents (Table 2) also leads to the conclusion that these values conform to their expenditure capacity, especially due to the single-payment nature of the policy implementation costs.

6. Conclusions

The discrete choice experiment (DCE) approach allowed us obtaining economic value estimates for longan farmers' preferences for conservation measures of wild pollinators and for preventing a decline in the pollinator population. Investigating the perspective of farmers is of utmost importance, as they would ultimately be the most directly concerned stakeholders regarding conservation policies. The results of our study thus inform Thai policy makers about which conservation strategies require a greater government intervention and which ones can be expected to engage more efforts and resources from the targeted farming communities. In this regard, we estimated that, on average, the share of longan farmers who did not believe in the positive contribution of native bees to their crop production valued both the bee-friendly pest control and the improving native bee habitat strategies at zero THB. In contrast, an on average considerably higher willingness to pay (WTP) for these strategies could be determined for those farmers who were aware of the importance of bee pollination to their yields. Most of the surveyed longan farmers were willing to pay for the implementation of the native bee husbandry conservation strategy and an even higher bid was estimated for those individuals, who already engaged in beekeeping (or in other economic activities involving bees).

We show that longan farmers very likely underestimate the true use value of pollination, when comparing their aggregated WTP for avoiding the presented hypothetical pollinator population declines (resulting from the DCE) with the expected production losses as calculated with a suitable pollination-dependence ratio. Indeed, the obtained WTP estimates for changes in the abundance of pollinating bees can be considered a byproduct of this study that, when compared to the actual costs of implementing the proposed conservation strategies, indicates how worthwhile this investment would be from the concerned farmers' perspective. Accordingly, implementing an adequate bundle of conservation measures costs less than the farmers' elicited WTPs for avoiding a 50% decline in bee population. Hence, from a social point of view and explicitly taking into account the preferences of stakeholders, a tailored conservation policy is worthwhile.

Our results suggest that to galvanize a greater stakeholder engagement in the implementation of the proposed bee conservation strategies, Thai policy makers should start by educating farmers about the role of pollination in agricultural production, such as to bring their preferences for native bee abundance closer to the true use value of this ecosystem service. This could be achieved by using the already existing agricultural extension services provided by the Thai government and by the Royal Project Foundation to communicate to the farmers the benefits that pollination represent to their respective crops.

Furthermore, longan flowers produce abundant nectar, of which honey can be sold at a premium price. This has attracted individuals and enterprises with great investment power to this region to develop a local beekeeping industry with the imported European honeybee (*A. mellifera*). Nevertheless, the potential for an additional income that beekeeping offers remains currently untapped by the great majority of longan farmers. Thus, fostering on-farm beekeeping with native bees can be seen as a strategy to reconcile private economic incentives of smallholders with the goals to conserve native pollinators and their habitats.

We conclude by recognizing that Northern Thailand's crop diversity presents a wide dependence range on animal-mediated pollination: from wind- or self-pollinated crops (e.g. rice and maize), through modestly animal-pollination dependent or profiting crops (e.g. strawberries and coffee), to crops substantially relying on pollination services (e.g. longan, litchi, squashes and pumpkins) (Klein et al., 2007). Therefore, realizing the full potential of a pollinator conservation policy in Northern Thailand would require promoting further research on the interdependency between the local pollinator fauna and the region's broader agricultural landscape, assessing its economic implications from the production perspective and accounting for the preferences of the relevant farming communities.

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