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Conceptualizing Interventions to Support On-Farm Genetic Resource Conservation

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Summary. — Interest is increasing worldwide in on-farm conservation as a component of a strategy to conserve crop genetic resources. This may require outside support to small-scale farmers in areas of crop diversity. This paper argues that crop diversity maintained by farming households results from the interplay between a demand and a supply for this diversity. Interventions to support on-farm conservation can be conceptualized by the way they influence these two factors. Demand interventions should increase the value of crop diversity for farmers or decrease the farm-level opportunity costs of maintaining it, while supply interventions should decrease the costs of accessing diversity.

Key words — crop diversity, genetic erosion, interventions, on-farm conservation, Mexico, Latin America

1. INTRODUCTION

Crop genetic diversity is the basis of our food supply and our survival. This is equally true of subsistence-based societies and technologically advanced societies. Genetic diversity allows farmers and plant breeders to adapt a crop to heterogeneous and changing environments by, for example, providing it with resistance to pests and diseases. For several decades, concern over the loss of crop genetic diversity has grown, especially where a few genetically uniform, high-yielding varieties have replaced genetically variable crop landraces, a process known as crop genetic erosion (Harlan, 1992; Hawkes, 1983; NRC, 1993; Plucknett, Smith, Williams, & Anishetty, 1987). This concern is especially relevant in areas where diversity is concentrated and where farmers maintain not only local seed of ancestral crop populations, but also the human knowledge and behavioral practices that have shaped this diversity for generations (Bellon, Pham, & Jackson, 1997).

The conventional explanation for crop genetic erosion is that farmers increasingly specialize and replace their diverse set of landraces with a few high yielding modern varieties that provide them with higher incomes. While farmers pursue their legitimate private interests, crop genetic diversity—to the extent that it is a public good—may be lost. Farmers as individuals may tend to underinvest in their

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conservation relative to what society at large would consider optimal to ensure the needs of future generations (Smale & Bellon, 1999). As long as this situation is true, the public should support the conservation of crop genetic diversity.

The recognition of the importance of conservation of crop genetic diversity has led to public investment in the creation and maintenance of gene banks around the world for many different crops (i.e., *ex situ* conservation) (Hawkes, 1983; Plucknett *et al.*, 1987). More recently, on-farm (*in situ*) conservation has emerged and is increasingly recognized as an important complement to *ex situ* conservation (Altieri & Merrick, 1987; Maxted, Ford-Lloyd, & Hawkes, 1997) and as part of a strategy to conserve genetic resources (Brush, 1999; IPGRI, 1993; Maxted *et al.*, 1997; Wood & Lenné, 1999). As with *ex situ* conservation, *in situ* approaches may require public support and investment.

On-farm conservation involves farmers' continued cultivation and management of a diverse set of crop populations in the agroecosystem where the crop evolved, or in secondary centers of diversity (Bellon *et al.*, 1997). This conservation strategy depends on farmers' active participation because it acts on farmers' reasons and incentives to maintain diversity (Bellon *et al.*, 1997), but it is not necessarily clear how to support farmers' efforts to maintain diversity on their farms. There is a need to identify and implement appropriate interventions based on a thorough understanding of factors that threaten crop diversity on-farm and farmers' reasons for abandoning rather than maintaining diversity.

This paper argues that the diverse set of farmer varieties of a crop—crop populations that a group of farmers recognize as distinct units [1]—planted by households in a community (referred to as "crop diversity" in the rest of the paper) results from the interplay between demand for diversity—the fact that farmers value different varieties and are willing to invest resources such as labor, money, and land to plant them, and supply of diversity—the mechanisms and transactions they depend on to access these diverse set of varieties. These diverse varieties and their management by farmers form the basis for on-farm conservation. To understand and respond to crop conservation threats on the farm, it is necessary to find out if these threats operate through the demand or the supply of this diversity, as demand and supply have different implications for the maintenance of diversity and necessitate distinct interventions.

This paper focuses on areas of crop domestication and high diversity, which are the most likely candidates for on-farm conservation efforts. Centers of domestication and diversity [2]—such as Mesoamerica for maize (*Zea mays* L.)—are particularly promising locations for on-farm conservation because they exhibit a high level of infraspecific diversity that reflects a long process of co-evolution between the crop and the local human population. 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.

It should be pointed out, however, that a large number of varieties planted by a farming household or a community does not necessarily mean that more genetic diversity is maintained or that there is higher evolutionary potential among them, as these varieties may not all be genetically different or contribute equally to crop evolution. Planting a diverse set of varieties may be a necessary but not a sufficient condition to maintain genetic diversity on farm. These issues however, are beyond the scope of this paper (see Smale & Bellon, 1999).

In this paper, a case study is presented to illustrate the issues raised here. The case study is based on an on-farm conservation project in the Central Valleys of Oaxaca, Mexico that was carried out during 1997–2001.

Section 2 defines the demand for crop diversity and describes how the nature of this demand changes as economies develop. This is followed by a discussion of the supply of crop diversity, an assessment of factors that threaten to reduce crop diversity, and an examination of the implications for the design of interventions to support on-farm conservation. Then the case study is presented in Section 6. Conclusions are drawn in Section 7.

2. DEMAND FOR CROP DIVERSITY ON THE FARM

Small-scale farmers in centers of crop domestication and diversity value crop diversity and are willing to invest resources to sustain it. Numerous studies have shown that farmers in these areas plant several varieties simultaneously; within a community different farmers maintain diverse varieties. An important knowledge base associated with this diversity has evolved and has been maintained for generations, which further illustrates the value of this diversity to farmers (Bellon *et al.*, 1997; Brush, 1995; Dennis, 1987; Jodha, 1980; Richards, 1986; Zimmerer, 1991). Demand for diversity arises from farmers' diverse interests and concerns, which include: (a) farming in a variety of environments; (b) coping with production risks; (c) managing pests and pathogens; (d) avoiding or minimizing labor bottlenecks; (e) fitting different budget constraints; (f) providing variety to monotonous diets; (g) providing special consumption items; and (e) fulfilling rituals, generating prestige, and forging social ties (Bellon, 1996). Crop diversity is a fundamental way to cope with these circumstances.

Demand translates into maintenance of diverse varieties because it is unlikely that one variety has all the traits to address these multiple interests or concerns. Varieties with desirable traits often have undesirable characteristics as well. The choice of varieties can be seen as a process by which farmers assemble various bundles of traits to suit specific production conditions, consumption preferences, or marketing requirements (Bellon, 1996; Smale, Bellon, & Aguirre, 2001). Crop diversity may be particularly important for farmers with limited opportunities to trade and participate in markets. Even for those who participate, agroecological heterogeneity and imperfect markets with high transaction costs—common in the rural areas of these regions—contribute to maintain a demand for diversity (Bellon & Taylor, 1993; Brush, Taylor, & Bellon, 1992).

3. SUPPLY OF CROP DIVERSITY ON FARM

Unlike farmers in developed countries or even commercially oriented farmers in developing countries who are able to purchase improved varieties from the formal seed distribution system, small-scale farmers in centers of crop diversity have to depend almost completely on themselves and other farmers to access crop diversity, particularly landraces. Individual farmers can maintain only a small fraction of the diversity present even at the community level and certainly at the regional level. Farmers rely on other farmers not only for seed but also for information on traits of the different varieties, for example, performance under different stresses and consumption characteristics. Only farmers that plant and have experience growing the varieties can provide this information and there should be mechanisms to share not only seed but also information.

A group of farmers can maintain more diversity at a lower cost and incur less probability of loss than an individual farmer. Therefore, individual farmers should have strong incentives to participate in an arrangement with other farmers to provide each other with seed and information on a diverse set of crop varieties. Individual farmers thus may depend on building and maintaining a network with other farmers to keep a greater amount of diversity. These networks may be important to regain valued local varieties that were lost because of climate changes or storage problems and to access new "foreign" varieties. Seed flows in the networks may include landraces and modern varieties. The introduction of "foreign" germplasm can also be a source of morphological and agronomic diversity rather than a cause of crop genetic erosion. For example, foreign varieties with new traits can be incorporated into a portfolio of varieties without displacing any of those already present, or farmers may foster the hybridization of foreign varieties with local ones to incorporate new traits from the former into the latter (Bellon & Risopoulos, 2001; Louette, Charrier, & Berthaud, 1997).

These networks may also play a role in what Zeven (1999) has named the "inexplicable replacement of seed." This phenomenon has been observed in many parts of the world and throughout history, as farmers replace home-grown seed with seed grown elsewhere without any evidence that this practice is needed (probably because of their experience or belief that lower yields are obtained if the seed is not replaced).

Given all these conditions, it is not surprising that the importance of informal seed systems is increasingly recognized. These systems can be complex, dynamic, and in many instances very efficient (Almekinders, Louwaars, & de Bruijn, 1994; Cromwell, 1990). They also have significant weaknesses in incentives, information, and resources (Tripp, 2001). Studies have found that mechanisms for farmer-to-farmer seed flow are based mostly on traditional social networks and family relationships (Almekinders *et al.*, 1994; Rice, Smale, & Blanco, 1998;

Sperling & Loevinsohn, 1993; Zeven, 1999). One should be careful not to assume that seed flows among farmers are always the result of seed exchanges among them (Tripp, 2001). In many instances, farmers obtain seed from other farmers as gifts, through purchase, or as exchanges for labor or grain. Even if seed is bought and sold among farmers, these transactions may occur among people with close social ties and within the same village. The local marketplace can also be an important source of seed, and might be included as part of the network (Tripp, 2001).

Although accessing seed of diverse varieties has direct costs to a farmer, such as the cost of seed and/or money given in exchange or obligations to the seed supplier, there is a set of costs that may be even higher: transaction costs. Transaction costs include the time, effort, and resources that a farmer has to invest to: (a) find out who has which variety, its characteristics, and, particularly, its performance; (b) make sure that the information is accurate and the seed reliable (i.e., it will have an acceptable germination rate); and (c) negotiate the conditions of the transaction with the supplying farmer. Negotiating conditions of transaction with a supplying farmer may be difficult if the farmer is from another village or if there are no social ties between them. Farmers' networks to access diversity may play an important role in decreasing and managing these transaction costs. We can hypothesize that to the extent that farmers perceive a shared interest in maintaining or improving access to diversity and knowledge about diversity, they have incentives to act collectively, for example, by creating and maintaining these networks. Unfortunately we know very little about the structure and function of these networks. There is a need to understand the "social infrastructure" that shapes seed and information flows, particularly in cases where seed systems are based on farmers themselves (Rice *et al.*, 1998).

4. THREATS TO CROP DIVERSITY ON FARM: DEMAND OR SUPPLY DRIVEN?

The conventional explanation for the loss of crop diversity on the farm is that such losses are demand driven. Farmers no longer want to grow diverse sets of varieties, particularly landraces. As they become integrated into the market and have greater opportunities to access modern varieties, sell surpluses, and purchase products, farmers may prefer to specialize and plant a few high-yielding modern varieties that provide them with higher incomes. Increasingly, small-scale farmers and their households participate in labor markets. In fact, this may be the most important link to the market, particularly compared to selling agricultural products (Taylor, Yunez-Naude, & Dyer, 1999). For most farmers, agriculture is one among many income-generating activities that include off-farm labor and temporary migration. Expanded participation in labor markets increases the opportunity cost of time for farmers and their families, i.e., the benefits that farming households would have to forgo by investing their time in other activities rather than participate in labor markets rise. To maintain crop diversity on their farms, farmers have to invest labor, management, and other input in this activity and may have to forgo other opportunities. Increased intensification and commercialization may increase the opportunity cost of maintaining crop diversity so much that farmers may not be willing to maintain it.

Zimmerer (1991) has argued, for example, that in the case of Peruvian peasants, off-farm labor is negatively correlated with the maintenance of crop diversity because cultivating diverse types of maize and potatoes (*Solanum tuberosum* L.) is highly labor intensive and entails high opportunity costs. Another example is the case of the Wagwag, a traditional group of rice (*Oryza sativa* L.) varieties grown in the Cagayan Valley of the Philippines, which contribute in an important way to the genetic diversity in this region (Bellon *et al.*, 1998). While the Wagwag varieties are highly appreciated by farmers for their consumption quality, their long duration makes them unattractive as farmers shift from rainfed to irrigated rice production. In irrigated rice production, farmers growing the traditional Wagwag rice have to sacrifice the production of a second crop, which they can produce with modern varieties. Farmers perceived on average a large difference (6 t/ha) between growing one crop with a traditional variety for a good season and growing two crops of a shorter-duration modern variety, a difference that remains important even in a poor season (1.5 t/ha). Not surprisingly, the main reason for abandoning traditional varieties in the irrigated ecosystem is their late maturity, which affects the timing of the next crop.

As farmers specialize with increased market integration and availability of new technolo-

Table 1. *Factors that modify the demand for crop diversity*

Reasons for demanding diversity	Factors that decrease the demand for diversity
To farm in a variety of agro-ecological environments	Availability of fertilizers and irrigation
To manage risk and uncertainty	Availability of insurance and nonfarm sources of income, including income from migration and remittances
To fit different budget constraints	Increased income or cheaper inputs
To avoid or minimize labor bottlenecks	Availability of hired labor or machinery
To provide variety to a monotonous diet	Availability of new consumer products
To manage pests and diseases	Availability of pesticides
To provide special products, such as snacks, cosmetics	Availability of substitutes or new products
To fulfill rituals or forge social ties	Cultural change, conversion to a new religion

gies, the number of concerns they have associated with crop production may decrease, thereby reducing the number of traits that they consider important in their varieties. Table 1 presents some of the factors that reduce the demand for crop diversity. Furthermore, consumers located in distant places, not farmers and their households, may determine some of these traits. Farmers may not require a diverse portfolio of varieties to fulfill their needs and concerns anymore. This may even be the case if multiple traits remain important for farmers, if a few introduced modern varieties are so simultaneously superior to local varieties in many traits. Cultural change may also play a role in farmers' choice of varieties, since the loss of local cultural elements and increased integration with a general or dominant culture may eliminate preferences and practices that make a diversity of crop types valuable.

Many examples, however, show that farmers may still value and continue to plant several varieties under these changing conditions. In many instances, newly introduced modern varieties are incorporated into their portfolios, increasing rather than decreasing on-farm diversity (Brush, 1995; Dennis, 1987; Louette *et al*., 1997; Rice *et al*., 1998).

The recognition that the supply of diversity is important and can be costly to farmers opens a new dimension to understanding threats to on-farm diversity. As pointed out earlier, the opportunity cost of maintaining diversity may become very high under increased intensification and market integration. These costs also impinge on the supply of diversity, particularly the cost of time to farmers and their families as they participate in labor markets and migrate. Accessing diversity requires time—time to search for the information on appropriate varieties, search for the seed, and create and maintain the social networks that supply this diversity. Therefore, a higher opportunity cost for time implies a higher cost to access crop diversity.

Higher costs of accessing diversity mean that once a farmer loses a variety, he or she may be less willing to look for it. The smaller the number of farmers who plant certain varieties or save seed from them, the more difficult it is for a farmer to find them in case of loss. A higher opportunity cost of time may also imply less time and willingness to maintain the social networks that supply diversity, and may create a vicious circle that increases the farmer's cost of accessing and maintaining crop diversity even though the demand for diversity stays constant. Migration and social changes may also influence the functioning of the social networks that supply diversity by affecting their cohesiveness and effectiveness. Even if more off-farm labor opportunities increase farmers' income, the lack of formal markets for diverse seed means that farmers may not be able to access this diversity even if they want and can afford to do so. An increased reliance in commercial seed systems may also contribute to a decrease in the access to diversity. Commercial seed systems favor the provision of seed from a few varieties in large quantities, not of diverse varieties, in small quantities. Table 2 presents some of the factors that contribute to the reduction of the supply of crop diversity.

In the case of maize, landraces in a specific area may be viewed as a metapopulation (Louette, 1994), defined as a set of populations

Table 2. *Factors affecting the supply of diversity*

Factors that decrease the supply of diversity	Reasons
Lack of seed locally of diverse local varieties	Abandonment of seed selection by farmers Increased reliance on commercial seed systems
Increased cost of seed of diverse varieties	Erosion of social networks leading to increased transaction costs to obtain seed, e.g., less time and energy to invest in these networks Erosion of reciprocity/social norms associated with the local provision of seed, e.g., farmers stop following the rules Out-migration, hence less farmers who save seed Immigration by farmers who do not share the same social norms and preferences regarding diversity Switching to other crops Abandonment of agriculture even without outmigration by an increased number of farmers
Availability of seed of only a few varieties	Increased reliance on commercial seed systems, commercial seed suppliers favor the provision of seed of few varieties in great quantities per variety

that are interconnected through migration (David, 1992). This view changes the perspective on genetic erosion and seed networks. The loss of particular populations may not be so important as long as their alleles and agromorphological characteristics are present in other linked populations. Seed networks that allow the migration and recombination of alleles may counteract the impact of the loss of certain populations. But, as these networks become more fragmented and costly to operate because of changes in off-farm employment, adoption of modern varieties, or shifts to other crops, the metapopulation structure becomes threatened, not necessarily by the total and direct replacement of varieties, but by social and technological changes. It should be pointed out that the focus on metapopulations may apply only to crops where migration and recombination between differentially adapted populations allow the interchange of alleles, such as open-pollinated crops, for example, maize. This perspective may not be applicable for self-pollinated crops, for example, wheat (*Triticum aestivum* L.) or rice, although a low rate of outcrossing can permit significant interchanges of alleles over time even in these crops. This may not be true for clonally propagated crops such as potato.

Another information problem is that farmers may not be aware of the range of varieties available (Tripp, 2001), especially as a result of problems with nomenclature. As Quiros, Brush, Douches, Zimmerer, and Huestis (1990) have shown, Andean potato names are very consistent at the local level but lose consistency with distance. Thus farmers who want to look for a particular variety outside their village may have a hard time identifying it using the local terminology.

It is important to distinguish between farm-level costs associated with growing a diverse set of varieties (for example, labor, management, production differentials) and the costs of accessing the seed and information about these varieties. The former costs involve the farming household, while the latter involve the community and the social networks to a greater extent.

The loss of on-farm crop diversity is not exclusively demand or supply driven. In some cases it is the former, in others the latter, and in still others it is both. It is important to realize however that these processes are different and to understand the precise causes, because policy interventions to foster on-farm crop diversity may be completely different.

5. IMPLICATIONS FOR THE CONSERVATION OF CROP DIVERSITY ON-FARM

If we believe that there is a need to conserve on-farm diversity as part of a strategy to conserve crop genetic resources, and that to accomplish this goal may require outside support to farmers, we need to find appropriate interventions to do so.

Given that the loss of crop diversity in farmers' fields may be driven by supply and/or demand, what are the implications for choosing appropriate interventions to maintain diversity?

We cannot force farmers to do what they do not want in cases where the loss of on-farm diversity is demand driven, but we can try to influence this demand. In fact, many of the interventions proposed to date for on-farm conservation are based on the principle of influencing farmers' demand for crop diversity. It has been argued, for example, that on-farm conservation programs should aim at increasing the value of local crop varieties for farmers who may otherwise stop growing them (Brush, 1999; Jarvis, Sthapit, & Sears, 2000). This can be done through market or nonmarket methods. Market methods entail developing market channels for local produce to increase the value of genetic resources for certain crops or to rely on legal mechanisms to restrict the supply of genetic resources, thereby raising their value. Nonmarket methods consist of educational or promotional campaigns, increased use of local crop resources, and farmers' participation in crop breeding and improvement programs. Participatory crop improvement can encourage the maintenance of more diverse, locally adapted plant populations (Witcombe, Joshi, Joshi, & Sthapit, 1996), lending support to on-farm conservation of crop genetic resources (Qualset, Damania, Zanatta, & Brush, 1997). It is also possible that participatory crop improvement may lead to the loss of diversity if only a few populations become desirable to farmers and displace an array of more diverse populations.

Another approach is to remove policies that—while well intentioned and focused on issues unrelated to crop diversity—may force farmers to abandon the diversity they maintain, such as government programs that provide subsidized external inputs, credit, and extension, focusing exclusively on a few modern varieties (Gauchan *et al.*, 2000). These policies can be seen as decreasing the value (demand) of diversity by raising the opportunity cost of maintaining it.

Further evidence of the importance of demand as a foundation for on-farm conservation projects is that most scientific studies pursued as the basis for these projects try to establish whether there is a demand for on-farm diversity among at least some farmers (Jarvis *et al.*, 2000). For example, Meng, Taylor, and Brush (1998) used surveys and econometric methods to identify farming households that were likely to plant wheat landraces in an area of wheat diversity spanning three provinces in Turkey. These farmers demand a diverse set of traits, which results in a diversity outcome that is potentially desirable for on-farm conservation efforts.

When farm-level opportunity costs hamper the maintenance of diversity, breeding or management interventions that reduce those costs may be an alternative. For example, in the case of the Wagwag rice varieties grown under irrigation, a modified cropping pattern could allow farmers to grow the long-duration Wagwag rice and a short-duration improved variety in irrigated conditions, making the former more attractive to farmers (Pham, Jackson, Moring, & Sebastian, 2000).

If the loss of on-farm diversity is supply driven, losses could be reversed through interventions that decrease the costs—particularly the transaction costs—of accessing diversity, both in terms of access to actual seed of diverse sets of varieties, and information about their performance. Methods to foster on-farm conservation, such as the establishment of community seed banks and organization of diversity fairs, can be seen as supply-side interventions. They respond to difficulties with the supply of seed or varieties. Community seed banks also involve some form of collective action. The Oaxaca case study to be described below is based on the idea of influencing the supply of diversity, but with a slightly different approach to community seed banks and diversity fairs.

Although projects to support farmers' efforts to conserve on-farm crop diversity should ideally be based on a thorough understanding of whether the constraints they face to maintain diversity are supply and/or demand driven, this is often easier said than done. Clearly, an incorrect understanding may lead to ineffective interventions and hence to the failure of the project or a waste of resources. For example, if the project interventions are aimed at increasing the value of crop diversity (demand) but the constraints faced by farmers are supply driven, the likelihood of failure will be high. Increasing demand may be futile in a system where farmers regularly expect to lose seed—thus a supply system is needed. Farmers may not want to continue maintaining crop diversity; therefore supply-based interventions may be completely irrelevant. Obviously, if both factors are present, supply- and demand-based interventions should be implemented. It may be difficult though to distinguish in the empirical work whether the constraints to diversity are related to demand or supply. This problem may be especially important in scaling upward from detailed village-level work to cross-sectional analyses of survey data and regional aggregation. Sometimes the type of constraint is not apparent until an intervention has taken place. The lesson from this is that while a proper diagnosis of the reasons for the loss or potential loss of crop diversity should be made, the implementation process should remain as open as possible and both demand- and supply-type interventions should be available.

6. A CASE STUDY FROM THE CENTRAL VALLEYS OF OAXACA, MEXICO

To illustrate the issues raised in this paper, data and results from an on-farm conservation project that was carried out in the Central Valleys of Oaxaca, Mexico are presented below (Bellon *et al.*, 2003; Smale, Aguirre, Bellon, Mendoza, & Manuel Rosas, 1999). This project compared different participatory interventions with small-scale farmers in six communities in Oaxaca. Around 90% of the study area is planted to maize and there is a negligible formal seed distribution system. This region was selected because there is a long history of maize cultivation, there is a strong cultural tradition associated with maize production and consumption, it is ethnically diverse, and it has a wide range in precipitation. In addition, local landraces dominate maize production. All these conditions are hypothesized to contribute positively to the maintenance of diverse maize populations (Bellon *et al.*, 2003). These farmers also face important socioeconomic changes, such as migration, increased integration into the nonfarm economy, increased urbanization, and a decreasing attractiveness for farming, that at least in theory should decrease their interest on maize production and maintaining maize diversity.

The project included a collection of the diversity of maize landraces present in the area and a careful characterization of the landraces under experimental conditions using agromorphological traits. During this characterization, farmers—both male and female—from the region were invited to observe the collected landraces in the experimental plots and to vote for the ones they liked. Their votes were combined with the characterization data to select a subset of landraces that captured most of the diversity present and had high potential value for farmers (for the method see Bellon *et al.*, 2003). Demonstration plots were established in the six communities with the subset of selected landraces, and field days were organized at harvest time when farmers could see the plant and ear characteristics of the selected landraces and get information on their performance. At the end of the field days, participating farmers could purchase seed from the landraces shown, at the local price for seed from a landrace. For the three years that the project distributed seed (1999–2001), 2,726 kg of seed were sold to a total of 371 farmers. [3] The average amount purchased was small, around 4.3 kg/purchase (one farmer could purchase different landraces). The idea of the seed distribution exercise was to foster experimentation rather than seeking to promote adoption, hence the relatively small seed quantities sold. Experimentation is a common behavior among these farmers. In addition, farmers were trained in seed selection and management techniques, and learned principles to assist them in maintaining the characteristics of landraces they value.

Data from the Oaxaca project illustrate issues related to the demand for diversity. During a collection of ears of all maize types grown in the region, donating farmers were asked about the advantages and disadvantages of each type they donated. With this information a list of 25 characteristics that may be important to farmers was compiled. Later a random sample of 40 households per community was interviewed and asked to rate the importance of each of these characteristics as: (a) very important, (b) somewhat important, or (c) not important. In addition, they were asked to rate the performance of each maize type they grew, with respect to each of the 25 compiled characteristics as: (i) very good, (ii) regular, or (iii) poor. Male and female members of the household were interviewed separately (Smale *et al.*, 1999).

Table 3 shows the percentage of male and female household members who rated each characteristic as very important. The data show the high demand for different characteristics by these farmers, particularly females. The number of women who rated more than 50% of characteristics as very important was twice the number of men—seven for males and 15 for females.

Table 3. *Demand for variety characteristics, Central Valleys of Oaxaca*

Characteristic	Percent of farmers rating characteristic as "very important"		
	Males	Females	Both
Agronomic			
Grain weight (kg/almud)[a]	76.3	76.6	76.4
Grain yield (kg/ha)	52.8	66.1	59.4
Length of growing period	46.5	46.9	45.7
Produces "something" even in bad years	63.8	89.8	76.8
Drought tolerant	91.1	89.9	90.5
Resistant to lodging	25.1	51.4	38.2
Weed tolerant	26.7	39.8	33.2
Disease resistant	31.5	61.4	46.4
Cold tolerant	22.9	34.7	28.8
Resistant to insects in storage	79.7	75.5	77.6
Shells easily	16.4	31.4	23.9
Consumption-related			
Number tortillas/almud	26.4	63.5	44.9
Good for nixtamal[b]	40.0	61.0	50.6
Taste of tortillas	50.8	78.4	64.6
Good for atole[c]	34.0	60.2	47.1
Good for nicuatole[c]	1.7	17.7	9.7
Good for tamales[c]	14.9	38.4	26.6
Good for tejate[c]	26.7	39.8	26.6
Good for pozol[c]	8.3	25.4	16.9
Good for tlayudas[c]	27.5	50.7	39.1
Good for forage	30.9	51.4	41.2
Good for feed	37.1	50.0	43.1
Management			
Good for sale	32.4	53.6	43
Produced with little labor	37.4	43.5	40.3
Produced with few purchased inputs	48.2	57.5	52.9

Source: Modified from Smale *et al.* (1999).
[a] *Note*: An almud is a commonly used volume measurement used in marketing grain or seed.
[b] Dough to make tortillas.
[c] Special maize preparations.

Table 4 shows the performance of different maize types identified by grain color—which is the primary taxonomic variable used by these farmers—for each of the 25 characteristics. It should be pointed out that using grain color for classification, although it is the most important criterion used by farmers, may underestimate the actual number of maize types, since farmers distinguish different types within a color class, however, they may not have specific names to differentiate among them. The nomenclature to distinguish these differences is not well developed among these farmers. For simplicity and since the point is to illustrate broad differences among maize types, the focus here is only on grain color. This issue is further discussed below.

The performance of each maize type for each characteristic is reported either as a quantitative estimate given by farmers for yield and duration or as the percentage of farmers who rated the maize type as "very good." The data show that the Blanco (white grain) type has superior performance compared to the other types in terms of yield by weight, different consumption-related characteristics and ease of marketing, but has the longest duration. The Amarillo (yellow grain) type has a shorter duration and lower yield, but was rated better for drought tolerance, resistance to lodging, feed, and certain special preparations. The Negro (black grain) type has an even shorter duration and, like the Blanco type, was rated superior for easy shelling and making tortillas.

Table 4. *Supply of variety characteristics, by maize type, Central Valleys of Oaxaca*

Characteristic	Blanco	Amarillo	Negro	Belatove	Improved
	Mean reported by farmers				
Agronomic					
Grain weight (kg/almud)[b]	3.96	3.96	3.94	3.87	4
Expected grain yield (kg/ha)	705	475	498	445	2,238
Days from emergence to flowering	78	72	68	69	101
Days from emergence to harvest	126	121	111	115	149
	Percent farmers rating maize type as "very good"[a]				
Produces "something" even in bad years	74	66	70	78	14
Drought tolerant	39	49	34	27	5
Resistant to lodging	40	53	47	32	33
Weed tolerant	30	20	13	18	19
Disease resistant	38	34	18	27	5
Cold tolerant	51	22	9	14	29
Resistant to insects in storage	19	22	9	14	29
Shells easily	74	77	84	86	52
	Mean reported by farmers				
Consumption-related					
Number tortillas/almud	46	39	40	37	58
	Percent farmers rating maize type as "very good"				
Good for nixtamal[c]	93	88	84	86	19
Taste of tortillas	95	90	95	91	19
Good for atole[d]	94	63	43	44	14
Good for nicuatole[d]	68	28	29	13	14
Good for tamales[d]	93	88	65	78	14
Good for tejate[d]	49	24	9	9	5
Good for pozol[d]	81	70	40	51	24
Good for tlayudas[d]	86	93	83	83	14
Good for forage	78	93	55	65	81
Good for feed	86	99	90	87	14
Management					
Good for sale	90	62	31	27	10
Produced with little labor	5	4	6	5	14
Produced with few purchased inputs	2	1	0	0	14

Source: modified from Smale *et al*. (1999).

[a] Includes both male and female members of household.

[b] An almud is a commonly used volume measurement used in marketing grain or seed. There are few observations for Belatove and improved maize.

[c] Dough to make tortillas.

[d] Special maize preparations.

The Belatove (red grain) type had the lowest yield, a short duration, the highest rating for yield stability (producing "something" even in bad years) and easy shelling, but was not rated high for ease of selling (as with the Negro type). Finally, although improved maize [4] was considered to have the highest yield, it also has the longest duration and was rated low for most of the other characteristics, particularly consumption characteristics. Farmers use grain color as an indicator of duration and recognize the tradeoff between yield and duration. The data illustrate the differential performance of the different maize types for the characteristics identified as potentially important for farmers in this study.

It should be pointed out that while the Blanco maize type had high yield and was very good for multiple uses, it also had the longest growing cycle. Its longer duration was a negative characteristic if the rains were delayed and it had to be planted late, because then the crop risked being exposed to drought and to frost. The other maize types had shorter growing cycles (white > yellow > black > red) and provided farmers with the flexibility to respond to the uncertain onset of the rains, even though they were considered inferior for certain characteristics. The use of grain color by farmers as an indicator of certain traits such as duration and yield and its use in planting decisions has been described for maize and other crops (Clawson, 1985). The different maize types show complementarities between themselves, and the fact that most farmers plant more than one maize type suggests that they may mix types to balance their portfolio of varieties. Other studies in Mexico have shown this (e.g., Bellon & Risopoulos, 2001; Clawson, 1985; Smale *et al.*, 2001).

Data from the Oaxaca project illustrate issues related to the supply of diversity. The average area planted to maize in the study area is 3 ha with an average of 1.6 varieties/household (this varies by community, however, with the greatest diversity reaching 2.13 varieties/household). An average of 11 maize varieties were collected from each of the six communities. While the collection strategy tried to maximize the diversity of maize landraces collected, not all varieties collected were necessarily different, and this number may overestimate the actual number of different varieties present in a community. Individual farmers usually face a high probability of losing varieties they plant because of climatic variation, storage problems, pests, and particularly because of the small areas planted. For example, very small areas (on average between 0.17 and 0.04 ha/farmer) are planted to maize types that do not have white grain, and farmers depend on other farmers to recover lost varieties and to access new varieties.

In these communities there is no access to a formal seed distribution system for landraces. In terms of common practices for acquiring seed, farmers said that 87.5% of the maize types planted frequently came from the previous harvest. But, for 47.3% of the maize types, they sometimes acquired seed from outside sources. This is particularly the case for nonwhite maize types, which increase to 64.9%, and rise up to 80% for the rare Belatove type. The main reasons to get new seed are seed loss or to try a new seed. Again, for the less common nonwhite maize types, farmers depend on other farmers to gain access. The seed flows in and out of the household usually involved transactions with family, friends, or neighbors for seed or money. Currently, research is underway in Oaxaca to understand the structure and functioning of farmers' seed supply networks (Badstue, Bellon, Juárez, Manuel, & Solano, 2003).

Identifying varieties outside their village is difficult for farmers because no clear naming system for local varieties exists. While farmers in the study area use grain color to distinguish among maize types and recognize different types within a color group, there does not seem to be a consistent naming system associated with the different types within a grain color even within a community. In many cases, farmers who said they planted two types of white maize could not provide specific names for each, even though they could describe their differences.

A conclusion reached in this project was that the constraints to diversity were related to supply rather than demand because the collection of local landraces encompassed many different maize varieties, even though farmers planted only an average of 1.6 varieties/household. As pointed out, the collection also showed that farmers valued many different characteristics, especially traits related to consumption and a representative random sample confirmed that farmers in this region considered many of these traits very important. The field demonstrations showing the diversity collected in the region drew a lot of attention and participation among farmers. The voting exercise described above showed that male and female farmers voted for an average of 10.8 and 13.7 varieties, respectively. Farmers showed interest in many different varieties, not just a few, and even the most popular types accounted for only 36% and 54% of the votes of male and female farmers, respectively. As noted, subsequent field days where farmers could purchase a subset of these maize varieties showed that farmers wanted to buy seed of a diverse set of the landraces present in the region.

7. CONCLUSIONS

Crop diversity maintained by small-scale farmers in areas of crop domestication and diversity is the result of the interplay of demand for this diversity and its supply. The loss of diversity may be supply and/or demand driven, posing different challenges for devising interventions that help farmers maintain crop diversity. If the loss of diversity is demand driven, interventions should increase the value of crop diversity to farmers or decrease the farm-level opportunity costs of maintaining diversity. If the loss of diversity is supply-driven, interventions should decrease the costs of accessing crop diversity—particularly transaction costs—both in terms of accessing the actual seed of diverse sets of varieties as well as information about their characteristics and performance. Failure to diagnose correctly the causes of a loss of diversity may lead to ineffective interventions. It may be difficult in the empirical work, however, to determine whether the constraints to maintaining diversity are related to demand or supply; therefore it may be important to keep the implementation process as open as possible and make demand and supply interventions available.

The case study showed that farmers in the study region have a high demand for diversity in spite of experiencing important socioeconomic changes such as migration, increased integration into the nonfarm economy, and increased urbanization which have reduced the economic attractiveness of farming. For farmers who participated, the project described above greatly reduced the cost of accessing the diversity and information about maize landraces present in the region. The high demand found for different maize landraces, even in an area where diversity is still present, shows that there is a problem of access. Therefore, interventions may be needed to support farmers to maintain their diversity on farm even if demand is present. Furthermore, the existence of 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 that may be required to encourage their conservation.

NOTES

1. This meaning is not the same as the one given to varieties in the context of industrialized agriculture (e.g., Union for the Protection of New Varieties of Plants), where a variety should be new, distinct, uniform, and stable. Farmer varieties do not necessarily conform to these criteria.

2. Other centers of diversity for important crops include the Near Middle East for bread wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.); Southeast Asia for rice (*Oryza sativa* L.); the Andes for potatoes (*Solanum tuberosum* L.); Africa for sorghum (*Sorghum bicolor* (L.) Moench); and Mesoamerica for the common bean (*Phaseolus vulgaris* L.) (Harlan, 1992).

3. This amount of seed is equivalent to an area planted of 170.4 ha at the normal seeding rate of the region (16 kg/ha).

4. It should be pointed out that modern varieties have had an almost negligible impact in this region. This should not be construed as conservatism on the part of the farmers, as discussions with farmers 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. Furthermore, there is a very small formal seed distribution system in the region based on small agricultural stores in the central market of Oaxaca city.

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