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IFPRI Discussion Paper 00726

October 2007

Farmer Preferences for *Milpa* Diversity and Genetically Modified Maize in Mexico

A Latent Class Approach

Ekin Birol, International Food Policy Research Institute

Eric Rayn Villalba, University College London

and

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Environment and Production Technology Division

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IFPRI's research, capacity strengthening, and communications work is made possible by its financial contributors and partners. IFPRI gratefully acknowledges generous unrestricted funding from Australia, Canada, China, Denmark, Finland, France, Germany, India, Ireland, Italy, Japan, the Netherlands, Norway, the Philippines, Sweden, Switzerland, the United Kingdom, the United States, and the World Bank.

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ACKNOWLEDGMENTS

We gratefully acknowledge the financial support of the Instituto Nacional de Ecología of Mexico (INE) and the 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 their support in data collection; to Sol Ortiz García and Jose Carlos Fernández Ugalde for their assistance in 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 and suggestions and fruitful discussions.

ABSTRACT

Maize, the second most globally important staple crop after wheat, originated in Mexico, where it is typically grown as part of a set of associated crops and practices called the *milpa* system. This ancient mode of production is practiced today in ways that vary by cultural context and agro-environment. *Milpa*s generate private economic value, in terms of food security, diet quality and livelihoods, for the two-million farm households who manage them. Furthermore, *milpas* generate public economic value by conserving agrobiodiversity, especially that of maize landraces, which have the potential to contribute unique traits needed by plant breeders for future crop improvement. In this way, *milpas* contribute to global food security in maize. However, the sustainability of the *milpa* system has been threatened by off-farm employment opportunities, long-distance migration, the increasing commercialization and intensification of maize production. Most recently, the *milpa* system has been negatively impacted by the contamination of maize landraces by genetically modified (GM) maize, cultivation of which is currently prohibited in Mexico. Here, we employ a choice experiment to estimate Mexican farmers' valuation of three components of agrobiodiversity (crop species richness, maize variety richness and maize landraces), and examine their interest in cultivating GM maize. Choice experiment data, household level social, economic and demographic data, community level economic development data, and information 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. Using these data, we analyzed the heterogeneity of farmer preferences using a latent class model, which can be used to simultaneously identify sample segments having homogenous preferences for *milpa* attributes, as well as farmer characteristics affecting preferences. We further 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, we identified three distinct segments of farmers: (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 at the Oaxaca site, where transgenic constructs have been found in maize landraces. (ii) *Milpa Diversity Managers* derive the highest economic value from managing all of the agrobiodiversity components of the *milpa*, and suffer fewer losses from management of GM maize. These are older farmers, who are curious and like to experiment with maize varieties. (iii) *Marginalized Maize Producers* derive little value from crop species and maize variety richness, receive minimal value from maize landraces, and also experience the smallest negative impact from the adoption of GM maize. These farmers are located in the most isolated communities, have the lowest level of productivity, and oversee the largest *milpa* areas. They are also the most tightly integrated into the maize output markets. These novel findings have implications for debates concerning the adoption of GM maize in Mexico and its associated costs and benefits, as well as for the design of targeted, cost-effective conservation programs on farms.

Keywords: Mexico, maize, genetically modified crops, conservation

1. INTRODUCTION

The Mexican *milpa* system refers 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 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 than others, each corresponding to the specific consumption practices, soil characteristics and agronomic needs of the farm and farm family. Approximately two million farm households across Mexico continue to cultivate *milpa*s on around six million hectares of land each year; most of these households depend on *milpa* production for food security, diet quality and livelihoods (Bellon and Berthaud 2004).

In addition to generating private benefits for farm families, the maize-based *milpa* systems of Mexico also generate public economic value of global importance, most notably by forming one of the last reservoirs of maize genetic resources for humanity (Bellon and Berthaud 2004). The *milpa* system is a poly-cropping system 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). The 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 global food security in maize, which is the second most globally important staple crop after wheat (Kloppenburg 1988; Harlan 1992; Fowler and Hodgkin 2004).

Despite general recognition of these points, however, there is considerable uncertainty regarding the sustainability of *milpa* management in Mexico (Van Dusen and Taylor 2005). Off-farm employment, particularly long-distance migration, negatively impacts the labor pool and knowledge transmission of 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 commercialization and intensification of maize production (Bellon 2004). Moreover, because maize is a cross-pollinating species, the introduction of genetically modified (GM) maize varieties may be potentially hazardous to maize-based systems. 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, the authors conclude that

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[1] Definitions of crop landraces are numerous in the international scientific literature (Zeven 1998). Landraces, which are often called traditional varieties or local varieties, may be simply understood as variants, varieties or crop populations comprised of plants that are often highly variable in appearance, but whose genetic structure has been shaped by farmers' seed selection practices and management, as well as by natural selection processes, over generations of cultivation.

the high rate 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, the presence of transgenic constructs was reported in maize landraces in the state of Oaxaca in 2001 (Dalton 2001). Since then, the potential effects of GM 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, and the option to cultivate GM maize in this system. The examined 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. Since these agrobiodiversity components are not traded in markets (Van Dusen and Taylor 2005) and cultivation of GM maize is currently prohibited in Mexico, we apply a stated preference, non-market valuation method, namely the choice experiment approach, to estimate the farmers' valuation and implied rankings of these *milpa* components (Hanley et al. 1998; Bateman et al. 2003). This method, which is based on asking farmers to choose between hypothetical *milpa* profiles, allows us to estimate the value of new *milpa* attributes outside the farmers' current set of experiences, such as the use of GM maize varieties (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 is analyzed explicitly with a latent class model (LCM), which allows 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 previous 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; Scarpa et al. 2003b; 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 paper is organized as follows. The next section (Section 2) examines recent public debates on transgenic maize and its effects on traditional maize varieties in Mexico. Section 3 presents the theoretical framework and explains the choice experiment design. Section 4 describes the sites, data collection, and calculation of indices used in the analysis. Section 5 reports and discusses the econometric results. In the final section (Section 6), we draw conclusions and discuss policy implications.

2. PUBLIC DEBATE ON GM MAIZE IN MEXICO

Mexico has been a focal point of the debate over GM maize since 2001, when evidence of transgenic material was reportedly found in Mexican maize landraces.[2] Since then, the potential effects of transgenic maize on traditional varieties of maize and other crop genetic resources in Mexico have been a topic of public debate. The flow of transgenic material to maize landraces may threaten the diversity of traditional maize,[3] which is the result of years of development and adaptation to particular soil types and microclimates. This has special relevance not only because of the social, cultural and economic importance of traditional maize agriculture, but also because this staple crop originated in Mexico.

Worldwide, advocates of biotechnology have promised to improve agricultural production by increasing yields and reducing the use of pesticides and other agrochemicals. Therefore, if traditional Mexican farmers perceive this technology as valuable and have access to it, they are likely to crossbreed maize landraces with GM varieties, which in turn may spread the modified genes and their characteristics among the landrace fields.[4]

The complexity of this issue is compounded due to the lack of scientific consensus with respect to the long-run impact of GM crops on the environment, human health, and crop genetic resources in Mexico, as well as the possible economic, social and cultural impacts of GM varieties. The debate about the potential effects of transgenic maize on traditional varieties of maize and other crop genetic resources in Mexico was so intense that in April 2002, the Commission for Environmental Cooperation of North America (CEC)[5] was petitioned by 21 indigenous communities of Oaxaca and three Mexican environmental groups, including Greenpeace Mexico, the Mexican Centre for Environmental Law (*Centro Mexicano de Derecho Ambiental,* Cemda), and the Union of Mexican Environmental Groups. The proposed initiative, which was supported by more than ninety letters from organizations and institutions from the three The North American Free Trade Agreement (NAFTA) countries (Canada, Mexico and the United States of America), urged the CEC to analyze the impacts of transgenic introgression into the maize landraces of Mexico, focusing on the actual and potential effects on the

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[2] The Secretariat of the Commission for Environmental Cooperation of North America**,** *Article 13 Initiative on Maize and Biodiversity: the Effects of Transgenic Maize in Mexico*, 2004.

[3] The central issue concerns the *gene flow* that usually occurs via the transfer of pollen, and includes the natural transfer of genes from genetically modified plants to traditional maize and its wild relatives. This is expected to threaten the diversity of both *teosinte*, the nearest wild relative of maize, as well as Mexican landraces.

[4] Farmers continually maintain cultivars through seed selection. They are aware that open-pollinated plants, such as maize, easily share their genes and thus might readily spread genes from GM crops to the farmers' own varieties.

[5] The Commission for Environmental Cooperation (CEC) is an international organization created by Canada, Mexico and the United States under the North American Agreement on Environmental Cooperation (NAAEC). The CEC was established to address regional environmental concerns, help prevent potential trade and environmental conflicts, and to promote the effective enforcement of environmental law. The agreement complements the environmental provisions of the North American Free Trade Agreement (NAFTA).

livelihoods and daily lives of members of these communities. Accordingly, the CEC carried out a study on transgenic maize in Mexico under Article 13, a section of the NAFTA environmental side agreement.[6] The final draft of the report, entitled *Maize and Biodiversity: The Effects of Transgenic Maize in Mexico*, was released on November 8, 2004.

[6] Article 13 gives the CEC the authority to prepare a report and provide recommendations from the Advisory Group on the issue of Transgenic Maize in Mexico.

3. THE CHOICE EXPERIMENT METHOD

Theoretical Framework

The choice experiment approach has a theoretical grounding in Lancaster's model of consumer choice (Lancaster 1966), wherein the author proposed that consumers derive satisfaction not from the goods themselves, but from the attributes they provide. The approach also has an econometric basis in models of random utility (Luce 1959; McFadden 1974), which are used to integrate behavior with economic valuation in the choice experiment. In this approach, the utility of a choice is comprised of both a deterministic component and an error component that 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. However, preferences are in fact heterogeneous, and accounting for this heterogeneity enables unbiased estimation of individual preferences, enhancing the accuracy and reliability when estimating demand, participation, marginal welfare and total welfare (Greene 1997). Furthermore, accounting for heterogeneity enables the formulation of policy recommendations that take equity concerns into account. Information on who will be affected by a policy change and the aggregate economic value associated with such change is necessary for the crafting of efficient and equitable policies (Boxall and Adamowicz 2002).

The latent class model (LCM) is one of the most recent models employed to investigate preference heterogeneity. The LCM casts heterogeneity as a discrete distribution, i.e. a specification based on the concept of endogenous (or latent) preference segmentation (Wedel and Kamakura 2000). The approach depicts a population as consisting 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. The slotting of an individual into a specific segment is probabilistic, and depends on the social, economic, and demographic characteristics of the respondents, as well as their perceptions and attitudes. Furthermore, respondent characteristics affect choices indirectly through their impact on segment membership. Scarpa et al. (2003a) recently employed his method in the agricultural context for valuation of pig attributes in Mexico. Similarly, LCM has been used by Ruto (2005) for valuation of cattle attributes in Kenya, and by Hu et al. (2004), Owen et al. (2005) and Kontoleon and Yabe (2006) for investigating consumer demand for GM food in Canada, Australia and the UK, respectively.

Formally, in the LCM employed here, the utility that 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 *milpa* attribute preferences 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:

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

M* is a segment membership likelihood function 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 farm family, such as their social, economic, and demographic characteristics, perceptions and attitudes, and farm agro-ecology. Assuming the error terms in the farmer membership likelihood function are independently and identically distributed across farmers and segments, and follow a Gumbel distribution, the probability that farmer *i* belongs to segment *s* can be expressed as:

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

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:

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

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 defining the *milpa* in terms of its attributes and the levels of these attributes. The most important *milpa* attributes and their levels were identified in consultation with experts from the Instituto Nacional de Ecologia (INE, the Mexican National Institute of Ecology), 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 given in Table 1.

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 was not 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 expected maize yield relative to the farmer's yield for the previous year	130, 115, 100, 85, 70

The first three attributes reflect 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 purposefully crossed and selected by the farmers (Bellon 2004). The richness of both maize varieties and crop species should be considered when studying *milpa* management choices, because *milpa* diversity is an outcome of competition both within and among species. Thus, 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.

This fourth attribute included in the choice set, the option to grow GM maize, was defined by INE scientists following various workshops (2001 to 2003) involving farmers from the Oaxaca and

Michoacán sites. GM maize was defined simply as a maize variety that has "new genetic information." The enumerators explained to the farmers 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 scientists to insert 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 avoid biasing the farmers' choices (please see the Appendix for the description in Spanish of the GM maize attributes).

The fifth attribute, that of maize yield, is included in the choice set as a proxy monetary variable used to estimate welfare changes. The maize yield attribute was defined 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. A percentage specification was preferred since it was difficult to include exact yield measures in the choice experiments due to the differences in yields, *milpa* areas, and the intensity of maize production across the study sites. Since the property rights of the *milpa* and their outputs and functions reside with the farmers (Freeman 2002), this proxy monetary attribute represents willingness to accept (WTA) compensation, i.e. a benefit, rather than a cost measured by willingness to pay (WTP). 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 rather is consumed by the farm families themselves. Hence, the respondents are not likely to be familiar with a direct monetary measure of their output. The proxy monetary attribute can easily be converted into actual monetary units by using secondary data on the price of maize. In the study presented here, the 'percentage yield' attribute is kept as percentage and the welfare changes are estimated as percentage of yield farmers are WTA in order to forego an attribute (in the case of positive WTA values) or percentage of yield farmers are WTA in order to adopt an attribute (in the case of negative WTA values).

A large number of unique *milpa* profiles can be constructed from the attributes and levels shown in Table 1[7]. Statistical design methods (see Louviere et al. 2000) are used to structure the presentation of the levels of the five attributes into choice sets. More specifically, an orthogonalization procedure is employed to recover only the main effects. Twenty-four pair-wise comparisons of *milpa* profiles are randomly blocked into four different versions, each having six choice sets. Each farmer is presented with a version of the six choice sets, each of which contain two *milpa* profiles and the decision to "opt out" by selecting neither of the *milpa* profiles presented to them, in which case they are choosing to continue cultivating his/her own *milpa* (the attribute levels of which are recorded by the interviewers). The "opt out" decision can be considered a status quo or baseline alternative; its inclusion in the choice set is

[7] 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 $3^2*2^2*5=160$.

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 changing to a new one; in our 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. 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

4. DATA

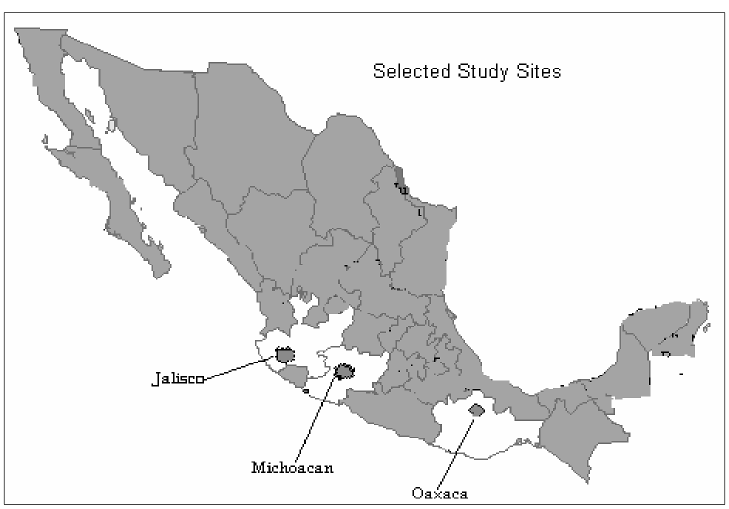
The choice experiment survey was implemented in October and November 2004 with face-to-face interviews. A total of 420 randomly-selected farm households were interviewed across 17 communities in three states of Mexico. The interviewed farmers were randomly selected from lists of all maize-producing farmers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

The survey consisted of four parts. The first three parts were designed to collect information on the farmers' observed characteristics (vector *Z*). First, each respondent was asked questions about his/her perceptions of and attitudes towards GM crops and food. The second part was used to obtain information on the farmer's *milpa* management practices and the agrobiodiversity managed on their *milpa*s. In part three, the interviewer collected social, demographic, and economic information on the farm households and *milpa* decision-maker(s) within that household. 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 each attribute was described, 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 the interviewers were only interested in their opinions.

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. Location of selected sites



Source: INE (2004).

These three sites were selected based on several criteria. First, farmers practice *milpa* cultivation in all three sites. According to the INE's collection missions, each site is also considered to be an important center of maize diversity in Mexico. Third, the three sites represent different agro-ecologies, patterns of participation in labor and maize markets, and levels of economic development. The Oaxaca site includes communities where the INE previously investigated claims that transgenic maize constructs had been found in the fields. The communities studied in the Michoacán site include those where the 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 the Biosphere Reserve Sierra de Manantlán, where *teosinte*, the nearest wild relative of maize, still grows. The characteristics of the communities at each study site are given in Table 2.

Table 2. Site characteristics and community characteristics at 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 percent of illiterate population over 15 years of age	20.8 (7.8)	18.8 (1.9)	11.1 (5.4)
Indigenous language	Average percent of population speaking indigenous language	1.2 (1.1)	13.4 (13.5)	34 (37.8)
Unemployment	Average percent of active population unemployed	0.4 (0.6)	2.5 (3.6)	0.3 (0.6)
Primary sector	Average percent of active population employed in the primary sector	67 (14)	38.7 (13.7)	51 (20.7)
Secondary sector	Average percent of active population employed in the secondary sector	12.5 (9.2)	40.1 (15.1)	18.8 (10.5)
Tertiary sector	Average percent 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)
Marginalization index	Average marginalization 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 Población (CONAPO) 2000.

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. The 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 speaking an indigenous language is the lowest in Jalisco compared to the other sites. The unemployment rate is low in Jalisco, 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 illiterate adults is also highest in Jalisco compared to the other sides. On average, the communities of this site do not have good access to commercial markets, and these communities are furthest from the main highway. There is only one main highway crossing the state, and the communities are linked by dirt and gravel rural roads (*terracería y brecha*).

The communities sampled in the Michoacán site make up an area of 434.11 km² and comprise a population of 13,318 inhabitants, making Michoacán the most densely populated of the study sites. The communities included in this study have an indigenous form of government, and 13.4 percent of the population speak an indigenous language. Illiterate inhabitants make up almost a fifth of the population, and the unemployment rate is the highest in Michoacán compared to the other two sites. The majority of the active population is employed in the secondary sector, followed by the 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, with the highest percentage of the population employed in the primary sector, followed by the tertiary and secondary sectors. This site has the lowest percentage of illiterate adults, and while the average distance of communities to the main highway is larger than that for the Michoacán site, it is only about a fourth of that found in the Jalisco site.

The marginality indices for the communities at each site are shown in Table 2. Commonly used to identify inequalities and design social programs in Mexico, this index assesses the relative deficiencies across communities in the country using four structural dimensions (education, housing, income from labor and population distribution) and nine variables[8] (CONAPO 2000). According to this index, the communities in Jalisco are the most marginalized and those in Oaxaca are the least marginalized.

Farm Families' Perceptions of and Attitudes towards GM Crops and Food

Farmers were asked 14 questions aimed at assessing their perceptions of and attitudes towards GM crops and food (Table 3). Ten of the questions were coded according to a Likert scale, and the remaining four

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[8] These include: the percentage of illiterates among individuals 15 years old and above; the percentage of individuals 15 years old and above without full basic education; the percentage of individuals living in houses without access to tap water, sewage, a toilet, or electricity, with soil floors and with some degree of overcrowding; the percentage of employed individuals with a level of income up to twice the minimum wage; and the percentage of individuals living in communities with less than 5,000 inhabitants.

were binary. These questions were developed in consultation with INE experts and drew on the results of workshops and focus groups they previously carried out with farmers of the Oaxaca and Michoacán sites. Two indices, the Producer Perception Index (PPI) and the Consumer Perceptions Index (CPI), were derived from a factor analysis of the farmers' answers to the questions. The results of the factor analysis are shown in Table 3.

Table 3. Distribution and factor analysis for perceptions of and attitudes towards GM food and crops

	Rotated Factor Loadings	
	Factor 1	Factor 2
Attitudinal and Behavioral Statements	*Producer Perceptions*	*Consumer Perceptions*
The first ten statements were coded according to the following 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 favor 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 are 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 a food is free of GM organisms 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 even 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
The final four statements were 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 thereafter	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.

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 interviewed farmers provided answers to all of the questions. However, 17 percent of the sample failed to respond to between one and three of the 14 questions. Missing responses did not exhibit any systematic bias, and data were imputed using mean values (Kontoleon 2003). Nine percent of the sample (38 farmers) chose not to answer more than three of the 14 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 consisted of 382 farmers.

Using these data, the factor analysis described in this paper is undertaken using the principal factor extraction method in the STATA 8.0 software package. Factors with eigenvalues >1 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, labeled "Producer Perception" consisted of questions related to farm families' attitudes and behaviors 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", consisted of farm families' attitudes and behavior as *consumers* of food. The questions that were grouped together included those related to taste, price, threat to family health and being informed about the GM content of food. The indices of these factors, namely the Producer Perception Index (PPI) and Consumer Perception Index (CPI), were created by calculating the factor scores of each index for each household using the factor score command in STATA 8.0. For both of the indices, higher values indicate a greater dislike of GM food and crops.

The pooled and site level averages for these indices are shown in Table 4. The farmers' CPIs do not differ significantly (at a 5 percent significance level) among the sites. Farm families from the Oaxaca site, where transgenic maize constructs were found and where most of the public debate on GM maize has taken place, have the highest PPI, while families located in Jalisco have the lowest PPI across the three sites.

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 the 1% significance level.

Milpa Characteristics

The production and agrobiodiversity characteristics of the *milpas* managed by the 382 farmers in the study sample are given in Table 5.

Table 5. Household *milpa* management characteristics 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 generated by 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* has good quality soil	36.07	27.07	41.88
Organic**	*Milpa* is managed without the use of fertilizers and herbicides	17.74	17.52	27.27
Livestock***	*Milpa* is 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 the 10% (*), 5% (**) and 1% (***) significance levels.

There is considerable heterogeneity in *milpa* outputs and inputs both across and 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 those in Michoacán having the lowest. Farm households in Jalisco manage a higher number of maize varieties compared to those in Michoacán, but there is no significant difference between number of maize varieties in Oaxaca versus the other two sites. Over 90 percent of the surveyed farm families across the three sites manage at least one landrace on their *milpa*, whereas Jalisco shows a significantly lower percentage of families cultivating at least one landrace (at 10 percent significance level) compared to those in Michoacán. There is no statistically significant difference between Oaxaca and the other two sites in terms of the number of farm families cultivating at least one landrace. Finally, a significantly higher number of farm families in Michoacán manage livestock alongside crops in their *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.

Both the amount of area cultivated in maize and the 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 labor 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 organically cultivated without the use of any chemical inputs in Oaxaca compared to the other two sites, which do not significantly differ in this parameter. Finally, the lowest percentage of farmers that sell some of their *milpa* produce is found in the Oaxaca site, whereas twice as many farmers in Jalisco sell at least some of their *milpa* produce.

Social, Economic and Demographic Characteristics of the Surveyed Farm Families

The characteristics of the households and *milpa* decision-makers represented by the sample of 382 farmers are shown in Table 6.

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-maker in years	38.8 (16.6)	38 (14.7)	29.5 (15.6)
Education**	Education of *milpa* decision-maker 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 the 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 the 5% (**) at 1% (***) significance levels.

The *milpa* decision-makers in Oaxaca have fewer years of *milpa* management experience than those in Michoacán and Jalisco, who show similar experience levels. Those in Michoacán have more education compared to those located at the other two sites, which do not differ with respect to this characteristic. Households in Jalisco are significantly smaller than those located at 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, whereas those located in Jalisco have the smallest percentage of households with at least one family member working off-farm, and report the lowest off-farm incomes. Finally, the highest percentage of households with at least one child younger than 12 years of age is greatest in Oaxaca and lowest at the Michoacán site.

5. RESULTS

Coding of the Data

The data were coded according to the levels of each attribute. Attributes with two levels (i.e. maize landrace and GM maize variety) entered the utility function as effects coded as binary with 1 to indicate presence and -1 to indicate absence (Adamowicz et al. 1994; Louviere et al. 2000). Attributes with three (i.e. crop species richness and maize variety richness) or five (i.e. yield) levels were entered in cardinal-linear form. Consequently, crop species richness and maize variety richness took the levels 1, 2 and 3, while yield was coded as 130, 115, 100, 85 or 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 labeled 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). A negative and significant ASC indicates a higher propensity for farmers to choose their own *milpas.*

Latent Class Model

To account for heterogeneity of preferences, the LCM specification included the CPI and PPI for each farmer, the marginalization 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 given in Table 7.

Table 7. Criteria for determining the 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

The 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).

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 increases 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 for all four statistics, the marginal effect becomes very small after the three-segment model. The BIC and AIC3 statistics are both minimized at four segments, indicating that a model with four segments is the optimal solution in this empirical application. However, Andrews and Currim (2003) demonstrated that the BIC and AIC3 statistics never under-fit the number of segments but may 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, as shown in Table 8.

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

	Segment 1 *Landrace Conservationists*	Segment 2 *Milpa Diversity Managers*	Segment 3 *Marginalized 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. Two-tailed tests showed 10% (*), 5% (**) and 1% (***) significance levels.

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

For segment one, the utility coefficients reveal that higher levels of crop species richness, maize variety richness, maize yield, and the presence of a landrace in the *milpa* have positive and significant effects on utility. The GM maize attribute has the largest absolute size, indicating that this attribute is the most important determinant of *milpa* choice, and has a negative and highly significant effect on utility. When the yield attribute is used as the normalizing 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 prefer the status quo, that is, their current *milpa* profiles.

The 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 of a given farmer belonging to this first segment. Households located in more marginalized communities, those with more experienced *milpa* decision-markers, and those with larger *milpa* areas are less likely to belong to this segment. We have labeled segment one the "*Landrace Conservationists*," because farmers in this segment derive the highest benefits from the maize landrace attribute and ascribe the highest costs to the GM maize attribute.

For the second segment, we see changes in the ranking of the attributes and the sign on the ASC. When the yield attribute is used as the normalizing 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 only a third as much as the 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 prefer the alternative *milpa* profiles presented to them over their current *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) 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 labeled 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, farmers in segment two 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 significantly affect utility. When the yield attribute is used as the normalizing 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 prefer the status quo, that is, their current *milpa* management practices.

The membership coefficients of this segment can be implicitly interpreted in relation to the signs of the estimated statistically significant parameters for the other two segments, as long as the parameters have the same signs in segments one and two (Kontoleon and Yabe 2006). Consequently, farmers who are located in more marginalized 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 labeled this segment the "*Marginalized Maize Producers.*"

Characterization of the Segments

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

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

Farm family characteristics	**Segment 1 Landrace Conservationists N=162**	**Segment 2 *Milpa* Diversity Managers N=66**	**Segment 3 Marginalized Maize Producers N=154**
	Mean (s.d.)		
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 the 10% (*), 5% (**), and 1% (***) significance levels.

Over half of the farmers in the *Landrace Conservationist* segment are located in Oaxaca, the state where most of the public debate on GM maize has taken place. This result is as expected, since this segment derives the highest disutility from the GM attribute across the three segments. Consequently, farmers in this segment have the highest CPI and PPI, indicating that they dislike GM food and crops the most, as both producers and consumers.

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 (i.e. their maize productivity) is the highest across the three segments. As a result of their smaller *milpa* areas and lower maize outputs, a significantly lower percentage of households in this segment sell their *milpa* produce compared to the other two segments. In terms of *milpa* production characteristics, a significantly higher percentage of *milpa*s in this segment have good soil quality compared to the other two segments. The percentage of households that get outside help and the percentage that engage in livestock production do not significantly differ across the three segments. In terms of the agrobiodiversity levels managed on farms, farmers in the *Landrace Conservationist* segment manage the highest levels of crop species richness across the three segments, though maize variety richness does not differ significantly across the segments. As expected, a statistically higher percentage of farm households in the *Landrace Conservationist* segment manage at least one landrace in their *milpa*s, although the average number of landraces managed on each *milpa* 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 12 years of age, compared to the other two segments. This result, combined with the finding that this segment produces mainly for household consumption, could help explain why this segment dislikes GM maize the most across the three 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 average 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. Households in this segment therefore have better access to labor markets (i.e. off-farm income) and food markets, and hence do not depend on their *milpa* yield for food self-sufficiency. This result could explain why food safety (in the form of the highest dislike for GM maize) and food quality (reflected in a high demand for agrobiodiversity components) are more pressing issues for farmers in this segment.

Almost 44% of farmers in the *Milpa Diversity Manager* segment are located in Jalisco, and over a third in Michoacán. The average size of the *milpa* they manage and their average output and productivity levels are intermediate between those from segments one and three. These farmers have the smallest percentage of *milpa*s with high soil quality across the three segments, and the highest percentage of *milpa*s managed without any chemicals. The percentage of farm families that manage landraces is similar between this group and segment one, both of which are 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. Even though the most important attribute affecting utility is the crop species richness attribute (see above), farm families in this segment manage significantly lower levels of crop species richness compared to those in segment one, showing levels similar to those in 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 than those in segment three.

Households in the *Milpa Diversity Manager* segment are smaller than and have fewer *milpa* participants than those in the first segment, though these parameters do not significantly differ from those in segment three. Almost a third of the households have at least one family member working off-farm, and the household off-farm incomes are lower than those in segment one, but higher than those in segment three. *Milpa* managers in segment two are the oldest and have the least education. A significantly lower percentage of the households have at least one child residing with them. Farmers in this segment reported the least dislike for GM food and crops (see Table 8), while this segment is the only one that does not exhibit the highest significant coefficient for the GM maize attribute amongst all the *milpa* attributes. Households in segment two show an intermediate distance from main roads, and the marginalization index of the communities in which they live is between those of segments one and three.

Similar to the case of segment two, almost half of the farmers in segment three, the *Marginalized Maize Producers*, are located in Jalisco and over a third are located at the Michoacán site. This segment does not derive any significant value from crop species and maize variety richness; instead, the farmers specialize in large-scale and more chemical input-oriented production of maize (see above and the descriptive statistics in Table 9). The *milpa*s in this segment are the largest, and the *milpa* outputs are the highest across the three segments. Moreover, this segment supports the lowest percentage of *milpas* managed with organic methods, and the productivity level is the lowest among the segments. A higher percentage of *milpa* producers in this segment sell their produce in markets, as opposed to household consumption, explaining the insignificant valuation of crop species and maize variety richness in this segment. A lower percentage of households in segment three have at least one member employed off-farm, and off-farm income is the lowest in this segment, implying that most of these farmers depend on maize sales for their livelihoods. Farm households in this segment are located furthest away from the main roads.

Farmer Valuation of *Milpa* Attributes

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

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

where β_y is the marginal utility of income, which is the coefficient of the monetary attribute (i.e. yield in this study) and β_k is the coefficient of the 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):

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

The WTAs reported in Table 10 were estimated for each of the three segments using the Wald procedure (Delta method) in LIMDEP 8.0 NLOGIT 3.0. The numerical results represent the percentage of the current *milpa* yield that farmers are WTA in order to forego an attribute (in the case of positive WTA values) or in order to adopt an attribute (in the case of negative WTA values).

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 *Marginalized 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 of the Wald procedure contained within LIMDEP 8.0 NLOGIT 3.0. Numbers 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 the 1% (***) and (**) 5% significance levels.

Across the three segments, the GM maize attribute is consistently negative and significant, while the maize landrace attribute is positive and significant. Furthermore, we see variation in the ranking of both *milpa* attributes and their impact on farmer utility. 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 level of compensation to forego growing landraces. They would also need to be compensated the most to use GM maize. Farmers in Oaxaca, the state where transgenic constructs were identified in maize landraces and where most of the public debate on GM maize has taken place, are most heavily represented in this segment. Farmers in this segment also value crop species richness and maize variety richness, but to a smaller extent.

Milpa Diversity Managers value all the agrobiodiversity attributes of the *milpa*, and their valuation of *milpa* attributes is more evenly distributed compared to members of segment one. Among the examined attributes, they derive the highest values from crop species richness, followed by the presence of a maize landrace and cultivation of an additional maize variety. Compared to segment one, farmers in segment two would need to be compensated less to use GM maize.

Marginalized 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 that of the *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 marginalized locations, greater distance from food markets and lower access to off-farm income, they are more reluctant to give up higher maize yields for higher levels of crop species richness or maize variety richness.

6. 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 from the three sites of Jalisco, Michoacán and Oaxaca. These sites were selected based on their importance as centers 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, such as the presence of a maize landrace, GM maize, crop species richness, maize variety richness, and maize yield. Derivation of welfare estimates from the LCM, combined with the characterization of different producer types, enabled us to characterize the farmers in terms of their propensity to continue managing *milpas* and their need for compensation for the introduction of GM maize into Mexico.

Three segments were identified. The first, characterized as *Landrace Conservationists*, value maize landraces the most and would need to be compensated the most for growing GM maize. These farmers manage the smallest *milpa*s, have younger and larger families, are better integrated into labor markets and have the highest off-farm incomes. Most of the farmers in this segment are located in the state of Oaxaca, where transgenic constructs were found in maize landraces and most of the public debate on GM maize has taken place. Furthermore, Oaxaca is the site with the highest percentage of population speaking 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 Conservationists* also derive significant values from other agrobiodiversity attributes of the *milpa* (i.e. crop species richness and maize variety richness), and thus would be the least-cost targets for maize landrace conservation within the *milpa* system, where landraces historically evolved.

By comparison, *Milpa Diversity Managers* (members of the second segment) derive the highest 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, although they express a dislike for GM maize, they are less reluctant to try it than *Landrace Conservationists*. Farmers in the *Milpa Diversity Manager* segment would be the least-cost targets for conservation of the *milpa* system. However, given that the size of this segment is less than half that of segment one, focusing on the farmers in segment two would entail a less widespread conservation effort.

Marginalized Maize Producers (members of segment three) derive the lowest values from maize landraces, and insignificant value from higher levels of crop species and maize variety richness. About 90 percent of this segment is comprised 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.

Marginalized 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 the least in local labor markets. Based on WTA estimates, they would be the least reluctant to adopt GM maize. This is of major policy interest, since most of the farmers in this segment are located in the Jalisco site, where the introduction of GM maize could have a serious impact on *teosinte*, the nearest wild relative of maize.

Thus, 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 the farm households of the studied sites. However, the findings also demonstrate that there is significant heterogeneity in preferences among Mexican farmers. This should be taken into consideration when designing programs to conserve maize-based systems in Mexico, as well as when estimating the losses and gains to farmers arising from the introduction of GM maize.

APPENDIX

Description of the GM Maize Attributes

Instituto Nacional de Ecología

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.

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