E C O N O M I C S

Working Paper 99-08

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Contents

Abstract

This study uses an approach derived from models of the private and public characteristics of goods to illustrate (1) the overriding importance of variety attributes in farmers' decisions to allocate area among varieties of maize landraces and (2) the significance of farmers' perceptions of changes in the maize germplasm base in the surrounding community in their choices. Diversity indices and the concept of "scale", as understood in ecology, are adapted and employed to test hypotheses empirically. Though a case study of maize farmers in Southeastern Guanajuato, the research raises methodological issues for models of variety choice and has policy implications for the potential to conserve maize genetic diversity on farms in Mexico.

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Introduction

The land races grown by farmers in centers of crop origin and diversity have social value because they are sources of novel alleles or gene combinations. Farmers and professional plant breeders use land races and other sources of genetic diversity to adapt crops to changing production environments and improve their genetic potential to produce the food, feed, and fiber on which societies depend. Land races are heterogeneous crop populations that continue to evolve genetically in response to the selection pressures of farmers and nature, retaining their potential to adapt (Jackson, 1995). By contrast, crop populations conserved in *ex situ* gene banks, while useful for many purposes, are "frozen" on the evolutionary clock at the time of their collection.

Among conservators and funding agencies there is a growing interest in the prospects for enhancing farmers' management of genetic resources as a strategy that complements their conservation *ex situ* (Maxted, Ford-Lloyd and Hawkes, 1997). Assuming that modern varieties will inevitably replace traditional varieties, critics have raised concerns about the economic costs of implementing such programs because they would necessarily entail foregone development opportunities. Brush (1995) and others have argued that the persistent cultivation of land races in centers of crop origin and diversity such as Turkey for wheat and Mexico for maize, termed *de facto* conservation, attests to their continued private value to farmers or their competitive advantage relative to modern alternatives (Brush and Meng, 1998; Perales, 1998). As long as farmers find it optimal to grow and manage these genetic resources, the social costs of mounting programs to encourage them to do so is minimal since private and social optima appear to converge.

Whether *de facto* patterns of cultivation reflect an equilibrium or a momentary lull in the process of replacing traditional varieties with the products of plant breeding programs is unclear. At least 80 percent of the maize area in Mexico is still planted to varieties of maize land races or "creolized" varieties (CIMMYT, 1999), which are improved varieties whose seed has been saved and re-selected by farmers to suit their own farming conditions. Maintaining maize genetic diversity is not solely a question of planting traditional varieties, however. Not all land races are equivalent in terms of the private benefits they generate for farmers or the conservation benefits they bestow on society. This implies that the private and social optima for genetic resource conservation may diverge even if farmers in crop centers of diversity still prefer to grow land races.

This study has two principal purposes. The first is to examine farmers' demand for varieties of maize land races by applying a choice model in which variety attributes and regional features, in addition to the farm household characteristics that are usually studied, determine area shares planted to traditional maize varieties. Variety attributes are their performance characteristics as evaluated by farmers who have grown them for many years, and generally cannot be observed in the shelled grain found in marketplaces. They are also "fixed" at a point in time by the genetic code embodied in the seed that determines their expression. By stratifying the analysis on potential productivity and infrastructure development of regions within the study area, the study enables us to test hypotheses related to the dynamics of development.

The second purpose is to investigate empirically the relationship between farmers' demand for variety diversity and the genetic diversity of maize land races in their communities. The theory of impure public goods shows why farmers may not choose to grow varieties with the level of crop genetic diversity that society in general views as desirable. Even if farmers were aware of changes in the supply of distinct maize materials in their community and considered the decisions of other farmers in their own, they could not completely control the level of genetic diversity among populations of open-pollinated species such as maize.

The framework we use also explicitly recognizes that *de facto* conservation is a complex process of interaction between biophysical, biological, and socioeconomic factors, each operating at different levels of aggregation or "scales" of analysis. The importance of "scale" has been well established in ecology and environmental sciences (e.g. Allen and Starr 1982; Michener et al. 1994).

The next section presents the background to the study, followed by the conceptual approach. The section on the empirical estimation procedure and hypothesis tests includes detailed descriptions of the data source, sample design, and variable definitions. Results are then reported. Conclusions, methodological and policy implications are summarized in the final section.

Background

Mexico is the center of domestication and diversity for maize. The southeast segment of Guanajuato, the study area, is located on the fringe of the Bajio, one of the most commercialized agricultural areas of Mexico. Despite its location, the cultivation of modern varieties in the survey zone is negligible and during the field research reported here, several unique land races and land race mixtures were identified and collected from among those grown by farmers for *ex situ* storage in the national genebank.

Many small-scale farmers in Mexico, like those in other areas of crop diversity (e.g., Brush, Carney and Huaman, 1981; Dennis, 1987), plant several maize varieties in one season. In a neoclassical model of decision-making, an unconstrained, risk-neutral farmer who maximizes profits would choose to grow only the variety with the highest profits per hectare. Understanding why a farmer grows more than one variety has motivated economists to propose a number of competing explanations that are extensions to the neoclassical model. Broadly categorized, alternative explanations include farmer attitudes toward yield, price, or consumption risk (Carter and Wiebe, 1990; Fafchamps 1990; Hammer 1986; Herath, Hardaker and Anderson, 1982; Just and Zilberman, 1983), experimentation and learning under uncertainty (Hiebert 1974; Tsur, Sternberg, and Hochman, 1990), missing markets (de Janvry, Fafchamps, and Sadoulet, 1991) or imperfect markets for fertilizer (McGuirk and Mundlak, 1991), or a jointly-produced output, such as fodder (Renkow and Traxler, 1994). Alternative explanations were recently reviewed and tested by Meng in her study of decisions to grow wheat land races in Turkey (1997), tested for maize in Malawi in Smale, Just and Leathers (1994), and tested within the class of risk models by Herath, Hardaker and Anderson (1982).

From the perspective of human ecology, variety choice can be viewed as a process by which a farmer assembles various bundles of traits to satisfy consumption preferences, satisfy specific production conditions, or fulfill marketing requirements (Bellon, 1996). Small-scale farmers with multiple objectives often consider several attributes of varieties when choosing among them, including traits related to yield of grain and fodder as well as those related to their home consumption of staple and specialty foods. Any single variety typically has both desirable and undesirable attributes, and no single variety is likely to possess all of those demanded by the farm household. For example, Bellon and Taylor (1993) have shown that differences in the adaptation of varieties to soil quality can explain partial adoption.

Many of the attributes that small-scale maize farmers in Mexico care about are unobservable in the shelled grain sold in a village marketplace—they are known only through years of growing the crop in variable climatic or soil conditions and consuming the output. When markets are missing and households cannot specialize through trade, they must meet their demand autarkically (de Janvry, Fafchamps, and Sadoulet, 1991). This implies that farmers allocate land among varieties according to the shadow values of their attributes, which are determined by household production processes and utility parameters.

Seed is unique as a commodity in that it has both private and public attributes (Morris, Rusike, and Smale, 1998). The private characteristics of seed are those that cannot be consumed by two farm households at once, such as those related to food and feed products. The public characteristics of the seed are its non-rival or non-exclusive genetic attributes, including its contribution to genetic diversity. The genetic diversity of maize grown in Mexico has been shaped for centuries by farmers' seed management and variety choice. Since maize is an open-pollinated crop and pollen flows across a landscape at flowering, the genetic diversity of maize populations in a community is also influenced by the spatial pattern of populations and their planting and flowering dates (Bellon and Brush, 1994; Louette, 1994). Farmers can influence the genetic structure of their varieties through allocating maize area and choosing the amount of seed to save from the harvest or mix with seed procured from other sources. In some cases, they may even be able to influence the variety choices of their neighbors. They cannot, in any case, control the pollen that flows from the fields of neighbors into their own and vice versa.

Conceptual Approach

Our approach draws conceptually from two types of models, both derived originally from Lancaster's model of consumer characteristics. The first type is an applied variety choice model (Adesina and Zinnah, 1993; Barkley and Porter, 1996) in which farmers maximize the utility from multiple attributes of the crop produced by their choice of varieties, rather than the varieties themselves or only a single trait such as grain output. The second is the theoretical model of impure public goods described by Cornes and Sandler (1986), and applied to the analysis of crop genetic diversity by Heisey et al (1997). According to this approach, each area allocation decision jointly produces or supplies characteristics of use to the farmer as well as a characteristic of social interest—a contribution to maize genetic diversity in the farmer's community.

We can view the choice as a model of decision-making in the farm household, using maize farming in southeast Guanajuato as an example. The household maximizes utility over a set of total maize attributes, represented by a 1 x m vector $\mathbf{q}$. For example, consumption attribute j might be ease of hand processing or taste of *tortillas.* The household can vary the total amounts of each element of $\mathbf{q}$ by changing the area allocations among n varieties (represented by an n x 1 vector α), since the grain output of each variety i jointly supplies, in fixed proportions, different amounts of each consumption attribute. The greater the total land area planted to maize (L), the higher the utility level that can be attained. The variety-specific supply of attributes is determined by a set of technical coefficients $\{q_{ij}\}$ that maps n stochastic outputs (vector $\mathbf{X}$) into m total attributes, and vice versa.

This technical relationship means that we can represent the utility function indirectly as $V(\alpha, L)$. The function V is conditional on a set of exogenous parameters which may change over time and location (W), including household characteristics, the productivity potential of the region and its level of infrastructure. The household chooses variety area shares (α) and the amount of total maize outputs to retain on the farm ($\mathbf{X}^c$), maximizing V subject to a budget constraint

$$\textbf{(1)} \qquad \max_{\alpha,\, \mathbf{X}^c} \; E\,[V(\alpha, L)] \,|\, \Omega \text{ W, Z} \quad \text{s.t.} \;\; C\,(\alpha, K, L) \leq I + \mathbf{p}'[\mathbf{X} - \mathbf{X}^c\,]$$

and a technology constraint

$$\textbf{(2)} \qquad F(\mathbf{X}, z \,|\, \alpha, K, L) = 0.$$

Outputs $\mathbf{X}$ are a function of their production attributes and non-seed inputs K. A functional relationship also maps levels of production attributes in the set of seeds for each variety $\mathbf{x}$ into outputs $\mathbf{X}$ by fixed technical coefficients x_{ik}. The quantities of seeds planted for each variety are determined by α and L. Production traits include, for example, tolerance of abiotic and biotic stresses, and performance on a specific soil type.

In most variety choice models, **X** is treated as a single homogeneous grain output or as the output of a modern or traditional variety. Here, it is represented by a set of distinct outputs of traditional varieties of maize land races, each produced and transformed into consumption attributes through a set of technical coefficients $\{q_{ij}, x_{ik}\}$. In applied characteristics models these coefficients are constant marginal products of a production or consumption technology and the problem is treated as in a linear programming algorithm (Ladd and Suvannunt, 1976). Here, the working parts of the technology are the gene combinations and alleles the seed embodies. These are fixed at a point in time and are exogenous to the farmer's decision in a single-period model. They are modified over time, through the deliberate decisions of farmers and plant breeders, natural selection processes, and genetic mutation.

Expenditures on maize production C cannot exceed exogenous income I (such as income from off-farm labor or migration that is earned before planting) and returns from sales of maize varieties[1] . The elements of $(\mathbf{X} - \mathbf{X}^c)$ may be positive or negative, depending on whether the household is a net seller or net consumer of maize. While there are local grain markets, there may not be markets for all attributes over which utility is defined. A commercial farmer producing maize varieties whose attributes are valued by the market might specialize and gain from trade. Since commercial producers are not concerned about consumption attributes unless they are reflected in price premia, they maximize utility over expected profits. Even when quality differences among varieties are not recognized in the market, however, production traits may affect the decisions of commercial farmers.

The impure public attribute of maize, its genetic diversity, is reflected in both the technology constraint and the utility function. Choice of any set α generates not only maize outputs (**X**), but the farm household's individual contribution (z) to maize genetic diversity in the community (Z). As argued above, maize genetic diversity in a community is influenced by the area allocation decisions of all farmers in the community:

(3) $Z = Z(z_1, \ldots, z_h, \ldots, z_H)$ for all farmers h=1,.......H..

A key analytical result of the impure public goods approach, developed fully in Cornes and Sandler (1986) and adapted to crop production in Heisey et al. (1997), is that farmers as a group are not likely to choose seed amounts and variety combinations that are socially optimal, because individuals do not take into account the choices of others. Mathematically, under the Nash-Cournot assumption that they take the decisions of other farmers as given, the private optimum deriving from the first-order conditions for H households diverges from the social optimum by a term that includes the interrelationships among all farmers' choices.

A concrete example of this divergence is when farmers assume that others are growing a variety they have ceased to plant, and the variety is planted in such small populations that frequencies for certain alleles become too low for effective survival. Once a farmer ceases

[1] We have implicitly assumed intra-seasonal borrowing between periods. For the purposes of this paper, relaxing this assumption would create further complications with little contribution to the analysis.

planting a variety, he or she must rely on other farmers of the community for seed. Community seed banks are one social mechanism for shifting the private optimum closer to the social optimum, as defined by the collective needs of that community. In other cases, we might define the social optimum according to the conservation goals of national or international policymakers, as expressed in a social welfare function, with Z measured by an indicator of genetic diversity in a targeted region.

Whether the genetic diversity of the maize land races grown in a community is considered by farmers in their decision-making is a testable hypothesis. When genetic diversity is defined in terms of allele frequencies observed at a molecular level, for example, the household's individual contribution to diversity is not observable and we would not expect the utility function to be defined directly over Z. However, utility may be conditioned on Z when genetic diversity is observable as pheno-morphological variation, which is genetically and environmentally determined. In Mexico, the variation in color and texture of maize is exploited to produce specialty dishes that are of importance for participation in *fiestas*. Farmers classify their maize according to observable ear characteristics (morphology) and growing period (phenology). Z can then be interpreted as the supply of distinct pheno-morphological characteristics associated with the different maize populations found in the community. Aguirre (1999) has found in these Guanajuato communities, as has Dennis (1987) among rice farmers in northern Thailand that some farmers choose to grow a variety simply to ensure a supply of the seed type.

The reduced-form equation of this conceptual model depicts the area share of variety i as an indirect, constrained demand:

(4) $$\alpha_i = \alpha_i\ [(\{q_{ij}, x_{ik}\},\ \mathbf{p}, K, I, L)\ |\Omega, Z]$$

The indirect demand for variety i is determined by it's capacity to supply the attributes demanded by the farm household, prices and costs of production, income, and total maize area. There are local maize markets, although not all attributes are reflected in market prices. Farmers' preferences over attributes, as represented in the parameters of their utility functions, depend on the socio-demographic characteristics of the household, economic and physical environment in which they grow maize (Ω). The supply of attributes in the varieties from among which they choose is constrained by the genetic diversity of maize in their community, the impure public good Z.

Empirical Estimation and Hypothesis Tests

Estimation of the reduced-form equation (4) provides information about land allocation among varieties of maize land races and farmer demand for variety diversity. The lower the area share predicted by the regression equation, the greater the predicted number of varieties the farmer grows. Area shares are bounded in the [0,1] interval, but predicted area shares may lie outside that interval. To correct for that problem, we use a two-limit Tobit procedure. The equation is estimated in LIMDEP.

With likelihood-ratio tests, we use regression results to test statistically whether the set of (a) variety-specific attributes, (b) household-specific characteristics, or (c) characteristics related to the productivity potential and infrastructure of the zone in which the farmer grows maize are jointly most likely to explain area shares. Each type of variable represents a different "scale" of analysis (variety, household, community, region) and is addressed by different types of policies. For example, technical incentives provided through breeding programs could be used to influence variety attributes. We also use specific hypothesis tests on individual coefficients. The test on the coefficient of productivity potential suggests how variety diversity may be maintained in areas that are "favorable" versus those that are "marginal" for production; the test on the coefficient of the infrastructure variable suggests how infrastructure development may affect average area shares. The coefficient of Z shows the nature of the association between the choices of individual farmers and the impure public attribute, maize diversity in the farmer's community.

The data source, variables, and hypotheses on individual coefficients are described in the following subsections. The definitions of variables used in the regression are summarized in Tables 1 and 2 and descriptive statistics are shown in Table 3.

Data Source

The study was conducted in Rural Development District 004 in the southeastern part of Guanajuato State. The data set combines: (1) a regional classification of the study area into four strata according to secondary data on productivity potential and infrastructure development; (2) survey data from 160 farm households located in 21 communities in the four strata; (3) a taxonomy of the maize land races they grow based on ear samples

Table 1. Definition of variables in regression equation

Variety choice equation	Definition
Dependent variable	proportion of household maize area planted to each variety
Regional characteristics	
productivity potential	1=outside 140-day isoline for growing period; 0=inside 80-day isoline
infrastructure development	1=infrastructure developed; 0=isolated
Variety characteristics	
p	best for sale in market=1; 0 otherwise
tortillas	best for *tortillas*=1; 0 otherwise
K	least cost in purchased inputs and/or management=1, 0 otherwise
culinary	best for preparation of a special dish =1; 0 otherwise
security	best for avoiding disastrous harvests =1, 0 otherwise
feed/forage	best for livestock feed or forage=1, 0 otherwise
Household characteristics	
head of household	female-headed equals 1; 0 otherwise
size of household	number of people residing in household in 1995-6
cash income	head contributed cash to household from off-farm work in 1994
percent sales	percent of maize output sold in 1994
total maize area (ha)	maize area cultivated in 1994
irrigated	farm has only irrigated land=1, 0 otherwise
rainfed	farm has only rainfed land=1, 0 otherwise
soils	number of soil types on-farm

collected from each household; (4) diversity indices adapted from the ecology literature and applied to the taxonomic data for each community.

Sample Design

Four strata were delineated based on contrasting maize yield potential and levels of infrastructure. First, two municipalities with contrasting maize yield potential were identified according to the classification of the Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP) in that state (García 1989). The classification is based on the probability that a growing period of a given length will occur, where growing period is defined as the number of days during a year when moisture and temperature are favorable for maize development, controlling for soil depth. The longer the growing period in an area, the higher its potential productivity. The municipalities selected for the study, Apaseo el Grande and Jerécuaro, are located in areas with the greatest contrast in length of growing period (within the 80-day and outside the 140-day isolines, respectively).

Next, secondary data on road surface, electricity supply, and numbers of schools, health centers and business establishments for the communities within each municipality were used to identify the zones with the greatest and lowest level of infrastructure development (INCA RURAL 1987; FMDR 1987).

A recently compiled census[2] of maize-farming households in Guanajuato State was then employed to enumerate approximately 400 households in each stratum. From each list of 400 households, a systematic random sample of 10 percent of households were selected, for a total of 160 households located in 21 communities in zones[3]. Socioeconomic characteristics of the household were elicited in on-farm interviews from August 1995 to January 1996.

After harvest, samples consisting of 6 ears that the farmer considered as representative of the variety were collected for each variety grown. A specialist in maize genetic resources from the INIFAP gene bank classified the 257 maize samples by race, using ear samples and information from farmers[4].

Variable Definitions

Variety Area Share

Understanding the term "farmers' varieties" is important for interpreting the estimating equation. Since maize cross-pollinates and farmers seed management practices vary, Farmer López' "Blanco Delgado" is not the same genetically as Farmer Gutiérrez' "Blanco Delgado", even though they may share the same name. The dependent variable α is a vector of area shares stacked by household, where each variety area share is treated as a single observation[5]. An area share for variety *i* is the proportion of maize area the farmer allocates to it. Large (small) expected area shares express the demand for fewer (more) varieties and or less (more) varietal diversity.

2 Secretaria de Agricultura y Recursos Hidráulicos.
3 There was no apparent periodicity in the sample. The sample is self-weighting, since the probability of selection for a household is equal across across zones.
4 Juan Manuel Hernández Casillas.
5 For example, the first six observations in α might be [0.5, 0.25,0.25, .80, .20] where the first three observations are for household 1 and the second two are for household 2.

Maize Diversity in the Community

The term "land race" refers generally to crop populations that have become adapted to farmers' conditions through natural and artificial selection. In maize, farmers' varieties are classified by genetic resource specialists into a larger grouping called a "race." The taxonomy used to classify races, originally developed by Wellhausen et al. (1952) and still used today, is based on ear criteria such as grain color, size, and form, ear breadth and length[6]. Ear criteria are also those used by farmers to select the seed of their varieties and to group them into what they refer to as "classes of maize"(*clases de maíz*). About 59% of the 257 maize samples were classified as pure races, 33% were racial mixtures, 4% were 'creolized' (*acriollados*) varieties and 4% were improved varieties[7]. In open-pollinated crops such as maize, *acriollados* are defined as improved varieties that have mixed with land races in farmers' fields for at least several years, either through deliberate farmer practices, or natural outcrossing, or both.

We represent maize diversity in the community (Z) with three variables. The first two are diversity indices adapted from those commonly employed in the ecology literature (Magurran 1988) to summarize inter-species diversity and applied to the classification of maize races (Table 2). The Margalef index expresses richness, or the number of species (races) encountered in a given sampling effort. A count of species, even when standardized as in the Margalef index, assumes that all species at (races) a site contribute equally to biodiversity (maize genetic diversity). "Evenness," also called "equitability," refers to the degree of equality in the abundance of the individuals, or the relative uniformity of the frequency distribution across species (races). When all species (races) in a sample are equally abundant, evenness reaches a maximum (Ludwig and Reynolds, 1988).

Since the ear characteristics used to classify farmers' varieties into broader racial categories are observable to farmers, we interpret diversity indices constructed from them as

Table 2. Definition of indicators of maize diversity in communities

Indicator	Concept	Mathematical Construction	Explanation	Adaptation in this paper
Margalef Index	Richness	$D_{mg}=(S-1)/\ln N$	number of species-1, weighted by the logarithm of the total number of samples	S = number of distinct classes of maize
Pielou Index	Evenness	$J=(-\Sigma p_i \ln p_i)/\ln S$	Shannon index corrected by the logarithm of the number of classes. Shannon $=-\Sigma p_i \ln p$	p_i is proportion of total samples in maize class i.
Farmer perceptions	Perceive loss/grow to conserve	dummy variable		=1 if farmer has observed loss of varieties in community *and* states that he grows a variety to conserve it.

Mathematical construction for Margalef and Pielou indices as defined by Magurran (1988) and adapted in Aguirre, Bellon, and Smale (1999).

6 "..a race is a group of individuals with a significant number of genes in common, major races having a smaller number in common than do sub-races" (Anderson and Cutler 1942:71). Despite the development of more powerful taxonomic tools, race remains an important concept for understanding maize in Mexico (Bretting and Goodman 1989; Doebley, Goodman, and Stuber 1985; Sanchez and Goodman 1992).

7 For detailed analyses of these populations see Aguirre (1999) and Aguirre, Bellon, and Smale (1999).

indicators of the richness and evenness in the "supply" of maize characteristics that distinguish one category from another. Two-tailed hypothesis tests on these variables indicate whether the supply of distinctive materials in the community, which is exogenous to individual farmers though shaped by their choices in the aggregate, constrains the number of varieties they grow.

The third indicator of Z is a binary variable measuring whether a farmer reported that varieties had been "lost" in his community *and also* stated that he grew a variety in order to "conserve" it. The two-tailed hypothesis test on this variable indicates whether farmers take the outcomes of the decisions of others into account when they allocate maize area among varieties.

Productivity Potential and Infrastructure Development

The hypotheses motivating the stratification of the sample into four study zones are that agroecological and infrastructural conditions (Ω) in a region are associated with maize diversity, although the direction of the effect is difficult to predict *a priori*. Agroecological conditions are the climate and soils that determine the yield potential for a crop in an area; infrastructural conditions include the presence of roads, stores, clinics, and schools. The presence of infrastructure delimits the potential of households and their members to participate in markets as consumers and producers as well as to acquire new ideas and information.

The four study zones can be represented conceptually along two axes of maize yield potential (favorable or marginal growing environment) and infrastructure (relatively isolated or developed), as in Figure 1. While maize yield potential does not change over time, infrastructure generally increases with the economic development of an agricultural region. Among other factors, the presence of infrastructure may contribute to cultural change in the region. Movements along the infrastructure axis may therefore be interpreted as representing changes in time. The two axes are represented by dummy variables in the regression, and hypothesis tests are two-tailed.

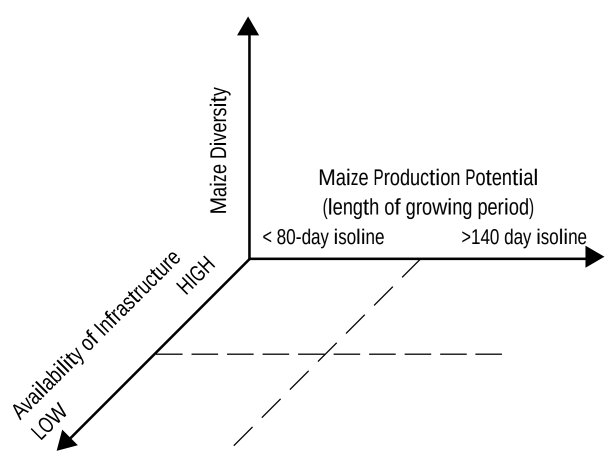

Figure 1. Conceptual representation of survey strata
Source: Aguirre, Bellon, and Smale, 1999

Variety Characteristics and Prices

In informal interviews and field research that preceded the formal household survey, farmers were asked to identify the attributes of varieties (**q**, **x**) that they considered important. The most frequently cited attributes including suitability for: market sale (p in Table 1), consumption of the staple food (called *tortillas*), preparation of food consumed on special occasions (called *culinary*), avoiding disastrous harvests (called *security*), and quality as feed or forage for livestock (called *feed/forage*).

During the formal survey, farmers then assessed the relative extent to which each of the varieties they grew each supplied the attributes previously identified, or the technical coefficients $\{q_{ij}, x_{ik}\}$[8]. Two-tailed tests of significance were conducted for the estimated coefficients of all variables representing attributes.

Suitability for market sales generally reflects a combination of quality and yield attributes. A variety rating high for market sales produces a lot of heavy, white grain, which makes it more attractive to CONASUPO (the government's food marketing and distribution agency) or to private traders purchasing maize for industrial processing. While informal markets exist for farmers' varieties, including colored maize, the official prices for white maize were artificially set and were uniform across white maize types during the period of the study. Though some differences in grain color, health, and form may be reflected in price variation for shelled grain in farmers' markets, farmers' varieties as we have defined them on pheno-morphological or genetic criteria are not observably distinct.

The producer price during the year of the study began to decrease under the liberalization policy of the North American Free Trade Agreement (NAFTA) in 1995. Although the consumer price was set below the world market price during the period of the study in urban areas, Levy and van Wijnbergen (1992) have argued that with both rural producers and rural consumers obtained most of their maize at the producer price. They differentiate between urban and rural prices for white maize, rather than producer and consumer prices. As shown by Taylor, Yuñez-Naude and Dyer (forthcoming) in their analysis of the effects or NAFTA on maize production, transactions costs in village and town economies of Mexico lead to price responses that are contrary to those predicted by conventional analyses. Farmers' assessment of the suitability of a variety for market sale (p) indicates its commercial attractiveness and is used here as a surrogate for gross profitability.

Farmers' assessments were also used to measure the relative cost of production (K) among varieties. K refers to both the purchased inputs and labor time used to produce the variety. We expect these differences to be minor among farmers' varieties, but they are often assumed to be major between farmers' and improved varieties. Less than 3 percent of survey farmers planted first-generation hybrids or open-pollinated varieties improved by plant breeding programs, however.

Seed prices are not measured as separate variables. Although some survey farmers also purchased or exchanged the seed of traditional varieties and improved varieties of advanced generations, the seed price for these maize types varies little by variety. Again, these characteristics are not fully observable in the marketplace. In exceptional cases, local farmers are known as suppliers of high quality seed for a given variety. In these cases, the farmers who purchase can observe the seed growing in the field of its producer and assess the genetic characteristics that determine its performance.

[8] Very few of the varieties grown were rated highly for religious use or seed sales, and none were cited as good sources of resistance to drought, pests, or diseases.

Household Characteristics

Whether or not the household head contributed cash earned through non-farm or off-farm activities in the preceding year (*I*) varied by zone (Table 3) and was associated with mean variety share. This variable, and the percent of the 1994 maize harvest sold by the farm household, were used to capture key differences in farming objectives[9]. No direction of effect was hypothesized for these factors, and their coefficients were evaluated with two-tailed tests.

Numerous tenure arrangements facilitate farmers' access to irrigation and soil type in the survey sites. Compared to rainfed fields, irrigated fields reduce the variability in yields due to moisture conditions, enabling a farmer to control with water what he might have controlled through growing varieties with different moisture response. Farmers often report that they grow a maize variety on a specific soil type. Bellon and Taylor (1993) have demonstrated the importance in land allocation decisions of differences in soil types on farms in Chiapas, Mexico. One-tailed Z-tests were used to estimate the significance of the whether the farmers had irrigated plots or rainfed plots, and the number of soil types on the farm as determinants of variety area shares. These variables are classified as household variables because they vary by household, but they are agroecological variables because they represent water regimes and differentiation in soils.

Table 3. Descriptive statistics for household characteristics and community by stratum

	80-day growing period		140-day growing period	
Variable	**isolated**	**infrastructure developed**	**isolated**	**infrastructure developed**
		Mean of households		
maize variety area share	.324	.743	.410	.598
size of household	6.93	6.38	6.95	4.77
percent maize sales	32.9	40.4	49.3	60.2
soils	2.91	2.14	2.39	2.48
total maize area (ha)	8.35	8.09	14.19	10.98
		Mean of communities		
maize richness	4.89	4.66	4.28	3.71
maize evenness	0.791	0.941	0.767	0.842
		Percent of households		
female-headed	5	3	3	3
irrigated	0	51	0	26
rainfed	95	9	70	34
both irrigated and rainfed	5	40	30	40
cash income	78	84	30	34
perceive loss/ grow to conserve	65	9	70	15

For variable definitions see Table 1.

[9] Whether or not migrant children sent remittances or the household head worked off-farm in the year preceding the survey did not vary significantly by zone and was not related to mean variety share. Credit for production of maize, previously provided in the study region for purchasing inputs and hiring labor, was obtained by only a handful of survey farmers, and was not used in the regression analysis.

Household size and sex of household head were retained in the regression equation to control for essential demographic factors, even though descriptive statistics reveal little variation among zones for household size, sex and age of household hold, years farming or years of education (Table 3). Only a minority of households were headed by women.

Results

Regression results for the variety choice equation are shown in Table 4. Z-tests demonstrate the relevance of several of the individual agroecological parameters, variety attributes and household characteristics in the decision to allocate area among varieties of maize land races. The greater the development of local infrastructure, the lower the expected area share per variety and the lower the varietal diversity per farm. This effect is counteracted by the productivity potential of the region, as indicated by the coefficient of the interaction term between productivity and infrastructure. A greater number of soil types per farm increases the number of maize varieties grown. Clearly the agroecology of the production zone, in interaction with and in addition to infrastructural development, shapes the area allocation among varieties of maize land races.

Table 4. Estimated variety area share equation

Explanatory variable	Marginal effects	S.E.
constant	.649 ++	.352
productivity potential	.0795	.0547
infrastructure development	.309 +	.0870
productivity-infrastructure	-.248 +	.0855
p	.130	.125
tortillas	.299 +	.112
K	.119	.115
culinary	-.202 ++	.111
security	.137	.118
feed/forage	.0759	.154
total maize area	-.00245	.00357
head of household	.0358	.0998
size of household	-.00545	.004244
irrigated	.0462	.0673
rainfed	-.0344	.0547
soils	-.0180 **	.0135
percent sales	-.000219	.000496
cash income	.0237	.0417
richness	.0253	.0304
evenness	-.378	.361
perceive loss/ grow to conserve	-.122 +	.0414
value of log-likelihood function	-114.82	

n = 319. Dependent variable is area share planted by household to each farmer-named variety. Marginal effects are partial derivatives of expected value, computed at means of variables.

* significant at .05 with one-tailed Z-test
** significant at .10 with one-tailed Z-test
\+ significant at .05 with two-tailed Z-test
\++ significant at .10 with two-tailed Z-test

Of variety attributes, those of statistical significance are related to the family's consumption of maize, rather than to the suitability of the variety for market sale or its cheapness to produce. While farmers cited the suitability for market sales and cost of production as important variety attributes, these do not contribute statistically to explaining variation in area shares. The expected area share of varieties best suited for producing the staple food (*tortillas*) is 0.29 percentage points higher than that of other varieties. Given that off-farm work, remittances, and non-farm activities are common sources of cash among survey households, this finding reflects the premium they place on the quality differential between homemade and industrially-processed *tortillas.* A variety most suited for the preparation of a special dish tends to occupy significantly less of the farm's maize area, since it is consumed less frequently.

In estimating equation (4), groups of explanatory factors vary differently according to the scale of analysis they represent and at which they were measured. Area shares are explained by characteristics that vary by farmer variety, as well as factors that vary by household, stratum, and community. Log-likelihood ratio tests were conducted on each of the sets of coefficients representing the different "scales" of factors. While the sets of variety attributes, community, and regional characteristics are each jointly significant, the set of household characteristics is not. Variety attributes are jointly of overriding importance in determining the area shares that survey households allocate among varieties of maize landraces, as indicated by the relative significance level of the test[10]. As the dependent variable is defined in this regression, this result implies that differences among varieties in the provision of attributes that farmers identify as important most explains the demand for different maize land races, and therefore the number they grow. Productivity potential and infrastructure development are jointly significant at the 1 percent level of significance.

The results of the joint hypothesis tests are of interest for several reasons. First, as has been argued by Adesina and Zinnah (1993), adoption studies may have focused on household characteristics to the exclusion of variety characteristics. Considering varieties in terms of their attributes rather than their improvement status may provide additional insights into adoption. Second, the importance of stratifying by agroecology and infrastructure points to the utility of keying adoption studies to a sampling frame such as those provided through geographical information systems (Hassan, 1998).

Third, the joint hypothesis tests have implications for policies. Variety characteristics, unlike household characteristics and the agroecological parameters that define a production zone, are amenable to plant breeding and other technical interventions. A finding of this type may assist in the development of policy incentives for conservation of crop diversity. In these communities of southeast Guanajuato, the cultural significance of food and culinary practices explains how farmers allocate their maize area and as a consequence, the number of varieties of maize land races they grow on their farms. While a variety that is best at the provision of good *tortillas* tends to occupy a larger percent of maize area, varieties that are used in the preparation of special dishes occupy smaller niches.

The hypothesis tests for the impure public attribute *Z* also have policy implications for conservation. As a group, the effects of three Z variables have jointly significant effects on the number of varieties farmers grow[11]. Neither the richness nor the evenness index constructed at the community level from the classification system of the genetic resource specialist is associated significantly with the variety area shares of individual farmers. By contrast, farmers' perceptions that materials have been "lost" from their community do appear to affect their choices. We may interpret this result in any one of several ways. First, while farmers may observe variation in morphological characteristics of the maize ear and

[10] The test-statistic for the log-likelihood ratio test, λ, is distributed $\chi 2$, d.o.f=number of restrictions. For variety characteristics, λ=53.2301 with 6 d.o.f.; for household characteristics; λ=5.2358 with 5 d.o.f.; for stratum, λ=13.3492 with 3 d.o.f.

[11] Again, a log-likelihood ratio test was used. For diversity indices as a group, λ=9.9936 with 3 d.o.f., which is significant at the 2.5 percent level. The absolute value of the correlation ceofficient between any pair of these variables is less than 0.23.

use them to define the classes of maize they grow, they may not be able to observe the distribution of these characteristics across many farmers in their community. This interpretation is consistent with the Nash-Cournot assumption that farmers do not take into account the decisions of others—because it is physically impossible to discern the combined effects of simultaneous decisions taken by numerous farmers. On the other hand, the positive effect of farmer perceptions on the number of varieties they grow conflicts with the Nash-Cournot assumption. This finding suggests that maize farmers grow more varieties when they recognize that the germplasm base in their communities may be narrowing.

Another related, methodological point is that the number of maize varieties as recognized by farmers is not necessarily related to the diversity of land races as recognized by geneticists, since these represent two taxonomies. Often, in empirical literature on crop genetic diversity, the number of varieties and genetic diversity are taken (incorrectly) as synonymous with diversity. Maize varieties and races of maize in Mexico are metered differently, as are any two taxonomies used to measure crop genetic diversity.

Conclusions and Implications

The approach used in this paper draws in two ways from Lancaster's model of characteristics. First, we have argued that the area allocation among varieties of maize land races in Southeastern Guanajuato is determined not by the utility of the varieties themselves but by the attributes they provide. Many of the attributes that matter to farmers in these communities cannot be observed in the market for shelled grain, but must be evaluated by observing their performance across soils and seasons. Regression results support this notion. Of the explanatory factors, the group of variables representing the relative provision of attributes among varieties is jointly most significant in explaining variation in the number of varieties of maize land races grown by farmers. Furthermore, suitability for marketing and relative cost of production did not appear as significant.

Second, we have argued that the area allocation decisions of individual farmers contributes to an impure public attribute, maize genetic diversity in the community. The public attribute is "impure" because the utility functions of individual farmers may be conditioned on it, even though it is simultaneously determined by the decisions of many farmers. Under the Nash-Cournot assumption that farmers do not take the outcome of the decisions of others into account, however, the private and social optima will diverge. Hypothesis tests indicate that while the geneticists' definition of maize diversity in the community either does not mesh with farmers' or does not affect their decisions, farmers' perceptions do. Perhaps there are farmers who choose to be "conservators" in Mexican communities such as these. If so, stimulating farmer awareness or working directly with self-proclaimed "conservators" may in contribute to reducing the divergence between the private and social optimum.

The signs and significance of the stratum variables provide a glimpse of the dynamic process of development occurring in Guanajuato. While growing periods may not change in the near future, infrastructure will. As roads, transportation, communication and educational systems change, the allocation of maize area among different varieties of land races may diminish as farmers purchase the attributes they value on the market or their utility parameters change. The regression results support this hypothesis. At the same time, they suggest that productivity potential counteracts the effects of infrastructure development in southeastern Guanajuato, influencing positively the numbers of varieties grown per farm.

In general, facile assumptions about the relationship of market changes to maize production in Mexico may not be borne out. Taylor, Yuñez-Naude and Dyer (forthcoming) have argued that the high transactions costs present in rural maize markets has eroded the predicted negative impact of liberalization and free trade on Mexican maize production. A recent study of an *ejido* in Chiapas demonstrates that both the area planted to land races and numbers of farmers planting land races was higher in 1997 that in 1988, even though the community enjoyed good access to infrastructure during that period (Bellon, unpublished data).

The scope of this study is necessarily confined to one region in Mexico and to the analysis of farmer behavior, ignoring the institutional issues concerning the roles and incentives for other players to participate in on-farm conservation programs. To answer pivotal policy questions regarding the potential for on-farm conservation, more is required than demonstrating *de facto* conservation by individual farmers–even though these studies serve the important purpose of inverting common misperceptions about genetic erosion. In the context of genetic resources with both private and public attributes, we will need to further develop our understanding and better specify the relationship between farmer behavior and community-based incentive mechanisms.

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