# ESTIMATING MEXICAN FARMERS' VALUATION OF *MILPA* DIVERSITY AND GENETICALLY MODIFIED MAIZE: A CHOICE EXPERIMENT APPROACH

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**Abstract:**
A *milpa* is a traditional intercropping system of maize, bean, and squash. *Milpa*s are repositories of agrobiodiversity in México, not only rich in inter- and infra-crop species diversity, but also in landraces of maize, which are building blocks for future improvements in this globally important staple crop. Even though they are still widely cultivated across México, sustainability of *milpa* cultivation is threatened by farmers' integration into labour and output markets and recently, by the flow of transgenic constructs from genetically modified (GM) maize varieties to landraces in *milpa*s. In this paper a choice experiment is employed to investigate farmer valuation of agrobiodiversity in traditional *milpa* systems and the option to cultivate GM maize varieties in *milpa*s. Data are collected from 414 farm households across three states of México, and analysed using random parameter logit model with interactions, which can detect for unobserved, as well as observed sources of heterogeneity in the sample. The results reveal that there is considerable heterogeneity in farmers' preferences for *milpa* diversity and GM maize across and within the three states. The location and characteristics of farmers who value *milpa* diversity the most, as well as those of farmers who value the option to cultivate GM maize the most are identified. These findings have policy implications in terms of designing least cost on farm conservation programmes for traditional *milpa*s, as well as for understanding the potential in adoption of GM maize in México.

**Keywords:** *milpa*, crop species and variety diversity, landrace, genetically modified maize, choice experiment method, conditional logit model, random parameter logit model, interactions

**JEL Classifications:** Q12, Q18, Q24, Q26

## 1. Introduction and Motivation

The *milpa* is a complex intercropping system of maize, bean, and squash, traditionally cultivated by Mexican farmers (López-Forment, 1998). Approximately 2 million farm households across México continue to cultivate *milpa*s on around 6 million ha of land every year, and most are dependent on their *milpa* produce for their food security, diet quality and livelihoods (Bellon and Berthaud, 2004). In addition to the private economic value *milpa*s generate for the farmers that manage them, *milpa*s also generate global public economic value, since they are considered to be one of the last reservoirs of maize genetic resources for humanity (Bellon and Berthaud, 2004). Traditional *milpa*s are rich in several components of agrobiodiversity, most specifically in inter- and infra-crop species diversity, and this diverse and complex poly-cropping ecosystem generates crop genetic resources (CGR) in individual crops, especially maize genetic diversity found in maize landraces[1] (OECD, 2002; Bellon and Berthaud, 2004; Van Dusen and Taylor, 2005). Maize landraces found in the traditional *milpa*s can potentially contribute unique traits needed by plant breeders (e.g., genetic resistance to certain plant diseases, pests and abiotic stresses) for future improvement of this crop, thereby contributing to global food security in maize, the most globally important staple crop after wheat (Fowler and Hodgkin, 2004; Harlan, 1992; Kloppenburg, 1988).

Even though continued management of the traditional *milpa* is crucial for *in situ* conservation of maize genetic resources, there is considerable uncertainty with regards to the long run sustainability of *milpa* management in México (Van Dusen and Taylor, 2005). Increasing rates of migration and off farm employment opportunities, as well as commercialisation of maize production is threatening the continued management of *milpa* systems. Moreover, maize is a cross-pollinating species, and there are potential threats to traditional maize varieties from genetically modified (GM) maize varieties. Although cultivation of GM crops is currently prohibited in México, presence of transgenic constructs was reported in maize

[1] Definitions of crop landraces are numerous in the international scientific literature (Zeven, 1998). Landraces, or traditional varieties or local varieties, are variants, varieties, or populations of crops, with plants that are often highly variable in appearance, whose genetic structure is shaped by farmers' seed selection practices and management, as well as natural selection processes, over generations of cultivation (Smale *et al.*, 2001).

landraces in the state of Oaxaca in 2001. Since then, the potential effects of transgenic maize on traditional varieties of maize and other CGR in México has been a topic of public debate (Dyer and Yunez-Naude, 2003).

The aim of this paper is to estimate Mexican farmers' valuation of the most important components of agrobiodiversity found in traditional *milpa*s, including inter-crop diversity (crop species diversity), infra-crop species diversity (maize variety diversity), crop genetic diversity (maize landrace), as well as their valuation of the option to cultivate GM maize varieties in the traditional *milpa* system. Given that most of the agrobiodiversity *milpa*s generate are not traded in the markets (e.g., maize landraces, see Van Dusen and Taylor, 2005), and since cultivation of GM maize is currently prohibited in México, a stated preference non-market valuation method, namely the choice experiment method, is employed to estimate the values of agrobiodiversity components and the option to cultivate GM maize in the *milpa*s. Data are collected from 414 farm households across three states of México, including Jalisco, Michoacán and Oaxaca. Data are analysed by using the random parameter logit model with interactions, which can detect for unobserved and observed sources of heterogeneity in the sample. The results reveal that there is considerable heterogeneity in farmers' preferences for agrobiodiversity management and GM maize cultivation in the milpas across and within the three sites. The locations and profiles of farm households who value agrobiodiversity on the traditional milpas the most are identified. These farmers would constitute least-cost targets for in situ conservation on farm programmes. Moreover location and characteristics of those of farm households who value the option to cultivate GM maize the most are also identified. These findings could aid in assessing the potential diffusion and impact of liberation of GM maize to the environment, as well as to farmers' welfare.

Contributions of this paper to the literature are threefold. First, only a few studies have investigated the social and economic factors that affect *milpa* and maize diversity in México, and these have mainly employed the revealed preference farm household model (e.g., Smale *et al.*, 2001; Van Dusen and Taylor, 2005). Second, this study is an addition to the growing literature that employs the choice experiment method adopted from environmental economics literature to estimate farmer valuation of various components of agrobiodiversity (e.g., Scarpa *et al.*, 2003a, b; Ndjeunga and Nelson, 2005; Ruto, 2005; Birol *et al.*, forthcoming). Finally, it is also an addition to the recent and scant literature that employs the choice experiment method to value non-market goods in the developing country context (e.g., Othman *et al.*, 2004; Naidoo and Adamowicz, 2005).

The paper unfolds as follows. The next section describes the choice experiment method and the econometric estimation models employed in this paper. Section three explains the choice experiment design, survey administration, and describes the sites and the sampled farm households. Section four reports the econometric results and the value of milpa diversity and GM maize to various farmer types across the three sites. The final section concludes the paper and draws policy implications for agrobiodiversity conservation on farm in Mexican milpas, and for potential adoption of GM maize across Mexico.

## 2. The Choice Experiment Approach

Since most of the agrobiodiversity components that *milpa*s generate are not traded in the markets, non-market valuation methods must be used to determine their economic value. The economic value that *milpa*s generate primarily accrues to farmers in non-market use values, or utility. The preferences of farmers, who are both producers and consumers of agrobiodiversity components of *milpa*, determine the implicit values they derive from *milpa*s and their agrobiodiversity components (Scarpa *et al.*, 2003a; Birol *et al.*, forthcoming).

Of the range of environmental valuation approaches, the choice experiment method is most appropriate for valuing *milpa*s, considering their multiple agrobiodiversity components, as explained above. The choice experiment method enables estimation not only of the value of the traditional *milpa*, but also of the implicit value of its agrobiodiversity components, as well as implied ranking of (and hence trade-offs between) different components of agrobiodiversity and the value of changing more than one component of agrobiodiversity at a time (Hanley *et al.* 1998; Bateman *et al.* 2003). Moreover, this method, which is based on farmers choosing between hypothetical *milpa*s, enables estimation of the value of new *milpa* attributes, such as GM maize varieties, which are outside the farmers' current set of experiences (Adamowicz *et al.*, 1994).

The CE method has its theoretical grounding in Lancaster's model of consumer choice (Lancaster, 1966), and its econometric basis in random utility theory (Luce, 1959; McFadden, 1974). Lancaster proposed that consumers derive satisfaction not from goods themselves but from the attributes they provide. To illustrate the basic model behind the CE presented here, consider a farmer's choice for a *milpa* and assume that utility depends on choices made from a set C, i.e., a choice set, which includes all the possible *milpa* alternatives. The farmer is assumed to have a utility function of the form:

$$U_{ij} = V(Z_{ij}) + e(Z_{ij}) \tag{1}$$

where for any farmer *i*, a given level of utility will be associated with any *milpa* alternative *j*. Utility derived from any of the *milpa* alternatives depends on the attributes of the *milpa* (*Z*), such as the levels of different components of agrobiodiversity it provides.

The random utility theory (RUT) is the theoretical basis for integrating behaviour with economic valuation in the CE method. According to RUT, the utility of a choice is comprised of a deterministic component (*V*) and an error component (*e*), which is independent of the deterministic part and follows a predetermined distribution. This error component implies that predictions cannot be made with certainty. Choices made between alternatives will be a function of the probability that the utility associated with a particular *milpa* option *j* is higher than those for other alternatives. Assuming that the relationship between utility and attributes is linear in the parameters and variables function, and that the error terms are identically and independently distributed with a Weibull distribution, the probability of any particular milpa alternative *j* being chosen can be expressed in terms of a logistic distribution. Equation (1) can be estimated with a conditional logit (CL) model (McFadden, 1974; Greene, 1997 pp. 913-914; Maddala, 1999, pp. 42), which takes the general form:

$$P_{ij} = \frac{\exp(V(Z_{ij}))}{\sum_{h=1}^{C} \exp(V(Z_{ih}))} \tag{2}$$

where the conditional indirect utility function generally estimated is:

$$V_{ij} = \beta + \beta_1 Z_1 + \beta_2 Z_2 + ...... + \beta_n Z_n \tag{3}$$

where $\beta$ is the alternative specific constant (ASC) which captures the effects on utility of any attributes not included in choice specific *milpa* attributes, $n$ is the number of *milpa* attributes considered, and the vectors of coefficients $\beta_1$ to $\beta_n$ are attached to the vector of attributes (*Z*).

The assumptions about the distribution of error terms implicit in the use of the CL model impose a particular condition known as the independence of irrelevant alternatives (IIA) property, which states that the relative probabilities of two options being chosen are unaffected by introduction or removal of other alternatives. If the IIA property is violated then CL results will be biased and hence a discrete choice model that does not require the IIA property, such as random parameter logit (RPL) model, should be used. Another limitation of the CL model is that it assumes homogeneous preferences across farmers. Preferences, however, are in fact heterogeneous and accounting for this heterogeneity enables estimation of unbiased estimates of individual preferences and enhances the accuracy and reliability of estimates of demand, participation, marginal and total welfare (Greene, 1997). Furthermore, accounting for heterogeneity enables prescription of policies that take equity concerns into account. An understanding of who will be affected by a policy change in addition to understanding the aggregate economic value associated with such changes is necessary (Boxall and Adamowicz, 2002).

The random parameter logit (RPL) model, not only does not require the IIA assumption, but can also account for unobserved, unconditional heterogeneity in preferences across respondents. The random utility function in the RPL model is given by:

$$U_{ij} = V(Z_j(\beta + \eta_i)) + e(Z_j) \qquad (4)$$

Similarly to the CL model, utility is decomposed into a deterministic component ($V$) and an error component stochastic term ($e$). Indirect utility is assumed to be a function of the choice attributes ($Z_j$), with parameters $\beta$, which due to preference heterogeneity may vary across farmers by a random component $\eta_i$. By specifying the distribution of the error terms $e$ and $\eta$, the probability of choosing $j$ in each of the choice sets can be derived (Train, 1998). By accounting for unobserved heterogeneity, equation (2) now becomes:

$$P_{ij} = \frac{\exp(V(Z_j(\beta + \eta_i)))}{\sum_{h=1}^{C} \exp(V(Z_h(\beta + \eta_i)))} \qquad (5)$$

Since this model is not restricted by the IIA assumption, the stochastic part of utility may be correlated among alternatives and across the sequence of choices via the common influence of $\eta_i$. Treating preference parameters as random variables requires estimation by simulated maximum likelihood. Procedurally, the maximum likelihood algorithm searches for a solution by simulating $k$ draws from distributions with given means and standard deviations. Probabilities are calculated by integrating the joint simulated distribution.

Recent applications of the RPL model have shown that this model is superior to the CL model in terms of overall fit and welfare estimates (Breffle and Morey, 2000; Layton and Brown, 2000; Carlsson *et al.*, 2003; Kontoleon, 2003; Lusk *et al.*, 2003; Morey and Rossmann, 2003). Even if unobserved heterogeneity can be accounted for in the RPL model, however, this model fails to explain the *sources* of heterogeneity (Boxall and Adamowicz, 2002).

One solution to detecting the sources heterogeneity while accounting for unobserved heterogeneity could be by including interactions of farmer specific household, farm level and market integration characteristics with choice specific attributes in the utility function. The RPL model with interactions can pick up preference variation in terms of both unconditional taste heterogeneity (random heterogeneity) and individual characteristics (conditional heterogeneity), and hence improve model fit (e.g., Revelt and Train, 1998; Morey and Rossmann, 2003; Kontoleon, 2003). When the interaction terms with farmers' characteristics are included, the indirect utility function estimated becomes:

$$V_{ij} = \beta + \beta_1 Z_1 + \beta_2 Z_2 + \ldots + \beta_n Z_n + \delta_1 S_1 + \delta_2 S_2 + \ldots + \delta_l S_m \qquad (6)$$

where, as before $\beta$ is the ASC, $n$ is the number of milpa attributes considered is and the vector of coefficients $\beta_1$ to $\beta_n$ are attached to the vector of attributes (*Z*). In this specification, *m* is the number of farmer specific household, farm level and market integration characteristics employed to explain the choice of the milpa, and the vector of coefficients $\delta_1$ to $\delta_l$ are attached to the vector of interaction terms (*S*) that influence utility. Since farmer specific household, farm level and market integration characteristics are constant across choice occasions for any given farmer, these only enter as interaction terms with the milpa attributes.

## 3. Choice Experiment Design and Administration

### *3.1. Choice Sets*

A choice experiment is a highly 'structured method of data generation' (Hanley *et al.*, 1998), relying on carefully designed tasks or "experiments" to reveal the factors that influence choice. Experimental design theory is used to construct profiles of the milpa in terms of its attributes and levels of these attributes. Profiles are assembled in choice sets, which are in turn presented to the farmers, who are asked to state their preferred milpa profile in each choice occasion.

The first step in choice experiment design is, therefore, to define the milpa in terms of its attributes and levels these attributes take. The most important *milpa* attributes and their levels were identified with Instituto Nacional de Ecología (Mexican National Institute of Ecology, INE) experts and agricultural scientists, drawing on the results of informal interviews with milpa farmers in the study sites, and previous research on milpa cultivation. The chosen attributes and their levels are reported in Table 1.

The first three attributes characterize the various components of agrobiodiversity found in the *milpa*. The first attribute, crop species diversity, represents inter-crop species diversity, found in the intercropping system consisting of maize, beans and squash. The maize variety diversity attribute represents infra-species diversity. Previous studies found that multiple maize populations still coexist in the traditional *milpa* system (Bellon and Brush, 1994). It is important to take the secondary crops of global importance (i.e., beans and squash) as well as multiple maize varieties into consideration, since competition among, as well as within species shapes diversity outcomes, hence focusing only on a single species or variety could cause biased econometric estimates and misleading policy prescriptions (Van Dusen and Taylor, 2005). The maize landrace attribute represents maize genetic diversity, which is crucial not only for food security of the farmer, and but also for research to enhance future productivity or product quality of maize, as explained in section 1. The GM maize attribute is included in the choice set in order to investigate, whether or not farmers would choose to cultivate a GM maize variety when presented with the opportunity in a hypothetical situation. The last attribute, yield, characterizes the maize production for a *milpa* profile as a percentage of the farmers' current maize production. This monetary proxy attribute is included in order to estimate welfare changes. This indirect measure is preferred over a direct monetary variable because for most families the outputs and functions of the *milpa*s are not traded in the markets, but consumed by the farm families themselves.

Table 1. *Milpa* attributes and attribute levels used in the choice experiment

| *Milpa* attribute | Definition | Attribute levels |
|---|---|---|
| Crop Species | The total number of crops that are grown | 1 (only maize), 2 (maize |

| | | |
|---|---|---|
| Diversity | in the *milpa*. | and beans), 3 (maize, beans and squash) |
| Maize variety diversity | The total number of maize varieties that are grown in the *milpa*. | 1, 2 or 3 |
| Maize landrace | Whether or not the *milpa* contains a maize variety that has been passed down from the previous generation(s) and/or has not been purchased from a commercial seed supplier. | *Milpa* contains a landrace vs. *Milpa* does not contain a landrace |
| GM maize | Whether or not the *milpa* contains a maize variety that has been genetically modified. | *Milpa* contains GM maize vs. *Milpa* does not contain GM maize |
| Yield | % of the expected maize yield relative to current *milpa* | 130, 115, 100, 85, 70 |

A large number of unique *milpa* descriptions can be constructed from this number of attributes and levels[2]. Statistical design methods (see Louviere *et al.*, 2000) were used to structure the presentation of the levels of the five attributes in choice sets. More specifically, an orthogonalisation procedure was employed to recover only the main effects, consisting of 24 pair wise comparisons of *milpa* profiles. These were randomly blocked to four different versions with 6 choice sets. Each farmer was presented with 6 choice sets, each containing two *milpa* profiles and an option to "opt out" by selecting neither of the *milpa* profiles presented to them, in which case they would continue cultivating their own *milpa*, whose attribute levels were recorded by the interviewers. Such an "opt out" option can be considered as a status quo or baseline alternative, whose inclusion in the choice set is instrumental to achieving welfare measures that are consistent with demand theory (Bennett and Blamey, 2001; Bateman *et al.*, 2003; Louviere *et al.*, 2000; Kontoleon, 2003). In this study the "opt out" option is the own *milpa* profile rather than no *milpa* profile, since in this context it is not realistic to ask the subsistence *milpa* farmers not to manage *milpas* at all (Louviere *et al.*, 2000). In addition, this "opt out" option can also be used to measure the participation levels. Given that one of the aims of this study is to asses if *milpa* production could be threatened by the adoption of GM crops, the inclusion of an "opt out" option provides information on whether or not some farm households would

[2] The number of *milpa*s that can be generated from 5 attributes, 2 with 2 levels, 2 with 3 levels and one with 5 levels is $3^2*2^2*5=160$.

prefer to continue cultivating their traditional *milpa*, even if they are presented with an option to cultivate GM maize. Figure 1 provides an example of a choice set.

Figure 1. Sample choice set

*Assuming that the following milpa profiles were the only choices you had, which one would you prefer to cultivate?*

| *Milpa* Characteristics | *Milpa* A | *Milpa* B | |
|---|---|---|---|
| Crop Species Diversity | Maize, beans and squash | Maize | Neither *milpa*, I prefer my own profile |
| Maize diversity | 3 varieties | 3 varieties | |
| Landrace cultivation | No | Yes | |
| GM content | Yes | No | |
| Yield | 115 | 115 | |
| I prefer to cultivate (Please tick as appropriate) | *Milpa* A ☐ | *Milpa* B ☐ | Neither ☐ |

*3.2. Study sites*

The choice experiment study was implemented in October and November 2004 with face-to-face interviews with farmers who have been producing maize for at least the last two harvesting seasons. An introductory section explained to respondents the context in which choices were to be made and described each attribute. The respondents were reminded that there were no right or wrong answers and that we were only interested in their opinions. In addition to the choice sets, respondents were also asked questions on their knowledge, perceptions and attitudes with regards to biotechnology and genetically modified crops and food. Social and economic information on farm households and *milpa* decision-makers were also collected.

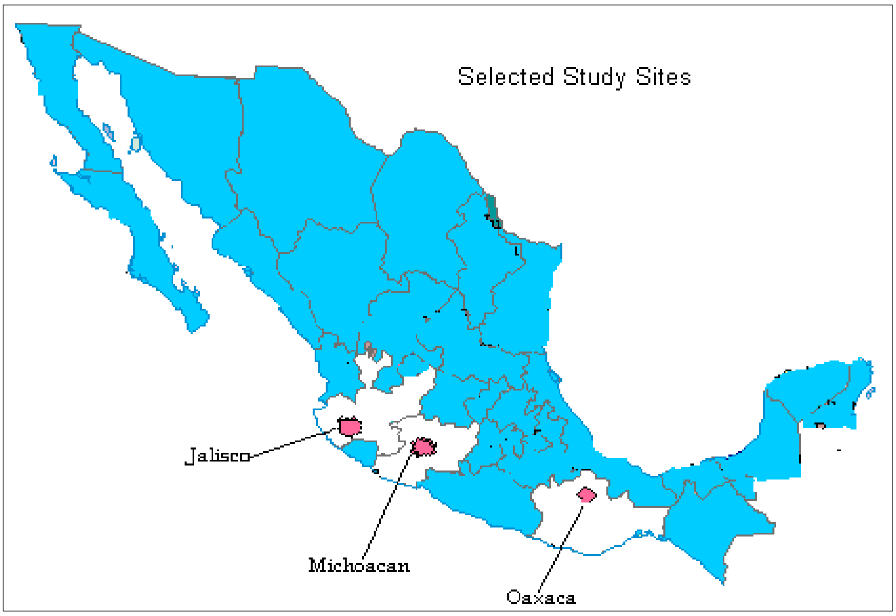
A total of 414 surveys were collected from randomly selected farm households across 16 communities in three states of Mexico. The three selected sites included four communities of the Sierra de Manantlán District in the state of Jalisco; five communities of the Lago de Patzcuaro District in the state of Michoacán and seven communities of the Ixtlan de Juarez District in the state of Oaxaca (Table 2 and Figure 2). The sites are named after the states in the remainder of the paper. These three sites were selected in order to represent different agro-ecologies, microclimates, market integration and economic development levels. In addition, in each one of these sites traditional *milpa* cultivation is still prevalent and each are considered to be centres of maize diversity, as confirmed by the findings of INE's collection missions.

Moreover, the Oaxaca site is where the traces of transgenic constructs have been found in maize landraces in 2001.

Table 2. Selected sites

| District and State | Community |
|---|---|
| 1. Sierra de Manantlán, Jalisco | 1. Ayotitlán |
| | 2. Ahuacapan |
| | 3. Cuzalapa |
| | 4. San Miguel |
| 2. Lago de Patzcuaro District, Michoacán | 1. Ajuno |
| | 2. Pichátaro |
| | 3. San Francisco Uricho |
| | 4. Santa Maria Huiramangaro |
| | 5. Sebina |
| 3. Ixtlan de Juarez District, Oaxaca | 1. Capulapam de Mendez |
| | 2. Santa Catarina Lachatao |
| | 3. San Juan Chicomezuchitl |
| | 4. Santa Maria Yahuiche |
| | 5. San Pablo Macultianguis |
| | 6. Santiago Comaltepec |
| | 7. Santiago Laxopa |

Figure 2. Location of selected sites




Most of the communities studied in Jalisco are located in the southern part of the state, in the buffer zone of Biosphere Reserve, with coordinates 19°16’20’’-19°37’30’’ northern latitude and 102°42’-104°02’ western longitude. They lie at an altitude of 900 meters above sea level. The climate in this site is semi-dry and warm with an average annual temperature of 23.5°C, and an average rainfall of 1,652.5 mm.

The rainy season is form June till August. The total area of the Jalisco site sampled is 1,178.67 $km^2$, and with a population of 4953 inhabitants this is the least densely populated site across the three. These communities are officially recognized as indigenous communities (*comunidades indígenas)* and have a traditional form of government (*usos y costumbres*). Jalisco is the most geographically and economically marginalized site across the three sites, with the marginality index[3] of its communities ranking above those in the other two sites. Although some of the agricultural produce (mainly maize) is sold outside the valley, on average the communities in this site are poorly integrated into commercial markets. There is only one main highway crossing the state (*Carretera* Guadalajara-Barra de Navidad), and the communities are linked with dirt and gravel rural roads (*terracería y brecha*). Cultural practices in this site continue to be relatively traditional compared to those found across the three sites (Gobierno del Estado de Jalisco, 2000).

The communities sampled in the Michoacán site are located in the northern part of the state, between the coordinates 19°30'-19º35' northern latitude and 101º43'-101º51' western longitude. The altitude across the communities in this site is between 1980 and of 2080 meters above sea level. The predominant climate is mild with temperatures ranging form 6.1 to 37° C. The rainy season is during summer and the average rainfall is 1100 mm, with some frost during winter. The sampled communities in the site make up an area of 434.11$Km^2$, with a population of 19,408 inhabitants. Michoacán is the most densely populated site across the three. The communities studied in this site also have a traditional indigenous form of government. The main economic activity in Michoacán is agriculture, where maize is the main crop, followed by avocado. The communities in this site present a medium to high level of depravation, although they have the lowest marginalisation ranking across the three sites. However, the communities in Michoacán are also poorly integrated into commercial markets, with one main highway crossing the state (*Carretera* Federal No. 175 Oaxaca-Tuxtepec). The communities in this site are also linked with dirt and gravel rural roads (Gobierno del Estado de Oaxaca, 2005).

The communities visited in the Oaxaca site are located in the northern part of the state, between the coordinates 17° 13' northern latitude and 96° 30' western

[3]Measurement of underdevelopment level of communities, calculated using indicators such as access to education, quality of housing infrastructure and income.

longitude. The altitude across the communities in the site is between 1,760 and 2040 meters above sea level. The predominant climate is cold and humid with rainy season during summer and some frost during winter. The area of the site is 734.29 $km^2$, with a population of 8678 inhabitants. The communities in the Oaxaca site also have a traditional indigenous form of government. The main economic activities across the communities are forestall logging and agricultural production, where maize is the principal crop. Overall, there is a high level of economic marginalisation and underdevelopment across the communities in this site. The marginality index is high for five of the communities and medium for two of them. Finally communities in this site are poorly integrated into commercial markets. There is only one main highway crossing the region (*Carretera* Federal No. 175 Oaxaca-Tuxtepec), and the communities within the site are linked with dirt and gravel rural roads (Gobierno del Estado de Oaxaca, 2005).

### *3.3. Farm families*

The household, farm level and market integration characteristics of the sampled households, as well as the three components of agrobiodiversity found on their *milpa*s are reported in Table 3. In terms of farm household characteristics, *milpa* decision makers in Michoacán have significantly higher years of farming experience compared to the farmers in the other two sites, which also significantly differ. The largest farm families are in Michoacán, the most densely populated site. Farm families in Jalisco are the smallest in size. Area cultivated in maize, however, is significantly larger in Jalisco, and smaller in Oaxaca. The sites also differ in terms of labour and output market integration. A significantly lower percentage of farm families located in Jalisco have at least one farm family member working off farm compared to the other two sites, which do not significantly differ. In Michoacán a significantly higher percentage of farm families sell at least some of their maize in the markets, compared to Jalisco and Oaxaca, which do not differ.

Farm families located in Oaxaca manage the *milpa*s that are richest in terms of crop species diversity, and those in Jalisco manage the lowest crop species diversity levels across the three sites. Similarly, farm families in Jalisco manage the least number of maize varieties across the three sites. Maize variety diversity in the *milpa*s of Oaxaca and Michoacán do not significantly differ. Percentage of farm families cultivating maize landraces is the highest in Michoacán, this percentage, however, does not significantly differ between Oaxaca and Jalisco.

Table 3. Family and *milpa* characteristics by region

| Variable | Definition | Jalisco (N=118) | Michoacán (N=163) | Oaxaca (N=132) |
|---|---|---|---|---|
| | | | Mean (s.d.) | |
| Experience*** | Farming experience of *milpa* decision makers in years | 37.51 (16.35) | 44.69 (3.70) | 30.80 (15.29) |
| Family size*** | Number of members in the family | 2.78 (1.47) | 3.55 (1.48) | 3.18 (1.53) |
| Area*** | Area (in ha) in maize cultivation | 7.84 (9.32) | 4.13 (6.27) | 1.13 (1.13) |
| Crop species diversity*** | Number of different crop species in the *milpa* | 1.42 (0.70) | 1.66 (0.80) | 2.52 (0.93) |
| Maize variety diversity*** | Number of maize varieties in the *milpa* | 1.15 (0.46) | 1.41 (0.58) | 1.47 (0.61) |
| | | | Percent | |
| Seller** | Family sells some (or all) of their *milpa* produce | 32.20 | 44.79 | 31.81 |
| Off farm employed*** | At least one member of the family works off farm | 13.56 | 29.45 | 31.81 |
| Maize landrace*** | *Milpa* has a landrace maize variety | 58.48 | 90.80 | 68.18 |

Source: Encuesta percepciones del productores de maíz en comunidades rurales con respecto a la liberación de materiales transgénicos dentro de alimentos y cultivos, y su impacto en la diversidad de su cultivo. Programa de Bioseguridad GEF/CIBIOGEM-INE, 2004. T-tests and Pearson Chi square tests show significant differences among at least one pair of regions (*) at 10% significance level; (**) at 5% significance level, and (***) at 1% significance level.

## 4. Results

The data were coded according to the levels of the attributes. Attributes with two levels (i.e., maize landrace and GM maize variety) entered the utility function as binary variables that were effects coded (Adamowicz *et al.*, 1994; Louviere *et al.*, 2000). For maize landrace cultivation, yes was coded as 1 and no was coded as –1. Similarly for GM maize variety, yes was coded as 1 and no as –1. The levels for the attributes with three levels (crop species diversity and maize variety diversity) and five levels (yield) were entered in cardinal-linear form. Consequently crop species diversity and maize variety diversity took the levels 1, 2 and 3, and yield attribute was coded as 130, 115, 100, 85 and 70. The attributes for the '"Neither *Milpa*, I prefer my current profile' were coded with the values that the farmer reported in the survey. Since this choice experiment involves generic instead of labelled options, the alternative specific constants (ASC) were equalled to 1 when either *milpa* A or B was chosen and to 0 when farmers' own *milpa* profile was chosen (Louviere *et al.*, 2000). In this choice experiment the ASC is specified to account for the proportion of choice of adoption of a different *milpa* system. A relatively more negative and significant ASC indicate a higher propensity to choose farmers' own *milpa* profile.

### *4.1. Conditional Logit Model*

The CE was designed with the assumption that the observable utility function would follow a strictly additive form. The model was specified so that the probability of selecting a particular *milpa* was a function of attributes of that *milpa* and of the ASC (equation (2) above). Using the 2484 choices elicited from 414 respondents, eight conditional logit (CL) models with logarithmic and linear specifications for the attributes with three and five levels were estimated and compared using LIMDEP 8.0 NLOGIT 3.0. The highest value of the log-likelihood function was found for the specification with all attributes in linear form.

It is hypothesised in the survey design and supported by the descriptive statistics that households in the three sites are likely to value *milpa* attributes differently. The null hypothesis that the separate effects of sites are equal to zero was rejected with a Swait Louviere log-likelihood ratio test at the 0.5% significance level, based on regressions with the pooled and separate site samples. When the same test is carried out to make pair-wise comparisons, it is found that the largest differences between regional preferences are those between Oaxaca and Jalisco and Michoacán and Jalisco. These results suggest that underlying parameters are distinct for each site. The results of the conditional logit estimates by site are reported in Table 4.

The overall fit of the models, as measured by McFadden's $\rho^2$, is satisfactory for Jalisco and Michoacán sites by conventional standards used to describe probabilistic discrete choice models[4] (Ben-Akiva and Lerman, 1985). Although the $\rho^2$ is low for Oaxaca the five of the six parameter coefficients are highly significant at less than 5% significance level. The ASC is negative and significant for all of the three sites implying that farmers are highly responsive to changes in choice set quality and they make decisions that are closer both to rational choice theory and the

[4] The $\rho^2$ value in multinomial logit models is similar to $R^2$ in conventional analysis, except that significance occurs at lower levels. Hensher and Johnson (1981) comment that values of $\rho^2$ between 0.2 and 0.4 are considered to be extremely good fits.

behaviour observed in reality (Dhar, 1997; Huber and Pinnell, 1994). Across the three sites the coefficient on the proxy monetary attribute, i.e. yield, is positive, as expected a priori, revealing that farmers would prefer those *milpa* profiles that provide higher levels of yield.

In Jalisco the only *milpa* attribute that affects *milpa* choice, other than yield, is crop species diversity, implying that farmers in this site demand *milpa*s mainly for the food security and diet quality they generate for the farm households. Across the three site this is the one in which farmers are least attached to their maize varieties and landraces, as observed by E. Rayn Villalba. In Michoacán, farmers prefer *milpa*s with higher levels of crop species diversity and maize landraces. However, in this site, which is the least marginalised among the three, and has the most market-integrated farmers, farmers derive negative utility from *milpa*s that are rich in maize variety diversity. Finally in Oaxaca, where transgenic constructs were identified in maize landraces, farmers derive significant disutility from *milpa* profiles with a GM variety. In this site, where farmers are attached to their maize varieties and landraces, farmers demand *milpa* profiles that are richer in maize variety diversity and maize landraces.

To test whether the CL model is appropriate, the Hausman and McFadden (1984) test for the IIA property is carried out for each site. The IIA test involves constructing a likelihood ratio test around the different versions of the model where the choice alternatives are excluded. If IIA holds then the model estimated on all choices should be the same as that estimated for a sub-set of alternatives. The results of the test for each site indicate that IIA property cannot be rejected at the 1% level. Therefore the CL model is the appropriate model for estimation of this data.

Table 4. Conditional logit estimates for *milpa* attributes by region

| Attribute | Jalisco | Michoacán | Oaxaca |
|---|---|---|---|
| | Coeff. (s.e.) | | |
| ASC | -1.38*** | -1.48*** | -0.26** |
| | (0.16) | (0.12) | (0.12) |
| Crop species diversity | 0.29*** | 0.12** | 0.04 |
| | (0.065) | (0.062) | (0.05) |
| Maize variety diversity | -0.11 | -0.24*** | 0.22*** |
| | (0.088) | (0.076) | (0.069) |
| Maize landrace | -0.060 | 0.20*** | 0.14*** |
| | (0.061) | (0.072) | (0.052) |
| GM maize | 0.013 | -0.070 | -0.11** |
| | (0.079) | (0.072) | (0.063) |
| Yield | 0.031*** | 0.019*** | 0.030*** |

| | | | |
|---|---|---|---|
| | (0.004) | (0.003) | (0.003) |
| Sample size | 708 | 984 | 794 |
| $\rho^2$ | 0.181 | 0.316 | 0.095 |
| Log likelihood | -637.20 | -739.64 | -787.82 |

Source: Encuesta percepciones del productores de maíz en comunidades rurales con respecto a la liberación de materiales transgénicos dentro de alimentos y cultivos, y su impacto en la diversidad de su cultivo. Programa de Bioseguridad GEF/CIBIOGEM-INE, 2004. (*)10% significance level; (**)5% significance level; (***)1% significance level two-tailed tests.

*4.2. Random Parameter Logit Model*

As explained in section 2, even if the CL model employed to estimate the present data does not violate the IIA property, it assumes homogeneous preferences across farmers within each site. In order to investigate whether or not the data exhibits unobserved unconditional heterogeneity the random parameter logit (RPL) model is estimated using LIMDEP 8.0 NLOGIT 3.0. All of the *milpa* attributes except the proxy monetary attribute, yield, were specified to be normally distributed (Train, 1998; Revelt and Train, 1998; Morey and Rossmann, 2003; Carlsson *et al.* 2003), and distribution simulations were based on 500 draws. The results are reported in Table 5.

For two of the three sites, namely Jalisco and Oaxaca, the Swait-Louviere log likelihood ratio tests reject the null hypothesis that the regression parameters for the CL and RPL models are equal at 0.5% significance level. Hence improvement in the model fit can be achieved with the use of the RPL model for these two sites. In Jalisco, the crop species diversity attribute has significant standard deviation, which supports large degree of variability around the utility levels with some farmers perhaps having preferences for lower levels of crop species diversity. Even though the maize landrace attribute has insignificant effect on average farmer utility, its standard deviation is significant and large, implying that some farmer might have preferences for maize landraces.

In Oaxaca, the RPL model reveals higher levels of maize variety diversity and landrace affect utility positively and significantly, whereas higher levels of crop species diversity affect utility negatively and significantly. The insignificant parameter on the standard deviation of the crop species diversity attribute reveal that every farmer in this site derives negative utility from higher levels of this attribute. Similarly the insignificant parameter on the standard deviation of the maize landrace attribute reveal that all the farmers in this site derive positive utility from having a maize landrace in their *milpa*. The standard deviation parameter on the maize variety diversity attribute is significant and large, indicating that although there is some degree of variability around the utility levels for this attribute, all farmers in this site prefer higher levels of maize variety diversity. Although the GM maize variety attribute has insignificant effect on the utility derived from a milpa, the standard deviation parameter on this attribute exhibits a high level of variability, with some farmers perhaps having preferences for a *milpa* with a GM maize variety.

For Michoacán site the RPL model resulted in significant standard deviations only for the maize landrace attribute, indicating that the data support the presence of choice-specific, unconditional, unobserved heterogeneity in preferences only for this attribute. The standard deviation parameter on the maize landrace attribute exhibits a high level of variability, with some farmers perhaps having preferences for a *milpa* without a maize landrace. The log-likelihood ratio test fails to reject the null hypothesis that the RPL and CL model estimates are equal at 20% significance level. In this site, therefore, allowing for unconditional heterogeneity by using the RPL model makes little difference to preference estimates. On the basis of this test it can be concluded that the CL model is appropriate for analysis of the data from Michoacán site.

Table 5. Random Parameter Logit estimates for *Milpa* attributes by region

| Attribute | Jalisco | | Michoacán | | Oaxaca | |
|---|---|---|---|---|---|---|
| | Coeff. (s.e.) | Coeff. s.d. (s.e.) | Coeff. (s.e.) | Coeff. s.d. (s.e.) | Coeff. (s.e.) | Coeff. s.d. (s.e.) |
| ASC | -2.03*** (0.29) | - | -1.55*** (0.14) | - | -0.20* (0.12) | - |
| Crop species diversity | 0.35*** (0.095) | 0.68** (0.42) | 0.13*** (0.069) | 0.006 (0.16) | -0.17** (0.09) | 0.068 (0.21) |
| Maize variety diversity | -0.045 (0.12) | 0.012 (0.24) | -0.25*** (0.084) | 0.014 (0.30) | 0.65** (0.12) | 0.55** (0.33) |
| Maize landrace | -0.055 (0.11) | 1.32*** (0.30) | 0.39*** (0.13) | 0.77*** (0.22) | 0.47*** (0.11) | 0.031 (0.72) |
| GM maize | 0.057 (0.11) | 0.085 (0.49) | -0.12* (0.0) | 0.014 (0.36) | -0.099 (0.16) | 2.60** (0.63) |
| Yield | 0.047*** (0.008) | - | 0.021*** (0.004) | - | 0.047*** (0.006) | |
| Sample size | 708 | | 984 | | 792 | |
| $\rho^2$ | 0.195 | | 0.319 | | 0.119 | |
| Log likelihood | -626.04 | | -736.32 | | -766.90 | |

Source: Encuesta percepciones del productores de maíz en comunidades rurales con respecto a la liberación de materiales transgénicos dentro de alimentos y cultivos, y su impacto en la diversidad de su cultivo. Programa de Bioseguridad GEF/CIBIOGEM-INE, 2004. (*)10% significance level; (**)5% significance level; (***)1% significance level two-tailed tests.

*4.3. Random Parameter Logit and Conditionl Logit Models with Interactions*

Even though the RPL can incorporate and account for heterogeneity by allowing model parameters to vary randomly over the individuals (e.g., Train 1997; 1998), it is not well suited to explaining the *sources* of heterogeneity in preferences. In many cases these sources relate to the characteristics of the individuals (Boxall and Adamowicz, 2002). Consequently, five farmer specific characteristics, i.e., years of experience in farming, family size, off farm employment, *milpa* sales and maize area, as reported in Table 3[5], are interacted with the five *milpa* attributes in order to investigate the possible sources of heterogeneity (i.e., equation 6 above). As in section 4.2., all of the *milpa* attributes except yield, were specified to be normally distributed, and distribution simulations were based on 500 draws. Interactions that are significant at 10% significance level and less are reported for each site in Tables 6 through 8.

For Jalisco site, the Swait-Louviere log likelihood ratio tests reject the null hypothesis that the regression parameters for the RPL model and RPL model with interactions are equal at 0.5% significance level. Hence improvement in the model fit can be achieved with the use of the farmer specific characteristics, which is also supported by the higher $\rho^2$. The results are reported in Table 6. The RPL model with interactions reveals that even though farmers derive positive utility from crop species diversity on average, the significant and high standard deviation parameter of this attribute reveal that some farmers might derive negative utility from higher levels of crop species diversity. The insignificant standard deviation parameter of the maize variety diversity attribute indicate that on average farmers in this site derive positive utility from higher levels of maize variety diversity. Even though the coefficient on the maize landrace attribute is insignificant and negative, its standard deviation parameter is significant and large, implying that some farmers in this site might derive positive utility from landraces of maize. Finally, the coefficient on GM maize attribute is negative and significant, and its significant standard deviation parameter indicate that there is a high variation in preferences for this attribute, and some farmers might prefer *milpa*s with GM maize varieties.

[5] Correlations and multicollinearity between these farmer characteristics were tested using correlation matrices and calculating Variance Inflation Factors (VIF) for each variable, and no evidence of multicollinearity or correlation between these characteristics were found.

The interaction results reveal that more experienced, i.e., older farmers prefer *milpa*s that have lower levels of crop species diversity, maize vareity diversity and yield. Those farm households that sell at least some of their *milpa* produce prefer *milpa*s with higher levels of crop species diversity and maize landrace. Those farm households that are larger in size, integrated into labour markets, as well as those that sell some of their *milpa* produce demand *milpa*s with GM maize variety. Farm families that are larger, however, prefer to manage *milpa*s that are less diverse in terms of crop species diversity. Finally, those farm households that manage larger maize fields prefer *milpa*s with fewer maize varieties and lower yields.

Table 6. Random parameter logit with interactions estimates for Jalisco

| Variable | Coeff. (s.e) | Coeff. S.d. (s.e.) |
|---|---|---|
| ASC | -1.96*** (0.42) | - |
| Crop species diversity | 0.39*** (0.47) | 1.23** (0.52) |
| Maize variety diversity | 0.78** (0.36) | 0.021 (0.31) |
| Maize landrace | -0.045 (0.14) | 1.03** (0.41) |
| GM maize | -1.52** (0.66) | 1.80** (0.75) |
| Yield | 0.091*** (0.024) | - |
| Crop species diversity * Experience | -0.023** (0.009) | - |
| Maize variety diversity * Experience | -0.02** (0.008) | - |
| Yield *Experience | -0.0005* (0.0004) | - |
| Crop species diversity *Seller | 1.49*** (0.47) | - |
| Maize landrace*Seller | 0.52** (0.29) | - |
| GM maize*Seller | 0.64* (0.4) | - |
| GM maize *Off farm employed | 0.94** (0.53) | - |
| Crop species diversity *Family size | -0.18** (0.09) | - |
| GM maize *Family size | 0.26** (0.13) | - |
| Maize variety diversity *Area | -0.028** (0.012) | - |
| Yield * Area | -0.0014**(0.0008) | - |
| Sample size | 708 | |
| $\rho^2$ | 0.252 | |
| Log likelihood | -542.44 | |

Source: Encuesta percepciones del productores de maíz en comunidades rurales con respecto a la liberación de materiales transgénicos dentro de alimentos y cultivos, y su impacto en la diversidad de su cultivo. Programa de Bioseguridad GEF/CIBIOGEM-INE, 2004. (*)10% significance level; (**)5% significance level; (***)1% significance level two-tailed tests.

For Michoacán site the Swait-Louviere log likelihood ratio tests reject the null hypothesis that the regression parameters for the CL model and CL model with interactions are equal at 0.5% significance level. Hence, similarly to the Jalisco site improvement in the model fit can be achieved with the use of the farmer specific characteristics. This result is also supported by the increase in the $\rho^2$. In this site, on average farmers demand lower levels of maize landraces, however, higher levels of crop species diversity and maize variety diversity, as well as GM maize.

Farm families who have more experienced *milpa* decision makers, who are more market integrated, i.e. sell at least some of their *milpa* produce and have at least one family member employed off farm, prefer lower levels of crop species diversity. Those with larger maize fields, however, demand *milpa*s that are richer in terms of crop species diversity. The only farm household characteristic that affects maize variety diversity significantly is the family size. Larger families, and those with at least one member employed off farm demand *milpa*s with maize landraces, whereas those with larger maize field areas do not prefer landraces. Those farm households that are larger and those that manage larger maize fields do not prefer *milpa*s with GM maize varieties. Finally, farm families that are larger, that are integrated into markets as sellers of *milpa* produce, and that manage larger field areas, prefer *milpa*s with higher yields, whereas those with at least one household member employed off farm prefer lower *milpa* yields (Table 7).

Table 7. Conditional logit with interactions estimates for Michoacán

| Variable | Coeff. (s.e) |
|---|---|
| ASC | -1.26*** (0.13) |
| Crop species diversity | 1.54** (0.70) |
| Maize variety diversity | 0.23* (0.18) |
| Maize landrace | -0.46*** (0.18) |
| GM maize | 0.38*** (0.17) |
| Yield | 0.007 (0.009) |
| Crop species diversity * Experience | -0.028** (0.015) |
| Crop species diversity * Seller | -0.34*** (0.13) |
| Yield* Seller | 0.011** (0.006) |
| Crop species diversity * Off farm employed | -0.24* (0.15) |
| Maize landrace* Off farm employed | 0.72*** (0.14) |
| Yield* Off farm employed | -0.029*** (0.008) |
| Maize variety diversity * Family size | -0.13***(0.05) |
| Maize landrace * Family size | 0.17*** (0.047) |
| GM maize * Family size | -0.12*** (0.043) |
| Yield * Family size | 0.0067*** (0.0024) |
| Crop species diversity *Area | 0.027** (0.014) |
| Maize landrace*Area | -0.024** (0.01) |
| GM maize*Area | -0.023** (0.01) |
| Yield *Area | 0.0012** (0.0006) |
| Sample size | 984 |
| $\rho^2$ | 0.363 |
| Log likelihood | -688.95 |

Source: Encuesta percepciones del productores de maíz en comunidades rurales con respecto a la liberación de materiales transgénicos dentro de alimentos y cultivos, y su impacto en la diversidad de su cultivo. Programa de Bioseguridad GEF/CIBIOGEM-INE, 2004. (*)10% significance level; (**)5% significance level; (***)1% significance level two-tailed tests.

Finally the results for Oaxaca site are reported in Table 8. Similarly to the other sites the Swait-Louviere log likelihood ratio tests reject the null hypothesis that the regression parameters for the RPL model and RPL model with interactions are equal at 0.5% significance level. Therefore improvement in the model fit can be achieved with the use of the farmer specific characteristics. The $\rho^2$ of the RPL model with interactions, is also higher than that of the RPL model. The results for this model are reported in Table 8. Farmer demand for crop species diversity is significant and negative, and the standard deviation parameter is insignificant revealing that on average farmers derive negative utility from this attribute. Farmers in this site demand maize variety diversity significantly and positively, although there is some variation in the level of demand, as represented by its significant standard deviation parameter. Farmer demand for GM maize is insignificant in this model, however the high and significant standard deviation parameter reveal that there is considerable variability among Oxacan farmers for demand for this attribute.

In this site, larger farm families prefer *milpa*s with higher levels of crop species diversity and maize landraces. Those farm families with at least one family member working off farm prefer *milpa*s without maize landrace and with lower levels of maize variety diversity and yield. These families also do not demand GM maize varieties on *milpa*s. *Milpa* decision makers with higher years of experience prefer those *milpa*s that have lower yields and fewer maize varieties. Finally, farm families who cultivate larger maize areas prefer fewer maize varieties on *milpa*s, whereas those that sell at least some of their *milpa* produce in the market prefer *milpa*s that yield more maize.

Table 8. Random parameter logit with interactions estimates for Oaxaca

| Variable | Coeff. (s.e) | Coeff. S.d. (s.e.) |
|---|---|---|
| ASC | -0.35** (0.18) | - |
| Crop species diversity | -0.48*** (0.17) | 0.11 (0.26) |
| Maize variety diversity | 2.46*** (0.47) | 0.58* (0.37) |
| Maize landrace | 0.18 (0.20) | 0.24 (0.53) |
| GM maize | 0.27 (0.23) | 3.26*** (0.75) |
| Yield | 0.088*** (0.016) | - |
| Maize variety diversity *Experience | -0.017*** (0.007) | - |
| Yield * Experience | -0.0005* (0.0003) | - |
| Yield* Seller | 0.027*** (0.009) | - |
| Maize variety diversity *Off farm | -1.23*** (0.24) | - |
| Maize landrace*Off farm | -0.28* (0.19) | - |
| GM maize*Off farm | -1.16** (0.47) | - |
| Yield *Off farm | -0.038*** (0.01) | - |

| | | |
|---|---|---|
| Crop species diversity *Family size | 0.061* (0.045) | - |
| Maize variety diversity *Family size | -0.14** (0.068) | - |
| Maize landrace*Family size | 0.14** (0.064) | - |
| Maize variety diversity *Area | -0.27*** (0.081) | - |
| Sample size | 792 | |
| $\rho^2$ | 0.178 | |
| Log likelihood | -715.16 | |

Source: Encuesta percepciones del productores de maíz en comunidades rurales con respecto a la liberación de materiales transgénicos dentro de alimentos y cultivos, y su impacto en la diversidad de su cultivo. Programa de Bioseguridad GEF/CIBIOGEM-INE, 2004. (*)10% significance level; (**)5% significance level; (***)1% significance level two-tailed tests.

### *4.4. Welfare Estimates*

The CE method is consistent with utility maximisation and demand theory (Bateman *et al.* 2003), therefore when the parameter estimates are obtained by the use of the most appropriate model, welfare measures can be estimated using the following formula:

$$CS = \frac{\ln \sum_i \exp(V_{i1}) - \ln \sum_i \exp(V_{i0})}{\alpha} \tag{7}$$

where CS is the compensating surplus welfare measure, $\alpha$ is the marginal utility of income (represented by the coefficient of the monetary attribute in the choice experiment, which is yield in this case) and $V_{i0}$ and $V_{i1}$ represent indirect utility functions before and after the change under consideration. For the linear utility index the marginal value of change in a single *milpa* attribute can be represented as a ratio of coefficients, which represents the marginal rate of substitution between yield and the *milpa* attribute in question, or the marginal welfare measure (willingness to pay or willingness to accept) for a change in any of the attributes. For the crop species diversity and maize variety diversity attributes equation (7) reduces to part-worth (or implicit price) formula

$$W = -1\left(\frac{\beta_{attribute}}{\beta_{monetary\,variable}}\right) \tag{8}$$

For the effects coded binary *milpa* attributes (i.e., maize landrace and GM maize) the marginal implicit price formula becomes (see, Hu *et al.*, 2004):

$$W = -2\left(\frac{\beta_{attribute}}{\beta_{monetaryattribute}}\right) \tag{9}$$

The demand functions conditional on the farm household characteristics reported in Tables 6 through 8 can be used to calculate the value assigned by the farm household to each *milpa* attribute (Scarpa *et al.* 2003a, Birol *et al.*, forthcoming), by modifying Equation (8):

$$W = -1\left(\frac{\hat{\beta}_{attribute} + \delta_{atribute} \times S_1 ... + \delta_{attribute} \times S_5}{\hat{\beta}_{monetaryattribute} + \delta_{monetaryatribute} \times S_1 + ... + \delta_{monetaryattribute} \times S_5}\right) \quad (8')$$

and Equation (9) to

$$W = -2\left(\frac{\hat{\beta}_{attribute} + \delta_{atribute} \times S_1 ... + \delta_{attribute} \times S_5}{\hat{\beta}_{monetaryattribute} + \delta_{monetaryatribute} \times S_1 + ... + \delta_{monetaryattribute} \times S_5}\right) \quad (9')$$

Variables $S_{1-5}$ are the five farmer specific characteristics under consideration. Using Wald Procedure (Delta method) in LIMDEP farm households' valuation of *milpa* attributes are calculated and these are reported in Table 9, for the regional average of farmer characteristics and for four household types. These household types include average household characteristics of 1) those with at least one family member working off farm; 2) those who sell at least some of their *milpa* produce in the markets; 3) those who have at least one family member working off farm and sell at least some of their *milpa* produce in the markets; and 4) those who are autarkic, i.e., not integrated into *milpa* output or labour markets.

The results reveal that on average farm households in Jalisco and Michoacán derive positive values from crop species diversity on *milpa*s, whereas the opposite is true for Oaxaca where farmers value maize landraces and maize variety diversity positively and highly. The average farm household in Michoacán, the most economically developed site among the three, also value maize landrace positively, however maize variety diversity negatively.

In Jalisco and Michoacán sites, the households that are integrated into labour markets do not derive significant values from *milpa* attributes. In Oaxaca labour market integrated farmers still value maize landraces positively, although their valuation of crop species diversity and GM maize cultivation on *milpa*s is negative, and the latter considerably high.

Across the three sites none of the farm households that sell at least some of their *milpa* produce value GM maize variety significantly, whereas all of them value maize landrace cultivation significantly and positively. Seller households in

Michoacán and Oaxaca derive negative values from crop species diversity, whereas those from Jalisco, the most economically marginalised site, derive positive and high values from crop species diversity. Finally Oaxacan farmers that are integrated into markets as sellers derive positive utility from maize variety diversity, revealing once again the importance of maize diversity in this region.

Oaxacan farm households that are integrated into markets as sellers of both labour and *milpa* produce do not derive significant values from *milpa* attributes. In Jalisco and Michoacán, however, these households derive positive and high values from crop species diversity. They also value GM maize variety positively, however, Jalisco farmers' valuation is considerably higher than those in Michoacán. Finally, market integrated farmers in Jalisco value landraces positively, whereas those in Michoacán derive high negative values from them.

In Jalisco and Michoacán, the autarkic farmers, i.e., those that are not integrated to output and labour markets, value GM maize variety negatively, whereas this attribute has insignificant value in Oaxaca. Autarkic farmers in Oaxaca derive positive values from maize variety and genetic diversity, however their valuation of crop species diversity is negative.

Table 9. Farm family types' valuation of *milpa* attributes by site as % change in yield

| | Regional Average | Off farm employed | Seller | Seller & off farm employed | Autarkic |
|---|---|---|---|---|---|
| Jalisco | | | | | |
| Crop species diversity | -8.6 | -- | -23.83 | -25.12 | -- |
| Maize variety diversity | --* | -- | -- | -- | -- |
| Maize landrace | -- | -- | -15.6 | -14.96 | -- |
| GM maize | 14.84 | -- | -- | -32.68 | 26.94 |
| Michoacán | | | | | |
| Crop species diversity | -4.94 | -- | 7.59 | -24.02 | -- |
| Maize variety diversity | 11.15 | -- | -- | -- | -- |
| Maize landrace | -25.12 | -- | -3.22 | 127 | -- |
| GM maize | 10.88 | -- | -- | -0.56 | 5.4 |
| Oaxaca | | | | | |
| Crop species diversity | 5.47 | 7.7 | 6.57 | -- | 4.2 |
| Maize variety diversity | -15.40 | -- | -23.28 | -- | -17.35 |
| Maize landrace | -20.84 | -17.78 | -27.96 | -- | -16.38 |
| GM maize | -- | 47.16 | -- | -- | -- |

*-- indicates that the Wald procedure resulted in insignificant welfare estimates for this attribute.

## 5. Conclusions and Policy Implications

This paper estimated the private economic use value of agrobiodiversity attributes and the option to cultivate GM maize variety in Mexican *milpa*s. Data were collected in personal interviews with a sample of 414 *milpa* farmers in three purposively selected sites. The choice experiment method was applied to investigate farmers' valuation of the *milpa* conditional on the characteristics of the sites and of the farm families. This study reveals that the choice experiment method can be successfully employed in a developing country with careful construction of the choice sets and effective field data collection (Othman *et al.*, 2004).

Findings support that overall *milpa* cultivation is an important economic activity in the three sites, as represented by farmers' highly significant demand for higher levels of maize yield from their *milpa*s. Farmer valuation of the various *milpa* attributes, however, exhibits a great deal of heterogeneity both across and within the sites. Overall, the inter crop diversity attribute (i.e., crop species diversity in the *milpa*, which consists of intercropping of maize, beans and squash) is valued most highly by the farm households in Jalisco, the most economically and geographically marginalized region, where households are located far from markets and are least market integrated among the three sites. Intra crop diversity (i.e. maize variety diversity) attribute is valued most highly by Oaxacan farmers on average, who also value maize genetic diversity embodied in maize landraces, regardless of the market integration level of the households. On average farmers in Michoacán, where about 90% of the farmers cultivate a maize landrace variety, value maize landraces the most across the three sites. However those Michoacán farmers who are fully integrated into output and labor markets derive the highest level of disutility from maize landrace cultivation across the three sites.

The option to cultivate a GM maize variety is valued positively by those farm households that are fully integrated into output and labor markets in Jalisco and Michoacán. Especially those farm families in Jalisco, who own the largest maize fields across the three sites and are also least attached to their maize landraces, value the option to cultivate a GM maize variety considerably highly. Autarkic, i.e. more traditional farmers in Jalisco and Michoacán, however, derive disutility from the GM maize attribute, whereas in Oaxaca, the region in which transgenic constructs were found in maize landraces, only the farm households that are integrated into labor markets derive significant and negative utility from this attribute.

The farmers that derive the highest private economic values from the agrobiodiversity components of the *milpa*s would constitute the least-cost targets for *in situ* conservation on farm programmes. The locations and characteristics of those of farm households who value the option to cultivate GM maize the most are also identified. These findings could aid in assessing the potential diffusion and impact of liberation of GM maize to the environment, as well as to farmers' welfare.

## 6. References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## 7. Acknowledgements

We gratefully acknowledge the financial support Instituto Nacional de Ecología of México (INE) and Programa de las Naciones Unidas para el Desarrollo (PNUD) as part of the Project GEF-CIBIOGEM.