In Situ Conservation of Crop Genetic Resources

in a Center of Diversity

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Abstract

The purpose of this paper is to model farmer behavior with respect to *in situ* conservation, extending the existing literature beyond competition within the principal crop to encompass a broader definition of on-farm diversity and testing the hypothesis that factors affecting the principal crop explain overall crop diversity on the farm . Primary survey data is used from a rural area of Puebla state, Mexico. A Poisson regression is run on the total number of species in the milpa system as explained by cultural, agricultural and economic variables. A set of Poisson regressions, one for each crop group, is run in order test whether factors affect different crops in different ways. Policy implication of the findings are discussed for an *in situ* conservation program.

Background

Crop genetic resources are the raw materials for crop breeding and a source of continuing advances in yield, pest resistance, and quality improvement. Genetic erosion has been documented in the cradle areas of crop domestication, where the loss of traditional cultivars accompanies the specialization and intensification that comes with the introduction and dissemination of modern, high-yielding varieties (FAO 1996, Qualset et al 1997). The conservation of crop genetic diversity in farmers' fields, *in situ*, is necessary to protect gains in crop breeding and provide for the possibility of further advances in the future.

An understanding of the processes of *in situ* conservation is emerging from a nascent literature that ties diversity outcomes in farmers fields to the theory of agricultural households. These studies have focused on competition between the modern and traditional varieties of major food crops, often in order to understand why traditional varieties persevere in certain areas without being completely displaced despite their allegedly inferior yields. Key research in this area includes Brush, Taylor, and Bellon (1992) for the case of potatoes in Peru; Bellon (1996) and Widawsky (1996) for the case of rice in China and the Philippines, respectively; Meng (1997) for wheat in Turkey; and Bellon and Taylor (1993) for maize in Mexico.

However, in reality, genetic erosion does not occur solely because of direct competition between traditional and improved varieties of the same species. A more general understanding of *in situ* conservation requires accounting for the genetic erosion that may result when traditional crop varieties are supplanted by other crop production or income activities. Furthermore, genetic erosion potentially occurs at multiple levels, including both principal crops and secondary crops in multiple cropping systems. These secondary crops are also of economic and biological interest. In the Mexican milpa system, diversity may be conserved within the principal crop, maize, but also within secondary crops of global importance including tomato, beans, squashes, chilies, etc. When competition among, as well as within, species shapes diversity outcomes, studies focusing on a single species are likely to produce econometrically biased estimates and potentially will produce misleading policy prescriptions. Thus, there is a need for understanding *in situ* conservation and diversity outcomes both within and across species. This paper will offer empirical tests for the effects of environment, wealth, level of market integration, and other household characteristics on farmer behavior regarding *in situ* conservation in a context of multidimensional diversity.

Policy Implications

A starting point for this research is that conservation is not static – it is an active and evolutionary process. Farmers experiment, trade seed, and adapt farming practices; both breeding and conservation programs need to take into account the economic contexts of farmer behavior. *In situ* conservation means more than that varieties continue to be sown, a broader sense of *in situ* conservation should encompass the framework for farmers to continue to adapt and select their local varieties. For this reason this investigation focuses on the economic, social, and ecological reasons that farmers would be more likely to conserve a greater number of varieties.

Previous to any active conservation program it is necessary to understand the process of "de facto" *in situ* conservation. In Mexico in general the story of maize landraces is puzzling: despite over 40 years of intense breeding activity, well developed extension and agricultural institutions, over 80% of Mexican maize is planted from farmer saved seed, and over 80% of Mexican maize production is for subsistence or technically non-commercial. In the sample used for analysis in this paper %100 of the seed is farmer-saved, %90 of farmers sold no maize, and arguably %100 of production is not commercial. In this sense farmers seem to be conserving "de facto", in the face of many apparent pressures to either stop farming or to change their practices. Thus it is important to focus on ways in which farmers are maintaining diversity while integrating into the process of development.

A related methodological impetus for this research is to look at the scale for conservation decisions. Local seed systems generally operate within villages, so we need to look at diversity in a regional and local level - within and across villages. For this work the villages are used to represent a sample stratification of different levels of infrastructure and market integration. The stratification across villages with different levels of development was planned in order to capture the dynamic effects while in a cross section model. A further policy implication for the interdisciplinary work is to determine how results obtained by breeders in one village can be extended to other villages in the region.

Furthermore, the Mexican economy is undergoing a broad transformation under NAFTA and a new environment of economic liberalization, including the elimination of subsidies and price supports. There is a need to look at how national and regional changes affect farming decisions shaping diversity. The regression results testing the effect of market variables and outside income opportunities on diversity conservation and competition with other crop or income opportunities will inform analysis of the effects of market changes and regional development which accompanies agricultural transformation.

Literature

The basic framework for household farm models of diversity is inherited from a literature that sought to explain the partial adoption of Green Revolution agricultural technologies. Reviews by Feder, Just and Zilberman (1985), Hayami and Ruttan (1985), and Feder and Umali (1993) outline the variety of explanations and empirical analysis of the 1970s and 80s. While the *in situ* conservation of traditional varieties can be seen as a failure to adopt, the key to the present research is to understand the positive benefits that diversity can provide for farmers and how choices among traditional varieties may shape diversity outcomes.

The review by Feder, Just and Zilberman (1985) points to the theme that larger farmers are able to adopt first and take advantage of differential land values, with significant equity implication of the new technology. A more recent review by Feder and Umali (1993) considers a later generation of Green Revolution studies of the aggregate diffusion process, many of which apply to the study of diversity because of their ability to tie adoption behavior to specific institutional, environmental, or infrastructure constraints faced by household farms.

Treatment of the demand for crop diversity as a risk issue has been inherited from a theme that has been central to the partial adoption literature. Among the most important for the application to the diversity modeling are safety first specifications, where consumption demand for a basic grain must be satisfied before the profit maximization decisions on other resources are made (Roumasset, 1977). Rosenzweig and Binswanger (1993) model the ability of different farmers to bear weather related risks. The ability of wealthier farmers to smooth their consumption ex post increases their ability to adopt more risky technologies. This led Rosenzweig and Binswanger to conclude that poorer households suffer more from an efficiency loss due to production diversification, including presumably their failure to adopt superior but risky technologies. In the crop genetic diversity case, the equity implications that poor households are the guardians of traditional cultivars need to be investigated. However, when other crop income or off farm income provides risk hedging against crop variability, there is less need for crop diversity as a means for risk spreading (Swanson et al 1994).

The demand for diversity may reflect consumption demands for basic grains and the demand for cash income from producing alternative crops. When households consume a large percentage of their production, an increase in price variability may lead households to dedicate a larger share of resources to producing the staple in order to cover subsistence needs (Finkelshtain and Chalfant 1991) The continued cultivation of traditional varieties to satisfy the subsistence requirements of the household may reflect high transaction costs in the marketing for specific consumption traits that households prefer.

If traditional varieties are locally consumed goods, the effect of wealth on farm-level diversity will depend partly on whether the traditional varieties are normal or inferior goods (Meng 1997). For instance, if a traditional variety is valued for family consumption or for ritual use it should receive a price premium. On the other hand, if a traditional variety or wild relative is an inferior good that will be substituted out with an increase in the use of markets for consumption, the signs of the wealth effect are ambiguous. Furthermore, factor and commodity substitutability usually is constrained in the developing country cradle areas of diversity. The effects of high transaction costs on the substitutability of hired for household labor and purchased for domestically produced food have been shown to have drastic effects on the impacts of Green Revolution technical change (De Janvry, Fafchamps and Sadoulet 1991). Missing markets decrease the own and cross price elasticities of supply for food crops-- the market or policy effects on basic grain diversity will be less than those predicted by a model that assumes the existence of perfect markets.

Recent studies have extended the partial adoption literature by taking into account a combination of these effects (Feder and Umali 1993). The nesting of a number of models to test for a multiple number of explanations by Smale, Just, and Leathers (1994) integrated questions of input fixity, portfolio behavior, safety first, and learning. The results for Malawi HYV maize adoption found that a nesting of hypotheses had more explanatory power than any single model, showing the need to incorporate multiple hypotheses into explanatory models. Meng (1997) included missing markets, risk aversion, and environmental constraints in an inclusive model. Meng found that the factors affecting variety choice more important than factors affecting post-choice diversity management; explanatory environmental variables found to be significant include regional effects, off-farm income and market integration.

Traxler and Byerlee (1993) show that the complementary effects of diversity demand can actually determine variety choice. Dwarf wheat varieties produced so much less straw for fodder that profit maximizing farmers stayed with the traditional varieties unless the yield gains surpassed a straw/grain price threshold. In the case of the diversity demand for multiple crops, the diversity of the system may have production complementarities across crops that will affect demand for total system diversity. The cross-crop effects of an inter-cropping system have been documented by agro-ecologists (Altieri and Merrick 1988) and farming systems research, but they have remained largely outside of the agricultural economics literature, perhaps because of the perceived limited economic importance of traditional agro-ecosystems. However, these system effects can lead to a higher level of diversity demand and utilization. In *in situ* conservation, there may be important cross effects of the adoption of a technology package: where adoption of an improved variety in the principal staple has no direct effect on secondary species, the adoption of complementary inputs such as herbicide or mechanical tillage may have adverse effects.

Finally, outside of the realm of economic theory but directly related to this work there is a small, but newer body of literature specific to the description of farmer behavior concerning maize in Mexico. In the Sierra de Manantlan reserve in Jalisco, Dominique Louette studied the interaction between farmer management of their seed lots by phenotypic characteristics and the implications for the genetics of the sample (Louette and Smale 1996). Hugo Perales documented the competitiveness of landraces in the Amecameca valley and pointed to the way in which farmers adapt and develop new varieties through constant selection (Perales 1998). Mauricio Bellon has worked both in Chiapas on looking at the way farmers match varieties to agronomic conditions, and in Oaxaca on looking at the traits or characteristics that farmers look for in a variety (Bellon and Taylor 1993).

Simplified Household-Farm Model

Diversity of the milpa is considered to be a function of the participation in activities j, each consisting of planting a specific species or variety. The Diversity function is increasing with respect to the number of species and the number of varieties within each species, but at a decreasing rate. The simplest function would be a count of milpa species N for crops i, i=1…N. More sophisticated measures of diversity can be composed from an indicator vector I, which is a vector of zeros and ones for the relevant species. The intricacies of the construction of diversity indices have been discussed above, for now it will suffice that:

$$I = [i_1 \quad i_2 \quad \dots \quad i_N];\ i_i = 1 \ \textit{if species i is planted}$$

$$D = \Phi(I),\ \Phi'(I) > 0,\ \ \Phi''(I) < 0$$

For the purposes of this paper, a count of the number of varieties or species is used. For maize the use of a seed lot as a principal unit of analysis has been tied to the fact that the seed lot is the basic population unit that the farmer manages. In self pollinated crops such as wheat and rice, a level of genetic diversity can be measured across improved varieties using phylogenetic trees and coefficients of parentage. For farmer varieties phenotypic and molecular techniques have been used to construct diversity indices implying a hidden or latent diversity within a given variety. In the case of an open pollinated farmers varieties, the case studied here, neither the metric for studying crop diversity, nor the link to farmer's behavior is analytically clear.[1]

Model Motivation

The modeling for this paper looks for explanatory variables to explain household farm motivations to conserve diversity. The theory of agricultural household models is utilized to focus on variables explaining how the addition of the jth variety to a household's "crop portfolio" can increase household welfare above what it otherwise would be.

Household Models

The household farm agents are modeled using a random utility model where utility, consisting of an observable and a stochastic component, is maximized subject to a set of constraints (McFadden). These constraints include the full income constraint present in all household farm models, but may include other constraints as well (e.g. risk, missing markets of various classes). The household chooses vector I to maximize household welfare, W, subject to a cash income constraint, with income composed of stochastic farm income from producing goods Qi and exogenous income $\overline{Y}$; a time constraint;

[1] An excellent attempt is made by Louette (1997) to correlate a morphological diversity index to a molecular index as measured by isozyme analysis. Louette found that while the phenotype for a farmer named variety was consistent,

technology constraints; market prices for inputs and outputs; and various types of market constraints if applicable. The set of activities j=1…J may include both farm (e.g. milpa, cash crop, livestock) and non-farm (wage labor, internal or international migration, handcrafts, services). Let Y(·) denote full income encompassing cash income and time constraints. Let G(·) denote other types of market constraints on production and or consumption.

The basic model is:

$$\max_{\Psi} W(X;Z1)\ s.t. \qquad (1.1)$$
$$Y(\Psi;Z2) \le 0 \qquad (1.2)$$
$$G(\Psi,Z3) \le 0 \qquad (1.3)$$

The vector Ψ of endogenous choice variables includes consumption levels of goods and leisure Xk, k=1…K; household time allocation (e.g. between production, wage work, and leisure); and production choices. Production and labor supply variables include decisions regarding both activity participation (Ij, j=1…J activities) and levels of output, Qj, or labor supply. The arguments in the household welfare function are the consumption levels of K consumption goods, including leisure, and a vector Z1 of exogenous household characteristics affecting welfare given consumption. The income constraint Y is a function of Z2, a vector of exogenous prices for the production (both input and output) and consumption goods; the family time endowment and the production technology for each activity j. The constraint vector G, if binding, represents other constraints, particularly those related to high transactions costs (i.e. the presence of non-traded goods). G is a function of Z3, a vector of exogenous variables affecting these constraints.

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the genotype varied widely.

The solution to equations (1a-1c) involves the choices of both discrete (Ij) and continuous (Qj, Xk) variables as functions of the exogenous vector Z=(Z1,Z2,Z3). Because participation, not level, determines diversity (D=Φ(I)), the focus of this paper is on the discrete choice of participation in the J household production and labor activities.

Participation can be modeled following the random utility framework proposed by McFadden. Let W_j^{C} (Xk;Z) denote the household's maximum welfare, given the constraints represented by 1.2 and 1.3, if the household participates in activity j, and let W_{-j}^{C} (Xk;Z) denote maximum constrained welfare otherwise. Both W_j^{C} (Xk;Z) and W_{-j}^{C} (Xk;Z) assume optimal choices of Qj ∀ j, I_{-j} , and Xk.

In the random utility model, $W_j^c(\mathrm{Xk;Z}) = \overline{W}_j^c(\mathrm{Xk;Z}) + e_j$, and $W_{-j}^c(\mathrm{Xk;Z}) = \overline{W}_{-j}^c(\mathrm{Xk;Z}) + e_{-j}$. The household chooses to participate in activity j if $\overline{W}_j^c(\mathrm{Xk;Z}) + e_j > \overline{W}_{-j}^c(\mathrm{Xk;Z}) + e_{-j}$ or $\overline{W}_j^c(\mathrm{Xk;Z}) - \overline{W}_{-j}^c(\mathrm{Xk;Z}) > e_{-j} - e_j$. The solution to this set of J participation decisions yields a set of optimal participation choices I*(Z), where the probability of observing a household's participation in activity j is given by

$$\Pr(j) = \Pr(Ij^* = 1) \tag{2.1}$$

$$= \Pr(\overline{W}_j^c(\mathrm{Xk;Z}) > \overline{W}_{-j}^c(\mathrm{Xk;Z})) \tag{2.2}$$

$$= H(\overline{W}_j^c(\mathrm{Xk;Z}) - \overline{W}_{-j}^c(\mathrm{Xk;Z})) \tag{2.3}$$

If the errors are each normally distributed with mean zero and constant variance, H(·) is the normal cumulative distribution function, and the model given by (2) can be estimated by a Probit for participation in each activity.

The Random Utility model can be extended to look at the choice of the total number of varieties grown as the result of a series of participation choices so that a count of the total number of activities (here varieties or species grown) indicates the increase in utility from an addition to the count. The summation of a series of discrete choices following a Random Utility framework can be approximated using a Poisson regression for a count of the total activities j (Hellerstein and Mendelsohn 1993) .

The form of the household welfare function W(X) and constraints Y(Ψ) and G(Ψ) determines what exogenous variables are in vectors Z1, Z2, and Z3. The range of possibilities includes two contrasting scenarios: 1) perfect markets, and 2) perfect markets, but one or more markets is missing.

1) In the first case the household faces perfect markets (i.e., exogenous prices) for all consumption goods and variable inputs. In this case the household is a perfect neo-classical farm household, and farm decisions are solved recursively; that is, farm input and output decisions are made first and the resulting income is used to solve the consumption decisions.

In this case, the diversity outcome takes the form of a simple derived demand, $D = \Phi(\mathrm{I}^*(\mathrm{Z2}))$, resulting from the farmer's profit maximizing production decision. This can also be called latent diversity as it exists only as a result of the farmers' behavior given market prices and does not enter the model as a choice variable. The only exogenous parameters necessary for the activity choice estimation are Z2, variables representing farm characteristics. Constant returns to scale in a given activity would lead to specialization into one agricultural activity (i.e., zero activity diversity). If, however, there are decreasing returns to scale in production activities, then an interior solution for a diverse production set is possible. For example, if yields for different crops depend on land quality, and the quality of the farm's land endowment is heterogeneous, a mix of crop activities is possible.

2)The second case is with one or more markets missing. Markets may be present in some form, but households may not use them for transactions or base their activity-participation decisions on exogenous market prices. The area in which field work was conducted for this paper is characterized by high transactions costs caused by geographic and cultural isolation. These transactions costs may introduce market imperfections which prevent a fully recursive, separable model solution. When transaction costs create a wide enough price band, households' internal equilibrium of supply and demand may fall within the band, leading to self sufficiency and making household production and consumption decisions a function of subjective valuations or "shadow prices.".

Obvious areas where there may be high transaction costs are in the hiring of labor and the availability of credit. A missing market for labor may mean that when a household has off-farm opportunities with a higher wage (and possible lower variance of income) an inability to hire in non-household labor may cause households to switch into less labor intensive agricultural technologies. Alternatively, when household labor allocations are guided by shadow wages, there may be a sluggish response to changes in the profitability of cash-crop production and a substitution out of labor intensive subsistence production.

Another possible missing market is that for insurance if farm output is stochastic. The demand for crop diversity as a portfolio in order to spread risk is common in the literature. However empirical measurement of variance of price or output, or a household level of risk aversion are difficult to obtain. In this model it will suffice that a missing market for insurance, similar to that of credit, will cause a household's level of wealth or exogenous income to affect the activity choice decisions.

Missing Market for Consumption Good

A particularly interesting case with important implications for modeling diversity levels is where there is a missing market for a crop (or a trait supplied by a crop) that increases farm level diversity. This could be a commodity with a consumption trait which the family may value but for which high transactions costs create a missing market, forcing the household to satisfy all of its demand for the good through its own production. If households demand a series of specific traits within in their consumption of staples, high transactions costs for staples tend to promote on-farm diversity in staple crops. Another possibility is that farm-households demand a level of quality that is higher in the local production than the level available in market varieties.

Simplifying the model in (1), the household derives utility from consuming the production-constrained staple, Xa, and all other consumption goods with market prices represented by total income Y. The simplified farm profit function is substituted into the cash income constraint, which is reduced to a combination of farm profits (from production of tradables) and exogenous income $\bar{Y}$.

$$\begin{aligned} &Max\ U(Ca, Y; Z1)\ s.t. \\ &l: Y = \sum_{i=1}^{I} \left(piQi - C(Qi; Z3)\right) + \bar{Y}, \\ &g:\ Qa = Ca \end{aligned} \tag{3.1}$$

The first order conditions for all commodities except the constrained staple are:

$$for\ i \neq a: Uy\left(pi - C'q(Qi)\right) = 0\ or\ pi = C'(Qi) \tag{3.2}$$

In the case of the subsistence good, however, the first order conditions include another term which reflects the need to meet the subsistence constraint:

$$for\ i = a:\ Uy(C'(Qa)) + Uxa = 0\ or\ C'(Xa) = \frac{g}{l} \tag{3.3}$$

Similar to a safety first formulation in the risk literature, the right hand term is the household shadow price or subjective valuation of the subsistence crop. Thus, the derived demands $Qi^*(Z1, Z2, Z3)$ now are functions of variables influencing this subsistence demand: the Z1 variables, household demographics and taste preferences, and Z3 the variables affecting the missing markets such as infrastructure and labor market constraints. Thus the level of diversity $D = \Phi(I^*(Z1, Z2, Z3))$ is no longer a production-derived demand but rather is affected by both consumption and production characteristics of the household, as well as village wide market constraints.

Hypotheses:

The first hypothesis to test is that the effects on diversity are similar within as well as across species (i.e. for infra-species diversity as well as inter-species diversity). The test is whether the determinants of farm level diversity are significant and of the same sign for diversity within the same crop as within the multiple-crop system as a whole.

The null hypothesis is: $\frac{\partial D_a}{\partial Y} = \frac{\partial D_b}{\partial Y}$

where D_a is the infra-species diversity within the principal species, here maize, and D_b is the interspecies diversity of all of the crops in the milpa cropping system.

Both within the principal crop and the crop system as a whole, the theoretical model leads to a test of whether the household decisions are made in a separable, recursive way. This will be carried out by testing a regression model to see whether the demographic and market related variables affect the household's level of diversity: $\frac{\partial D}{\partial Z1(demographic)} = 0, \frac{\partial D}{\partial Z3(market)} = 0$

If the Z1 and Z3 variables affect the diversity outcomes, important hypotheses to test are:

Culture affects Diversity - $\frac{\partial D}{\partial Culture} > 0$

Diversity is Labor Intensive - $\frac{\partial D}{\partial Labor} > 0$

Subsistence behavior affects diversity demand - $\frac{\partial D}{\partial Subsistence} > 0$

Wealth and Exogenous Income affect diversity - $\frac{\partial D}{\partial Y_{MIGRATION}} < 0, \frac{\partial D}{\partial Wealth} < 0$

Description of Site and Survey Sample

This research was carried out as a part of the McKnight Foundation Collaborative Crop Research MILPA project, composed of a joint Mexico-US research team of botanists, biologists, crop breeders, and social scientists. Research teams are based around the principal crops of the milpa: maize, beans, squash, and quelites (a broad category of other edible plants found in the milpa). The fifth research group, the socio-economic group, concentrates on local and regional analysis of the motivations behind farmer behavior.

The sample was structured to cover a mountainous region roughly delimited (and isolated) by two major river valleys. The region is also characterized by the dependence on two major market towns serving as commercial poles, and is served by one major highway with two branch roads. There is also a basic correspondence to an administrative region in the provision of different levels of government services from the commercial poles. Within the sample area the principal regions are dictated by the topography and climate of the region. Tierra Caliente (Hot Lands) are roughly below 1200 masl, and are characterized by sub-tropical vegetation and include a lowland transition zone to the coastal plain of Veracruz state. Tierra Fria (Cold Lands) are those above 1200 masl and are characterized by temperate vegetation and a transition towards the higher altitude zone of the high plateau of Puebla state. The principal agronomic and economic differences are that the Tierra Caliente lands 1) grow coffee, the most important cash crop in the region, and 2) can grow two cycles of maize in a year.

The survey was applied across a series of 281 households in a series of 24 villages. The survey sample was structured to cover a representative sample of villages in the study area. Five of the smallest communities were sampled once ($n \approx 6$) while most communities were sampled twice ($n \approx 12$). Within each village, households were selected at random. The focus on the farming systems meant that the commercial centers were not sampled, but some commercial activity was picked up in the sample frame.

The distribution in climate zones is 9 villages with a total of 118 households in Tierra Fria, and 15 villages with 163 households in Tierra Caliente. Of these households 225 cultivated maize in the last year, 216 planted white maize, 42 planted yellow maize, and 17 planted blue maize. In the area of beans, 113 households planted Frijol Gordo, and 65 planted Frijol Negro and 38 reporting the existence of wild beans. Although the area is not a major producer of squash, 95 households reported growing Calabaza Pipian for household consumption, 41 grew calabaza chilacayote, and 71 grew chayote. In the area of quelites, several quelites were recorded of the various ones that grow in the areas; using quintonil (amaranth greens) as an indication 180 reported quintonil growing in their fields, 177 reported consuming them, and 11 reported selling them in the market. Descriptive statistics for the variables used in this paper are in Table 1.

The survey used as a basic unit of analysis farmer named varieties. In this region the farmers do not differentiate racial types, so colored types were used as varieties. Area and yield, basic morphological characteristics, farmer preferences and history were collected for each variety. Information on the other principal milpa crops: beans, squash and quelites were collected to characterize the intensity of the diversity in the milpa system.

In order to look at the correlation of diversity demand with agronomic constraints, farmer characterization of land quality, soil type, slope and distance to each plot were recorded. The marketing of maize, the portions of the harvest sold and used for subsistence, were recorded. In addition to the household survey village level variables such as prices and transactions costs were recorded.

Age, education, sex, languages spoken, and principal occupation were recorded for each family member. Characteristics of the home were recorded to provide an indication of the level of wealth as well as the principal language spoken as an indication of ethnicity.

Table 1 - Descriptive Statistics

The variables used for the basic household characteristics in this regression specification are the age of the household head, age squared as a quadratic term, the years of education of the household head, the family size and the principal language spoken (0 is Spanish, 0.5 is bilingual, and 1 for monolingual in the indigenous language, either Nahautl or Totonaco).

In the study of the farmer management of maize diversity one interesting pattern was observed with cultural relevance. Many farmers plant red maize and manage it as a sub-population within the white maize. One cob per ten liters of seed, mixed or planted in the corners seems to be a cultural practice that had a variety of folk interpretations. However the management of the other color variants, yellow and blue, is as a separate population, with selection against mixed types. While only 3 households reported sowing red maize as a separate population, 60 reported sowing red maize within the white maize. Therefore in study the sowing of red maize is used as a 0-1 dummy variable to indicate the ritual planting of seed as a more "indigenous" practice.

The principal variables used to describe the agronomic links to higher levels of on-farm diversity are the total hectares farmed, a dummy for being located in the high altitude zone (Tierra Caliente), the use of multiple parcels for growing the milpa crops and having multiple parcels with multiple slopes. Finally a dummy variable is used for whether the farmer has an established coffee plantation (planted before the current time period) to indicate participation in the principal cash crop in the region.

Village level characteristics such as level of commercial activity, access to paved roads, and being an municipal capital were used to construct an infrastructure variable, here represented as a dummy variable set equal to one for better infrastructure.

A set of village level variables were constructed from household level data in order to get at important characteristics that are complicated by the endogeneity of household choices concerning activity participation with other input allocations. A village level average of households who sold maize in at least two of the last five years was constructed to indicate the relative intensity of maize markets. Household consumption of manufactured tortillas was recorded to describe the substitution in consumption (and allocation of household time) of an industrial, non-local maize, here the village level averages are presented. The household characteristics were also used to calculate a village level average for the percent of family labor of the total used in maize production, and the percent of the total land area used in maize production.

Finally exogenous income from migrants living outside of the household is included. An objective wealth variable was also constructed from a count of major durable goods and surveyor recording of household construction and services.

Empirical Results

As discussed above the Poisson model is used because of the nature of a discrete dependent variable in the form of count of varieties allows an improvement of model specification over a least squares model. A nested model is run with all of the possible explanatory variables so that if the household characteristics or the market related characteristics are significant then we can reject the separable model. Furthermore the model is run for a single aggregated count of varieties, and a separate set of three regressions for the principal crop groups of maize, beans and squash. Different signs or significance in the explanatory variables indicates whether or not the principal crop model is useful for the total system diversity.

In the single equation, nested model (Table 2) we reject the hypothesis that decisions related to diversity are made separably on production characteristics alone. The coefficients for the age of the household head and the planting of ritual varieties are positive and significant, implying that household characteristics influence the choices leading to total system diversity. Furthermore the age variables with the linear term positive and significant, and the quadratic term negative and significant, indicate that it is the middle-aged farmers who have more diverse systems. Education is a variable that has been previously found correlated with farm productivity (Taylor and Yunez 2000), and is here positive and significant with diversity.

The agronomic characteristics that are significant are the location in a high altitude ecological zone, and the planting of multiple parcels having different slopes. This second finding is consistent with Bellon's findings in Chiapas (Bellon and Taylor 1993). Finally the planting of coffee is also found to be positive and significant, which may be surprising, but in this model specification other important factors such as wealth and ecological zone are held constant.

Finally the significant village level variables include the level of infrastructure, which is negative and significant. This is an important finding for the hypothesis that missing markets may increase the level of diversity in farmer's fields as they seek to supply products which they cannot trade for. The intensity of family labor is positive and significant which is consistent with the farmers observations that the growing of secondary crops is relatively labor intensive.

In the system of equations model (Table 3), different variables are significant for each of the crops, leading us to reject the hypothesis that the total system diversity is predicted by the principal crop diversity. The education level of the household head is positive and significant for beans and squash, but not for the principal crop maize. The ritual planting of maize is positive and significant for maize and squash, but not for beans.

Within the agronomic characteristics, the high altitude ecological zone favors the level of diversity for both beans and squash, but not significantly for maize. Multiple parcels was significant for all three crops, but distinct by the multiple parcels significant for maize but multiple slopes significant for beans and squash. Finally the coffee growing dummy is highly significant only for squash, and not for maize or beans.

The infrastructure variable is negative and highly significant for the growing of beans, but not significant for either squash or maize. Perhaps the case for missing markets can be made most strongly for beans, where local varieties are less substituted by market consumption. Finally the intensity of family labor is positive and significant for beans and squash, but not for maize, as commented upon above.

Conclusions

The first conclusion is that the models for multiple crop diversity cannot follow the primary crop. Prescriptions to address genetic erosion or to form conservation plans if based on the principal crop will be missing crucial diversity outcomes in other crops. Secondly the model specification must include exogenous variables which can describe the household-farm whether at the household, demographic level, or at the village, market level. Third the use of village level variables constructed from household information is useful in providing indications of both villages and households conserving higher levels of diversity.

An important policy outcome is that consumption and market variables are important explanatory variables. Markets may not be able to fulfill the household demand for certain crops, specific consumption characteristics, or aspects of diversity that are of interest to farmers. Therefore whether looking at genetic erosion or searching for some temporary diversity equilibrium (i.e. de facto *in situ* conservation), important factors will be farmers' preferences and levels of market integration, both of which are changing through time.

Furthermore, culture does affect diversity, in this case even when holding other characteristics constant. Indigenous farmers, holding constant wealth and market integration, do tend to conserve a higher level of diversity. While this not necessarily a new result this model has used ethnicity to indicate preferences which affect diversity within an econometric specification.

Finally, diversity is negatively affected by improved infrastructure and off-farm income. This points to the difficult reality that *in situ* conservation must face the tradeoffs between development and diversity. While local diversity may reach temporary equilibria of de facto conservation, any long term policy will have to carefully address the apparent contradictions of economic development and genetic conservation.

Table 1: Descriptive Statistics

	Mean	Std.Dev.	Min	Max
Total Varieties Grown	2.41	1.82	0	9
Total Varieties of Maize Grown	1.01	0.73	0	4
Total Varieties of Beans Grown	0.66	0.73	0	3
Total Varieties of Squash Grown	0.74	0.88	0	3
Z1 - Household Variables				
Age of Household Head	51.33	13.68	20	96
Age Squared	2821.75	1465.45	400	9216
Years of Education of Household Head	3.33	2.84	0	15
Family Size	5.16	2.17	1	10
Adults	0.40	0.47	0	1
Principal Language (Spanish=0, Nahuatl=1)	0.22	0.41	0	1
Ritual Planting of Seed				
Z2 - Farm Variables	1.63	1.87	0	16
Total Hectares	0.42	0.49	0	1
High Altitude Dummy	0.11	0.32	0	1
Multiple Parcels	0.06	0.25	0	1
Multiple Slopes on Parcels	0.44	0.50	0	1
Grows Coffee Dummy				
Z3 - Village Level Market Variables	0.16	0.14	0	0.5
Village Sales of Maize	0.28	0.22	0	0.67
Village Sales of Tortillas	0.37	0.21	0	0.75
Infrastructure (1=better infrastructure)	0.56	0.50	0	1
Percent Family Labor used in Maize Production	0.44	0.17	0.092	0.788
Percent of Total Land Area used in Maize Production	0.56	0.25	0.137	0.926
Income Variables				
Remittances	1200.57	4198.34	0	49300
Wealth	7.64	2.90	0	15

N=281 Households in 24 villages

Table 2: Poisson Model of Total Varieties Planted

N=281	Total Varieties	
Intercept	-1.77809	-(2.93) ***
Household Variables		
Age of Household Head	0.044777	(2.18) **
Age Squared	-0.00033	-(1.72) *
Years of Education of Household Head	0.0413	(2.13) **
Family Size	0.006305	(0.33)
Principal Language (Spanish=0, Nahuatl=1)	0.089025	(0.91)
Ritual Planting of Seed	0.283581	(3.06) ***
Farm Variables		
Total Hectares	0.013916	(0.65)
High Altitude Dummy	0.549125	(2.82) ***
Multiple Parcels	0.18466	(1.54)
Multiple Slopes on Parcels	0.449158	(3.20) ***
Grows Coffee	0.416804	(3.01) ***
Village Level Variables		
Village Sales of Maize	-0.18677	-(0.56)
Village Sales of Tortillas	0.438007	(1.38)
Infrastructure (1=better infrastructure)	-0.35491	-(2.47) **
Percent Family Labor used in Maize Production	1.15684	(2.79) ***
Percent of Total Land Area used in Maize Production	0.252328	(0.62)
Income Variables		
Remittances	-1.06E-05	-(0.87)
Wealth	-0.01685	-(1.07)
R-Squared (Deviance)	0.3242	

Note: t-statistics are reported in parentheses; *denotes significance at the %10 level, ** denotes significance at the 5% level, ***denotes significance at the 1% level.

Table 3: Poisson Model of Varieties Planted by Crop

N=281	Maize		Beans		Squash	
Intercept	-1.98967	-(2.15) **	-3.36821	-(2.83) ***	-3.80434	-(3.42) ***
Household Variables						
Age of Household Head	0.0418826	(1.29)	0.0494487	(1.28)	0.04704	(1.27)
Age Squared	-0.0003774	-(1.25)	-0.0002824	-(0.81)	-0.000313	-(0.92)
Years of Education of Household Head	-0.0001318	(0.00)	0.0708	(1.82) *	0.0748614	(2.15) **
Family Size	-0.0042599	-(0.14)	0.0131557	(0.36)	0.016683	(0.47)
Principal Language (Spanish=0, Nahuatl=1)	0.129205	(0.89)	-0.0046552	-(0.02)	0.142304	(0.80)
Ritual Planting of Seed	0.23806	(1.68) *	0.0973424	(0.53)	0.513265	(3.09) ***
Farm Variables						
Total Hectares	0.0395729	(1.28)	0.0172949	(0.43)	-0.0442669	-(0.97)
High Altitude Dummy	0.0995794	(0.34)	0.884817	(2.37) **	0.933806	(2.56) **
Multiple Parcels	0.342876	(1.91) *	0.122782	(0.52)	0.0170935	(0.08)
Multiple Slopes on Parcels	0.346478	(1.62)	0.55912	(2.02) **	0.52016	(2.04) **
Grows Coffee	0.254515	(1.26)	0.308507	(1.15)	0.79214	(2.96) ***
Village Level Variables						
Village Sales of Maize	0.304806	(0.61)	-0.189801	-(0.29)	-0.837403	-(1.36)
Village Sales of Tortillas	0.352817	(0.74)	1.33279	(2.03) **	-0.0535753	-(0.10)
Infrastructure (1=better infrastructure)	-0.253572	-(1.17)	-0.862033	-(2.87) ***	-0.0998967	-(0.39)
Percent Family Labor used in Maize Production	0.232675	(0.37)	2.07312	(2.50) **	1.7208	(2.24) **
Percent of Total Land Area used in Maize Production	0.715519	(1.15)	-0.537443	-(0.69)	0.235749	(0.32)
Income Variables						
Remittances	-1.72E-05	-(0.88)	-1.86E-05	-(0.75)	3.64E-06	(0.18)
Wealth	-0.0027828	-(0.12)	-0.0474307	-(1.59)	-0.0130435	-(0.45)
R-Squared (deviation)	0.284		0.256		0.197	

Note: t-statistics are reported in parentheses; *denotes significance at the %10 level, ** denotes significance at the 5% level, ***denotes significance at the 1% level.

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