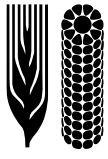
E C O N O M I C S

Working Paper 01-01

Demand and Supply of Crop Infraspecific Diversity on Farms: Towards a Policy Framework for On-Farm Conservation

Mauricio R. Bellon



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Contents

Abstract

Interest is increasing worldwide in on-farm conservation as a component of a strategy to conserve crop genetic resources. On-farm conservation may require outside support to small-scale farmers in areas of crop domestication and diversity. This paper argues that crop infraspecific diversity maintained by farming households in these areas results from the interplay between demand and supply for this diversity (i.e., its loss may be demand- or supply-related). In the first instance, interventions should be aimed at increasing the value of crop diversity for farmers or decreasing the farm-level opportunity costs of maintaining diversity. In the second instance, interventions should decrease the transaction costs of accessing crop diversity. It may be difficult, however, to distinguish in empirical research, whether the constraints to diversity are demand- or supply-related. Therefore the process of supporting on-farm conservation should be kept as open as possible and both demand and supply interventions should be available.

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Demand and Supply of Crop Infraspecific Diversity on Farms: Towards a Policy Framework for On-Farm Conservation

Mauricio R. Bellon

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 (in other words, as genetic erosion has occurred) (Brush 1991; Harlan 1992; Hawkes 1983; NRC 1993; Plucknett et al. 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 et al. 1997; Brush 1991).

The conventional explanation for genetic erosion is that farmers specialize and replace their diverse set of landraces for 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 conservation relative to what society at large would consider optimal to ensure the needs of future generations (Smale and 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 and Merrick 1987; Maxted et al. 1997) and as part of a strategy to conserve genetic resources (Brush 1999; IPGRI 1993; Maxted et al. 1997; Wood and 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 (Brush 1991; Bellon et al. 1997). However, it is not 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 of farmers' reasons for abandoning rather than maintaining diversity.

This paper argues that the set of farmer varieties[1] of a crop planted by households in a community (crop infraspecific diversity[2]) results from the interplay between the demand and supply for this diversity. These 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.

The research described in this paper focuses on areas of crop domestication and high diversity, which are the most likely candidates for on-farm conservation efforts. 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. However, these issues are beyond the scope of this paper (see Smale and Bellon 1999).

Data and other results from an on-farm conservation project in the Central Valleys of Oaxaca, Mexico (Bellon et al. 2000a; Smale et al. 1999) illustrate how threats to the supply and demand of diversity influence interventions to preserve diversity. Around 90% of the study area in Oaxaca is planted to maize varieties. There is no formal seed distribution system. In 1997, 34.8% of farmers said that they gave seed to other farmers (Smale et al. 1999). The Oaxaca project conducts and compares different participatory interventions with small-scale farmers in six communities in the study area. Through the project, farmers gain access to the diversity of maize landraces present in the region, are trained in seed selection and management techniques, and learn principles to assist them in maintaining the characteristics of landraces they value.

The rest of the paper is organized as follows. The next section defines demand for crop diversity and describes how the nature of this demand changes as economies develop. A discussion of the supply of crop diversity follows. The next sections assess the factors that threaten to reduce crop diversity and examine the implications for the design of interventions to support on-farm conservation. Conclusions are drawn in the final section.

Demand for Crop Diversity on Farm

Small-scale farmers in centers of crop domestication and diversity demand crop diversity. Numerous studies have shown that farmers in these areas plant several varieties simultaneously; within a community different farmers maintain diverse varieties (Bellon et al. 1997; Brush, 1995; Dennis, 1987; Louette et al. 1997; Richards, 1986; Zimmerer, 1991). This demand arises from farmers' diverse interests and concerns that include: a) farming in

1 *Farmer varieties* (referred to as "varieties" in this paper) are the crop populations that a group of farmers recognize and name as distinct units. Each of these varieties combines a particular set of characteristics that farmers recognize, such as yield potential, growing cycle, particular performance under biotic and abiotic stresses, response to management, or culinary and storage properties (Bellon 1996; Smale and Bellon 1999). The set of farmer varieties managed by a group of farmers is the genetic resources they maintain.

2 Referred to as "crop diversity" in the rest of the paper.

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 et al. forthcoming). 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 the demand for diversity (Bellon and Taylor 1993; Brush et al.1992).

Supply of Crop Diversity on Farm

Small-scale farmers in centers of crop diversity, such as Mesoamerica for maize, depend almost completely on themselves and other farmers for access to genetic resources, mainly landraces. Individual farmers can maintain only a small fraction of the diversity present (even at the community level and certainly at the regional level). For example, the average area planted to maize is 3 ha with an average of 1.6 varieties / farmer in the six communities in Oaxaca (this varies by community, however, with the greatest diversity reaching 2.13 varieties / farmer). An average of 11 maize varieties[3] was collected per community during a collection undertaken in the region. 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. In Oaxaca, for example, very small areas (0.17 to 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. Farmers rely on other farmers not only for seed but also for information on traits of the different varieties (e.g., performance under different stresses, 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 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 than any individual can do alone. These networks may be important to regain

3 The collection strategy tried to maximize the diversity of maize landraces collected. However, not all varieties collected were necessarily different. Therefore this number may overestimate the actual number of different varieties present in a community.

valued local varieties that were lost because of climatic 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 genetic erosion (Louette et al. 1997), a point to which we will return later.

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 homegrown 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 et al. 1994; Cromwell 1990). However, they also have significant weaknesses in incentives, information, and resources (Tripp 2000). 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; Oldfield and Alcorn 1987; Rice et al. 1998; Sperling and 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 2000). 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 marketplace can also be an important source of seed, and might be included as part of the network (Perales 1998; Tripp 2000).

Unfortunately we know very little about the structure and function of these networks. 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. Without these networks, a farmer may face very high transaction costs in accessing crop diversity. He or she has to find out who has which variety, its characteristics, and, particularly, its performance. He or she has to make sure that the information is accurate and the seed reliable (i.e., it will have an acceptable germination rate). Finally, the farmer may have to negotiate the conditions of the transaction with the supplying farmer, and this may be difficult if the farmer is from another village or if there are no social ties between them. 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).

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 et al. 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. To maintain crop diversity on their farms, farmers have to invest labor, management, and other input in this activity, and they may also 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 is highly labor intensive and entails high opportunity costs. Another example is the case of the Wagwag, a traditional group of rice 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. There is a large difference (6 t / ha) between growing one crop with a traditional variety for a good season and growing two crops of a modern variety, and this difference remains important even in a bad 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 technologies, the number of concerns they have associated with crop production may decrease and therefore 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 be the case even 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 acculturation eliminate preferences and practices that make a diversity of crop types valuable.

Many examples show that farmers under these changing conditions may still value and continue to plant several varieties. In many instances, newly introduced modern varieties are incorporated into their portfolios, increasing rather than decreasing diversity on farm (Bellon 1991; Brush 1995; Louette et al. 1997; Dennis 1987; 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, 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. A higher opportunity cost of time 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. 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. For example, in Oaxaca no formal seed distribution system for local landraces exists. A study in Turkey reported similar findings (Meng and Brush 1998).

In the case of maize, landraces in a specific area may be viewed as a metapopulation (Louette 1994), defined as a set of populations that are interconnected through migration[4] (David, 1992; Olivieri and Gouyon 1990). 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. However, as these networks become more fragmented and costly to operate because of changes in off-farm employment,

Table 1. Factors that modify the demand for crop diversity

Reasons for demanding diversity	Factors that decrease demand for diversity
To farm in a variety of agroecological environments	Availability of fertilizers and irrigation
To manage risk and uncertainty	Availability of insurance and non-farm 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

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.

Another information problem is that farmers may not be aware of the range of varieties available (Tripp 2000), especially as a result of problems with nomenclature. As Quiros et al. (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. However, it is important to realize that these processes are different and to understand the precise causes, because policy interventions to foster on-farm crop diversity may be completely different.

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 et al. 2000). This can be done through market or non-market 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. Non-market methods consist of educational or promotional campaigns, increased

4 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 (maize, sorghum). A metapopulation perspective may not be applicable for self-pollinated crops (wheat, rice), although even in these crops a low rate of outcrossing can permit significant interchanges of alleles over time. This may not be true for clonally propagated crops (potato).

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 (Ceccarelli et al. 1997; Joshi and Witcombe 1996), lending support to on-farm conservation of crop genetic resources (Qualset et al. 1997). However, 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 tying credit to planting a few specific varieties. 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 et al. (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 (J.L. Pham, personal communication).

If the loss of on-farm diversity is supply driven, losses could be reversed through interventions that decrease 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 project described earlier, which is based on the idea of influencing the supply of diversity, is an example of a slightly different approach to community seed banks and diversity fairs. This 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. With the characterization data, and through consultation with farmers, a subset of landraces that captured most of the diversity present and had high potential value for farmers was identified (for the method see Bellon et al. 2000b). 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. In the project's first year (1999), 804 kg of seed were sold in 197 purchase events (i.e., a farmer purchasing seed of a landrace), with a total of 123 farmers purchasing seed (the same farmer could purchase seed of more than one landrace). For farmers in the six communities, the project greatly reduced the cost of accessing the diversity of maize landraces present in the region and information about them. The high demand found for this diversity, even in an area where diversity is still present, shows that it is not easily accessible to farmers. Currently, the project is exploring alternative strategies with farmers to devolve this process to them. As part of this effort, the structure and functioning of farmers' seed supply networks are being studied.

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 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. Usually only the joint determination of supply and demand is observed. This problem may be especially important in scaling upwards 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 situation is that the implementation process should remain as open as possible and both demand- and supply-type interventions should be available.

In the case of Oaxaca, 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 1.6 varieties / household. The collection also showed that farmers valued many different characteristics, especially traits related to consumption. 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. Participant farmers were invited to vote on the maize varieties they liked, and 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 from a diverse set of the landraces present in the region.

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 is supply-driven, interventions should decrease the transaction costs of accessing crop diversity, both in terms of accessing the actual seed of diverse sets of varieties as well as information about their performance. Because it may be difficult in the empirical work to determine whether the constraints to maintaining diversity are related to demand or supply, it is important to keep the implementation process as open as possible and make demand and supply interventions available.

References

Almekinders, C.J.M., N.P. Louwaars, and G.H. de Bruijn. 1994. Local seed systems and their importance for an improved seed supply in developing countries. *Euphytica* 78:207-216.

Altieri, M.A., and L.C. Merrick. 1987. *In situ* conservation of crop genetic resources through maintenance of traditional farming systems. *Economic Botany* 41:86-96.

Bellon, M.R. 1991. The ethnoecology of maize variety management: A case study from Mexico. *Human Ecology* 19:389-418.

Bellon, M.R., 1996. The dynamics of crop infraspecific diversity: A conceptual framework at the farmer level. *Economic Botany* 50:26-39.

Bellon, M.R. and J.E. Taylor. 1993. "Folk" soil taxonomy and the partial adoption of new seed varieties. *Economic Development and Cultural Change* 41:763-786

Bellon, M.R., J.L. Pham, and M.T. Jackson. 1997. Genetic conservation: A role for rice farmers. In: N. Maxted, B. V. Ford-Lloyd, and J. G. Hawkes (Eds.), *Plant Conservation: The* In Situ *Approach,* pp. 263-289. Chapman and Hall. London, UK.

Bellon, M.R., J.L. Pham, L.S. Sebastian, S.R. Francisco, G.C. Loresto, D. Erasga, P. Sanchez, M. Calibo, G. Abrigo and S. Quilloy. 1998. Farmers' perceptions of varietal diversity: Implications for on-farm conservation of rice. In: M. Smale (Ed.), *Farmers, Gene Banks and Crop Breeding*, pp. 95-108. Kluwer Academic Publishing. Boston, MA.

Bellon, M.R., M. Smale, A. Aguirre, F. Aragón, S. Taba, J. Berthaud, J. Díaz, and H. Castro. 2000a. Farmer management of maize diversity in the Central Valleys of Oaxaca, Mexico: Methods proposed for impact assessment. In: N. Lilja, J.A. Ashby, and L. Sperling (Eds.), *Proceedings of the Seminar Assessing the Impact of Participatory Research and Gender Analysis*. CGIAR Program on Participatory Research and Gender Analysis. Cali, Colombia.

Bellon, M.R., M. Smale, A. Aguirre, S. Taba, F. Aragón, J. Díaz and H. Castro. 2000b. *Identifying Appropriate Germplasm for Participatory Breeding*: *An Example from the Central Valleys of Oaxaca, Mexico.* CIMMYT Economics Working Paper 00-03. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT).

Brush, S.B. 1995. *In situ* conservation of landraces in centers of crop diversity. *Crop Science* 35:346-354.

Brush, S.B. 1999. The issues of *in situ* conservation of crop genetic resources. In: S. B. Brush (Ed.), *Genes in the Field,* pp. 3-26. International Plant Genetic Resources Institute, International Development Research Center, Lewis Publishers. Rome, Ottawa, and Boca Raton.

Brush, S.B., J.E. Taylor, and M.R. Bellon. 1992. Biological diversity and technology adoption in Andean potato agriculture. *Journal of Development Economics* 39:365-387.

Ceccarelli, S., E. Bailey, S. Grando, and R. Tutwiler. 1997. Decentralized, participatory plant breeding: A link between formal plant breeding and small farmers. In: *New Frontiers in Participatory Research and Gender Analysis: Proceedings of the International Seminar on Participatory Research and Gender Analysis for Technology Development*, pp. 65-74. Centro Internacional de Agricultura Tropical (CIAT). Cali, Colombia.

Cromwell, E. 1990. *Seed diffusion mechanisms in small farmer communities: Lessons from Asia, Africa and Latin America.* Agricultural Administration Network (Research and Extension). Network Paper 21. Overseas Development Institute. London, UK.

David, J. 1992. Approche Methodologique d'une Gestion Dynamique des Ressources Genetiques chez le Blé Tendre (*Triticum aestivum L.*). These de Doctorat de l'Institut National Agronomique Paris-Grignon, pp. 144.

Dennis, J. V. 1987. Farmer management of rice variety diversity in northern Thailand. Unpublished Ph. D. dissertation, Cornell University. University Microfilms, Ann Arbor, MI.

Harlan, J.R. 1992. *Crops and Man*. 2nd ed. American Society of Agronomy. Madison WI.

Hawkes, J.R. 1983. *The Diversity of Crop Plants.* Harvard University Press. Cambridge MA.

IPGRI (International Plant Genetic Resources Institute). 1993. *Diversity for Development: the Strategy of the International Plant Genetic Resources Institute*. International Plant Genetic Resources Institute. Rome, Italy.

Jarvis, D., B. Sthapit, and L. Sears (Eds). 2000. Conserving agricultural biodiversity in situ: A scientific basis for sustainable agriculture. International Plant Genetic Resources Institute. Rome, Italy.

Joshi, A. and J.R. Witcombe. 1996. Farmer participatory crop improvement. II. Participatory varietal selection, a case of India. *Experimental Agriculture* 32:461-477.

Louette, D. 1994. Gestion traditionnelle de variétés de maïs dans la Réserve de la Biosphère Sierra de Manatlan (RBSM, états de Jalisco et Colima, Mexique) et conservation *in situ* des ressources génétiques de plantes cultivées. These de Doctorat, l'Ecole Nationale Supérieure Agronomique de Montpellier, France.

Louette, D., A. Charrier, and J. Berthaud. 1997. *In situ* conservation of maize in Mexico: Genetic diversity and maize seed management in a traditional community. *Economic Botany* 51: 20-38.

Maxted, N., B.V. Ford-Lloyd, and J.G. Hawkes (Eds.). 1997. *Plant Conservation: The* In Situ *Approach*. Chapman and Hall. London, UK.

Meng, E. and Brush, S.B. 1998. Farmers' valuation and conservation of crop genetic resources. *Genetic Resources and Crop Evolution* 45: 139-150.

Meng, E., J.E. Taylor and S.B. Brush 1998. Implications for the conservation of wheat landraces in Turkey from a household varietal choice. In: M. Smale (Ed.), *Farmers, Gene Banks and Crop Breeding*, pp. 127-142. Kluwer Academic Publishing. Boston MA.

NRC (National Research Council). 1993. Managing global genetic resources: Agricultural crop issues and policies. National Academy Press. Washington, DC.

Oldfield, M. L., and J. B. Alcorn. 1987. Conservation of traditional agroecosystems. *Bioscience* 37:199-208.

Olivieri, I., and Gouyon, P.H. 1990. The genetics of transient populations: Research at the metapopulation level. *Tree* 5: 207-210.

Perales-Rivera, H.R. 1998. Conservation and evolution of maize in Amecameca and Cuautla Valleys of Mexico. Ph.D. thesis, University of California, Davis. University Microfilms International, Ann Arbor.

Plucknett, D.L., N.H.J. Smith, J.T. Williams, and N.M. Anishetty. 1987. *Gene Banks and the World's Food.* Princeton University Press. Princeton, NJ.

Qualset, C.O., A.B. Damania, A.C.A. Zanatta, and S.B. Brush. 1997. Locally based crop plant convservation. In: N. Maxted, B.V. Ford-Lloyd and J.G. Hawkers (Eds.), *Plant Genetic Conservation: The In Situ Approach*, pp. 160-175. Chapman and Hall. London, UK.

Quiros, C. F, S. B. Brush, D.S. Douches, K.S. Zimmerer, and G. Huestis. 1990. Biochemical and folk assessment of variability of Andean cultivated potatoes. *Economic Botany* 44:254-266.

Rice, E., M. Smale, and J.L. Blanco. 1998. Farmers' use of improved seed selection practices in Mexican maize: Evidence and issues from the Sierra de Santa Marta. *World Development* 26: 1625-1640.

Richards, P. 1986. *Coping with Hunger: Hazard and Experiment in an African Rice-Farming System*. Allen and Unwin. London, UK

Smale, M. and M.R. Bellon. 1999. A conceptual framework for valuing on-farm genetic resources. In: D. Wood and J. M. Lenné (Eds)., *Agrobiodiversity: Characterization, Utilization and Management*, pp. 387-408. CABI Publishing. Wallingford, UK.

Smale, M., A. Aguirre, M. Bellon, J. Mendoza, and I. Manuel Rosas. 1999. *Farmer Management of Maize Diversity in the Central Valleys of Oaxaca, Mexico: CIMMYT/INIFAP 1998 Baseline Socioeconomic Survey*. Economics Working Paper 99-09. Mexico, D.F.: CIMMYT.

Smale, M., M.R. Bellon, and A. Aguirre. Forthcoming. Maize diversity, variety attributes and farmers' choices in southeastern Guanajuato, Mexico. *Economic Development and Cultural Change.*

Sperling, L., and M.E. Loevinsohn. 1993. The dynamics of adoption: Distribution and mortality of bean varieties among small farmers in Rwanda. *Agricultural Systems* 41:441-453.

Taylor, J.E., A. Yuñez-Naude, and G. Dyer. 1999. Agricultural price policy, employment, and migration in a diversified rural economy: A village-town CGE analysis from Mexico. *American Journal of Agricultural Economics* 81: 653-662.

Tripp, R. 2000. The organization of farmer seed systems. Relevance for participatory plant breeding. Paper presented for the symposium "Scientific Basis for Participatory Improvement and Conservation of Crop Genetic Resources," Oaxtepec, Mexico, 8-14 October 2000.

Wood, D. and J.M. Lenné (Eds.). 1999. *Agrobiodiversity: Characterization, Utilization and Management*. CABI Publishing. Wallingford, UK.

Zeven, A.C. 1999. The traditional inexplicable replacement of seed and seed ware of landraces and cultivars: A review. *Euphytica* 110: 181-191.

Zimmerer, K.S. 1991. Labor shortages and crop diversity in the southern Peruvian sierra. *Geographical* Review 81: 414-432.

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