



## Participatory landrace selection for on-farm conservation: An example from the Central Valleys of Oaxaca, Mexico

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### Abstract

On-farm conservation is recognized as a key component of a comprehensive strategy to conserve crop genetic resources. A fundamental problem faced by any on-farm conservation project is the identification of crop populations on which efforts should be focused. This paper describes a method to identify a subset of landraces for further conservation efforts from a larger collection representing the diversity found in the Central Valleys of Oaxaca, Mexico. Mexico is a center of origin and diversity for maize (*Zea mays* L.). The 17 landraces selected from an initial collection of 152 satisfy two criteria. First, they represent the diversity present in the larger collection. Second, they appear to serve the interests of farmers in the region. Data for applying the method were elicited through participatory as well as conventional techniques. They incorporate the complementary perspectives of both men and women members of farm households, and of plant breeders and social scientists.

### Introduction

On-farm conservation is increasingly recognized as a key component of any comprehensive strategy to conserve crop genetic resources (Brush 1991; IPGRI (International Plant Genetic Resources Institute) 1993; Maxted et al. 1997; Wood and Lenné 1999). On-farm conservation involves farmers' continued cultivation and management of a diverse set of landraces in the agro-ecosystem where they were developed (Bellon et al. 1997). This approach depends on farmers' active participation because it only succeeds to the extent that farmers find it in their interest to maintain diversity (Brush 1991).

Centers of domestication and diversity – such as Mesoamerica for maize (*Zea mays* L.) – are par-

ticularly promising locations for on-farm conservation because they exhibit a high level of infra-specific diversity that reflects a long process of co-evolution between the crop and the local human population (Piperno and Flannery 2001; Pope et al. 2001). Hence the cultural significance of the crop, its multiple uses by rural communities, and specialized tastes and preferences for foods prepared from the crop are expressed in farmers' selection criteria and the diversity present among the crop populations they grow.

Today, in areas such as the Central Valleys of Oaxaca, though migration and other sources of income play an increasingly prominent role in family incomes, households consume as well as sell the maize they grow. A priori, then, we expect that in such areas farmers' demand for diverse materials

should be relatively high. In other words, we expect those farmers to value different maize populations and therefore to be willing to invest resources such as labor, money, and land to cultivate them. This demand lowers the costs of on-farm conservation, since the greater the benefits farmers derive directly from growing diverse crop types, the more modest the interventions required to encourage their conservation. Even in these areas, however, outside interventions may be required to support farmers' efforts because the costs of growing and/or gaining access to crop diversity may be rising while the desirability of growing it may be declining due to economic, technological, and cultural changes.

A crucial problem in any on-farm conservation project is the identification of crop populations to focus on. Not all crop populations contribute equally to the diversity present in an area, and there may be some genetic redundancy – a problem also faced by gene bank managers. Furthermore, not all crop populations are likely to be of interest to farmers.

We encountered these problems during a pilot project for on-farm conservation in the Central Valleys of Oaxaca, Mexico (Figure 1). This paper de-

scribes a method we used to identify a subset of maize landraces from among a larger set of landraces collected in the area. The method enabled us to select landraces that represented both the maximum diversity in the collection and the expressed interests of farmers. These landraces then served as the basis for subsequent project interventions, including breeding, farmer experimentation, seed exchanges and distribution (Aragón-Cuevas et al. 2000; Bellon et al. 2001; Smale and Bellon 1999; Taba et al. 1998a).

The project, jointly implemented by the International Maize and Wheat Improvement Center (CIMMYT) and the Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP) of Mexico, has two goals. The first, broader goal is to collect and characterize the genetic diversity of the race Bolita (Wellhausen et al. 1952) for *ex situ* conservation, which included the designation of a core collection of the local landraces. The second is to determine whether it is possible to improve maize productivity while maintaining or enhancing genetic diversity, thereby contributing to on-farm conservation. We define maize productivity broadly in terms of yield, stability, and other characteristics of interest to



Figure 1. Map of Mexico, the state of Oaxaca and the Central Valleys.

farmers. To attain this goal, it is necessary to identify the crop populations that contribute most to crop genetic diversity in the target area and best serve farmers' interests.

The method presented here can be conceptualized as a way to identify a core collection of maize landraces for on-farm conservation. The concept of core collection – a collection which captures the most diversity in a reduced number of accessions (Frankel and Brown 1984) has been used in the context of *ex situ* conservation but not in on-farm conservation. We believe that this concept is appropriate for both types of conservation. In the case of on-farm conservation, besides the problem of capturing the most diversity in a limited number of accessions, there is the additional challenge of including landraces and traits that will be of interest to farmers.

The Central Valleys of Oaxaca were chosen for the project for several reasons. First, the maize race grown by the region's farmers, Bolita, has been described as one of the most interesting and productive races of maize in Mexico, although it has not been widely studied or collected (Ortega 1995). According to Wellhausen et al. (1952), the race Bolita is probably the result of the hybridization of the races Zapalote Chico and Tabloncillo. Its distribution is restricted to the Central Plateau of Oaxaca at elevations between 900 and 1,500 masl. This restricted distribution suggests that it may be a new race of recent origin. It is dominant in the Central Valleys of Oaxaca, where the purest forms have been collected. Newer collections, however have shown introgressions from other races, such as Cónico, Tabloncillo, Zapalote Chico, Pepitilla, Tepecintle, Conejo and Celaya (this one most likely introduced through improved germplasm) (Ortega 1995). These introgressions suggest an open genetic system, with current and historic inflows of exotic germplasm into the Bolita race and the region where it is cultivated. Furthermore, the Bolita race has contributed to the development of drought resistant cultivars such as Cafime and Celita (Ortega et al. 1991). However, only a small number of accessions of this race are found in Mexican gene banks.

Second, modern varieties have had an almost negligible impact in the Central Valleys of Oaxaca. This should not be construed as conservatism on the part of the farmers, as discussions with farmers in this region revealed that available modern varieties do not meet their agroecological and cultural requirements. They considered that improved varieties have a long cycle

that is not compatible with rainfall patterns in the area or that these varieties are not well suited for the special preparations and culinary tastes that are very important in this region. Our own research has shown that these farmers are dynamic and innovative, and constantly exchange seed and experiment with local and exotic materials (Smale et al. 1999). The introgression of other races into the Bolita race further attests to this dynamism.

Third, the region is ethnically diverse and presents a wide range in precipitation (535 to 1,126 mm/year). Ethnic diversity and variation in rainfall throughout the region are hypothesized to contribute positively to the maintenance of diverse maize populations. Despite the economic importance of labor migration to the local economy, communities in the Central Valleys place a recognizable emphasis on culture, including culinary practices for maize. However, this diversity also faces threats, mainly from demographic and economic changes. Many farmers are older and their children are not interested in farming. The young tend to migrate or have jobs in surrounding urban areas. Another threat is the increased difficulty to obtain seed, particularly of certain maize types such as maize with black and red kernels. While there are still strong incentives for farmers here to maintain their landraces, there is no guarantee that they will remain interested in maintaining maize diversity as their economic and social conditions change. Therefore, it is important to explore policy options or technical interventions that might support them.

In this paper we use the term crop population as a generic term for any group of plants under management by breeders or farmers (similar to the concept of population in population genetics). The concept of a landrace is complex (Zeven 1998), and here we used this term for a locally grown maize population that a farmer cultivates and manages as a seed lot. A seed lot is defined as "...all kernels of a specific type of maize selected by a farmer and sown during a cropping season to reproduce that particular maize type" (Louette et al. 1997). Finally, we use the concept of maize race as developed by Anderson and Cutler (1942) and defined as a group of related maize plants with enough common characteristics to permit their recognition as a group. We preferred not to use the term "variety" because while it is well-defined for commercial purposes, it is not in the context of indigenous agriculture. However, here it is only used to refer to an improved variety that fits the common commercial meaning.

The rest of this paper is divided into five sections. The first section presents the conceptual framework for research. Materials and methods are summarized in the second section. The analysis presented in the third section shows how the approaches of plant breeders and social scientists were combined with the perspectives of farmers to identify maize landraces for subsequent project interventions. Results are discussed in the fourth section, followed by conclusions.

### Conceptual framework

For crop genetic resources to be conserved on farms, farmers' needs and expectations must be fulfilled while genetic diversity at the farm, community or regional level is maintained or enhanced. Farmers in any reference area must have incentives to continue growing the crop populations that scientists identify as key genetic resources. "Incentives" refer to the usefulness of the materials or their "use value" as perceived by the farmers who grow them – whether they are commercially or subsistence-oriented, or both. With limited resources and when crop populations are genetically redundant, not all crop populations can or should necessarily be conserved.

The conceptual framework is designed to support strategic decisions about which crop populations are suitable candidates for *ex situ* and on-farm conservation in a well-defined reference area within a crop's center of diversity (Figure 2, Smale and Bellon (1999)). The set of crop populations in any study area can be classified along two axes representing: (1) the use value of a population to a farmer or group of farmers, and (2) the contribution of the population to the overall genetic diversity in the area.

The probability that farmers will maintain any crop population is clearly a function of its use value (commercial or noncommercial) to them. In our framework, the probability that a crop population will be maintained reflects the number of production and consumption characteristics for which a population ranks highly, and the relative importance of these characteristics to farmers in meeting their objectives. All populations can be ranked according to their capacity to supply the characteristics farmers demand.

It is difficult to rank each maize population according to its contribution to crop genetic diversity in the study region because they are interconnected through gene migration, and hence constitute a meta-population (David 1992; Olivieri and Gouyon 1990). Within

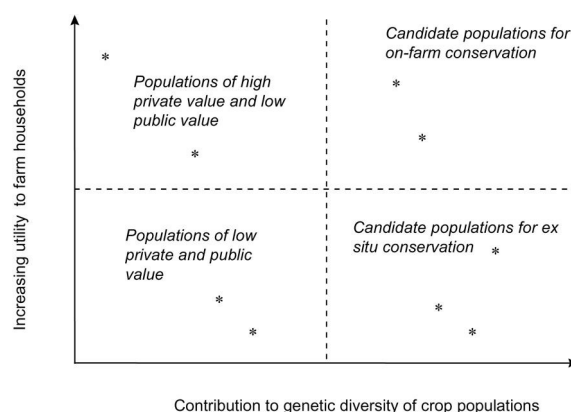


Figure 2. Framework for choosing crop populations for on-farm and *ex situ* conservation in a given reference area (source: Smale and Bellon (1999)).

a meta-population, some populations are more similar than others in terms of their allelic complement, allele frequencies, and agro-morphological characteristics. Clearly, two populations that are very similar contribute less to the overall genetic diversity of the meta-population than two that are different. So we tried to maximize the genetic diversity by identifying homogenous groups of populations based on their similarity, but limiting the redundancy by selecting only a few populations per group.

The position of a crop population with respect to these two axes indicates its suitability for conservation. Populations located to the northeast of the graph in Figure 2 are prime candidates for on-farm conservation and *ex situ* conservation since they have both a high private value to farmers and a high public value as genetic resources. A population located to the southeast is a prime candidate for *ex situ* conservation; although it has great value for genetic diversity, it is of little value to farmers. Populations to the west of the quadrant can be ignored; those highly valued by farmers will be maintained by them, and those valued less may be discarded-but without major consequences for farmers or society in the reference area.

### Methods

The methodologies used are a combination of procedures employed by crop scientists and geneticists to collect and characterize maize germplasm, classify its diversity and select core subsets of materials for *ex situ* conservation and for breeding, and participatory

procedures used by social scientists to elicit farmers' perception of the desirability of different maize landraces. A combination of both types of procedures is used to create a core collection for on-farm conservation.

#### *Collection of maize diversity*

The objective of collection efforts was to maximize the genetic diversity sampled for storage in *ex situ* genebanks at CIMMYT and INIFAP. These efforts focused on the Bolita race (Wellhausen et al. 1952), which is mainly cultivated in the Central Valleys of Oaxaca, Mexico. The Bolita race was not well represented among genebank accessions.

Data from the INIFAP maize experiment station in Oaxaca, along with the expert knowledge of the INIFAP breeder who has worked in the area for more than ten years, were used to select villages representing a range of agroecological and social conditions and wide variation in local maize materials. The selection goal was to include sites that represented the variation in these conditions throughout the Central Valleys of Oaxaca. Selection criteria included physical features such as rainfall conditions and elevation, as well as social factors such as ethnicity and the diversity of ways that farm households use maize. Time and financial resources limited the number of villages visited to 15.

With the help of key informants – mainly local authorities that dealt with farming and people in charge of maize milling outlets – the different landraces that were grown were identified and farmers willing to donate samples were located in each village. During collection, farmers who donated the samples were asked about the traits and uses of each type of maize. Their responses were classified and used to compile a list of maize characteristics that were important. Traits included grain quality for cooking, fodder quality, and resistance to pests or abiotic stress. Information on farmer management of each landrace was also obtained, along with its history. This constituted the first step in discovering which landraces were valuable to farmers and why.

Each sample consisted of 25 ears from a “seed lot” planted by the farmer. Traditionally farmers store maize seed on the ear from harvest to planting time. Most seed lots collected were therefore unshelled. Though 25 ears is close to the recommended size for a collection sample (Balfourier et al. 1994; Marshall and Brown 1975) it is a low number relative to the

ideal size if one wants to collect most of the diversity of the seed lot (Crossa and Vencovsky 1999). However, farmers often manage very small seed lots in the Central Valleys of Oaxaca as well as elsewhere in Mexico (Aguirre Gómez 1999; Louette et al. 1997), and it is difficult to request bigger samples from them. The number of farmers visited depended on the number of seed lots donated by each. Roughly 10 seed lots per village were collected. In total, 152 seed lots were collected for *ex situ* conservation.

#### *Characterization and evaluation*

After the survey, the seed lots were first classified by race according to the criteria described by Wellhausen et al. (1952). Agromorphological traits were then used for the characterization of genetic diversity present among collected materials, based on multivariate statistical techniques previously employed by Taba et al. (1998b) to classify maize landraces. While Taba et al. (1998b) based their analysis on data from on-station experiments, the Oaxaca study used data drawn from on-farm trials conducted under farmer conditions in the area where the seed lots originated. On-farm trials enabled farmers to assess the materials using their own criteria and their conditions.

During the rainy season (May to November) of 1997, fertilized trials were established on farms in 15 communities. The trials were planted between May 21 and July 1, and harvested between November 15 and December 15. A total of 170 materials were planted, including the 152 maize samples donated by farmers, 17 accessions already maintained in the CIMMYT and INIFAP germplasm banks and belonging to the Bolita race, and one improved variety bred by INIFAP from the race Bolita. In each site the 170 materials were planted on a non-replicated incomplete block design (Federer 1995). Each block consisted of two of the 170 materials paired randomly. Each trial site consisted of 85 incomplete blocks. Materials were only replicated across and not within a site as it would have been impossible to carry out replicated experiments given the small size and high heterogeneity of farmers' fields. On-farm trials were designed and supervised by researchers but managed by farmers. The trials were affected by drought during the months of July and August and three were lost entirely. Complete morphological and agronomic data for 27 traits were recorded only in the five trials that received supplemental irrigation. These data were subsequent-

ly used for clustering the 170 maize samples into homogenous groups.

Clustering into homogenous groups was done using multivariate classification methods based on only 11 of the 27 traits measured. The adjusted means of the following traits were used: days to anthesis; days to silking; plant height (cm); ear height (cm); grain moisture (% at harvest); grain shelling (% of the weight of the shelled grains relative to the weight of the unshelled ear where they came from); ear length (cm); ear diameter (cm); kernel row number; kernel length (cm); and kernel width (cm). These traits were chosen because they have been shown to be stable across environments (Goodman and Paterniani 1969; Sanchez et al. 1993). They do not show much genotype by environment interaction and usually have high heritability estimates.

The analysis was done using CLUSTAN (Wishart 1987) software and employing the sequential strategy proposed by Franco et al. (1997). First, clusters were formed using the Ward (1963) hierarchical method, with an optimal number of clusters determined using the upper tail rule (Wishart 1987). Next, the maximum likelihood Normix method (Wolfe 1970) was used to reclassify accessions among groups, using the maximum change in likelihood as a criterion to obtain the final number of clusters. For this analysis, all traits were checked for continuity using PROC UNIVARIATE (SAS Institute Inc., Cary, North Carolina 1996). Once the clusters had been established, canonical discriminant analysis using PROC CAN DISC (SAS Institute Inc., Cary, North Carolina 1996) was performed to evaluate the pattern of phenotypic diversity within the clusters.

#### *Designation of a core collection for ex situ conservation*

Based on the characterization and evaluation of the collected landraces, a core subset was designated for *ex situ* conservation by applying the method described in Taba et al. (1998b). The core subset was determined with the use of a selection index based on yield ( $\text{Mg ha}^{-1}$ ), ear rot (%), erect plants (%) and moisture (%) calculated for each accession (landrace seed lot). The selection index was used to account for grain yield, grain quality, and standability. The selection index is a linear function of the four variables mentioned above, adjusted so as to give a score of 100 to the best entry (landrace seed lot). The indices for the rest of the entries express the gap between their

performance and that of the best entry. The upper 20% of accessions that represented the phenotypic diversity within the clusters and which had high selection indexes were chosen for the subset.

#### *Evaluation by farmers*

First, the perceptions of farmers donating samples were tabulated and analyzed in terms of landrace uses and positive and negative traits. This analysis provided essential information on farmers' concerns. Next, at three of the on-farm trials, field days were organized when the maize crop reached physiological maturity (September 13, 14, 20) and again at harvest (October 25, November 8, 13). Farmers from adjacent communities were invited to attend, as well as scientists, government officials and extension workers. During the first field day, participants walked through the trial, observed the landraces, and recorded the numbers of plots that contained populations they liked. During the second field day, all ears from the inner two rows of the experiment were harvested and laid out in front of the stand, so farmers could judge grain yield and examine the ears. A sign placed beside each landrace provided basic information about the material, including its duration, trial yield, and plant height. Although most participants were literate, team members assisted those who were not able to write down their votes.

The purpose of this exercise was to obtain a rapid "sort" or classification of landraces according to farmers' expression of interest. The exercise enabled us to deal in a systematic manner with many materials (170) and many farmers (approximately 70/field day) in a relative brief time period (2–3 h). Field days were open to all those who wished to participate. We viewed the participants' choices as votes and assumed that the higher the percentage of farmers voting for a landrace, the more potentially valuable it is to participants. Originally we intended to ask participants to rank the materials for a set of traits. However, the large number of materials shown and the high number of participants per demonstration precluded this.

The challenge for the creation of a core collection for on-farm conservation was to combine the set of landraces delimited according to the procedures of maximizing the genetic diversity present – the strategy used for an *ex situ* core collection – with the set of landraces with the highest number of votes by farmers.

## Results

### *Maximizing the genetic diversity to be conserved*

As mentioned earlier, 152 samples were collected from 15 villages in the study area. They were obtained from 101 farmers, who each provided an average of 1.5 (s.d.±0.7) landraces (from 1 to 4). Landraces that were provided by the farmers had been cultivated for 1 to 67 years, with an average of 25 (s.d.±18) years.

While most of the collected seed lots were closely related to the Bolita type, some introgression from races cultivated in other areas of Mexico, and especially from nearby states, was visible in 34 (22%) of the 152 seed lots. These races included: Vandeño-Tuxpeño (Veracruz), Pepitilla (Morelos and Guerrero), Cónico (Puebla and Michoacán), Zapalote Chico (Oaxaca and Chiapas), and Tabloncillo (Jalisco). This pattern of introgression demonstrates that farmers in the area have shared seed over distances as large as several hundred kilometers and altitudes ranging from sea level to the sierra (above 2000 masl), incorporating some traits from other races into the Bolita race. For example, in one of the communities (Santa María Sola de Vega), farmers stated that they deliberately introduce seed from tropical races (Tuxpeño and Zapalote Chico) into their own seed lots.

Maximizing the diversity to be conserved is accomplished by: (a) collecting a representative sample of existing diversity, biased toward the most diverse material whenever possible and (b) reducing redundancy in farmers' seed lots that is generated by gene flows from cross-pollination and active seed exchanges. The application of the multivariate clustering procedures described above led to the identification of the least overlapping groups to reduce genetic redundancy. One hundred and seventy maize samples were grouped into five groups. Figure 3 shows the results of the application of a canonical discriminant analysis on the clustered data. It presents these five groups in the first two canonical axes, which explain 97% of the total variation. The X-axis (CAN1) is correlated with the days to anthesis (AN,  $\sigma = .369$ ) and the kernel row number (KR,  $\sigma = .311$ ), while the Y-axis (CAN2) is correlated with the ear diameter (ED,  $\sigma = .707$ ), kernel width (KW,  $\sigma = .560$ ), plant height (PH,  $\sigma = .514$ ) and ear height (EH,  $\sigma = .412$ ).

Table 1 presents the means of key agromorphological characteristics of each group. Since grain color was not used as a factor determining group structure, most grain colors are found in each group. The variance or diversity with respect to key traits is greater among than within groups, reducing the genetic redundancy or similarity that can be found among the collected materials. The characteristics that

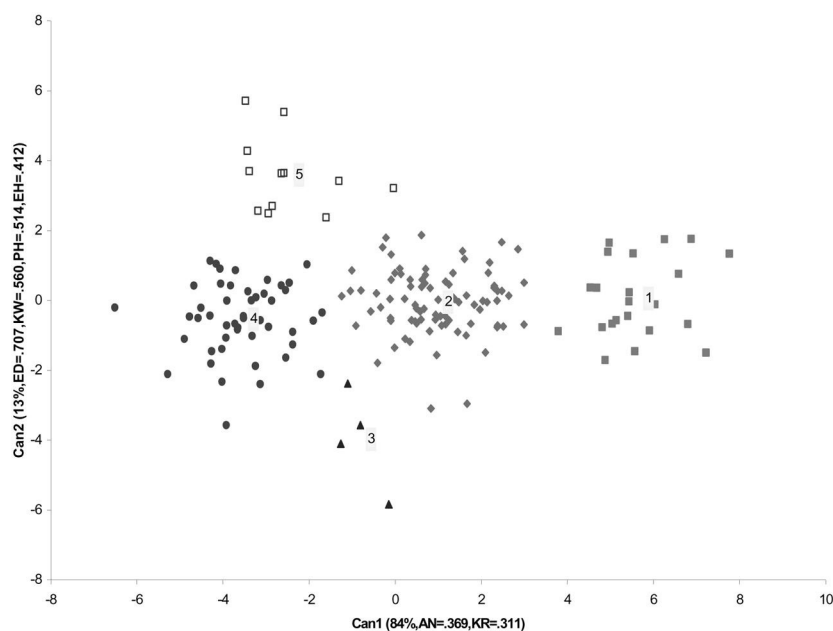


Figure 3. Canonical ordination of the 170 landraces collected in the Central Valleys of Oaxaca, Mexico (first two canonical axes) into five agromorphological groups.

Table 1. Means of key characteristics of the five agromorphological groups.

Agromorphological group	No. of samples	Yield kg/ha	Anthesis No. of days	Silking No. of days	Plant height cm	Ear height cm	Grain moisture at harvest %	Grain shelling %	Ear length cm	Ear diameter cm	No. of kernel rows	Kernel length cm	Kernel width cm
1	22	2,385	72	77	220	121	27.6	80	14	5	13	1.2	0.9
2	84	2,322	68	73	208	109	24.6	80	14	5	11	1.2	1.0
3	4	1,714	61	65	181	83	18.9	81	14	4	12	1.2	0.9
4	48	2,230	63	69	192	93	22.5	80	14	5	10	1.2	1.1
5	12	2,740	67	73	215	108	25.1	74	15	5	10	1.3	1.2

carry greatest weight in defining the genetic groups are number of days from planting to anthesis (days to male flowering) and the number of kernel rows on the ear. These agromorphological groups also serve as a proxy for genetic diversity in this paper.

The core collection designated for *ex situ* conservation was composed of five core subsets representing the five clusters or agromorphological groups that were identified with the multivariate clustering methods. Each subset is composed of 20% of the seed lots belonging to the cluster, consisting of a total of 37 accessions (seed lots).

#### Considering the expressed interests of farmers

Analysis of farmers' statements about the maize samples they donated shows that they considered many traits relevant (Table 2). The most frequently cited positive characteristics are associated with consumption, such as taste and suitability for special preparations (e.g., atole) followed by good yield, particularly as indicated by grain weight and short duration. The most frequently cited negative traits were low yields and poor resistance to storage pests. Farmers identified 11 different uses for their maize, including nine special preparations (Table 3). The salience of consumption characteristics in farmers' statements and the high number of food uses they discussed highlights the cultural importance of maize in the region.

There were a total of 306 participants in the field days. These included men and women members of rural households, members of academic institutions, extension agents, and government officials. Of these, 213 belonged to households that planted maize, 57 that did not plant maize, and 36 could not be located or classified. Of the 213 individuals involved in maize farming, 54% were women. Only the votes of maize farmers were used in the analysis presented here.

Figure 4 compares the votes of men and women participants. Each point is a collected landrace. The x-axis represents the percentage of men who voted for any particular landrace, while the y-axis represents the same information for women. While there was a high correlation between the votes of males and females (0.70,  $p < .0001$ ), it does not mean that their voting patterns are the same. For example, a higher number of females voted for particular landraces compared to males, suggesting that there was a higher level of agreement among females in their choices relative to males.

Table 2. Farmers' perceptions of the positive and negative characteristics associated with the landraces collected in the Central Valleys of Oaxaca, Mexico.

Traits	Positive characteristics			Negative characteristics		
	Response	Percentage	Cumulative	Responses	Percentage	Cumulative
Consumption	Good for making atole	3.87				
	Good quality	1.66				
	Grain color	8.29				
	Good for pasture	2.76				
	Good taste	12.15				
	Good for making tortillas	13.26				
	Good dough	1.66				
	Good for making tostadas	0.55	44.20			
Yield	Thick grain	0.55		Low production	7.41	
	Produces cobs	0.55		Low yield	18.52	
	Weight	12.71		Small cobs	7.41	
	Good production	1.66		Few rows	3.70	37.04
	Good yield	0.55				
	Good yield by volume	18.23				
Duration	A lot of grain	0.55	34.80			
	Early	10.50	10.73			
Sale	Saleable	2.21	2.26			
	Easy to shell	1.66	1.69			
Adaptation	Well adapted	1.66	1.69			
Abiotic stress	Withstands drought	1.10		Tall plants (lodging)	14.81	14.81
	Withstands cold	0.55	1.66			
Biotic Stress	Withstands pests	0.55		Tall plants (lodging)	14.81	14.81
	Withstands weeds	0.55	1.10			
Storage	Stores well	2.21	2.21	Rots	22.22	
				Not resistant to weevils	7.41	
				Cob rots	11.11	
				Grain rots	3.70	44.44
Total		100.00		100.00		

The least desirable landraces were those chosen infrequently by both men and women and are located in the lower left portion of the graph. The landraces located in the upper right portion of the graph are the most desirable. Results from the voting exercise show

Table 3. Special culinary preparations and uses for maize identified by farmers during the collection of maize landraces, Central Valleys of Oaxaca, Mexico.

Preparation/use	Description
Tortillas	Flat bread made of maize
Atole	Maize-based beverage
Nicuatole	Type of gelatin made of maize
Buñuelos	Fried thin wafer
Nixtamal	Dough to make tortillas
Pinole	Powder made of maize
Pozol	Maize-based drink
Tamales	Steamed maize mixture with a filling wrapped in a maize husk or a banana leave
Tejate	Sweet maize drink with cacao
Tlayudas	Special type of tortillas
Animal feed	Grain given to poultry, leaves and stalk to cattle

that there is great interest in diversity among participating farmers, as well as gender differences (Table 4). While male farmers voted for many landraces, on average women chose more landraces than men. Only about a third of the men and half of the women voted for the most popular landraces. Few landraces received no votes, suggesting that participants want a range of materials and that there is no "best" landrace. Only a few participants voted for no landraces, which indicates a high degree of interest in these landraces. Finally, there was a significant and positive correlation between the votes received by a landrace and its selection index. Farmers appear to consider agronomic performance and their voting patterns are far from random.

How do the participants' choices relate to groups identified through applying the multivariate statistical techniques on agromorphological traits? Table 5 presents the 10 top choices by gender, together with the agomorphological group to which each belongs and the grain color of the landrace. Both men and women

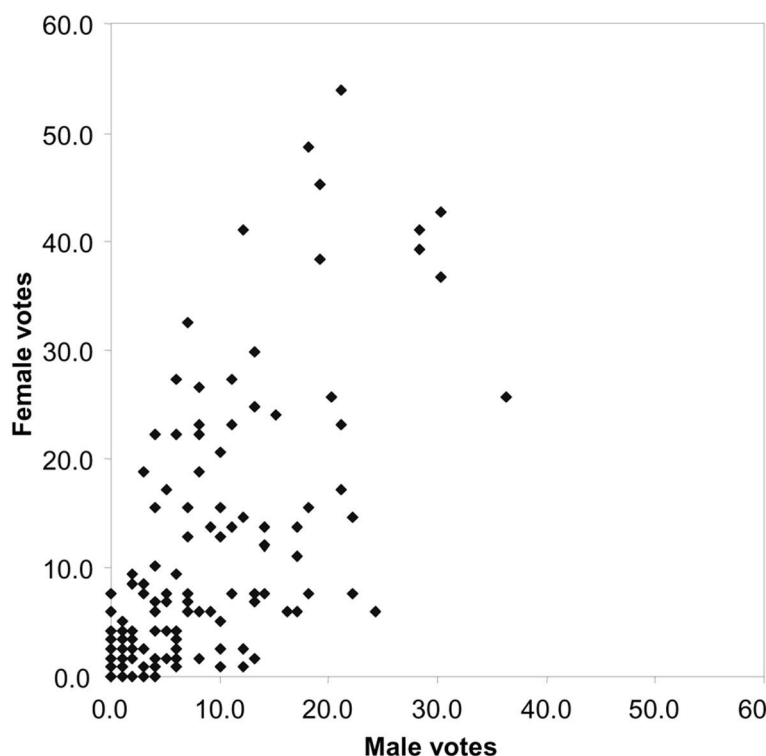


Figure 4. Comparison of the votes cast by men and women participating in field days.

frequently selected materials belonging to group 2. All selections made by women belonged to this group, with the exception of one, as compared to five selections made by men. In fact, men's choices represented more diversity in terms of the numbers of agromorphological groups (four) than women's (two).

Farmers generally chose "less diversity" than represented in the population of samples, however, because group 2 was overwhelmingly represented in their votes. In this respect, it is important to recall that farmers cannot "see" the agromorphological groups identified by the statistical analysis since neither all of

the 11 traits nor the full range of variation in the traits can be observed at any one location or point in time. In terms of grain color – which is easily observed and on which the farmers base part of their classification of maize types – both men and women chose a similar mix of white (6), yellow (3), and purple (1) maize types. Clearly, if we chose to work only with the most popular landraces selected by field day participants, we would end up with a set of landraces that are more homogenous than those identified by applying multivariate statistical techniques on agromorphological traits. The significant correlation between farmers'

Table 4. Voting patterns of male and female participants in field days, Central Valleys of Oaxaca, Mexico.

	Males	Females
Landraces voted:		
Average number	10.8	13.7 <sup>a</sup>
Maximum number	40.0	38.0
Minimum number	00.0	00.0
Landraces with zero votes (%)	12.5	15.8
Maximum votes awarded to one landrace (%)	36.4	53.9
Participants who did not vote for any landrace (%)	5.1	3.4
Correlation between votes received and selection index for landraces	0.369 <sup>b</sup>	0.362 <sup>b</sup>

<sup>a</sup> T-test for equality of means significant at the 0.01 level (2-tailed)

<sup>b</sup> Correlation significant at the 0.01 level (2-tailed)

Table 5. Top ten voted landraces by gender.

Men				Women			
Entry	Ag <sup>a</sup>	Color	Votes (%)	Entry	Ag <sup>a</sup>	Color	Votes (%)
152	1	White	36.4	25	2	White	53.9
49	2	Yellow	30.3	27	2	White	45.3
123	5	White	30.3	49	2	Yellow	42.7
42	2	Purple	28.3	42	2	Purple	41.0
30	2	Yellow	28.3	23	2	White	41.0
95	5	White	24.2	30	2	Yellow	39.3
121	5	White	22.2	123	5	White	36.8
118	4	white	22.2	129	2	White	32.5
37	2	yellow	21.2	140	2	Yellow	29.9
35	5	White	21.2	72	2	White	27.4

<sup>a</sup> Agromorphological group

votes and the selection index also implies that farmers and scientists employ at least some of the same characteristics when they assess maize populations.

#### *Creating a core collection for on-farm conservation*

The voting exercise identified a few landraces that would not have been considered if we had relied entirely on the criterion of maximizing genetic diversity based on statistical analysis of agromorphological data. Although at that stage we did not know the specific reasons why, choices appear to differ between men and women farmers. We were also able to show that relying exclusively on farmers' voting patterns, and particularly those of women, would have led to the dominance of only one of the agromorphological groups identified with statistical techniques.

These findings illustrate that choosing populations in a project whose purpose is to enhance diversity through participatory selection of landraces may involve trade-offs between social welfare and conservation objectives if we rely exclusively on either multivariate statistical techniques on agromorphological traits or on farmers' perspectives. The former is ideal for identifying core subsets for *ex situ* conservation but is not ideal for representing the expressed interests of farmers. The converse is also true, since farmers' choices do not conform entirely to those determined by the application of scientific methods.

To select the final set of landraces for an on-farm core collection, we combined both types of information in an attempt to reduce the apparent trade-off between objectives. First, materials were organized by agromorphological group and grain color. Agromor-

phological group is used as an indicator of genetic diversity, while grain color is the basis of the local maize taxonomy and an important "marker" for several useful traits for men and particularly for women, such as duration. From each combination of diversity group and grain color, landraces that garnered the highest numbers of votes from men and women participants were chosen for inclusion in the subsequent phase of the project. A landrace was excluded if the scientists involved in the agronomic evaluations questioned its adaptation or performance, since they had observed landrace performance in many different environments.

Table 6 presents the 17 materials chosen for distribution, part of a subsequent phase of the project. All are local landraces, except for an improved variety bred from Bolita landraces by the INIFAP breeder on the project. The set encompasses the range of agromorphological groups and grain colors. Collection sites from varying altitudes of the Central Valleys of Oaxaca are represented.

#### **Discussion**

As mentioned, the approach we have developed addressed the dual purposes of *ex situ* and on-farm conservation. For *ex situ* conservation, we applied the methods proposed by Franco et al. (1997), Taba et al. (1998b) to identify core subsets. These methods involve: (1) collection of a range of material types; (2) trial evaluation of multiple traits; (3) identification of agromorphological groups based on results of statistical analysis; (4) extraction of subsets of materials from groups using a selection index constructed from agronomic performance criteria.

Table 6. Landraces selected for distribution.

Entry	Donating farmer	Community	Ag <sup>1</sup>	Kernel color	Altitude of collection (masl)	Selection index	Male votes (%)	Female votes (%)	Total votes (%)	Race
23	Juan Flores M.	Santiago Suchilquitongo	2	White	1,700	94.2	12.1	41.0	27.8	Bolita
25	Juan Espinoza H.	Santiago Suchilquitongo	2	White	1,680	54.2	21.2	53.8	38.9	Bolita/zap <sup>a</sup>
29	Fidencio de la Luz	Santiago Suchilquitongo	4	Purple	1,710	30.5	8.1	18.8	13.9	Bolita
30	Fidencio de la Luz	Santiago Suchilquitongo	2	Yellow	1,710	95.7	28.3	39.3	34.3	Bolita
34	Bartolo Ambrosio O.	Santa Ana Zegache	4	Red	1,520	72.4	18.2	15.4	16.7	Bolita
39	Florentino Chompa A.	Santa Ana Zegache	5	White	1,500	81.2	10.1	20.5	15.7	Bolita
40	Florentino Chompa A.	Santa Ana Zegache	2	Yellow	1,500	98.6	17.2	13.7	15.3	Bolita
42	Matías Reyes Chávez	Santa Ana Zegache	2	Purple	1,530	88.2	28.3	41.0	35.2	Bolita
95	Bernardo Ortega Ramirez	San Martín Tilcajete	5	White	1,600	50.5	24.2	6.0	14.4	Bolita
118	Erasto Ramos López	Valdeflores, Zimatlán	4	White	1,447	46.6	22.2	14.5	18.1	Bolita
123	Timoteo Cruz Arango	Valdeflores, Zimatlán	5	White	1,447	72.9	30.3	36.8	33.8	Bolita/tab <sup>b</sup>
124	Alejandro Cruz Gijón	Valdeflores, Zimatlán	4	Yellow	1,447	78.0	17.2	6.0	11.1	Bolita
134	Ramón Ríos Pérez	Sta. Marta Chichihuatepec	4	White	1,500	93.4	11.1	23.1	17.6	Bolita/tabp <sup>c</sup>
145	Pedro Jimenez Ramirez	San Agustín Amatengo	1	White	1,310	71.8	16.2	6.0	10.6	Bolita/pep <sup>d</sup>
151	Ignacia Juárez J.	San Agustín Amatengo	1	Purple	1,310	48.0	6.1	27.4	17.6	Bolita
152	Cleto López Pérez	San Agustín Amatengo	1	White	1,310	76.7	36.4	25.6	30.6	Tuxpeño/bol <sup>e</sup>
170 <sup>2</sup>	INIFAP		2	White		79.9	7.1	7.7	7.4	bolita

<sup>1</sup>Agromorphological groups <sup>2</sup>Improved variety (V-233)<sup>3</sup>Zapalote chico, <sup>4</sup>Tabloncillo, <sup>5</sup>Tabloncillo perla, <sup>6</sup>Pepitilla, <sup>7</sup>Bolita

For on-farm-conservation we analyzed farmers' expressions of interest in landraces during collection and at participatory exercises at field days. At field days, farmers were exposed to many landraces they had no opportunity to know. From the farmers' votes during field days, we assembled a set of interesting landraces rather than selecting any single landrace. The lesson we deduced from farmers' voting patterns was that it is advisable to seek a repertoire of landraces rather than a single "best" landrace.

The method described here is an initial attempt to address an important issue faced by practitioners of on-farm conservation in areas of diversity: on what crop populations, from among the diverse populations present in a center of diversity, should we focus? Focus is necessary because resources are limited. In addition, not all populations are equally important for the current needs of farmers, and some populations may be to a large extent genetically redundant. Since on-farm conservation depends a priori on farmers' active participation, and farmers will grow only what they perceive as valuable (regardless of the contribution of a particular crop population to genetic diversity), it is essential that the populations selected for conservation initiatives reflect their interests. Identifying this set of populations that satisfies both longer-term genetic criteria and the immediate interests of the farmers who grow them is not a trivial problem.

To do so requires the application of multi-disciplinary methodologies and the perspectives of farmers and scientists. We combined several types of statistical and participatory research methods, as well as the perspectives of both men and women members of farm households and those of plant breeders and social scientists. These perspectives and methodologies appear to complement one another – meaning that the use of both generates a better overall outcome. When choices of materials are based exclusively on methods that rely only on agromorphological traits, characteristics and materials that are important to farmers in the targeted conservation area may be ignored – leading to choices that are less valuable to these farmers or have a less impact on their livelihoods. At the same time, relying exclusively on the perspectives of farming households may lead to a narrower range of materials conserved and the dominance of a single agromorphological group.

On the basis of our experience, we can also suggest improvements in the approach or adaptations for other purposes. A two-stage approach of this type is expensive, especially considering the costs of establishing

on-farm experiments for all materials collected. If the purpose of a project is on-farm conservation, farmer concerns' are of preeminent importance. Then it is more appropriate to focus on the criteria used by farmers to choose among landraces. To learn about the genetic aspects of the material, trials and demonstration plots could be established on a more limited basis, but still allowing farmers to express their choices for subsequent work over a more manageable or targeted set of landraces.

Another option worth exploring is the identification of key persons or "experts" such as seed savers or seed sellers who are keenly aware of the needs and constraints of local farmers. These experts could help to reduce the number of collected landraces to those that are of greatest interest to farmers and therefore in high demand. Farmers still would be requested to express their choices of landraces based on demonstration plots, but on a more limited group of landraces. In this case it may also be more feasible to elicit from participants the reasons for their choices or to ask them to rank the materials according to their desirability.

We attempted to use the revealed preferences of farmers and the diversity analyses to choose landraces to focus our on-farm conservation efforts, as depicted in the conceptual framework. The indicators we used have obvious limitations. The utility of field days as a research instrument depends on the extent to which farmers are able to deduce what they care about from a snapshot of landrace characteristics observed at a single point in time. To evaluate many of the characteristics that matter to them, they need to experiment with materials on their own farms for several seasons. Although this shortcoming may be addressed through providing seed for experimentation, this always involves a risk, and the magnitude of the risk depends very much on the farmer. An issue that we identified as we reflected on this exercise is that we did not really know what farmers would favor most. Did they vote for the varieties they like the most because they represented a type of diversity that was novel to them or because they represented "better" versions of genetic material they were already planting?

It is important to point out that while we have emphasized the use of the regional diversity as the basis for this on-farm conservation project, we recognize that this is only one approach. Introducing new diversity, exotic to the system, is another valid approach. In fact our results suggest that farmers in the Central Valleys of Oaxaca are introducing exotic

diversity, a process that has also been documented for other Mexican small-scale maize farmers (Aguirre Gómez 1999; Bellon and Brush 1994; Louette et al. 1997). The introduction of “foreign” germplasm can be a source of morphological and agronomic diversity rather than a cause of genetic erosion (Louette et al. 1997). Examining the role of foreign germplasm in on-farm conservation is however, outside the scope of this paper.

The materials selected for conservation depend on the specific conservation strategy and interventions that are envisioned, such as (a) seed multiplication and distribution, (b) market development, or (c) participatory plant breeding. The method presented here seems to be particularly appropriate for (a). While a discussion of the relationship between the selection of materials and different conservation strategies is beyond the scope of this study, the method and results presented here have implications for other strategies. For example, in the cases of participatory breeding or of landrace selection for market development, there is also a need to identify not only the germplasm that has the greatest potential for genetic progress but that can benefit the farmers most. The method described here may serve in the initial phases of a participatory breeding project to identify suitable donor or parent materials. Unfortunately, some published studies on participatory breeding do not explicitly report how the materials farmers evaluated were originally selected (Ceccarelli et al. 2000; Sperling et al. 1993), and it is therefore difficult to compare approaches. In studies such as those conducted by Witcombe et al. (1996), farmers’ needs are identified through participatory rural appraisals, while the Oaxaca farmers’ concerns were elicited at the time of collection. While these studies used rating or ranking techniques to elicit systematically the traits of interest to farmers, we used preferences expressed through votes.

In general, these studies have not focused on landraces, although some include them (Ceccarelli et al. 2000). Most depended on farmer experts as participants, while in our approach, all farmers in the study communities were invited to participate. These studies involved more in-depth participation in terms of farmers’ experiments. In our case, this constituted the next stage of the project. However, the studies share with ours the appreciation for the need to offer diversity to farmers and to involve them actively, merging their perspectives with those offered by scientific disciplines.

Finally, a major finding is that the Oaxaca farmers

with whom we worked expressed great interest in diversity, valued many traits, voted for many landraces, and participated enthusiastically in the field days. This finding suggests that we can enhance farmer welfare while conserving diversity. A subsequent intervention of the project supports this view. This intervention consisted of selling seed of the 17 materials identified to farmers in six of the fifteen villages where landraces were collected over two seasons (1999 and 2000). This was a success— a total of 1,884.5 kg of seed of these materials were sold to 282 farmers (Bellon et al. 2001).

## Conclusions

A major finding of relevance for on-farm conservation is that at least some farmers seem to “demand” diversity. The diversity that exists in an area like the Central Valleys of Oaxaca is not accidental; it reflects a long co-evolutionary process of farmers and their crop, and the strength of indigenous cultures in this area that generates farmers’ interests in many traits of maize. This interest has its origin in the different indigenous cultures and is still very alive in this area. There is no single “best landrace” in our study. Therefore, there is a need for methods to identify sets of landraces that would be of interest to farmers and that contribute to the maintenance of genetic diversity. This paper has presented a method to address this need.

At least in the case presented here, enhancing farmers’ welfare is consistent with the maintenance of a local repertoire of varieties, and genetic erosion may be neither inevitable nor irreversible. The challenge is to make the existing diversity known and available to farmers willing to use it, rather than organizing rescue operations for genetic resources. This provides a positive outlook for on-farm conservation as part of a strategy to conserve crop genetic resources.

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