FARMER PREFERENCES FOR MILPA DIVERSITY AND GENETICALLY MODIFIED MAIZE IN MEXICO: A LATENT CLASS APPROACH

Ekin Birol [1], Eric Rayn Villalba [2] and Melinda Smale

[1] Contact author: Homerton College and Department of Land Economy, University of Cambridge, Hills Road, Cambridge CB2 8PH, UK. E-mail: eb337@cam.ac.uk

[2] Department of Geography, University College London, UK.

[3] International Food Policy Research Institute, USA.

Abstract:

Mexico is the centre of origin of maize. Maize is typically grown as part of a set of associated crops and practices called the *milpa* system, an ancient mode of production that is practiced today in ways that vary by cultural context and agro-environment. We use a choice experiment to estimate the farmers' valuation of three components of agrobiodiversity: crop species richness, maize variety richness and maize landraces. We include the option to cultivate genetically modified (GM) maize. Data were collected from 420 farm households across three states of Mexico. We analyze the heterogeneity of farmer preferences with a latent class model, which enables us to identify the characteristics of farmers who are most likely to continue growing maize landraces, as well as those least likely to accept GM maize. Findings have implications for debates concerning the use of GM maize in Mexico and the design of on-farm conservation programmes.

Summary:

Mexico is the centre of origin of maize, the most globally important staple crop after wheat. Maize is typically grown as part of a set of associated crops and practices called the *milpa* system, an ancient mode of production that is practiced today in ways that vary by cultural context and agro-environment. *Milpa*s generate both private economic value, in terms of food security, diet quality and livelihoods, to the two million farm households who manage them, as well as public economic value, in terms of conservation of agrobiodiversity, especially of maize landraces, which have the potential to contribute unique traits needed by plant breeders for future crop improvement, contributing to global food security in maize. Sustainability of the *milpa* system is threatened by the off-farm employment opportunities, especially, long-distance migration; increasing commercialisation and intensification of maize production, and most recently, by the contamination of the maize landraces by genetically modified (GM) maize, cultivation of which is currently prohibited in Mexico. We employ a choice experiment to estimate the farmers' valuation of three components of agrobiodiversity: crop species richness, maize variety richness and maize landraces. We include the option to cultivate GM maize. Choice experiment data, as well as household level social, economic and demographic data; community level economic development data; and data on *milpa* production characteristics, and farmers' attitudes and perceptions with regards to GM food and crops were collected from 420 farm households across 17 communities in three states of Mexico. We analyze the heterogeneity of farmer preferences with a latent class model, which can simultaneously identify the segments in the sample with homogenous preferences for *milpa* attributes, and the farmer characteristics, which affect preferences. By the use of this method we identified the characteristics of farmers who are most likely to continue growing maize landraces and managing *milpa* systems, as well as those least likely to accept GM maize. Specifically, three distinct segments of farmers are identified: (i) *Landrace* *conservationists*, derive the highest private economic value from continued management of landraces, and the highest economic loss from the possible adoption of GM maize. These farmers are young; dislike GM foods and crops, and are mainly located in the Oaxaca site, where transgenic constructs in maize landraces were found. (ii) *Milpa Diversity Managers*, derive the highest economic value from managing all of the agrobiodiversity components of the *milpa*, however, lower loss from management of GM maize. These are older farmers, who are curious and like to experiment with maize varieties. (iii) *Marginalised Maize Producers,* derive insignificant values from crop species and maize variety richness, the lowest value from maize landraces, and the lowest loss from the adoption of GM maize. These farmers are located in the most isolated communities; have the lowest level of productivity, and the largest *milpa* areas. They are also most integrated into maize output markets. Findings have implications for debates concerning the adoption of GM maize in Mexico and associated costs and benefits, as well as for the design of targeted, cost-effective on-farm conservation programmes.

Word count for the main body of text: 7615 words

1. Introduction

The Mexican *milpa* system refers in most general terms to a complex combination of agronomic practices, crop associations and rotation sequences. Ancient in origin, the system is now practiced in ways that vary widely in form from one agro-environment or cultural context to another. The most fundamental components of the system are a cluster of maize, bean, and squash landraces planted in association. Several maize landraces are typically grown, some more extensively cultivated than others, each corresponding to specific consumption, soils and agronomic needs of the farm family. Approximately 2 million farm households across Mexico continue to cultivate *milpa*s on around 6 million hectares of land every year, and most are dependent on their *milpa* produce for their food security, diet quality and livelihoods (Bellon and Berthaud, 2004).

Clearly, the maize-based *milpa* systems of Mexico continue to generate private benefits for the farm families who manage them, but they also generate public economic value of global importance. These systems are considered to be one of the last reservoirs of maize genetic resources for humanity (Bellon and Berthaud, 2004). *Milpa* systems are a poly-cropping system that is characterized by species and variety richness as well as genetic diversity, particularly in maize landraces[1] (Roseland, 2002; Bellon and Berthaud, 2004; Van Dusen and Taylor, 2005). Maize landraces found in these systems have the potential to contribute unique traits needed by plant breeders (e.g., genetic resistance to certain plant diseases, pests and abiotic stresses) for future crop improvement, thereby contributing to

---

[1] Definitions of crop landraces are numerous in the international scientific literature (Zeven, 1998). Landraces are often called traditional varieties or local varieties. Landraces are simply understood as variants, varieties, or crop populations, 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.

global food security in maize, the most globally important staple crop after wheat (Kloppenburg, 1988; Harlan, 1992; Fowler and Hodgkin, 2004).

Despite general recognition of these points, there is considerable uncertainty with regards to the sustainability of *milpa* management in Mexico (Van Dusen and Taylor, 2005). Off-farm employment, and in particular, long-distance migration compete with the use of labour and transmission of knowledge in the *milpa* system (Taylor et al., 1999; Taylor and Martin, 2000; Bellon, 2004; Van Dusen, 2006). In zones with higher potential productivity, the continued management of *milpa* systems is also threatened by the increasing commercialisation and intensification of maize production (Bellon, 2004). Moreover, because maize is a cross-pollinating species, there are potential hazards to maize-based systems from the introduction of genetically modified (GM) maize varieties. Bellon and Berthaud (2004) argue that as long as Mexican farmers continue to manage their maize landraces as open, dynamic systems, the cultivation of GM maize poses little direct threat to landraces from a biological standpoint. Nonetheless, they conclude that high rates of gene flow in this heavily cross-pollinating species, combined with the continual mixing and exchange of seed, could create situations that have not yet been considered in the biosafety assessments conducted in the commercial farming systems for which GM maize was developed. Although cultivation of GM crops is currently prohibited in Mexico, presence of transgenic constructs was reported in maize landraces in the state of Oaxaca in 2001(Dalton, 2001). Since then, the potential effects of transgenic maize on traditional varieties of maize and other crop genetic resources in Mexico 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 the *milpa* system, as well as the option to cultivate GM maize in this system. The agrobiodiversity components include: crop species richness (maize, beans, and squash); maize variety richness; cultivation of a maize landrace; and the option to grow GM maize. Generally, these agrobiodiversity components are not traded in markets (Van Dusen and Taylor, 2005). Cultivation of GM maize is currently prohibited in Mexico. Thus, we apply a stated preference, non-market valuation method, namely the choice experiment approach, which enables estimation of farmers' valuation of agrobiodiversity components, as well as their implied rankings (Hanley *et al.,* 1998; Bateman *et al.*, 2003). Moreover, this method, which is based on farmers choosing between hypothetical *milpa* profiles, 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).

Data were collected from 420 farm households across three states of Mexico (Jalisco, Michoacán and Oaxaca). The heterogeneity of farmer preferences across cultural contexts and agro-environments has been analyzed explicitly with a latent class model. Application of the latent class model has enabled us to identify the characteristics of farmers who are most likely to continue growing maize landraces and managing traditional *milpa* systems rich in agrobiodiversity components, as well as those least likely to accept GM maize. Recognition of the heterogeneity of farmer preferences is important for estimating unbiased models and accurately predicting the benefits and costs of agrobiodiversity management and GM maize adoption in the *milpa* system of Mexico.

This paper contributes to the literature in three ways. First, only a few applied economics studies have investigated the determinants of *milpa* and maize diversity in Mexico, and these have been based on the theoretic framework of the household farm (Smale *et al.*, 2001; Van Dusen and Taylor, 2005). Second, this study adds to the growing literature that employs the choice experiment method to estimate farmer valuation of various components of agrobiodiversity (Scarpa *et al.*, 2003a, b; Ndjeunga and Nelson, 2005; Ruto, 2005; Birol *et al.*, 2006a). Third, it contributes to an emerging literature that employs the choice experiment method to value non-market goods in developing country contexts (Scarpa *et al.*, 2003a, b; Othman *et al.*, 2004; Ndjeunga and Nelson, 2005; Ruto, 2005).

The next section presents the theoretical framework and explains the choice experiment design. Section 3 describes the sites, data collection, and calculation of indices used in the analysis. Section 4 reports and discusses the econometric results. The final section draws conclusions and discusses policy implications.

2. The Choice Experiment Method

2.1. Theoretical Framework

The choice experiment approach has a theoretical grounding in Lancaster's model of consumer choice (Lancaster, 1966), and an econometric basis in models of random utility (Luce, 1959; McFadden, 1974). Lancaster proposed that consumers derive satisfaction not from goods themselves but from the attributes they provide.

The random utility approach is the theoretical basis for integrating behaviour with economic valuation in the choice experiment. In this approach, the utility of a choice is comprised of a deterministic component and an error component, which is independent of the deterministic part and follows a predetermined distribution. The error component implies that predictions cannot be made with certainty. Choices made among alternatives will be a function of the probability that the utility associated with a particular option is higher than that associated with other alternatives.

Earlier applications of the approach assumed homogeneous preferences across respondents, though preferences are in fact heterogeneous. Accounting for heterogeneity enables estimation of unbiased estimates of individual preferences, enhancing 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. Information on who will be affected by a policy change and the aggregate economic value associated with such changes is necessary for making efficient and equitable policies (Boxall and Adamowicz, 2002).

The latent class model (LCM) is one of the most recent models that has been employed to investigate preference heterogeneity. The LCM casts heterogeneity as a discrete distribution, a specification based on the concept of endogenous (or latent) preference segmentation (Wedel and Kamakura, 2000). The approach depicts a population that consists of a finite and identifiable number of segments, or groups of individuals. Preferences are relatively homogeneous within segments but differ substantially from one segment to another. The number of segments is determined endogenously by the data. Belonging to a specific segment is probabilistic, and depends on the social, economic, and demographic characteristics of the respondents, as well as their perceptions and attitudes. Respondent characteristics affect choices indirectly through their impact on segment membership. This method has recently been employed in the agricultural context by Scarpa *et al.* (2003a) for valuation of pig attributes in Mexico, and by Ruto (2005) for valuation of cattle attributes in Kenya. Hu *et al.* (2004), Owen *et al.* (2005) and Kontoleon and Yabe (2006) have employed the LCM to investigate the consumers' demand for GM food in Canada, Australia and the UK, respectively.

Formally, in the LCM employed here, the utility that the farmer *i,* who belongs to a particular segment *s,* derives from choosing *milpa* alternative $j \in C$ can be written as

$$U_{ij/s} = \beta_s X_{ij} + \varepsilon_{ij/s}, \tag{1}$$

where X_{ij} is a vector of attributes associated with *milpa* alternative *j* and farmer *i,* and β_s is a segment-specific vector of taste parameters. The differences in β_s vectors enable this approach to capture heterogeneity in preferences for the *milpa* attributes across segments. Assuming that the error terms are identically and independently distributed and follow a Type

I (or Gumbel) distribution, the probabilistic response function is given by:

$$P_{ij/s} = \frac{\exp(\beta_s X_{ij})}{\sum_{h=1}^{C} \exp(\beta_s X_{ih})} \qquad (2)$$

Consider a segment membership likelihood function M* that classifies the farmer into one of the *S* finite number of latent segments with some probability P_{is}. The membership likelihood function for farmer *i* and segment *s* is given by $M_{is}^* = \lambda_s Z_i + \xi_{is}$, where *Z* represents the observed characteristics of the farmer, such as their social, economic, and demographic characteristics, their perceptions and attitudes, and the agro-ecologies in which they farm. Assuming the error terms in the farmer membership likelihood function are independently identically distributed across farmers and segments, and follow a Gumbel distribution, the probability that farmer *i* belongs to segment *s* can be expressed as

$$P_{is} = \frac{\exp(\lambda_s Z_i)}{\sum_{k=1}^{S} (\lambda_k Z_i)}, \qquad (3)$$

where $\lambda_k (k = 1,2,...S)$ are the segment-specific parameters to be estimated. These denote the contribution of the various farmer characteristics to the probability of segment membership. A positive (negative) and significant λ implies that the associated farmer characteristic, Z_i, increases (decreases) the probability that the farmer *i* belongs to segment *s*. P_{is} sums to one across the S latent segments, where $0 \le P_{is} \le 1$.

In order to derive a mixed-logit model that simultaneously accounts for *milpa* choice and segment membership, (2) and (3) are brought together. The joint probability that individual *i* belongs to segment *s* and chooses *milpa* alternative *j* is given by:

$$P_{ijs} = (P_{ij/s}) * (P_{is}) = [\frac{\exp(\beta_s X_{ij})}{\sum_{h=1}^{C} \exp(\beta_s X_{ij})}] * [\frac{\exp(\lambda_s Z_i)}{\sum_{k=1}^{S} \exp(\lambda_k Z_i)}]. \qquad (4)$$

2.2. Choice Experiment Design

In this study, utility function (1) is associated with the preferred *milpa* alternative $j \in C$. The first step in choice experiment design is the definition of 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 Ecologia (INE, the Mexican National Institute of Ecology) experts, drawing on the results of informal interviews and workshops with *milpa* farmers in the study sites, and a thorough review of previous research on *milpa* management (Bellon and Brush, 1994; Louette *et al.*, 1997; Bellon, 2004; Bellon and Berthaud, 2004). The chosen attributes and their levels are reported in Table 1.

[Table 1 around here]

The first three attributes characterize the various components of agrobiodiversity found in the *milpa*. Crop species richness refers to the count of major species cultivated in the field (maize, beans, squash). Maize variety richness refers to the number of maize varieties grown. Previous studies found that multiple maize populations still coexist in the traditional *milpa* system (Bellon and Brush, 1994; Louette *et al.*, 1997). These maize populations are not limited to landraces, but may also include modern varieties (hybrid or non-hybrid), as well as "creolized" modern varieties purposively crossed and selected by farmers (Bellon, 2004). The richness of both maize varieties and crop species should be considered when studying *milpa* management choices. This is because *milpa* diversity is an outcome of competition among, as well as within species, and hence focusing only on a single species or variety could cause biased results and misleading policy prescriptions (Van Dusen and Taylor, 2005). The third agrobiodiversity component is the presence of a maize landrace.

A fourth component included in the choice set is the option to grow GM maize. This attribute was defined by the INE scientists following various workshops they have held with farmers in Oaxaca and Michoacan sites, since 2002. The GM maize variety was defined in a simple manner, as a maize variety, which has "new genetic information". It was explained that genetic material (DNA) is similar to a book of instructions used to build living organisms such as humans, plants and animals, and biotechnology enables inserting a paragraph from the book of one organism into the book of another. The enumerators did not specify any (positive or negative) traits pertaining to GM maize, in order to not to bias farmers' choices

Maize yield is included in the choice set as a monetary proxy in order to estimate welfare changes. Maize yield was measured as the yield that the hypothetical *milpa* is expected to provide as a percentage of the yield obtained by the farmer in the previous season. This indirect measure is preferred over a direct monetary variable because for most families, maize produce from the *milpa* is not traded in markets but consumed.

A large number of unique *milpa* profiles can be constructed from attributes and levels shown in Table 1[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 the decision 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" decision 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 (Louviere *et al.*, 2000; Bennett and Blamey, 2001; Bateman *et al.*, 2003). In this study, the "opt out" decision is to continue with the current *milpa* profile rather than change to a new one. In our

[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 $3^2*2^2*5=160$.

study areas in Mexico, it is not realistic to ask farmers not to manage *milpas* at all (Louviere *et al.*, 2000). Figure 1 provides an example of a choice set.

[Figure 1 around here]

3. Data

The choice experiment survey was implemented in October and November 2004 with face-to-face interviews. A total of 420 randomly selected farm households were interviewed across 17 communities in three states of Mexico. The farmers interviewed were randomly selected from the lists of all maize producing farmers in each community, provided by the local authorities (*comisario ejidal* or *comisario de bienes comunales*).

The survey consisted of four parts. In the first three parts, information on the farmers' observed characteristics (vector *Z*) were collected. First, farmers were asked questions about their perceptions of and attitudes towards GM crops and food. Second, information on their *milpa* management practices and the agrobiodiversity managed on their *milpa*s was collected. In part three, social, demographic, and economic information on farm households and *milpa* decision-makers was collected. The final part consisted of the choice experiment. Prior to the presentation of the six choice sets, farmers were told the context in which choices were to be made and described each attribute, so as to ensure uniformity in comprehension of the attributes and their levels. The farmers were reminded that there were no right or wrong answers and that we were only interested in their opinions.

3.1. Study sites

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 eight communities of the Ixtlan de Juarez District in the state of Oaxaca (Figure 2).

[Figure 2 around here]

These three sites were selected based on several criteria. First, in all three sites, farmers practice *milpa* cultivation. According to INE's collection missions, each site is also considered to be an important centre of maize diversity in Mexico. Third, the three sites represent different agro-ecologies, patterns of participation in labour and maize markets, and levels of economic development. The Oaxaca site comprises of those communities where INE previously carried out research to investigate the claims that transgenic maize constructs had been found. The communities studied in the Michoacán site consist of those where INE held informative workshops regarding the issue of GM maize, following the discovery of transgenic maize constructs in the state of Oaxaca. The communities studied in Jalisco are all located in the southern part of the state, in the buffer zone of Biosphere Reserve Sierra de Manantlán. *Teozintle*, the nearest wild relative of maize, grows in this site. These communities were selected in order to investigate the possible impact of adoption of GM maize on *teozintle*. Characteristics of the communities in each site are reported in Table 2.

[Table 2 around here]

The total area of the site sampled in Jalisco is 1178.7 km^2. With a total population of 2452 inhabitants, this is the least densely populated of the three sites. Communities sampled in Jalisco are officially recognized as indigenous communities (*comunidades indígenas)* and have a traditional form of government (*usos y costumbres*), although the percentage of the population who speak an indigenous language is the lowest of the three sites. The unemployment rate is low in the Jalisco site, and a majority of those who are employed work in the primary sector. Across the three sites, the percentage of the active population employed in the primary sector is the highest in Jalisco, whereas the percentages of those employed in the secondary and tertiary sectors are the lowest. The percentage of adults who are illiterate is also the highest in this site. On average, the communities in this site do not have good access to commercial markets. There is only one main highway crossing the state, and the communities are linked by dirt and gravel rural roads (*terracería y brecha*). Among the sites, communities in this site are the farthest from the main highway.

The communities sampled in the Michoacán site make up an area of 434.11km², with a population of 13318 inhabitants. Michoacán is the most densely populated site. Communities included in this study have an indigenous form of government, with 13.4% of the population speaking an indigenous language. Illiterate inhabitants make up almost a fifth of the population. The unemployment rate is the highest in Michoacán. The majority of the active population is employed in the secondary sector, followed by primary and tertiary sectors. Compared to the other sites, communities in this site are nearest to the main highway.

The area of the site sampled in Oaxaca is 734.29 km^2, with a total population of 4484 inhabitants. The communities in this site also have an indigenous form of government, and over a third of the population speaks an indigenous language. The unemployment rate is lowest in this site. The highest percentage of the population is employed in the primary sector, followed by tertiary and secondary sectors. The percentage of the population who are illiterate is the lowest in this site. The average distance of communities to the main highway is larger than that of for the Michoacán site, but only about a fourth of that found in the Jalisco site.

The marginality index for the communities in each site is also reported in Table 2. Commonly used to identify inequalities and to design social programmes in Mexico, the index assesses the relative deficiencies across the communities in the country using four structural dimensions (education, housing, income from labour and population distribution) and nine variables[3] (CONAPO, 2000). According to this index, communities in Jalisco are the most marginalised and those in Oaxaca are the least marginalised.

3.2. Farm families' perceptions of and attitudes towards GM crops and food

Farmers were asked fourteen questions on their perceptions of and attitudes towards GM crops and food (Table 3), ten of which were coded according to a Likert scale. The remaining four were binary. These questions were developed in consultation with the INE experts, drawing on the results of the workshops and focus groups they have carried out with farmers in Oaxaca and Michoacán sites. Two indices, namely the Producer Perception Index (PPI) and the Consumer Perceptions Index (CPI), were derived from a factor analysis of the farmers' answers to these questions. The results of the factor analysis are reported in Table 3.

[Table 3 around here]

Factor analysis collapses the number of variables, classifying them according to their correlations and structure. Though common in social statistics, this approach has been used only recently to assess heterogeneity in stated preference methods (e.g., Boxall and Adamowicz, 2002; Nunes and Schokkaert, 2003; Birol *et al.*, 2006b; Kontoleon and Yabe, 2006). The majority of the farmers interviewed provided answers to all of the questions. However, 17% of the sample failed to respond to between one and three of the fourteen questions. Missing responses did not exhibit any systematic bias, and data were imputed using mean values (Kontoleon, 2003). 9 % of the sample (38 farmers) chose not to answer

[3] These include percentage of illiterates among population 15 years old and above; percentage of population 15 years old and above without full basic education; percentage of population that live in houses without access to tap water, sewage and toilet, electricity, with soil floor and with some degree of overcrowding; percentage of employed population with a level of income up to two minimum wages; percentage of population that live in communities with less than 5,000 inhabitants.

over three of the fourteen perceptional and attitudinal questions. Even though these missing responses did not exhibit any systematic bias, these farmers were dropped from the sample, since there was not enough data to impute values. The final sample consists of 382 farmers.

The factor analysis in this paper is undertaken using the principal factor extraction method in STATA 8.0. Factors with an eigenvalue above one were retained. Varimax rotation suggested the existence of two factors. Loadings above 0.40 were considered as factoring together (Kontoleon, 2003). The factors were named on the basis of the variables that "factored" together as well as the relative magnitude of the factor loadings in absolute terms.

The first factor, labelled "Producer Perception" (PPI) consisted of those questions that were related to farm families' attitudes and behaviour as *milpa producers.* This index included questions on introduction of GM crops; cultivation of high yielding varieties (HYVs) and landraces; acquisition of maize seed and the relationship of GM crops to the environment. The second factor, "Consumer Perceptions" (CPI), consisted of farm families' attitudes and behaviour as *consumers* of food. The questions that were grouped together included those related to taste, price, threat to family health and being informed about GM content of food. Using the factor score command in STATA 8.0, each household was assigned a value for each index. For both of the indices, higher values indicate a greater dislike of GM food and crops.

The pool and site level averages are reported for these indices in Table 4. The CPIs of farmers do not differ significantly (at a 5% significance level) among the sites. Farm families in Oaxaca site, where the transgenic maize constructs were found, have the highest PPI. Those located in Jalisco have the lowest PPI across the three sites.

[Table 4 around here]

3.3. Milpa Characteristics

Management and agrobiodiversity characteristics of *milpas* are reported for the sample of 382 farmers in Table 5.

[Table 5 around here]

There is considerable heterogeneity in *milpa* outputs and inputs across, as well as within each site. The number of crop species managed statistically differs across the three sites, with *milpa*s in Oaxaca having the highest crop species richness and Michoacán the lowest. Farm households in Jalisco manage a higher number of maize varieties compared to Michoacán, although there is no significant difference between Oaxaca and the other two sites. Over 90% of farm families across the three sites manage at least one landrace on their *milpa*, with those located in Jalisco having a lower percentage compared to Michoacán, at a 10% significance level. There is no statistically significant difference between Oaxaca and the other two sites. Finally, a significantly higher number of farm families in Michoacán manage livestock alongside crops in *milpa*s, thereby generating agro-diversity, or diversity in agricultural management practices (Brookfield and Stocking, 1999). The Oaxaca site supports the lowest percentage of farm families that manage livestock across the three sites.

Area cultivated in maize, as well as volume of maize production, are significantly larger in Jalisco, and smaller in Oaxaca. Yield per hectare is highest in Oaxaca and lowest in Michoacán. The number of *milpa* participants is significantly lower in Jalisco, compared to the other two sites, which do not differ significantly. The percentage of households that obtain labour from outside the household to help in *milpa* production is the lowest in Michoacán, and largest in Oaxaca. A significantly higher percentage of households in Oaxaca reported having *milpa*s with good quality soil, whereas this percentage is the lowest in Michoacán. Moreover, a significantly higher percentage of *milpa*s are cultivated without the use of any chemical inputs (organically) in Oaxaca compared to the other two sites, which do not significantly differ. Finally, the lowest percentage of farmers that sell some of their *milpa* produce is in the Oaxaca site, whereas twice as many farmers in Jalisco sell at least some of their *milpa* produce.

3. 4. Social, economic and demographic characteristics of farm families

The characteristics of households and decision-makers for the sample of 382 farmers are reported in Table 6.

[Table 6 around here]

Milpa decision-makers in Oaxaca have fewer years of *milpa* management experience than those in Michoacán and Jalisco, which are similar. Those in Michoacán have more education compared to those located in the other two sites, which do not differ. Households in Jalisco are significantly smaller than those located in the other sites. Households located in Oaxaca support the highest percentage of households with at least one family member working off-farm, and the highest off-farm incomes, and those located in Jaliso have the smallest percentage of households with at least one family member working off-farm, with the lowest off-farm incomes. Finally, the highest percentage of households with at least one child younger than twelve years of age is greatest in Oaxaca and the lowest in the Michoacán site.

4. Results

4.1. Coding of the Data

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, effects coded as 1 to indicate presence and -1 to indicate absence (Adamowicz *et al.*, 1994; Louviere *et al.*, 2000). Attributes with three levels (crop species richness and maize variety richness) and five levels (yield) were entered in cardinal-linear form. Consequently, crop species richness and maize variety richness took the levels 1, 2 and 3, and yield was coded as 130, 115, 100, 85 and 70. The attributes for the response '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 set equal to 1 when either *milpa* A or B was chosen and to 0 when the farmers' own *milpa* was chosen (Louviere *et al.*, 2000). In this choice experiment, the ASC was specified to account for the proportion of farmers who chose a different *milpa* system. A relatively more positive and significant ASC indicates a higher propensity for farmers to choose their own *milpas.*

4.2. Latent Class Model

To account for heterogeneity of preferences, the LCM specification included the CPI and PPI for each farmer, the marginalisation index (MI) of the farmer's community, the years of experience of the *milpa* decision-maker, and area of the *milpa*. The model was estimated using LIMDEP 8.0 NLOGIT 3.0, with two, three, four and five segments. The log likelihood, ρ^2, Bozdogan Akaike Information Criterion (AIC3) and Bayesian Information Criterion (BIC) statistics for these models are reported in Table 7.

[Table 7 around here]

Determination of the optimal numbers of segments requires a balanced assessment of the statistics reported in Table 7 (Louviere *et al.,* 2000; Wedel and Kamakura, 2000; Andrews and Currim, 2003). The log likelihood decreases and ρ^2 increase as more segments are added, indicating the presence of multiple segments in the sample. The BIC and AIC3 statistics decrease monotonically as the number of segments increases, but all four statistics the marginal effect becomes very small after the three-segment model. Both BIC and AIC3 statistics are minimized at four segments, indicating that a model with four segments is the optimal solution in this empirical application. However, Andrews and Currim (2003) have demonstrated that the BIC and AIC3 statistics never under-fit the number of segments but sometimes over-fit, and that over-fitting the true number of segments produces larger parameter bias (Andrews and Currim, 2003). Therefore, we chose the three-segment model, which is reported in Table 8.

[Table 8 around here]

The first part of Table 8 displays the utility coefficients associated with *milpa* attributes and the second part reports coefficients of membership in segments. The membership coefficients for the third segment are normalised to zero in order to identify the remaining coefficients of the model. All other coefficients are interpreted relative to this normalised segment (Boxall and Adamowicz, 2002).

For segment one, the utility coefficients reveal that higher levels of crop species richness, maize variety richness, maize yield, as well as having a landrace in the *milpa* affect utility positively and significantly. The GM maize attribute has the largest absolute size. Thus, this attribute is the most important determinant of *milpa* choice, affecting the utility of farmers negatively and highly significantly. When the yield attribute is used as the normalising variable, the most important agrobiodiversity attribute in the *milpa* is the presence of a maize landrace, followed by crop species richness and maize variety richness. The negative and significant ASC reveals that farmers in segment one are more likely to choose *milpa* profiles with higher levels of agrobiodiversity attributes than the status quo, and especially those with maize landraces.

Membership coefficients for segment one reveal that having a greater dislike of GM foods both as a producer and a consumer, as evidenced by higher CPI and PPI indices, increases the probability that a farmer belongs to this first segment. Households located in more marginalised communities, those with more experienced *milpa* decision-markers, and those with larger *milpa* areas are less likely to belong to this segment. We have labelled segment one "*Landrace conservationists*" because farmers in this segment derive highest benefits from the maize landrace attribute and ascribe the highest costs to the GM maize attribute.

For the second segment, the ranking of the attributes, as well as the sign on the ASC, change. When the yield attribute is used as the normalising variable, the most important *milpa* attribute for farm families in this segment is crop species richness, and the second most important attribute is GM maize, though this attribute affects utility a third as much as crop species diversity attribute. Maize landrace and maize variety richness affect farmer utility at only a fourth the level of crop species richness. The positive and significant ASC reveals that, unlike the farmers of segment one, farmers in this segment would be more likely to continue to manage their own *milpa* profiles.

Membership coefficients for segment two reveal that those farm households with a greater dislike of GM foods and crops (higher CPI and PPI indices) are less likely to belong to this segment. Those with larger *milpa* areas and more experienced (older) farmers are more likely to belong to segment two. We have labelled this segment "*Milpa diversity managers"* since these farmers derive positive, significant, and more equally distributed values from all agrobiodiversity components of the *milpa* compared to the *Landrace conservationists*. Interestingly, they have a less negative attitude toward GM foods and crops.

The utility coefficients for the third segment reveal that only maize landrace, GM maize and yield attributes affect utility significantly. When the yield attribute is used as the normalising variable, the GM maize attribute is a more important determinant of *milpa* choice than the maize landrace attribute. The negative and significant ASC indicates that farmers in this segment are more likely to want to change their *milpa* management practices. By comparing the ASC with this segment with that of the first segment (dividing the ASCs for each segment with the corresponding yield coefficient), it can be shown that farmers in segment three are about twice as likely to choose a *milpa* profile that differs from their own.

Segment membership coefficients of this segment can be implicitly interpreted in relations to the signs of the estimated parameters for the other two segments that are statistically significant, as long as these have the same signs in segments one and two (Kontoleon and Yabe, 2006). Consequently, farmers who are located in more marginalised communities and those who cultivate larger *milpa* areas are more likely to belong to segment three. It is likely that these households depend relatively more on their *milpa* production for subsistence, although they would prefer a change from the status quo. Accordingly, we have labelled this segment "*Marginalised maize producers.*"

4.3. Characterisation of the Segments

The relative size of each segment is estimated by inserting the estimated coefficients into equation (3), which generates the series of probabilities that each farm household belongs to each of the three segments. Farm households are then assigned to one of the segments on the basis of the largest probability score among the three segments. According to this procedure, 42.4% of the sample belongs to the first segment, 17.3% to the second and 40.3% to the third. The descriptive statistics for the characteristics of each segment are reported in Table 9.

[Table 9 around here]

Over half of the farmers in the *Landrace conservationists* segment are located in Oaxaca, over a third are located in Michoacán, and a relatively small percentage are found in the Jalisco site. Even though farmers in this segment manage the smallest *milpa* areas and have the lowest maize outputs across the three segments, their yield per hectare is the highest. A significantly lower percentage of households in this segment sell their *milpa* produce compared to the other two segments. A significantly higher percentage of *milpa*s in this segment have good soil quality compared to the other two segments. Farmers in this segment manage the highest levels of crop species richness across the three segments, though maize variety richness does not differ significantly across the segments. A statistically higher percentage of farm households in the *Landrace conservationists* segment manage at least one landrace in their *milpa*s, although the average number of landraces managed on *milpa*s is slightly less than those in the other two segments.

Household in this segment are the largest and have the highest number of *milpa* participants across the three segments. *Milpa* managers in this segment are also the youngest, least experienced and most educated across the three segments. A higher percentage of households have at least one child younger than twelve years of age, compared to the other two segments. A higher percentage of households in this segment have at least one household member working off farm, and households in this segment have the highest off farm income across the three segments. Finally, farm households in this segment are located closest to the main roads, in the least marginalized communities, across the three segments.

Almost 44% of farmers in the *Milpa diversity managers* segment are located in Jalisco, and over a third in Michoacán. The average size of the *milpa* they manage, their average output and productivity levels are between those in segments one and three. They have the smallest percentage of *milpa*s with high soil quality across the three segments and the percentage of *milpa*s managed without any chemicals is the highest across the three. The percentage of farm families that manage landraces is similar to segment one, but higher than segment three. A significantly higher proportion of farmers in this segment cross maize landraces with other maize types, indicating that they like to experiment with maize varieties. Farm families in this segment manage significantly lower levels of crop species richness compared to segment one, though similar levels to segment three. Compared to segment one, a higher proportion of farm households in segment two sell at least some of their *milpa* produce, but significantly less so compared to segment three.

Households in the *Milpa diversity managers* segment are smaller than and have fewer *milpa* participants than those in the first segment, though differences with households in segment three are not statistically significantly. Almost a third of the households have at least one family member working off-farm, and the off-farm income of the household is lower than those in segment one, but higher than those in the third segment. *Milpa* managers in this segment are the oldest, but have the least education. A significantly lower percentage of the households have at least one child residing with them. Farmers in this segment dislike GM food and crops the least. Their distance from main roads, and the marginalization index of the communities in which they live, are between those of the other segments.

Similarly to segment two, almost half of the farmers in segment three, *Marginalised maize producers*, are located in Jalisco and over a third are located in the Michoacán site. *Milpa*s in this segment are the largest and the *milpa* outputs are the highest across the three segments. Even though this segment has the lowest percentage of *milpas* produced with organic production methods, the productivity level is the lowest among the segments. A higher percentage of *milpa* producers in this segment sell their produce. A lower percentage of households have at least one member employed off-farm, and off-farm income is the lowest in this segment. Farm households in this segment are located furthest away from the main roads.

4.4. Farmer Valuation of Milpa Attributes

The marginal value of each *milpa* attribute represents the farmer's willingness to accept (WTA) compensation to forego this attribute or to adopt it. The WTA can be derived from the parameter estimates reported in Table 8, by using the following formula:

$$WTA = -\ \frac{\beta_k}{\beta_y} \qquad (5)$$

where β_y is the marginal utility of income, which is the coefficient of the monetary attribute (i.e., yield in this study). β_k is the coefficient of crop species richness or maize variety richness attributes. For the binary *milpa* attributes (maize landrace and GM maize) the marginal implicit price formula becomes (see, Hu *et al.*, 2004):

$$WTA = -2\left(\frac{\beta_l}{\beta_y}\right) \qquad (6)$$

The WTAs reported in Table 10 were estimated for each one of the three segments with the Wald Procedure (Delta Method) in LIMDEP. Figures represent the percentage of the current *milpa* yield that farmers are WTA to forego an attribute, in the case of positive WTA values, or to adopt an attribute in the case of negative WTA values.

[Table 10 around here]

Across the three segments the GM maize attribute is consistently negative and significant and the maize landrace attribute is positive and significant. The ranking of the *milpa* attributes, as well as their impact on farmer utility, varies. These results highlight the importance of analyzing the heterogeneity of farm households.

Landrace conservationists derive the highest positive values from maize landraces, and would require the highest levels of compensation to forego growing landraces. They would also need to be compensated the most to use GM maize. Farmers in the Oaxaca, the state where transgenic constructs were identified in maize landraces, are most heavily represented in this segment. Farmers in this segment also value crop species richness and maize variety richness, but to a much lesser extent.

Milpa diversity managers value all the agrobiodiversity attributes of the *milpa*, and their valuation of *milpa* attributes is more evenly distributed across attributes than that of segment one. Among attributes, they derive the highest values from crop species richness, and much lower values from a maize landrace or an additional maize variety. Compared to segment one, farmers in segment two would need to be compensated less to use GM maize.

Marginalised maize producers derive the lowest value from maize landrace cultivation in the *milpa* across the three segments. Their willingness to accept GM maize is not significantly different from *Milpa diversity managers.* Farmers in this segment do not derive any significant benefits from the attributes of crop species richness and maize variety richness. Given their marginalised locations and greater distance from food markets and lower access to off-farm income, they are more reluctant to given up higher maize yields for higher levels of crop species richness or maize variety richness.

5. Conclusions and Policy Implications

This paper has investigated farmer valuation of *milpa* diversity and GM maize in traditional *milpas* of Mexico. A choice experiment survey was conducted with a random sample of 420 *milpa* farmers in three sites of Jalisco, Michoacán and Oaxaca. Sites were purposively selected based on their importance as centres of maize diversity, *milpa* cultivation, and public concerns about the unintentional introduction of transgenic constructs. A latent class model (LCM) was estimated in order to simultaneously identify the characteristics that differentiate *milpa* producers and the values that different types of producers derive from *milpa* attributes. *Milpa* attributes included the presence of a maize landrace, GM maize, crop species richness, maize variety richness, and maize yield. Derivation of the welfare estimates from the LCM, combined with the characterisation of different producer types, enabled us to profile the farmers in the survey sites who are most likely to continue to manage *milpas* and those who would need to be compensated the least for the introduction of GM maize in Mexico.

Three segments were identified. The first, characterized as *Landrace conservationists*, value maize landraces the most and would need to be compensated the most to grow GM maize, though they manage the smallest *milpa*s. The families of these farmers are younger and larger. They are better integrated into labour markets and have the highest off-farm incomes. Most of the farmers in this segment are located in the state of Oaxaca, where the transgenic constructs were found in maize landraces. Furthermore, Oaxaca is the site with the highest percentage of population that speak an indigenous language, and previous studies have found that cultural (ethno-linguistic) diversity has a significant and positive effect on maize diversity (Brush and Perales, 2007). *Landrace conservations* also derive significant values from other agrobiodiversity attributes of the *milpa* (i.e., crop species richness and maize variety richness). Since these farmers also derive significant value from crop species richness and maize variety richness, they would be the least cost targets for maize landrace conservation within the *milpa* system where landraces historically evolved.

By comparison, *Milpa diversity managers* derive the largest values from crop species richness and maize variety richness, although they also value maize landraces. Most of these farmers are located in Jalisco, followed very closely by Michoacán. They are the oldest and most experienced *milpa* farmers, managing *milpa*s with the lowest soil quality and least use of chemicals. *Milpa diversity managers* are curious and like to experiment with maize varieties. Thus, though they express a dislike for GM maize, they are less reluctant than *Landrace conservationists* to try it. Farmers in this segment would be the least-cost targets for conservation of the *milpa* as a system. However, given that the size of this segment is less than half of segment one, focusing on these farmers would entail a less widespread conservation effort. The extent of area needed for effective conservation depends on biological considerations, and many of these farmers are located nearby or within an already protected Biosphere.

Marginalised maize producers derive the lowest values for maize landraces, and insignificant values from higher levels of crop species and maize variety richness. About 90 % of this segment comprises of farmers located in Jalisco and Michoacán. Though migration from Oaxaca has been increasing steadily, Jalisco and Michoacán have historically exhibited and continue to exhibit higher rates of migration to the United States (Canales, 2003). As suggested elsewhere (Van Dusen and Taylor, 2005; Van Dusen, 2006), a major threat to agrobiodiversity in the *milpa* system is posed by long-distance migration, as compared to local off-farm employment or regional migration.

Marginalised maize producers farm the largest *milpa* areas and harvest the most maize, but have the lowest yields. They also sell the most maize, although they are farthest from the main roads and participate least in local labour markets. Based on WTA estimates, they are the least reluctant to adopt GM maize. This is of major policy interest for two reasons. First, most of the farmers in this segment are located in the Jalisco site, where the introduction of GM maize could have serious impacts on *teozintle,* the nearest wild relative of maize. If GM maize is introduced in Mexico, farmers in this site, who are least reluctant to adopt GM maize, would need to be compensated more in order to conserve *teozintle*. Second, there are equity issues that need to be taken into consideration. In 2008, as part of the free trade agreements, the quotas and other barriers for the entry of US-grown maize into Mexico will be eliminated. It is expected that Mexican farmers will not be able to compete with the lower prices of US maize, a considerable proportion of which is GM. Farmers in this segment, therefore, might need to be compensated somehow in the case that the adoption of GM maize remains prohibited in this country.

The results of this choice experiment support the a priori assumption that the multiple attributes of the *milpa* production system, especially maize landraces, provide private benefits to farm households in the sites studied. However, the findings also demonstrate the heterogeneity in preferences among Mexican farmers. This heterogeneity should be taken into consideration when designing programmes to conserve maize-based systems in Mexico, as well as when estimating the losses and gains to farmers from the introduction of GM maize.

6. Acknowledgements

We gratefully acknowledge the financial support Instituto Nacional de Ecología of Mexico (INE) and Programa de las Naciones Unidas para el Desarrollo (PNUD) as part of the Project GEF-CIBIOGEM. We are indebted to Patricia de Anda Hurtado, Dilhery Oros Nakamura, Saúl Castañeda Contreras, Gloria Miranda Herrera and Rafael Pompa Vargas for data collection; to Sol Ortiz García and Jose Carlos Fernández Ugalde for survey design, and to Javier Miranda Arana for providing us with the secondary data. We would like to thank Svetlana Edmeades, Andreas Kontoleon, Unai Pascual, Eric Ruto and the participants of the 3rd World Congress of Environmental and Resource Economists, held in Kyoto, Japan, July 3-7, 2006, for useful comments, suggestions and fruitful discussions.

7. References

Adamowicz, W.L., J. Louviere and M. Williams. (1994), 'Combining Stated and Revealed Preference Methods for Valuing Environmental Amenities', *Journal of Environmental Economics and Management,* **26**: 271-292.

Andrews, R. L., and I. S. Currim (2003), 'A comparison of segment retention criteria for finite mixture logit models', *Journal of Marketing Research*, **40**(2): 235– 243.

Bateman, I.J., Carson, R.T., Day, B., Hanemann, W.M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Ozdemiroglu, E., Pearce, D.W., Sugden, R. and S. Swanson

(2003), '*Guidelines for the Use of Stated Preference Techniques for the Valuation of Preferences for Non-market Goods*', Cheltenham: Edward Elgar.

Bellon, M.R. and S.B. Brush (1994), 'Keepers of maize in Chiapas, Mexico', *Economic Botany*, **48**: 196-209.

Bellon, M.R. (2004), 'Conceptualizing Interventions to Support On-Farm Genetic Resource Conservation', *World Development*, **32**(1):159–172.

Bellon, M.R. and J. Berthaud (2004), 'Transgenic Maize and the Evolution of Landrace Diversity in Mexico. The Importance of Farmers', *Plant Physiology*, **134**: 883-888.

Bennett, J.J. and R.K. Blamey. (2001), *The Choice of Modelling Approach to Environmental Valuation,* Cheltenham: Edward Elgar.

Birol, E., M. Smale and Á. Gyovai. (2006a), 'Using a Choice Experiment to Estimate Farmers' Valuation of Agricultural Biodiversity on Hungarian Small Farms', *Environmental and Resource Economics*, **34**(4): 439–469.

Birol, E., A. Kontoleon and M. Smale (2006b), 'Farmer Demand for Agricultural Biodiversity in Hungary's Transition Economy: A Choice Experiment Approach', in M. Smale (Ed.) *Valuing Crop Biodiversity on Farms during Economic Change*, Wallingford: CAB International.

Boxall, P.C. and W.L. Adamowicz. (2002), 'Understanding Heterogeneous Preferences in Random Utility Models: A Latent Class Approach', *Environmental ad Resource Economics*, **23**: 421-446.

Brookfield, H. and M. Stocking (1999), 'Agrodiversity: Definition, Description and Design', *Global Environmental Change* **9**: 77–80.

Brush, S.B. and H.R. Perales (2007), 'A maize landscape: Ethnicity and agro-biodiversity in Chiapas Mexico', *Agriculture, Ecosystems and Environment*

Canales, A.I. (2003), ‘Mexican labour migration to the United States in the age of globalisation’ *Journal of Ethnic and Migration Studies* **29**(4): 741–761.

Dalton, R. (2001), ‘Transgenic corn found growing in Mexico’, *Nature*, **412**: 337.

Dyer, G. and A. Yunez-Naude (2003), ‘NAFTA and Conservation of Maize Diversity in Mexico’, Paper prepared for The Second North American Symposium on Assessing the Environmental Effects of Trade, Commission for Environmental Cooperation.

Fowler, C. and T. Hodgkin (2004), ‘Plant Genetic Resources for Food and Agriculture: Assessing global availability’, *Annual Review of Environmental Resources*, **29**(10):1-37.

Greene, W.H. 1997. *Econometric Analysis,* Third Edition, Prentice Hall.

Hanley, N., R. E. Wright and W.L. Adamowicz (1998), ‘Using Choice Experiments to Value the Environment’. *Environmental and Resources Economics,* **11**(3-4): 413-428.

Harlan, J. R. (1992) Crops and man, Madison, WI, American Soc. Agronomy.

Hu, W., Hünnemeyer, A., Veeman, M., Adamowicz, W.L. and L. Srivastava (2004), ‘Trading off health, environmental and genetic modification attributes in food’, *European Review of Agricultural Economics*, **31**: 389 – 408.

Kloppenburg, J.R. (Ed.) (1988), *Seeds and Sovereignty: The Use and Control of Plant Genetic Resources*, Durham and London: Duke University Press.

Kontoleon, A. and M. Yabe (2006), ‘Market Segmentation Analysis of Preferences for GM Derived Animal Foods in the UK,’ *Journal of Agricultural & Food Industrial Organization*. **4**(1): Article 8. http://www.bepress.com/jafio/vol4/iss1/art8

Lancaster, K. (1966), ‘A new approach to consumer theory’, *Journal of Political Economy*, **74**:132-157.

Louviere, J. J., D.A. Hensher, J.D. Swait and W.L. Adamowicz (2000), *Stated Choice Methods: Analysis and Applications*, Cambridge: Cambridge University Press.

Luce, D. (1959), *Individual Choice Behaviour*, New York: John Wiley.

McFadden, D. (1974),’Conditional Logit Analysis of qualitative choice behaviour’, in p. Zarembka (Ed.) *Frontiers in Econometrics*, New York: Academic Press.

Ndjeunga, J. and C. H. Nelson (2005), ‘Toward understanding household preference for consumption characteristics of millet varieties: a case study from western Niger’, *Agricultural Economics*, **32**(2): 151-165.

Othman, J., Bennett, J. and R. Blamey (2004), ‘Environmental values and resource management options: a choice modelling experience in Malaysia’, *Environment and Development Economics*, **9**: 803–824

Owen, K., Louviere, J. and J. Clark (2005), *Impact of Genetic Engineering on Consumer Demand*. Rural Industries Research and Development Corporation. http://www.rirdc.gov.au/reports/GLC/05-015.pdf.

Roseland, C.R. (2002), ‘LMOS and the Environment: Proceedings of an International Conference’ Paris: Organisation of Economic Cooperation and Development.

Ruto, E. (2005), ‘Valuing Animal Genetic Resources: A Choice Modelling Application to Indigenous Cattle in Kenya’, Paper presented at the Seventh Annual BIOECON Conference “Economics and the Analysis of Biology and Biodiversity” Kings College Cambridge, 20-21 September 2005

Scarpa, R., A. Drucker, S. Anderson, N. Ferraes-Ehuan, V. Gomez, C. R. Risopatron and O. Rubio-Leonel (2003a), ‘Valuing Animal Genetic Resources in Peasant Economies: The Case of the Box Keken Creole Pig in Yucatan’, *Ecological Economics,* **45**(3): 427-443.

Scarpa R., E.S.K. Ruto, P. Kristjanson, M. Radeny, A.G. Drucker and J.E.O. Rege (2003b), ‘Valuing indigenous cattle breeds in Kenya: An empirical comparison of stated and revealed preference value estimates’, *Ecological Economics*, **45**(3): 409-426.

Smale, M., R.M. Bellon and J.A. Aguirre Gomez (2001), ‘Maize Diversity, Variety Attributes, and Farmers’ Choices in Southeastern Guanajuato, Mexico’, *Economic Development and Cultural Change*, **50**(1): 201-225.

Taylor, J. E., Yunez-Naude, A., and G. Dyer (1999), ‘Agricultural price policy, employment, and migration in a diversified rural economy: a village–town CGE analysis from Mexico’, *American Journal of Agricultural Economics* **81**(3): 653–662.

Taylor, J. E., and Martin, P. L. (2000), ‘Human Capital: Migration and Rural Population Change’, in, G. Rausser and B. Gardner, (eds.), *Handbook of Agricultural Economics*, New York: Elsevier.

Van Dusen, M.E. and J.E. Taylor (2005), ‘Missing markets and crop diversity: evidence from Mexico’, *Environment and Development Economics*, **10**(4): 513-531.

Van Dusen, M.E (2006), ‘Missing Markets, Migration and Crop Biodiversity in the Milpa System of Mexico: A Household Farm Model’ in M. Smale (ed.), *Valuing Crop Biodiversity: On Farm Genetic Resources and Economic Change*, Wallingford, Oxon: CAB International.

Wedel, M. and W. Kamakura (2000), *Market Segmentation: Conceptual and Methodological Foundations*. Boston: Kluwer Academic Publishers.

Zeven, A. C. (1998), ‘Local crop varieties: a review of definitions and classifications’, *Euphytica*, **1**.

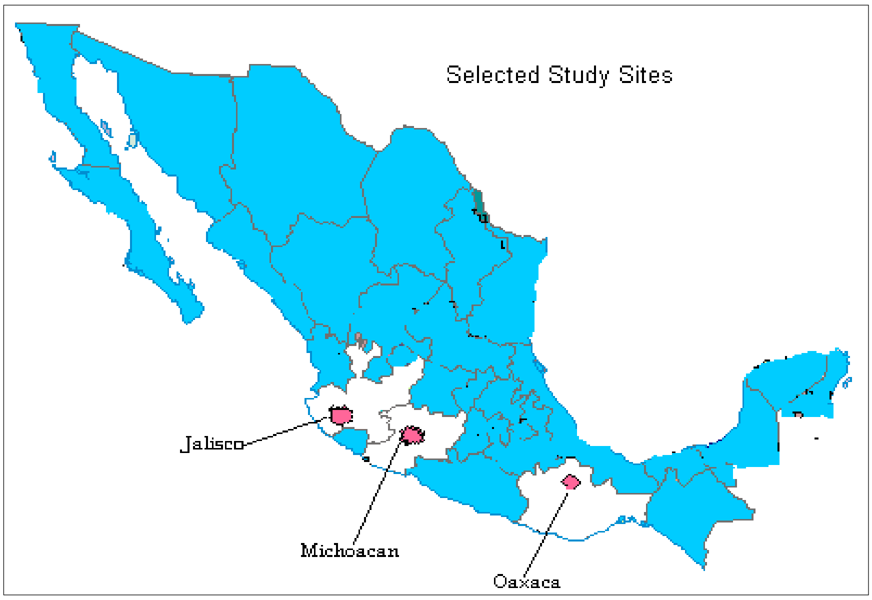
8. Figures

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 & squash	Maize	Neither *milpa*, I prefer my own profile
Maize variety diversity	3 varieties	3 varieties	
Maize landrace	No	Yes	
GM maize	Yes	No	
Yield	115	115	
I prefer to cultivate	*Milpa* A ☐	*Milpa* B ☐	Neither ☐

Figure 2. Location of selected sites



Source: INE (2004).

9. Tables

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

Milpa attribute	Definition	Attribute levels
Crop species richness	Total number of crops cultivated in the *milpa*.	1 (only maize), 2 (maize and beans or maize and squash), 3 (maize, beans and squash)
Maize variety richness	Total number of maize varieties cultivated in the *milpa*.	1, 2, 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 maize landrace variety vs. *Milpa* does not contain a maize landrace variety
GM maize	Whether or not the *milpa* contains a maize variety that has been genetically modified.	*Milpa* contains a GM maize variety vs. *Milpa* does not contain a GM maize variety
Yield	% of the expected maize yield relative to the farmer's yield last year	130, 115, 100, 85, 70

Table 2. Site characteristics, average of communities in each site

Variable	Definition	Jalisco (N=4)	Michoacán (N=5)	Oaxaca (N=8)
			Mean (s.d.)	
Total population	Average of the total population	613 (354.1)	2663.6 (1202.7)	560.5 (393.6)
Illiteracy	Average of percentage of illiterate population over 15 years of age	20.8 (7.8)	18.8 (1.9)	11.1 (5.4)
Indigenous language	Average of percentage of population speaking indigenous language	1.2 (1.1)	13.4 (13.5)	34 (37.8)
Unemployment	Average of percentage of active population unemployed	0.4 (0.6)	2.5 (3.6)	0.3 (0.6)
Primary sector	Average of percentage of active population employed in the primary sector	67 (14)	38.7 (13.7)	51 (20.7)
Secondary sector	Average of percentage of active population employed in the secondary sector	12.5 (9.2)	40.1 (15.1)	18.8 (10.5)
Tertiary sector	Average of percentage of active population employed in the tertiary sector	18.6 (7.9)	19.1 (3.4)	27.4 (14)
Distance to *Carretera*	Average distance of the communities to the main road in km	16.05 (7.8)	0.22 (0.3)	3.83 (2.12)
Marginalisation index	Average marginalisation index of the communities in each site as calculated by CONAPO	-0.06 (0.8)	-0.46 (0.08)	-0.98 (0.41)

Source: Instituto Nacional de Estadistica Geographia e Infomatica (INEGI) and Consejo Nacional de La Poblacion (CONAPO), 2000.

Table 3. Distribution and Factor Analysis of Statements on Perceptions of and Attitudes towards GM food and crops

Attitudinal and Behavioural Statements	Rotated Factor Loadings Factor 1 *Producer Perceptions*	 Factor 2 *Consumer Perceptions*
Statements coded according to the 5 point Likert Scale: 1.Strongly disagree; 2.Disagree; 3.Neither agree nor disagree; 4. Agree; 5. Strongly agree:		
1. It is very important that the food has GM content	-0.037	0.45
2. I am not in favour of introduction of GM crops in Mexico	0.65	0.39
3. Eating GM food would be harmful to me and my family	0.28	0.53
4. GM crops is a threat to the natural order	0.50	0.20
5. Cultivating GM crops is harmful for the environment	0.60	0.31
6. If some food are free of GMO I would like to know	0.13	0.47
7. I would be less likely to buy food with GM content	0.21	0.67
8. I would be less likely to buy food with GM content event if it were cheaper	0.21	0.61
9. I would be less likely to buy food with GM content even if it were more ecological	0.08	0.55
10. I would be less likely to buy food with GM content even if it tasted better	0.21	0.71
Statement coded according to a binary scale: 1.Yes; 2. No:		
11. I would prefer to cultivate a landrace with constant yield over a HYV which has high yield first couple of years and low yield after then	0.46	0.07
12. I would cultivate and eat GM maize	-0.76	-0.17
13. I would cross GM maize with maize landraces	-0.63	0.02
14. I have obtained maize seeds from outside the community in the past	-0.41	-0.11
Eigenvalues	3.75	1.07

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.

Table 4. Consumer and Producer Perceptions Indices

Index	Jalisco (N=124)	Michoacán (N=137)	Oaxaca (N=121)
		Mean (s.d.)	
CPI	1.16	1.2	1.25
	(0.49)	(0.38)	(0.38)
PPI***	0.62	0.78	1
	(0.56)	(0.5)	(0.46)

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 show significant differences among at least one pair of sites (***) at 1% significance level.

Table 5. Milpa management characteristics of the households by state

Variable	Definition	Jalisco (N=124)	Michoacán (N=137)	Oaxaca (N=121)
			Mean (s.d.)	
Crop species richness***	Number of different crop species in the *milpa*	1.78 (0.76)	1.66 (0.78)	2.54 (0.85)
Maize variety richness**	Number of maize varieties in the *milpa*	1.53 (0.79)	1.41 (0.67)	1.47 (0.59)
Area***	*Milpa* area managed by the household in hectares	7.2 (8.95)	3.11 (2.63)	1.23 (1.12)
Output***	Volume of maize production in the *milpa* in kg	8.39 (15.67)	2.96 (4.35)	0.99 (1.07)
Yield **	Kg of maize obtained from each hectare of *milpa* cultivated by the household	1.47 (1.57)	0.95 (0.78)	1.74 (6.31)
Participants***	Number of *milpa* cultivation participants in the household	1.83 (1.09)	2.52 (1.44)	2.44 (1.26)
			Percent	
Landrace*	*Milpa* has at least one landrace maize variety	92.7	97.08	95.04
Soil***	*Milpa* with good quality soil	36.07	27.07	41.88
Organic**	*Milpa* managed without the use of fertilisers and herbicides	17.74	17.52	27.27
Livestock***	*Milpa* managed alongside livestock	67.74	71.11	49.59
Help***	Paid or voluntary outside help is employed for milpa cultivation	58.07	37.04	65.29
Sell***	Some of the *milpa* produce is sold	57.85	47.45	28.57

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 sites (*) at 10% significance level; (**) at 5% significance level, and (***) at 1% significance level.

Table 6. Farm household characteristics

Variable	Definition	Jalisco (N=124)	Michoacán (N=137)	Oaxaca (N=121)
			Mean (s.d.)	
Experience***	Farming experience of *milpa* decision makers in years	38.8 (16.6)	38 (14.7)	29.5 (15.6)
Education**	Education of *milpa* decision makers in years	4.56 (3.50)	5.22 (2.27)	5 (2.6)
Household size ***	Number of household members	2.73 (1.49)	3.08 (1.4)	3.22 1.57
Off farm income***	Total monthly household off farm income in Mexican pesos	1808.8 (1193.9)	2001.5 (995.6)	3137.7 (1571.3)
			Percent	
Off farm employed***	At least one member of the family works off farm	18.6	30.2	43.8
Child*	At least one member of the family is =< 12 years of age	15.3	11.7	19

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 sites (**) at 5% significance level and (***) at 1% significance level.

Table 7. Criteria for determining optimal number of segments

No. of Segments	No. of Parameters (P)	Log likelihood (LL)	ρ^2	AIC3	BIC
1	6	-1736.712	0.31029	3491.424	1754.548
2	17	-1563.191	0.37920	3177.382	1613.727
3	28	-1473.564	0.41479	3031.128	1556.800
4	39	-1417.582	0.43702	2952.164	1533.518
5	50	-1417.016	0.43725	2984.032	1565.652

Sample size is 2292 choices from 382 farmers (N); ρ^2 is calculated as 1-(LL)/LL(0); AIC3 (Bozdogan AIC) is (-2LL+3P); BIC (Bayesian Information Criterion) is –LL+(P/2)*ln(N)

Table 8. Three-Segment LCM estimates for *milpa* attributes

	Segment 1 *Landrace Conservationists*	Segment 2 *Milpa Diversity Managers*	Segment 3 *Marginalised Maize Producers*
Utility function: *Milpa* attributes			
		Coefficient (s.e.)	
ASC	-3.35***(0.57)	0.47*** (0.15)	-2.13*** (0.11)
Crop species richness	2.92***(0.41)	0.46***(0.07)	-0.04 (0.04)
Maize variety richness	0.48** (0.21)	0.13**(0.07)	-0.004 (0.05)
Maize landrace	5.21***(0.68)	0.12**(0.07)	0.08* (0.05)
GM maize	-6.92*** (0.91)	-0.17***(0.07)	-0.34***(0.05)
Yield	0.25*** (0.03)	0.04***(0.003)	0.08*** (0.004)
Segment membership function: Farm families' characteristics			
		Coefficient (s.e.)	
Intercept	-1.81*** (0.8)	1*(0.63)	-
CPI	0.88** (0.49)	-1.1*** (0.43)	-
PPI	0.62** (0.35)	-0.4**(0.19)	-
MI	-0.72**(0.32)	0.37(0.37)	-
Experience	-0.01*(0.008)	0.008**(0.005)	-
Milpa area	-0.1** (0.06)	-0.053*(0.04)	-
Log likelihood		-1473.564	
ρ^2		0.4148	
Sample size		2292	

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 with two-tailed tests.

Table 9. Characteristics of farm families belonging to the three segments in LCM

Farm family characteristics	Segment 1 *Landrace Conservationists* N=162	Segment 2 *Milpa Diversity Managers* N=66	Segment 3 *Marginalised Maize Producers* N=154
		Mean (std.dev)	
Distance to *Carretera****	3.23 (4.47)	7.78 (8.69)	9.18 (9.82)
CPI***	1.45 (0.19)	0.49 (0.22)	1.25 (0.31)
PPI***	1.17 (0.25)	0.43 (0.52)	0.6 (0.49)
MI***	-0.84 (0.46)	-0.36 (0.42)	-0.18 (0.44)
Age***	51.87 (14.25)	59.44 (12.27)	54.01 (13.52)
Experience***	31.14 (16.33)	41.89 (14.57)	37.47 (15.39)
Education***	5.27 (2.49)	4.15 (2.8)	4.92 (3.05)
Household size***	3.25 (1.58)	2.82 (1.24)	2.84 (1.42)
Off farm income***	2764.9 (1548.7)	2224.7 (1410.7)	1840.3 (988.6)
Crop species richness***	2.26 (0.87)	1.74 (0.89)	1.79 (0.82)
Maize variety richness	1.42 (0.63)	1.47 (0.61)	1.52 (0.77)
Number of landraces*	1.35 (0.62)	1.47 (0.63)	1.46 (0.69)
Milpa area***	1.67 (1.37)	2.71 (2.57)	6.62 (8.28)
Milpa output***	1.7 (2.09)	3.64 (6.75)	6.81 (14.19)
Yield *	1.67 (5.47)	1.28 (1.02)	1.09 (1.43)
Milpa participants***	2.52 (1.44)	2.09 (1.17)	2.08 (1.19)
		Percent	
Off farm employed***	43.21	32.31	16.88
Child**	19.75	9.1	12.99
Landrace***	98.15	95.46	86.36
Cross landrace **	50	59.26	40.68
Soil***	40.76	15.39	36.67
Organic*	21.61	27.27	16.88
Help	52.17	50	54.9
Livestock	63.35	57.58	65.36
Sell***	28.4	40.91	65.43
Jalisco***	11.73	43.94	49.36
Michoacán	33.95	31.82	39.61
Oaxaca***	54.32	24.24	11.04

T-tests and Pearson Chi square tests show significant differences among at least one pair of segments at (*)10% significance level; (**) at 5% significance level, and (***) at 1% significance level.

Table 10. Segment specific valuation of *milpa* attributes % change in yield (95% Confidence Interval)

Milpa attribute	Segment 1 *Landrace Conservationists* N=162	Segment 2 *Milpa Diversity Managers* N=66	Segment 3 *Marginalised Maize Producers* N=154
Crop species richness	11.89 (9.02-15,67)	13.14 (10.24-16.57)	--*
Maize variety richness **	1.95 (0.98-3.23)	3.66 (1.48-6.23)	--
Maize landrace***	42.41 (32.54-55.35)	7.09 (2.96-11,96)	2.08 (0.76-3.55)
GM maize***	-56.38 (-73.69 -43.18)	-9.77 (-15.2- -5.17)	-9.01 (-10.99- -7.24)

Welfare measures are calculated with the Delta method, Wald procedure contained within LIMDEP. Figures represent percentage change in total maize yield. *-- indicates that the Wald procedure resulted in insignificant WTA values for this attribute. T-tests show significant differences among at least one pair of segments at (***) at 1% significance level and (**) at 5% significance level.

Appendix

Description of the GM maize attribute

Encuesta en hogares rurales sobre la diversidad del cultivos

Presentación
Encuestador antes de comenzar la encuesta presentarse ante el individuo como lo sugiere el siguiente guión:

Mi nombre es ……………………………… represento al Instituto Nacional de Ecología realizando una investigación cuyo objetivo es identificar las variedades tradicionales de cultivos en México los métodos de cultivo de estas variedades tradicionales, y además investigar si la presciencia de variedades transgénicas tendría un impacto en ellas.

Como parte de este estudio, estamos realizando esta encuesta, y quisiéramos que usted participara. Su participación en esta encuesta es voluntaria y puede no contestar a las preguntas con las que no se sienta cómodo.

La encuesta es anónima y su respuesta va ser tratada con estricta confidencialidad. Con su participación en esta encuesta usted contribuye inmensamente para el desarrollo acertado de nuestra investigación. La encuesta no durará más de 40 minutos.

Gracias de antemano por su cooperación.

Descripción de OGM (organismo genéticamente modificado)

Encuestador recuerde explicar el concepto de material genético (DNA) como un libro con instrucciones sobre como se crea un organismo (plantas, animales, personas) un OGM tendría un párrafo adicional con instrucciones de otro organismo. No hacer referencia a ningún tipo de juicio que pueda sesgar las percepciones de los encuestados.

Descripción de maíz transgénico
Es un maíz el cual a través de nuevas técnicas contiene material genético de otros organismos (plantas y animales) dentro de él.