An Heuristic Framework for Identifying Multiple Ways of Supporting the Conservation and Use of Traditional Crop Varieties within the Agricultural Production System

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This paper reviews and discusses how studies on (i) on-farm diversity assessment, (ii) access to diversity and information, (iii) extent of use of available materials and information, and (iv) benefits obtained by the farmer or farming community from their use of local crop diversity, are necessary to identify the different ways of supporting farmers and farming communities in the maintenance of traditional varieties and crop genetic diversity within their production systems. Throughout this paper two key themes are emphasized. First, any description or analysis within the four main areas (assessment, access, use and benefit) can, and most probably will, lead to a number of different actions. Second, the decision to implement a particular action, and therefore its success, will depend on farmers and the farming community having the knowledge and leadership capacity to evaluate the benefits that this action will have for them. This in turn emphasizes the importance of activities (whether by local, national and international organizations and agencies) of strengthening local institutions so as to enable farmers to take a greater role in the management of their resources.

**Keywords** adaptability, agroecosystem resilience, collective action, biodiversity, community management, farmer selection, genetic diversity, incentives, local institutions, participatory breeding, seed systems

I. INTRODUCTION

The last two decades have provided substantial evidence that significant crop genetic diversity continues to be maintained in farmers’ fields in the form of traditional varieties (Bellon et al., 1997; Brush, 1995; 2004; Jarvis et al., 2004, 2008; Bezançon et al., 2009; Kebebew et al., 2001; Guzman et al., 2005; Bisht et al., 2007; FAO, 2010). This diversity constitutes an important element for the livelihood strategies of these farmers. Traditional crop varieties are used because of their adaptation to marginal or specific agricultural ecosystems (Barry et al., 2007), heterogeneous environments (Bisht et al., 2007), rainfall variability, variable soil types (Bellon and Taylor, 1993; Duc et al., 2010), and as insurance against environmental risk (Sawadogo, 2005; Bhandari, 2009), to meet changing market demands (Smale, 2006; Vandermeer, 1995; Brush and Meng, 1998; Gauchan and Smale, 2007), for pest and disease management (Thurston et al., 1999; Zhu et al., 2000; Trutmann et al., 1996; Finckh et al., 2003; Jarvis et al., 2007a), because of post harvest characteristics (Tsehaye et al., 2006; Teshome et al., 1999, Latournerie-Moreno et al., 2006), distance to market, adult labor availability and other social and economic characteristics of the household (Gauchan et al., 2005; Fu et al., 2005; Benin et al., 2006; Van Dusen, 2006; Bela et al., 2006), and cultural and religious needs (Rana et al., 2008; Naban, 1989; Tuxill et al., 2009). They may be kept for their dietary or nutritional value (Johns and Shapit, 2004; Belanger et al., 2008), taste (Shapit et al., 2008a) or for the price premiums they attract because of high-quality traditional properties, which compensate for lower yields (Smale et al., 2004). A diversity of traditional varieties within the production system can enable the farmers’ crop populations to better adapt and evolve to changing environmental and economic selection pressures, through increasing the farmers’ option value (Evenson et al., 1998; Gollin and Evenson, 1998; Smale et al., 2004; Smale, 2006; Swanson, 1998; Brush, 2004; Kontoleon et al., 2007; Pascual and Perrings, 2007; Aguilar-Støen et al., 2009), and by widening the genetic base of the crop population (Scarcelli et al., 2006; Barnaud et al., 2008; Sagnard et al., 2008; Carpenter et al., 2006; Elmqvist et al., 2003; Jackson et al., 2007, 2010; Bezançon, et al., 2009). The utility of crop varietal diversity within the production system also lies in its potential to provide ecosystem services (Hajjar et al., 2008; Ceroni et al., 2007; IAASTD, 2009), such as the regulation and control of pest and diseases (Finckh and Wolfe, 2006; Abate et al., 2000; Garret and Mundt, 1999; Zhu et al., 2000; Strange and Schott, 2005), sustain pollinator diversity (Richards, 2001; Kremen et al., 2002), and support below-ground biodiversity and soil health (Swift et al., 2004; Brown et al., 2007). This can in turn reduce the financial and health risks of high levels of agricultural inputs, such as fertilizer and pesticides to small-scale farmers and the environment (Tilman et al., 2001; Mosely et al., 2010). This diversity maintained both by farmers in situ and by genebanks ex situ, continues to be fundamental in trying to achieve global food security (Frankel et al., 1995; Gollin and Smale, 1999; Gepts, 2006; Jarvis et al., 2007b).

The continuing maintenance of traditional varieties is largely undertaken by poor, small-scale farmers, and is often associated with poverty (Keleman et al., 2009; Kontoleon et al., 2009; IAASTD, 2009). In these areas, diversity of traditional crop varieties is one of the few options that farmers have to meet their livelihood needs (Sawadogo et al., 2005). As long as farmers themselves find it in their best interest to grow genetically diverse traditional varieties of crops, both farmers and society as a whole will benefit at no extra cost to either party (Smale et al., 2001; Dusen et al., 2007). In areas where genetic diversity is significant, but farmers have few market or non-market incentives to maintain it, different public activities will be necessary to help support the conservation of this valuable resource (Smale, 2006; Bellon, 2004).

Although it was widely assumed for many years during the 1970s and 1980s that traditional varieties would be rapidly and completely replaced by modern varieties (Frankel and Soule, 1981), this has not been the case in many production systems. Traditional crop varieties still meet the needs of the farmers and communities where they occur. Indeed, recent studies suggest that one of the responses of poor rural communities to climate change is to increase the use of traditional materials in their production systems (Bezançon et al., 2009; Platform for Agrobiodiversity Research, 2010). Their continued maintenance in situ also meets a wider social need for evolving and adapted materials to meet changing production needs and challenges. Given the continuing importance to the farmers who grow them, there are good reasons to embed the continued use of traditional varieties into development and improvement strategies designed to
improve the well-being of some of the world’s poorest communities. A part of this will involve the implementation of appropriate different public activities that can support their maintenance and use.

Over the last few decades, a range of actions or practices has become available to help farmers and farming communities continue to benefit from the maintenance and use of local crop genetic diversity in their production systems (Friis-Hansen and Sthapit, 2000; CIP/UPWARD, 2003; Sthapit et al., 2006a; Jarvis and Hodgkin, 2008; Lippet et al., 2010; Kontoleon et al., 2009) (Table 1).

Most actions are small in scale and site and crop specific, resulting from a local evaluation of farmers’ constraints to their current use of local crop genetic resources. Along with the advancement of these actions has been the development of tools and methods to work out which action would be most relevant for a specific situation. There has also been an emphasis on the need to understand the different situations and circumstances of different communities with respect to different crops before deciding on an approach to use.

Although the actions that can support the maintenance and use of traditional varieties are often apparently site, culture or crop specific and varied, we suggest that an overall framework can be usefully created to help conservation and development workers and communities discern which action will most likely be the most relevant in different situations. This framework, a kind of heuristic device, is based on categorizing into four main groups the issues or constraints that farmers face, which may decrease their ability to benefit from the conservation and use of crop genetic resources within their agricultural production systems: (1) the lack of sufficient diversity of traditional crop varieties within the production system; (2) the lack of access by farmers to available diversity, (3) the limitations in information on and the performance of varieties available in key aspects, and, (4) the inability of farmers and communities to realize the true value of the materials they manage and use. Figure 1 contains a descriptive diagram of the relationships within this heuristic device and connects the outcome of analyses of the different types of information to an array of potential actions (Table 1).

Based on a review of literature, this paper discusses how studies on (i) on-farm diversity assessment, (ii) access to diversity and information, (iii) extent of the use of available materials and information, and (iv) benefits obtained by the farmer or farming community from their use of local crop diversity, are necessary to identify the different ways to support farmers and farming communities in the maintenance of crop genetic diversity within their production systems. Throughout this paper two key themes are emphasized. First, any description or analysis within the four main groups can, and most probably will, lead to a number of different actions. Second, the decision to implement a particular action, and therefore its success, will depend on the farmer and the farming community having the knowledge, institutions and leadership capacity to evaluate the benefits that this action will have for them. This in turn promotes an emphasis on the importance of strengthening local institutions to enable farmers to take a greater role in the management of their resources.

II. ON-FARM DIVERSITY ASSESSMENT

The assessment of diversity provides the necessary description of the extent and distribution of genetic diversity of traditional varieties, and of the way in which that diversity is partitioned within and among varieties at household and community levels. It allows exploration of the relation of the observed diversity to factors such as ecology, gender or poverty. Description in terms of variety names and the traits farmers use to describe their varieties is important for understanding how well their materials are adapted to the farmers’ environments and preferences, as well as the farmers’ perspectives of diversity distribution. Genetics, particularly molecular genetics, provides further information on patterns of diversity distribution and allows the investigation of the relation of observed diversity with environmental, social and cultural factors, providing a means to reconcile classification schemes using farmers’ varietal names with genetic distinctiveness. It also helps determine whether there is a wide enough genetic base for future improvement of the in situ materials, or whether there is sufficient diversity to provide system resilience (Figure 1: 1a, 1b).

A. Understanding Farmers’ Diversity Units and Estimating the Diversity of Traditional Varieties

Diversity within the agricultural production system can be assessed at different levels: within and among households, villages, communities and countries. Many studies are now available which describe the amount and distribution of genetic diversity of individual crops in farmers’ fields, at different scales, using a wide range of methods. These studies range from counting the names of varieties to biochemical and molecular studies which assess allelic richness and heterozygosity (Berg, 2009; Brown, 2000). Some studies have developed and used indices of diversity or other methods to compare the amount and distribution of diversity within the farmers’ production system across sites and crops. Not all production systems have the same amounts of diversity or the same reliance on traditional cultivars (Bajaracharya et al., 2006; Eyzaguirre and Linares, 2004; Gautam et al., 2008). The diversity found within one community may or may not be representative of a much wider geographical area (Chavez et al., 2000; Guzman et al., 2005).

Many studies have reported the numbers of farmer-named varieties at household and community levels for major crops, including corn (Bellon and Taylor, 1993; Bellon and Brush, 1994; Louette et al., 1997), common bean (Martin and Adams, 1987; Voss, 1992), potatoes (Quiros et al., 1990; Brush et al., 1995; Zimmerer, 2003), sorghum (Tesema et al., 1997) and cassava (Boster, 1985; Salick et al., 1997; Kizito et al., 2007), barley (Kebebew et al., 2001; Gupta et al., 2003; Banya et al., 2005).
### TABLE 1

Descriptions and references to actions used to support the conservation and use of traditional crop varieties within agricultural production systems. Numbers and letters in the column, "Where applicable," refer to specific constraints outlined in the heuristic framework shown in Figure 1. Actions can be used to overcome multiple constraints.

<table>
<thead>
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<tbody>
<tr>
<td>Improving availability of materials</td>
<td>Reintroduction of materials from <em>ex situ</em> collections</td>
<td>1a, 2a</td>
<td>Local landraces from national gene bank or community gene bank are re-introduced based on ecological adaptive characteristics and human preferences.</td>
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<td>Seed Cooperative for collection and distribution and multiplication of seeds</td>
<td>Community seed production groups; Participatory Seed Exchange (PSE); Grassroots seed savers networks; Cooperative is formed to market successful varieties or to establish seed enterprises for farmers to have a clean source of seeds.</td>
<td>1b, 2a, 2b, 2c, 2d, 4c</td>
<td>Shrestha, Pitamber et al., 2010; Janssen et al., 1992 (Colombia), Musa 1998, Tripp 2006, Kabambe et al., 2008; Ramirez et al., 2009; Thijssen et al., 2008; de Boef et al., 2010.</td>
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<tr>
<td>Community Seed Bank</td>
<td>To improve access to locally adapted varieties, local crops germplasm is collected together with associated information and knowledge, stored, regenerated or multiplied as needed and distributed to fulfill seed demands of farmers.</td>
<td>1b, 2a, 2b, 2c, 2d 3a,4b, 4c</td>
<td>Shrestha P et al., 2006; 2010; Maharjan et al., 2010a; Balma et al., 2005; Bertuso et al., 2000; Lewis and Mulvany, 1997; Ramprasad, 2009; Sateesh, 2000; Feyissa, 2000; Mazhar, 2000; Mujaju, et al., 2003; Bertuso et al., 2000; Almekinders et al., 2007; Garforth et al., 2005; Mujaju and Chakaya, 2008; Bezbiba, 2008; Lewis and Mulvany, 1997; Poudel et al., 2005; Thijssen et al., 2008; Swaminathan, 2001; FAO 2006a.</td>
</tr>
<tr>
<td>Community Gene bank</td>
<td>Local crop germplasm accessions are deposited by farmers for short term storage, and later multiplication and regeneration by other groups.</td>
<td>1a, 1b, 2a, 2d</td>
<td>Kesavan and Swaminathan 2008; Ramirez et al., 2009; Swaminathan, 2001; Engels et al., 2008.</td>
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<tr>
<td>Community managed nurseries</td>
<td>1b, 2a, 2b, 2c, 2d 3a,4b, 4c</td>
<td>Community nurseries allow growers to access both mother plants (scion and rootstocks) and the associated information. They also are a place for farmers to learn about better nursery management practices.</td>
<td>Oyedele et al., 2009; Shalpykov, 2008; Kerimova, 2008; Djavakyants, 2010</td>
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<tr>
<td>Diversity field flora</td>
<td>1b, 2a, 2b, 2c, 2d, 3a, 3b, 3c, 4b, 4c</td>
<td>In order to supply an evolving diversified gene pool through exchange and selection to allow the continued adaptation to changing conditions through the informal seed system, farmers’ groups in low heritability environments test both improved and local cultivars and the selected cultivars are multiplied and disseminated within and outside the groups. The approach can be used to meet preferences of women and men farmers that often different.</td>
<td>BUCAP, 2002; Smolders &amp; Caballeda, 2006; Bioversity International, 2009; Jackson et al., 2010; Huvio and Sidibe, 2003; Grum et al., 2003; Bhandari, 2009</td>
</tr>
<tr>
<td>Diversity Kit</td>
<td>1b, 2a, 2b, 2c, 2d 3a, 4b, 4c</td>
<td>Diversity kit is a set of small quantity of different seeds made available to farmers to enhance their access to a wider range of local varieties. Seeds are harvested from diversity blocks, research farms or farmer’s fields and distributed among the farmers.</td>
<td>Sthapit et al., 2006d; Sthapit et al., 2008b; Joshi and Sthapit, 1990; Sperling et al., 2001; Almekinders et al., 2006, Halewood et al., 2007</td>
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<tr>
<td>Diversity Fairs</td>
<td>1b, 2a, 2b, 2c, 2d 3a, 4b, 4c</td>
<td>Diversity fairs aim not only at promoting the exchange of knowledge and germplasm between farmers, but they are also organized to explore diversity-rich areas and to recognize communities as custodians of traditional knowledge and biodiversity. Farmers from different communities are brought together to exhibit a range of traditional varieties and the farmer’s knowledge of their varieties. Diversity fairs are organized differently to fit the culture of a specific community.</td>
<td>Tapia, and Rosa 1993; Sthapit, 1998; Rijal et al., 2000; Sthapit et al., 2003a; Rusike et al., 2003; Guerette et al., (undated); Sperling et al., 2008; Adhikari 2006b; UNORCAC, 2008; CIP/UPWARD, 2003; Hardon, and de Boef, 1993; Satheesh, 2000</td>
</tr>
<tr>
<td>Seed vouchers</td>
<td>1a,1b,2a,2b,3c,2d,</td>
<td>Seed vouchers are coupons or certificates with a guaranteed cash value that can be exchanged for seed from approved sellers. Seed sellers can then redeem their vouchers for cash from the issuing agency.</td>
<td>CRS, ICRISAT and ODI. 2002; Makokha et al., 2004; Remington et al., 2002; van der Steeg et al., 2004; Alexander et al., 2004</td>
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TABLE 1
Descriptions and references to actions used to support the conservation and use of traditional crop varieties within agricultural production systems. Numbers and letters in the column, "Where applicable," refer to specific constraints outlined in the heuristic framework shown in Figure 1. Actions can be used to overcome multiple constraints. (Continued)

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<tr>
<td>Reduce transportation costs of traditional variety material closer to farmer communities</td>
<td>2a,2b,2c</td>
<td>In order to reduce transportation costs, NGO, Community based organizations, extension and other development organizations assess transportation costs as a regular annual program. Private fruit processor such as Gallias provides transportation cost of mango and other fruits directly to factories rather than middlemen so they can pay higher price to farmers.</td>
<td>Phiri et al., 2004</td>
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<tr>
<td>Cross site visits for farmers and local extension workers</td>
<td>1a, 2a, 2b,3a, 3c</td>
<td>Cross-site visits aim at exposing each participating farmer to good practices adopted by another community and to demonstrate these practices to five farmers in their site. Participating farmers must present the learning from the visit to rest of the farmers immediately after the completion of the exposure visit.</td>
<td>LI-BIRD, 2005; Jarvis et al., 2000; UNORCAC, 2008; Nassif and Birouk, 2002; Nassif, 2002; Jarvis et al., 2004</td>
</tr>
<tr>
<td>Microfinance or credit schemes to enable purchase of local materials</td>
<td>2a,2b,2c</td>
<td>Micro credit facilities provided by national banks, foundations, and international and national NGOs.</td>
<td>Kesavan and Swaminathan, 2008, UNORCAC, 2008</td>
</tr>
<tr>
<td>Improving information and availability of information</td>
<td>On-farm Diversity blocks</td>
<td>1b, 2a, 2b, 2c, 2d 3a, 4c</td>
<td>A diversity block is an experimental block of farmers’ varieties for research and development purposes managed by local institutions. A group of knowledgeable farmers is invited to observe the diversity block during cultivation. The block can also be used for the multiplication of planting materials, following cultivation of rare germplasm in the block.</td>
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Comparing traditional and modern varieties in field and laboratory trials gives quantitative differences of productive and adaptive characteristics under farmers’ conditions. It also helps to demystify technology for farmers; Various methods such as Farmer Field Trials (FFT), PVS and Mother-Baby Trials are developed for this purpose.

Community Biodiversity Register (CBR) is a record, kept in a register by community members, of the genetic resources in a community, including information on their custodians, passport data, agroecology, and cultural and use values. The method is to document traditional knowledge on genetic resources and provide defensive protection from bioprospecting.

Literacy training enables farmers, particularly women, to have more access and control over their resources, and to have access to new options.

Variety and plot data linked to GIS systems that are in farmer friendly formats allow farmers to see visually the distribution of different varieties in their community. They may also be used to map soil types and disease infestation to help farmers to make decisions on which varieties would be suitable for different agroecological conditions on their farmers.

Knowledge empowerment can be obtained by taking advantage of the new information and communication technology and providing internet connections. Using solar power where electricity is not continuous or available and through cell phone connections, a wire-wireless hybrid technology can be developed.
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<tr>
<td>Small weather stations that can be linked to internet sites</td>
<td>3a,3c,4b,4c</td>
<td>In the developed world networks of weather stations in farming regions are becoming the norm. Farmers tap into these for real-time weather data and in some cases, use models for crop growth development and pest/disease forecasts. In some cases, farmers have their own weather stations. A relatively inexpensive weather station can be purchased for a farming community and added to a free weather networks such as Wunderground Weather, the network that makes local data available to others in a region or globally.</td>
<td>T. Murray personal comm, 2010; <a href="http://www.wunderground.com/weatherstation/index.asp#hardware">http://www.wunderground.com/weatherstation/index.asp#hardware</a></td>
</tr>
<tr>
<td>Rural radio program that includes talks on the importance of crop biodiversity</td>
<td>3a,3d,4a,4b,4c</td>
<td>Radio broadcasting is one of the quickest and more powerful means for providing information and raising awareness of people living in rural and semi-urban areas. Rural radio not only disseminates information to stakeholders but also provides forum for sharing opinions on various issues related to the conservation and management of biodiversity to a larger audience. Some CBOs have their own farmer-managed station to disseminate information and knowledge useful to the community.</td>
<td>Shah et al., 2009; Baral et al., 2006; Ballantyne 2009; Balma et al., 2005</td>
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Drama, music and poetry traveling shows that have crop biodiversity as the theme

Often traditional knowledge is embedded in folk songs, poem and folk tales as they reflect social and cultural values in the community. The information or message passed on through this medium is easily acknowledged by the people and acts as an effective tool to sensitize the communities in developing countries when songs, poems and local theater as also a mode of entertainment.

Sthapit, 1999; Rijal et al., 2000; Dewan et al., 2006; Satheesh, 2000

Painting and art competitions that reward farmer groups for knowledge and descriptions of agricultural diversity

A contest takes place among participants from the villages belonging to different communities, or different schools. Prizes decided with the communities are give for the painting or art that best depicts the ideas of conservation and use of traditional varieties.

Tapia, 2000; Sunwar et al., 2005

Improving traditional variety materials and their management

Participatory crop improvement (Grassroots breeding; Participatory Plant Breeding (PPB); Participatory Varietal Selection (PVS))

The value of local crop diversity can be enhanced in three broad ways: 1) simple trait selection from existing diversity of local population (e.g. grassroots breeding), 2) selection of fixed (stable variety) for target environment (PVS), and 3) cross local parent with exotic variety to remove the bad traits from local diversity (PPB). Locally based, participatory plant breeding exploits the diversity of local germplasm to produce cultivars that are superior in marginal environments compared to the products of formal, centralized programs, but at the same time continue to have a broad genetic base. The most key elements of this exercise are setting breeding goal by the farming community; plant breeders assist them to improve local materials under their target environments and farmers contribute to the pre- and post-harvest selection.

Witcombe et al., 1996; 2005; 2006; Sthapit et al., 1996; 2000; 2003b; Joshi et al., 2000; Joshi et al., 2001; 2002; Cecarelli and Grando, 2007; Witcombe et al., 2005; Gyawali et al., 2006a; 2006b; 2007; Gibson, 2009; Chiffoleau, & Desclaux, 2006; Danial et al., 2007; Almekinders et al., 2006; Ortiz et al., 2009; Lacy et al., 2006; Valdivia Bernal et al., 2007; Sunwar et al., 2007; Belay et al., 2006, 2009; Cecareeli et al., 2009; Halewood et al., 2007;

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<td>Using genomics to improve in situ crop populations</td>
<td>2d, 3b, 3c, 3d, 4a, 4b</td>
<td>Breeding desirable traits into materials adapted to abiotic and biotic conditions in a specific environment; backcross breeding of specific traits into locally adapted material</td>
<td>Witcombe et al., 2008; Steele et al., 2004; 2007; Barr, 2010</td>
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<tr>
<td>Changing the formal breeding institutions to increase the use of farmer selection materials and traditional varieties in their programs</td>
<td>2d, 3a, 3b, 3c, 3d, 4a, 4b, 4c</td>
<td>National resistance breeding procedures integrate farmer selection practices and local material and participatory breeding practices to improve other production and quality traits of locally-resistant varieties as well as the resistance of locally adapted non-resistant varieties.</td>
<td>Mendum and Glenna 2010; Finckh 2008; Gibson, 2009; Mgonja et al., 2005; FAO 2010</td>
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<tr>
<td>Planting of intra-specific mixtures to reduce pests and diseases</td>
<td>2d, 3a, 3b, 3c, 3d, 4a, 4b, 4c</td>
<td>Traditionally, farmers use diversity for any adversity by employing mixed farming, intercropping and varietal mixture within the species. Varietal mixtures or sets of varieties should have with non-uniform resistance and a lower probability that migrations of new pathogens or mutations of existing pathogens will damage the crop. Mixtures are based on the analysis of the resistance background, agronomic character, economic value, local cultivation conditions and farmer preferences. Traditional farming practices suggest that cultivation of a mixture of crop species in the same field through temporal and spatial management may be advantageous in boosting yields and stability and preventing disease.</td>
<td>Pradhanag and Shapit, 1995; Finckh, 2008; Finckh, and Wolfe, 2006; Di Falco and Perrings 2006; Zhu et al., 2000; Thinlay et al., 2000; Finckh, 2003; Trutmann and Pyndji, 1994; Ghaoti et al., 2005, Li et al., 2010; Benton et al., 2003; Willey, 1997</td>
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<td>Improve seed storage facilities and methods</td>
<td>Seed cleaning/seed treatment</td>
<td>Improved Processing</td>
<td>Alternatives and modification to seed certification systems</td>
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<tr>
<td>3c, 3d, 4a, 4c Seed storage devices and methods determine the vulnerability of seeds to pests, diseases and physiological deterioration. Some common methods are improving the air tightness of containers or head treatment. Some tested examples combine traditional with modern methods e.g. cow dung ash was combined with air tight storage to increase the seed longevity.</td>
<td>3c, 3d, 4a, 4c Seed cleaning technology for seed born diseases, normally recommend for certified varieties can be used on traditional varieties to increase yield. This includes supporting farmers for small seed cleaning machines.</td>
<td>3c, 3d, 4a, 4c Complementary technical solutions will be necessary to integrate the future use of agricultural strategies that include the use of diverse traditional varieties. These may include simple adjustments of planting and harvesting devices to new separation of the harvest products.</td>
<td>3c, 3d, 4a, 4c Training of farmers in improved processing techniques enables farmers to process traditional varieties into improved market products. This can be linked to micro credit to purchase processing equipment.</td>
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<tr>
<td>Gepts, 1990; Yupit-Moo, 2002; Latourniere et al., 2006; Grum et al., 2003a; Wambugu et al., 2009; Thamaga-Chitja et al., 2004; Beckett et al., 2007</td>
<td>Sadiki et al., 2002</td>
<td>Finchk, 2008; Walsh et al., 2004</td>
<td>Giuliani, 2007; Devaux et al., 2006; Kontoleon et al., 2007</td>
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</table>

‘Common knowledge’ can be defined as having shared information or understanding among members of a specific ‘community’, including a nation, a region, a city, a particular race, an ethnic group, or a professional society, which permits a variety to be precisely defined and distinguished by the members of that particular community.

Prasann et al., 2008; Mazhar, 2000

(Continued on next page)
TABLE 1  
Descriptions and references to actions used to support the conservation and use of traditional crop varieties within agricultural production systems. Numbers and letters in the column, “Where applicable,” refer to specific constraints outlined in the heuristic framework shown in Figure 1. Actions can be used to overcome multiple constraints. (Continued)

<table>
<thead>
<tr>
<th>General category actions (Note: Actions can be applicable to more than one category)</th>
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<tbody>
<tr>
<td>Registration and release of farmers’ varieties with acceptance of enhanced bulk varieties</td>
<td>2d, 3a, 3d, 4a, 4b, 4c</td>
<td>Following participatory assessment of the enhanced bulk variety in the field together with farmers, mill owners and retailers, a formal seed registration board may establish that a bulk population is phenotypically similar to agronomic, post-harvest, quality traits and market preferences and can recommend the formal registration and release of the enhanced bulked variety adapted to local conditions.</td>
<td>Joshi et al., 1997; Gyawali et al., 2007; Bishaw and van Gastel, 2009; Bealy, 2007; Halewood et al., 2007</td>
</tr>
<tr>
<td>Geographic Indications</td>
<td>2d, 3a, 3d, 4a, 4b, 4c</td>
<td>A Geographical Indication is a form of protection within the Trade Related Aspects of Intellectual Property Rights (TRIPS) Agreement of the World Trade Organization (WTO). It protects intangible economic assets such as the quality and reputation of a product through market differentiation. It is a tool to maintain multifunctionality in rural landscapes and involve local populations in biodiversity management and conservation by providing incentive for marketing special products.</td>
<td>Ramakrishnappa 2006; Garcia et al., 2007; Nagarajan, 2007; Salazar et al., 2007; <a href="http://www.origin-gi.com/">http://www.origin-gi.com/</a></td>
</tr>
<tr>
<td>Quality declared seed (QDS) - that certify the vendor rather than the seed</td>
<td>2d, 3a, 3d, 4a, 4b, 4c</td>
<td>Small scale farmers are registered to produce seed for local sale. A QDS producer is trained in QDS production of a crop they can decide later to add additional crops or varieties to their seed production at their own risk. The QDS vendors are inspected by authorized seed inspectors at district level</td>
<td>FAO 2006b; Granquist, 2009</td>
</tr>
</tbody>
</table>
Truthfully labeled seed laws that focus on seed quality rather than seed purity:

Truthfully labeled seed laws have been designed to focus on seed quality rather than varietal purity.

Registries of native crops:

The registry identifies and recognizes the individuals, institutions, or communities who maintain, conserve, and work on native crops, but does not grant specific rights to those who are applicants to the registry. The registry contains the main agronomic, agroecological, and taxonomic characteristics of the varieties of native crops. It clearly identifies the origin and diversification centers, and raises awareness through verified technical and scientific official information. It identifies groups of farmers, individuals, and institutions that care about conservation and use of agricultural biodiversity and those persons that have been instrumental in ancestral efforts of conservation. It contributes to preventing actions of biopiracy.

Links between intellectual property rights protection and benefit-sharing:

Some legislations like the Thai Plant Variety Protection Act require the holders of plant breeders’ rights to give part of the benefits arising from the commercialization of the protected varieties to a fund dedicated to on-farm conservation of crop diversity. Similarly, at the international level, the multilateral system on access and benefit-sharing of the International Treaty on Plant Genetic Resources for Food and Agriculture creates a benefit-sharing fund for conservation projects where vendors of new plant varieties that are not freely available for research and breeding must put part of the benefits derived from the varieties’ commercialization.
<table>
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<tbody>
<tr>
<td>Plant variety protection systems adapted to farmers varieties</td>
<td>3d</td>
<td>Effective <em>sui generis</em> systems of farmers’ varieties protection can empower individual farmers and farmers communities and prevent misappropriation of farmers’ varieties by others.</td>
<td>Leskien and Flitner, 1997; Correa, 2000</td>
<td></td>
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<tr>
<td>Market creation and Market promotion</td>
<td>Market promotion through taxes and subsidies</td>
<td>4a, 4b, 4c</td>
<td>Market promotion through taxes for environmental damage and subsidies for environmental friendly practices or for the use of traditional crop varieties within the farmers’ production system.</td>
<td>Knuijssen and Mysore, 2007</td>
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<tr>
<td>Market creation for traditional varieties or products from traditional varieties including niche markets</td>
<td>2d, 3a, 3b, 3d, 4a, 4c</td>
<td>Demand for unusual heirloom or niche market varieties exists among urban residents or other consumers. Niche markets might be for traditional varieties that are “best fit” to particular ecosystems, such as particular traditional varieties shown to grow well on swampland soil or on poor upland soils. Marketing social-cultural aspects of traditional varieties for particular culinary aspects and associated ethnic identity has also been used to create niche markets.</td>
<td>Lee, 2005; Iruengu <em>et al</em>., 2007; Giuliani, 2007; van Dusen, 2006; Gauchan and Small, 2003; Rana, 2004; Gruere <em>et al</em>., 2007; Caviglia and Kahn, 2001; UNORCAC, 2008; de Boef, 2010; Bhandari <em>et al</em>., 2006; Bhandari, 2009</td>
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<tr>
<td>Education and financial support to farmers’ groups to develop a marketing strategy</td>
<td>3a, 4a, 4c</td>
<td>Institutions support farmer unions and cooperatives for educating farmers in production and marketing, assisting with price negotiations, collecting land taxes, information sharing.</td>
<td>Knuijssen and Somsri, 2006; Ramirez <em>et al</em>., 2009; Caviglia and Kahn, 2001.</td>
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</table>
Micro credit facilities to set up small businesses particularly for rural men and women

Micro-finance and micro-insurance schemes are innovative ways of providing the poor with access to capital and thus a way out of poverty. Micro credit is a small amount of money loaned to a client by a bank or other institution. Micro credit can be offered, often without collateral, to an individual or through group lending. Micro credit schemes can enable farmers, especially women to engage in economic activities and join social networks through which both poverty and social dependency can be overcome.

Kesavan and Swaminathan, 2008; UNORCAC, 2008; Kapila and Mead, 2002; Gine and Yang, 2009; Andersen et al., 2008

Advertisement campaigns to improve consumer and retailer awareness of important traits (nutritional, adaptive)

Marketing nutritional and health (both human and environmental) related information to wider consumers to add value. This includes providing consumers and retailers with information on traditional variety traits.


Cook books with traditional recipes; gardening books that promote traditional varieties for particular management practices

Recipes that require traditional varieties; organized synthesized and published; Gardening books that promote traditional varieties for their uses can be useful for raising awareness.

Yucatan cook book; Sthapit et al., 2008a; Gruere et al., 2007; Ramirez et al., 2009

Fair trade price premiums - Eco-labeling (paying the full production value through price premiums)

Fair trade or eco-labeling is a conservation strategy that is market based, in which consumers pay a price premium for a product which is produced on certified farms that are committed to the preservation of biodiversity or fair working conditions; the label of fair trade requires that the buyers agree to: pay a price that covers the production costs and a social premium; make an advance payment; purchase directly from the producer; and establish long-term contracts.

Kitti et al., 2009; Perfecto et al., 2005; Swallo and Sedjo, 2000; 2002; Renard, 2003

(Continued on next page)
TABLE 1

Descriptions and references to actions used to support the conservation and use of traditional crop varieties within agricultural production systems. Numbers and letters in the column, “Where applicable,” refer to specific constraints outlined in the heuristic framework shown in Figure 1. Actions can be used to overcome multiple constraints. (Continued)

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<tr>
<td>Building Partnerships and Trust</td>
<td>Organization of meetings involving market-chain actors to discuss how to enhance market potential.</td>
<td>Stakeholder meetings, involving as many as possible of the market chain actors including producers and traders, cultivation experts, NGOs, representative of relevant ministries, and community members to develop ideas for enhancing market potential for traditional varieties.</td>
<td>Giuliani, 2007; Kruijssen et al., 2009</td>
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<tr>
<td>Private and public partnership for the construction of small infrastructure for the production of a better quality product</td>
<td>3a,3b,3c, 4a, 4c</td>
<td>The formulation of producer marketing groups, and micro-enterprise that provides better access to local, national, and international markets for locally grown and processed products.</td>
<td>Giuliani, 2007; Audi et al., 2010; Friss-Hansen, 2008; Pretty, 2008; Jarvis, and Ndung’u-Skilton, 2000; Swaminathan, 2003; UNORCAC, 2008</td>
</tr>
<tr>
<td>Strengthened and cooperative extension service that includes farmers, are more demand driven or establishment of new farmer-governed local institutions</td>
<td>1a, 1b, 2a,2b,2c, 2d, 3a, 3b, 3c, 4a, 4b, 4c</td>
<td>Transformation of local government staff and establishment of new farmer-governed local institutions specifically focusing on the management of local varieties, Particularly for poor and marginalized groups.</td>
<td>Triomphé et al., 2008; Sthapit et al., 2008c; Adhikari et al., 2006a; Friis-Hansen et al., 2008; Birner and Anderson, 2007; Neuchatel Group, 2007 (<a href="http://www.neuchatelinitiative.net/english/index.htm">http://www.neuchatelinitiative.net/english/index.htm</a>)</td>
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<tr>
<td>Category</td>
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<td><strong>Changing norms</strong></td>
<td>Advertising and social campaigns that promote better adapted varieties that reduce need for chemical inputs to change social norms such as nutritional cultural values of food. Advertising campaigns to change norms on nutrition and taste, and to reduce chemical inputs for better environmental protection. These campaigns may opt to demonstrate the full cost to the environment and human health of high input fertilizer and pesticide systems and emphasize social obligations to the reduction of pesticides and fertilizer and other harmful practices for the environment.</td>
<td>McGuire, 2008; Meinzen-Dick and Eyzaguirre, 2009; Sthapit et al., 2008a</td>
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<tr>
<td><strong>School biology curriculum</strong></td>
<td>Modification of curriculum content of primary and middle school, and high education institutes to include traditional crop varieties as an agricultural resource and provider of ecosystem services.</td>
<td>Ramirez et al., 2009; Jarvis et al., 2000; Visser and Jarvis, 2000; Bioversity International, 2008</td>
<td></td>
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<tr>
<td><strong>Gender sensitive response policy</strong></td>
<td></td>
<td>MEA 2005; Tapia and De la Torre, 1998</td>
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<tr>
<td><strong>Promoting ecological land management practices</strong></td>
<td>Areas oriented to the conservation and sustainable use of native cultivated species by indigenous peoples.</td>
<td>Mar 2002; Birol et al., 2006; Amend et al., 2008</td>
<td></td>
</tr>
<tr>
<td><strong>Environmentally sensitive areas (ESA)</strong></td>
<td>Areas oriented to the conservation and sustainable use of native cultivated species by indigenous peoples.</td>
<td>Mar 2002; Birol et al., 2006; Amend et al., 2008</td>
<td></td>
</tr>
<tr>
<td><strong>Agrobiodiversity Zones</strong></td>
<td>Agricultural zones of important native cultivated germplasm under management of native communities are designated formal legal status.</td>
<td>Ruis, 2009; UNORACA, 2008</td>
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<td>Agrobiodiversity Ecotourism</td>
<td>3a, 3b, 3c, 4a, 4b, 4c</td>
<td>Agrobiodiversity ecotourism is aimed toward amateur interest in the diversity of cultivated plants and in the cultural practices associated with crop. Agrobiodiversity tourism projects are managed in close partnership with local communities and can involve such activities as farm and market visits, participation in agricultural activities and food preparation, tastings of local foods and beverages and attendance at specific feasts and celebrations.</td>
<td>Ramirez, 2001, Ramirez and Williams, 2003; Ramirez et al., 2003; UNORACA, 2008</td>
</tr>
<tr>
<td>Organic farming and organic seed breeding with traditional variety used as planting materials</td>
<td>2d, 3a, 3b, 3c, 4b, 4c</td>
<td>Utilize traditional varieties in organic farming where traditional varieties are well adapted to local conditions. Organic farmers are obliged to use organically produced seeds and propagating material.</td>
<td>Bela et al., 2006</td>
</tr>
<tr>
<td>Investment in agricultural research that includes the use of agricultural biodiversity within the production system</td>
<td>1, 2, 3, 4</td>
<td>Investment in agricultural research and extension has contributed significantly to agricultural growth and rural poverty reduction in rural areas.</td>
<td>MEA, 2005; Fan et al., 2007</td>
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</table>
By integrating biodiversity, including agriculture biodiversity, in the legislation on environmental impact assessment, decision-makers can adopt informed decisions with regard to agrobiodiversity conservation and use.

The real value of agrobiodiversity and its services is not captured by the market because of a failure to internalize external costs. Farmers who provide environmental services are compensated, either by the immediate beneficiary or by the general public. Payment for Environmental Services (PES) schemes permit “capture” of public conservation values at the farmer level, thereby creating incentives for the conservation of agrobiodiversity and supporting poverty alleviation.

An example is an environmental payment system initiated in 2002 in the Rupa Lake area, Nepal. The Rupa Lake Cooperative pays 10% of its income from fishery management to the upstream communities. The realization among the users of the Rupa Lake about the potential role of upstream and downstream communities in management of the lake has led to expansion of members within the cooperative. The 360 membership in the cooperative in 2006 is now more than 600 members.

A way of realizing farmers’ rights and support farmers who conserve and generate crop diversity is by sharing the monetary benefits arising from the commercialization of new varieties with farmers, in combination with other forms of benefit-sharing. A number of countries have developed legislation on benefit-sharing and some of them refer to traditional farmers as final beneficiaries.
FIG. 1. Heuristic framework for identifying constraints and related actions to support the conservation and use of traditional crop varieties within agricultural production systems.

2003; Tanto et al., 2009), apricot (Baymetov et al., 2009), walnut (Butkov and Turdieva, 2009; Djumabaeva, 2009), apple and pear (Djavakyants, 2010), and grape (Djavakyants, 2009; Turgunbaev, 2009). While the numbers of varieties provides a useful first approximation of the extent and distribution of diversity, there has been discussion both of the extent to which variety names adequately reflect agro-morphological, biochemical or molecular diversity, and of whether variety names are used consistently by farmers at different geographic scales.

Sadiki et al. (2007) reviewed studies which correlated names of varieties to the agromorphological descriptors used by farmers. He and his colleagues compiled information globally for different communities, which suggested that variety names, when complemented by farmer descriptions, could be used as a basis for arriving at estimates of traditional variety numbers, and provide a useful estimate of the amount of genetic diversity within the farmers’ production systems. As shown by Jarvis et al. (2008), variety names can also be used to provide a valuable global estimate of diversity, focusing attention on the role of farmers themselves in the maintenance of crop diversity in production systems.

Variety names also provide information on the nature, status and management of varieties. Nuijten et al. (2008) found that three types of names could be distinguished for rice in the Gambia; those referring to common old varieties, common new varieties, and uncommon varieties, thus showing that variety names supply information on the period of time the variety was used in a village and on the flow of varieties between and within villages. The farmers’ or community beliefs that a named recognizable population has particular properties and identity is likely to lead to management practices that tend to reinforce separate identities. This creates a powerful selection practice able to maintain the preferred traits in specific populations (Brown and Brubaker, 2002).

Methods to analyze diversity information when farmers use the same name for different varieties or different names for the
same varieties, have been discussed by Chavez-Servia et al. (2000), Arias et al. (2000), and Tuxtill et al. (2009) for maize and beans in Mexico, by Sawadogo et al. (2005) for sorghum in Burkina Faso, by Karamura et al. (2004) and Gold (2002) for banana, and by Bajracharya et al. (2006) and Bisht et al. (2007) for rice. Gender has been shown to play a role in the number of descriptors used (Rijal, 2007), and the type of characteristics described (Karamura et al., 2004). The work has also shown the importance of using information from farmers on the traits they use for distinguishing their traditional varieties, to define consistent units of farmer managed diversity (Sadiki and Jarvis, 2005).

A range of studies is now available which have tried to quantify the amount of diversity within farmers’ fields by comparing the descriptions given by farmers to distinguish their varieties according to agromorphological field data: in faba bean (Sadiki et al., 2001; 2006), barley (Tsehay et al., 2006; Tanto et al., 2009), maize (Mar and Holly, 2000; Arias, 2004; Burgos-May et al., 2004; Latournerie-Moreno et al., 2006) and taro (Rijal, 2007; Canh et al., 2003; Hue et al., 2003). Other studies have examined the diversity of adaptive and ecophysiological traits within the production system (Teshome et al., 2001; Weltzien et al., 2006; Thinlay et al., 2000; Hue et al., 2006). The diversity of quality and nutritional traits (Duch-Gary, 2004; Cazarez-Sanchez, 2004) has also been described, as has the relationship of levels of crop genetic diversity to geographical regions (Taghouti and Saidi, 2002; Bouzeggaren et al., 2002, Teshome et al., 2001).

Brown and Hodgkin (2007) reviewed some of the molecular methods available to assess the extent and distribution of diversity, including single nucleotide polymorphisms (SNPs), phylogenetic analysis (Clegg, 1997; Brown and Brubaker, 2000) and functional genomics (Aharoni and Vors, 2001; Peacock and Chaudhur, 2002). Kumar and colleagues (2009) reviewed the potential advantages and disadvantages of different molecular markers in assessing genetic diversity, while Witcombe et al. (2008) reviewed the use of traditional and new genomic technologies for breeding for tolerance to abiotic stress of low nitrogen, drought, salinity and aluminum toxicity. Laurentin (2009) recently synthesized data analysis methods for molecular characterization of plant genetic resources.

Various studies have tried to compare the descriptions supplied by farmers to distinguish their crop varieties by means of agromorphological, biochemical and molecular descriptors, so as to provide an overall diversity assessment in traditional varieties. In some cases, genetic data have substantially confirmed information that the number of traditional varieties distinguished by their names is a good representation of diversity within a production system. In other cases, names were not correlated with diversity patterns of either agromorphological or molecular descriptors, but with the sets of traits farmers used to describe different units (Sadiki et al., 2007; Baymetov et al., 2009).

Sagnard et al. (2008) showed a low correlation between the diversity of farmer names and the genetic diversity assessed by microsatellites for sorghum in West Africa. The relationship between molecular markers, variety names and agromorphological traits, has also been reported to be poor or complex in sorghum traditional varieties from Mali (Chakauya et al., 2006), cassava in Uganda (Kizito et al., 2007), and sorghum in Zimbabwe (Mujaju et al., 2003; Mujaju and Chakauya, 2008). Busson et al. (2000) found that farmer management of the outcrosser–pearl millet—resulted in more differences with respect to microsatellite maker variation among farmers, than among same named varieties grown by different farmers; thus, the traits used by farmers to distinguish the different named varieties did not give genetic identity at the molecular level. Presoir and Berthaud (2004) found that high variation in flowering time among populations of maize in Mexico suggested that these agromorphological traits would be different from those described with molecular markers. In Jumla, Nepal (a high altitude site), over 20 traditional rice varieties were identified by farmers using grain color. These 20 varieties were found to differ with respect to a small number of key morphological traits, and by using SSR analysis had only limited molecular genetic diversity (Bajracharya et al., 2001; 2006). In contrast, in the low lands and middle hill sites of Nepal, the richness of farmer named rice diversity agreed with the diversity measured by SSR markers (Bajracharya et al., 2010).

Most of the molecular studies were undertaken using what are believed to be neutral markers on a rather small scale and, particularly for cross-pollinated crops, it is perhaps not surprising that it is difficult to find a good correlation between variety names, or agromorphological traits, and molecular markers. There is a need to collect much more complete data sets using a much wider range of markers.

An understanding of the extent and distribution of diversity using both farmer-determined categories and a range of genetic markers, underpins the identification of ways of supporting the maintenance of traditional varieties. Community biodiversity registers (Subedi et al., 2005) (Table 1) enable farmers to maintain information on diversity within their community and to provide the information needed to address bio-piracy concerns. Information on the extent and distribution of diversity also provides the information needed to assess whether there is enough diversity within the system for selection, or whether the system will be able to adapt to environmental and economic change (Figure 1: 1a, 1b).

Information on consistency with respect to names is also essential when reintroduction of materials is envisaged and various approaches have been tested to support this process, in Ethiopia and elsewhere (Worede, 1997; Worede et al., 2000; Feyissa, 2000; 2006; De, 2000) (Table 1). Ecuador won the 2008 Ecuador Initiative award for the return of 10,000 plants of 15 traditional crop varieties (roots, tubers, grains, and fruit) to local communities (UNORCAC, 2008). In Burkina Faso, a series of local genebanks are being established in high-priority
conservation areas. These gene banks are part of the National Plant Genetic resources system and will both emphasize conservation of local varieties and be a source of local seeds that can be deployed in the event of natural disasters such as extreme drought (Balma, et al., 2004; Bragdon et al., 2009).

B. Patterns of Diversity Within and Among Households, Communities and Landscapes

The analysis of patterns of diversity and the distribution of diversity over greater or lesser areas has provided information on the importance of biological, ecological, environmental, and social characteristics, which can usefully guide the development of supporting management practices for traditional varieties (Brown, 2000). Measurements of richness, evenness and divergence, often used in ecological studies, have more recently been applied to the partitioning of traditional varieties within and among communities on-farm (Jarvis et al., 2008). Richness is the number of different kinds of individuals regardless of their frequencies; evenness describes how similar the frequencies of the different variants are, with low evenness indicating dominance by one or a few types (Frankel et al., 1995; Magurran, 2003). Divergence is a measurement of the proportion of community evenness displayed among farmers. A recent evaluation of Jost (2010) discusses evenness related to the maximum and minimum possible for a given richness, by decomposing richness into independent diversity and evenness components.

Measurements of richness, evenness, and divergence were used to bring together varietal data of 27 crop species over five continents, collected by partners from over 50 government and non-government institutes, to determine overall trends in crop varietal diversity on-farm (Jarvis et al., 2008). As well as showing that considerable crop genetic diversity continues to be maintained on-farm, in the form of traditional crop varieties, this synthesis provides a baseline for estimating future genetic erosion on-farm, and information on the relationship between richness and evenness for traditional varieties maintained at farm and community levels. The results showed that as farmers increase the number of traditional varieties they grow, they often plant relatively even areas for each of the different varieties.

The mode of reproduction (whether inbreeding, outbreeding or vegetatively propagated) of a species is an important factor in understanding the patterns of genetic diversity observed in traditional varieties. The breeding and reproductive systems of crop species affect the farmer’s perception of diversity and his or her management practice. Clonal and inbred species are more strongly differentiated genetically and can be more easily separated into identified types or varieties. In a number of cases, fields of clonal or inbred crops are planted to a mixture of traditional varieties, which can later be separated at harvest (Brown, 2000; Jarvis et al., 2000). In contrast, for outcrossed species such as maize, a traditional variety appears to be a more polymorphic entity in which any particular genotype is ephemeral (Louette et al., 1997; Teshome et al., 2001). Hamrick and Godt (1997) summarized the effect of breeding systems on partitioning variation within and among crop populations, with self-pollinating crops showing twice as much population differentiation as outcrossers. Clearly, breeding systems and crop biology are important in identifying supportive management options. Communities and farmers are usually both aware of this and have embedded a variety of procedures for crops with different characteristics (Jarvis et al., 2004).

It is widely expected that patterns of diversity will reflect differences in climate, altitude and other agro-ecological factors. In fact, the amount of variation that can be attributed to agro-ecological factors has often been found to be relatively small by comparison with that found within populations, although clustering of varieties with similar agromorphological characteristics has been described (e.g., sorghum in Zimbabwe, Mujaju and Chakauya, 2008). Thus, in rice in Nepal, genetic variation was mostly due to intra-population diversity (within a farmer-named variety) and was independent of agroclimatic zones, variety names, and altitude (Bajracharya et al., 2006). In contrast, phenotypic traits in Ethiopian barley arid sorghum were strongly related to altitudinal range (Demissie and Bjørnstad, 2004; Teshome et al., 2001). Microsatellite diversity of traditional sorghum varieties across Mali, Burkina Faso and Niger, has shown that sorghum exhibited more genetic diversity in terms of allelic richness in Niger than in Mali, despite a lower agroclimatic range in Niger, suggesting that anthropogenic management practices, together with agro-ecological factors, form the structure of sorghum genetic diversity in this region (Sagnard et al., 2008). On balance, the evidence suggests that when introduction of new diversity is planned, it is better to use materials that come from similar agro-ecological zones.

The area in which individual varieties occur varies substantially and while some are maintained very locally, others may be part of extremely extensive seed systems extending over more than one region or country (Louette et al., 1997; Zimmerer, 2003; Valdivia, 2005). The agromorphological diversity of 15 traditional maize varieties from a single site, Yàxaca in the Yucatan State, was comparable with that of 314 maize varieties from all three States of the Yucatan Peninsula (Chavez-Servia et al., 2000; Camacho-Villa and Chavez-Servia). Similary, in Morocco, Belgachi (2003) showed that a major portion of agromorphological variation diversity for the Moroccan faba bean was captured in populations from the two northern provinces, and Barry et al. (2007) reported that in Guinea each of the villages studied had more than half of the regional allelic diversity of African rice, with genetic differentiation among varieties from the same village accounting for 70% or the regional variation. These studies have helped identify areas where local diversity is representative of a much wider area for a given crop and could be used to reintroduce diversity into a larger area.

At a more local level, the “four cell” analysis has proved to be a useful method of exploring the distribution of varieties in Nepal, Vietnam, Brazil, Ethiopia, Mali, India, Indonesia and Malaysia (Sthapit et al., 2006b; reviewed in Sadiki et al.,...
C. Ensuring the Existence of Sufficient Quantities of Materials

Estimating the extent and distribution of diversity provides the information needed to determine whether there is sufficient diversity of a crop within a production system to meet the various needs of farming communities (Figure 1: 1b). This is not always the case, as illustrated by Smale et al. (2009) who describe the shortage of well-adapted millet and sorghum seed in the Sahel. They found that local markets were important sources of seed in riskier, more isolated villages, indicating a need to legitimize local seed markets and, perhaps, to separate them from grain markets, through product information including marking with geographic origin. Such studies also provide information that can guide support for local seed systems, the introduction or reintroduction of traditional varieties and conservation actions.

A number of projects and studies have explored the ways in which varieties are best introduced when it is believed that farmers do not have the desired diversity. However, the majority of such programs had the aim of facilitating dissemination of new varieties (Rohrback et al., 2002; Tripp et al., 2001; Scheidegger et al., 2000; Bentley et al., 2001) and took little or no account of existing traditional varieties and traditional seed systems (Tripp, 2006).

While the decision to add new diversity into the farmers’ production systems, or to rehabilitate an area with lost diversity, rests ultimately with the farmers, the provision of traditional varieties is associated with a number of difficulties, in addition to those associated with establishing the identity and the range of the desired materials mentioned above. Kouressy et al. (2008) have argued that population sizes of varieties should be large enough to allow adaptation. Kouressy et al. (2008) have shown that large enough population sizes of traditional sorghum varieties allowed farmers in Mali to shift to short cycle varieties in adaptation to changing environmental conditions. However, few gene banks are equipped to provide sufficient seeds for direct sowing by farmers or to provide population sizes sufficient for adaptation to changing environmental conditions and management practices (Iriarate et al., 2000). Further, most genebanks are not easily accessible to farmers and communities. In the absence of a gene-bank, the Western Terai Landscape Project (WTLCP), in Western Terai, Nepal, used a systematic, participatory, seed exchange meeting to exchange seeds of local varieties of traditional crops and vegetables that are neglected by commercial seed retailers and extension system (Shrestha, 2009).

One approach that appears to be successful has involved the development of community seed banks and community gene banks (FAO, 2006a). This has occurred in several countries, including Ethiopia, Nepal, India, Bangladesh and the Philippines (Bertuso et al., 2000; Ramprasad, 2007; Poudel and Johnsen, 2009; Swamanathan 2001; De Boef et al., 2010) (Table 1). These banks are usually established in collaboration with local organizations and national or regional genebanks, and sometimes universities, to conserve and distribute local varieties through a farmer-led on-farm conservation approach. The selection of the materials to be multiplied relies on an assessment of the local diversity and on ensuring that the diversity of the population of the different traditional varieties is adequately covered. Deciding which varieties to target may be based on whether they are rare versus common, on particular traits for particular soil types or on market opportunities. Empowerment of local communities and their institutions is a precondition to implementing such community-based activities (Cromwell and Almekinders, 2000; Bartlett, 2008). The varieties can be used also to target the niche markets discussed in Section 5 below. The analysis of diversity also provides conservation guidance. Measurements of richness and evenness indicate which varieties are more likely to be lost and how much of the landscape they represent; they guide decisions on the maintenance of representative samples in community seed banks, or in national and international gene banks, or on whether to develop incentive mechanisms to promote endangered varieties.

III. ACCESS TO DIVERSITY

Access to crop seed or planting material diversity requires people having adequate land (natural capital), income (financial capital) or connections (social capital) to purchase or barter for the varieties they need (Sperling et al., 2008). Used in this sense, “seed” includes other planting materials such as tubers, cuttings or bulbs. Farmers may not have the desired access they need because they lack the resources necessary to acquire planting materials. They may lack funds to purchase or exchange the preferred planting material from within their communities (Figure 1: 2a.1). Appropriate seeds may not be available within the village, and the farmers may lack the resources to go to where seeds are being sold or exchanged (Figure 1: 2a.2). Planting materials for traditional varieties may also not be accessible due to social constraints. There may be pressure from both formal extension services and community peers against obtaining and using planting materials of local varieties (Figure 1: 2b.1). In addition, a farmer may lack the correct social ties or social status to obtain varieties (Figure 1: 2b.2). Seed quality and seed management practices can also be an issue and are discussed in Section 4, as can seed regulations (Figure 1: 1d). The availability of materials and the ways in which farmers
access and manage seeds are expected to affect genetic diversity both within and among traditional varieties and, over time, may lead to changes in patterns of diversity (Hodgkin et al., 2007; Figure 1: 2c).

A. Seed Sources, Scale, and Patterns

The seed system is composed of individuals, networks, institutions and organizations involved in the development, multiplication, processing, storage, distribution and marketing of seeds (Maredia and Howard, 1998; Locha and Boyceb, 2003; Dominguez and Jones, 2005). Seed flows influence the pattern and dynamics of material that move in and out of the farmers’ systems, and analysis of these flows give an insight into the constraints farmers face in acquiring preferred and quality planting material at the time it is needed for planting (Brocke vom et al., 2003).

Although there is no one systematic way in which farmers acquire and manage seeds, many, if not most rural farming communities in developing countries continue to use traditional or informal sources to meet most of their seed needs (Almekinders et al., 1994; Gaifani, 1992; Hardon and de Boef, 1993; Tripp, 2001; Cromwell et al., 1993; Tahiri, 2005; Muthoni and Nyamongo, 2008; Thijsen et al., 2008). The seed a farmer plants may have been selected from his or her own crop in the preceding season, exchanged or purchased from other farmers or institutions, or be a mixture of seeds from a combination of sources (Jarvis et al., 2000; Bellon and Risopoulos, 2001; Sperling and McGuire, 2010; Badstue et al., 2002; Ashfaw et al., 2007). Recent studies have quantified the amounts of farmers’ own saved seeds versus seeds obtained from friends, relatives, neighbors, or local markets, and have confirmed that farmers prefer to save their own seeds in most situations (Gildemacher et al., 2009; Rana et al., 2008; Hodgkin et al., 2007; Lipper et al., 2010). These studies have described a range of techniques and opportunities that farmers use under different circumstances to access and save seeds (Cromwell and Almekinders, 2000). The different practices used are expected, over a period of years, to produce a dynamics of movement and mixing in which the progenies of individual populations are transferred among farmers, become mixed during exchange or marketing, become sources for new exchanges, or are lost.

Farmers’ demands for off-farm seeds often result from an emergency, which may be personal (poor health, individual production failure) or more general (floods, drought, war), and affect the whole community or region. Reasons identified for accessing new seed stocks include low yields, consumption or sale of seed stocks, poor seed quality, the desire to access new varieties, and changes in national policy that affect subsidies and grain imports (Tripp, 2000; Mosely et al., 2010). There have been a number of studies on the ability of informal seed systems to meet users’ needs during emergencies and disasters, such as floods, drought, or war (Almekinders et al., 1994; Richards and Ruivenkamp, 1997; Sperling, 2001; Ashfaw et al., 2007). In a number of cases, informal markets were found to be critical to restocking traditional variety seed resources, both in normal and stress periods (Sperling and McGuire, 2010). Diversity fairs, diversity-kits, micro-credit schemes, and community seed banks are also interventions which can increase access (e.g. Mazhar, 2000; Shhapit et al., 2006a, c, d; UNORCAC, 2008) (Table 1).

Seeds may be acquired via cash transactions, barter, as gifts, by exchanging one variety of seed for another, as a loan to be repaid upon harvest, or even by surreptitious expropriation from another farmer’s field (Badstue et al., 2002; Mbabwine et al., 2008). Seeds of varieties developed by the formal sector are often maintained and distributed informally (Mellas, 2000; Bellon and Risopoulos, 2001), largely independently of government institutions. In some societies, there is a significant dependence on farmer-to-farmer seed transactions for traditional varieties (Hodgkin et al., 2007) as these sources are regarded as more trustworthy than alternatives such as local markets (Latourniere-Moreno et al., 2006). In South Asia, community seed banks are becoming an increasingly important intervention which also preserves local varieties and provides a source of local material for seed multiplication (Mazhar, 2000; Satheesh, 2000).

Various approaches are being used by non-government and government research, education and development agencies at local and national levels to support seed acquisition and increased numbers of transactions within and among communities, including community seed banks and seed diversity fairs (Tapia and De la Torre, 1998; Guerette et al., 2004; Shrestha et al., 2006; UNORCAC, 2008; De Boef et al., 2010) (Table 1). During a diversity fair, farmers from different communities are brought together to exhibit a range of landraces: this allows farmers to locate rare and unique diversity and provides an opportunity to exchange seeds and associated knowledge. Participatory seed dissemination (Rios, 2009) integrates seed diversity fairs and farmers’ seed experimentation and dissemination. Seeds from diversity fairs are tested in the farmers’ production systems to be further multiplied and diffused to other farmers. Identifying whether there are farmers who are known for reliably and regularly producing a good crop which provides seeds of high quality can be important for developing local practices that help maintain traditional varieties.

Analysis of patterns of seed transfer and exchange of traditional varieties provides important information for maintenance of traditional varieties helping to assess, for example, the effective population size, extent of mixing, degree of gene flow, and existence of defined subpopulations (Hodgkin et al., 2007). Studies among diverging subpopulations in model systems have shown that an uneven migration rate reduces the effective population size of the system, particularly when the seed of one farm is replaced (Maruyama and Kimura, 1980; Wang and Caballero, 1999; Whitlock, 2003). Heerwaarden and colleagues (2010) have used empirical data from maize in traditional agricultural systems in Mexico to demonstrate that seed dynamics in human-managed environments differ from existing
megalopolis models of natural ecosystems. In particular, the assumptions of most meta-population models (Kimura and Weiss, 1964; Slatkin, 1991, Wang, 1997) as to the absence of population bottlenecks following extinction and single-source migration, do not apply to systems under farmer management (Louette et al., 1997; Dyer and Taylors, 2008; Heerwaarden et al., 2010). High levels of pollen migration, such as occur in cross-pollinated crops such as maize and pearl millet may mask the effects of seed management on structure (Heerwaarden et al., 2010). In general it seems that farmer selection practices may not be a constraint in terms of having the diversity needed, as long as the effective population sizes are large enough to allow for evolution and adaptation, supported by adequate seed or gene flow.

Seed migration in traditional varieties can be fairly local–within communities or among neighboring communities (Collado-Panduro et al., 2005; Mar, 2002; Bela et al., 2006; Latourniere-Moreno et al., 2006; Banyia et al., 2003). Along the central Amazon River in Peru, most seed exchange of maize, cassava, peanut, chili peppers and cotton, occurred within rather than among the 13 communities. This seemed to reflect difficulties of access and communication among communities. Similarly, Tanto et al. (2009) found that seed flow for barley does not occur independently across the years within two seasons in areas of Ethiopia where there are two cropping seasons for the crop. Sagnard et al. (2008) found no genetic structuring among traditional sorghum varieties in villages in Burkina Faso, Mali and Niger, indicating that traditional seed systems operate at a very local scale in these study sites. However, some seed networks can be extensive covering distances that cross national boundaries and ecosystems (Zimmerer, 1996; Valdivia, 2005; Coomes, 2001).

While farmers may prefer to obtain desired seeds from others immediately after harvest, they may also need to obtain seeds at planting time when germination failed. At this point, farmers often have little choice in the variety obtained although they may try to obtain material from a microenvironment similar to theirs (Rana, 2004). Usually under such situations, farmers rely on social connections for their immediate needs, but community seed banks can be seed sources. Community biodiversity registers can provide information to locate the relevant variety within the community, but this requires very good documentation of local crop diversity in the register (Subedi et al., 2005), as well as access by farmers to the information. In cases of difficulty in acquiring seeds, local markets, middlemen, NGOs and experts, or nodal farmers, become increasingly important as sources of seed supply (Table 1).

B. Seed Custodians and Social Networks

Trust has been shown to be an important factor in farmers’ choice of which seeds to acquire (Badstue, 2007). Public extension services may not always be seen as a trusted source, because the system is perceived to deliver too narrow a range of varieties which are not suited to the diverse growing conditions that a farmer may be managing (Adato and Meinzen-Dick, 2007). The response to seed needs is usually to look first for a family member or a friend as a reliable source (Almekinders et al., 1994; Badstue et al., 2007; Barnaud et al., 2008), and social relations play an important role in seed acquisition throughout the world (e.g., Ethiopia; McGuire, 2008). Poudel et al. (2005) reported that communities with weak social networks are more vulnerable to accessing locally adapted seeds in adverse conditions, compared to those with strong social networks. Social seed networks can be strengthened by interventions that improve access to existing varieties and new diversity (e.g., seed fairs, diversity kits, community seed banks, participatory variety selection programs; Table 1). With better exposure of farmers to breeding skills and knowledge, participatory plant breeding (PPB) can strengthen farmer seed systems and promote on-farm management and sustainable use of local crop diversity (Sperling et al., 2001; Almekinders et al., 2006; Halewood et al., 2007) (Table 1).

Access to seeds may require appropriate social ties and kin networks (Lopez, 2004). Heritage and cultural identity values can be enhanced when a traditional variety is acquired from someone who is a relative or an elder in the community (Meinzen-Dick and Eyzaguirre, 2009). Analysis of rice seed supply networks in Nepal (Subedi et al., 2003) revealed their complexity and dependence on a range of social variables. In many communities, certain individuals may act as nodal farmers, characterized by their involvement in a large number of exchanges (Subedi et al., 2003; Subedi and Garforth, 1996). Further investigation has shown that the people who act as “nodal” farmers may change from one year to another (Poudel et al., 2008). Social prestige and religious values can be used to enhance the incentives to both maintain and share traditional crop varieties (Meinzen-Dick and Eyzaguirre, 2009).

Seed networks can be dependent on gender, wealth status, and age (Lope, 2004; Rana et al., 2008; Howard, 2003; Silitoe, 2003; Song and Jiggins, 2003; Morales-Valderrama and Quiñones-Vega, 2000), but in some cases, they have been found to be gender-independent (Subedi and Garforth, 1996). Poor women often have less access to finance, markets, technologies, education systems, thus inhibiting ability to diversify (Vernooy and Fajber, 2004). Community seed networks, which were men-men, men-women (men led), women-men (women led), and women-women, have all been found in certain communities (Belem, 2000; Okwu and Umoru, 2009).

Gender, wealth, social status, and market-related variables have different effects on diversity in different parts of the world. In Ethiopia, education positively influenced the amount of diversity on farm for maize, wheat, and teff, but not for barley. Female-headed households grew more evenly distributed wheat varieties. Households with substantial outside sources of income grow a greater range of barley varieties, but this was not the case for maize (Benin et al., 2006). Labour policies that affect household labour supply and its composition are likely to
have a large impact on traditional crop variety diversity. Loss of adult male labour has been correlated with the reduction of the diversity of crops and varieties grown (Van Dusen, 2006; Gauchan et al., 2006). Several studies have found that female-headed households are more likely to grow more traditional varieties (Gauchan et al., 2006; Edmondes et al., 2006; Benin et al., 2006; Dossou, 2004).

A number of ways to support key groups and hence increase the use of traditional varieties have been proposed and tested (Table 1). Most methods include training key seed producers and women in seed cleaning, multiplication and distribution and support for local institutions and social networks. Common approaches involve the development of community seed banks and diversity fairs and the identification of reliable farmers who can underpin farmer-to-farmer exchanges, as in Syria (Aw-Hassan et al., 2008). Diversity seed fairs that are organized by public institutions together with communities or non-governmental organizations, can help to increase transparency in seed quality and bridge knowledge across institutions and farmers on variety quality (Meinzen-Dick and Eyzaguirre, 2009; Nathaniels and Mwijage, 2006). Such interventions are likely to work best when the characteristics of the different families, communities and groups (gender, ethnic, religious, and wealth) who are most likely to conserve diversity are known (Smale et al., 2004).

C. Adaptability and Change

The characteristics of the seed systems and the ways in which they change over time are likely to have a substantial impact on the genetic diversity present in individual crops and varieties. The seed systems of specific crops are subject to substantial variation in the availability of different materials as a result of variation in production, market fluctuations, government policies, climate variability, and in the framework of catastrophes such as droughts and hurricanes (Latourniere-Moreno et al., 2006). The ability to access seeds promotes resilience in the farmers’ production systems. Access to seeds can buffer against uncertainty and periods of rapid change across temporal and spatial scales. Lack of funds to purchase seeds, particularly during times of environmental uncertainty, reduces where coping strategies are needed, such as high seeding rates to counter uncertainty (Mcguire, 2007; Tuxil et al., 2009; Latourniere-Moreno et al., 2006; Bisht et al., 2007). Analysis is needed to ensure that the planting materials have enough diversity to adapt to farmer selection and management. Modeling social-ecological systems are needed to explore attributes that affect resilience, particularly in systems with high predictability (Walker et al., 2010).

The extent of migration can change substantially from year to year with significant migration occurring in years where production is poor, or as a result of major seed losses through disasters such as floods and hurricanes (Hodgkin et al., 2007). In the Western Terai of Nepal, farmers maintain a portfolio of local rice varieties (usually of short duration such as Sauthariya) to replant the crop when total crop failed because of stochastic events or poor rain after planting (Bhandari, 2009). Every year small nurseries are maintained for such cultivars in case the crop fails by community seed banks where farmers “borrow” seeds at planting time and return them after harvest (Table 1).

D. Seed Regulations and Access to Diversity

Farmers’ ability to maintain and acquire seed from the informal sources described above may be affected by the establishment of formal seed systems, e.g., seed distribution and release systems are regulated and monitored by the state (Figure 1; 3d). The original elements that defined the formal seed systems were put in place as a result of the development of specialized plant breeding products in Europe in the mid-nineteenth century, in order to create transparency in a seed market where variety names were rapidly proliferating. (Bishaw and Van Gastel, 2009; Louwaars and Burgoud, in press). Current variety registration for commercial purposes requires that the new variety be distinct from all varieties of common knowledge, uniform in its essential characteristics and highly stable after repeated multiplication (DUS = Distinctness, Uniformity and Stability, Bishaw and Van Gastel, 2009). These criteria guarantee that when a farmer buys seeds of a registered variety, these will be indeed of that variety and it will perform as such over time. In addition, testing for cultivation and use values (VCU) was introduced as a requirement for commercial release, in order for farmers to have an independent assessment of the yield, quality and value of the grain. As developing countries have established seed production systems greatly inspired by the ones in Europe, they have adopted seed certification and variety registration schemes that are similar to the European model (Louwaars and Burgoud, in press; Grain, 2005).

Some civil society organizations, organic food producers and environmentalists have denounced the rigidity of the uniformity criteria, and the costs involved in variety registration and seed certification, which make the formal system unfriendly for farmers’ varieties such as landraces and new varieties developed through participatory plant breeding, leaving these varieties outside the legal market of seeds (Farm Seed Opportunities, 2009). In addition to limiting the opportunities for farmers to obtain revenues from the varieties they produce, this situation results in less genetic diversity available in the market and may ultimately threaten diversity on farm (Leskien and Flitner, 1997; Louwaars, 2000; Kastler, 2005; Farm Seed Opportunities, 2009).

A number of studies have shown that the formal seed sector does not have the capacity to supply the variability needed in low input farming systems, nor to meet the need for locally adapted varieties (De Boef et al., 2010; Kesavan and Swaminathan, 2008; Lipper, 2010). Common figures suggest that the formal system provides for around 15% of the total seeds used by farmers in developing countries (Cooper, 1993; FAO, 1998; 2010; Hodgkin et al., 2007), although the situation varies by crop and region. In Europe, there is still an important demand for traditional varieties among small farmers and amateurs for direct
cultivation and for participatory breeding programs sponsored by organic agriculture associations (Toledo, 2002; Negri, 2003; Chable, 2005; Negri et al., 2009). According to European Union regulations, farmers are allowed to reproduce non-certified seeds for themselves, but they are not able to sell it. Depending on how strict governments are, exchange of non-registered seeds may be considered illegal as well (Louwaars and Burgaud, in press). The situation in developing countries is quite different: Seed regulations are rarely enforced at the local level, and both traditional and modern varieties are exchanged freely among farmers and sold in local markets (Louwaars, 2002). However, the existence of a formal seed system can affect the dynamics of the informal systems and have an impact on the diversity available to farmers. Firstly, the use of certified seeds of modern varieties is either recommended by extension services, linked to credit facilities and subsidies, or is obliged by the processing industry (Jaffe and Van Wijk, 1995; Tripp, 1998; Pascual and Perrings, 2007; Mosely, 2010). Subsidies can lock farmers into a pest-control technology linked to the distribution of modern crop varieties (Wilson and Disdell, 2001). Secondly, the illegality of selling non-certified seeds discourages the development of alternative models of seed supply (Biroil, 2007; Lipper, 2010).

Different models have been proposed and tested to create a space for different ways of seed production and supply, within the formal seed system. Keeping the formal system’s original objectives of providing transparency and ensuring seed quality, these models try to address the information gaps commonly found in informal seed systems by regulating the commercialization of traditional and modern varieties in a way that better adapts to farmer and small breeder needs. The European Union has recently approved a special treatment for the so called conservation varieties by which landraces adapted to local and regional conditions and threatened by genetic erosion can be registered for commercialization under certain conditions. The special treatment consists of (i) a certain degree of flexibility in the level of uniformity that is required, and (ii) an exemption from official examination if the applicant can provide sufficient information about the variety through other means such as un-official tests and knowledge gained from practical experiences. In Nepal, the uniformity requirements of the Nepalese Seed Act were applied in a relaxed manner in order to accommodate farmers’ application for the registration of certain varieties developed by participatory plant breeding together with traders and hoteliers in 2006 (Gyawali et al., 2009; Halewood et al., 2007). In Argentina, seeds of ancient varieties of forages can be commercialized as “Clase Identificada Común” (Common Identified Variety), without indicating the name of the variety on the seed package. An alfalfa landrace known as alfalfa pampeano can therefore be sold under the general name of alfalfa seed.

Since the name of the variety is not required in this case, the landraces can be legally sold without having to meet the DUS criteria required for variety registration (Gutierrez and Penna, 2004). This alternative, however, may lead to information gaps once the landraces’ seeds are commercialized beyond a limited and reliable circuit.

Some countries recognize partial or full auto-certification systems for traditional varieties (Table 1). The Quality Declared Seed System proposed by the Food and Agriculture Organization of the United Nations (FAO, 1993) has been widely used in areas where seed markets are not functional and government resources are too limited to effectively manage comprehensive certification systems. Under this system, seed producers are responsible for quality control, while government agents check only a very limited portion of seed lots and seed multiplication fields. The system has been recently revised with the aim of recognizing the role of national policies and providing a clearer explanation on how quality declared seeds can accommodate local varieties (FAO, 2006b).

IV. IMPROVING USE THROUGH BETTER INFORMATION, MATERIALS AND MANAGEMENT

The use of the traditional crop diversity by farmers or communities might often be increased (i) if there were more information on the characteristics (eco-physiological, adaptive, quality traits) or uses of these materials, (ii) if the materials themselves were enhanced, or (iii) if the agronomic management of the materials were improved. Farmers may perceive that traditional varieties are not competitive with other options because of a lack of characterization and evaluation information on the varieties, or because of a lack of information on appropriate management methods (Figure 1: 3a). This lack of information may occur either because the information does not exist, e.g., the varieties have never been characterized or evaluated on farm (Figure 1: 3a.2) or because the information is not available to the user community (Figure 1: 3a.1).

Even when traditional varieties meet some of the farmers’ needs, there may be a number of constraints which limit their use and prevent them reaching their full potential. Thus, environmental or market conditions may have changed, or varieties may have become susceptible to new pests and diseases (Figure 1: 3b). If the varieties available to the community lack the diversity needed to adapt to these changes, new materials may be needed with the required traits, or different management methods that improve the performance of the varieties may be required (Figure 1: 3c).

A. Producing and Providing Characterization and Evaluation Information for Traditional Varieties

Farmers who have to access seed from other sources have to depend on information offered by the seed provider or on common shared knowledge on traits, consumption characteristics, environmental adaptation and seed quality etc. to manage their crops. Often their information about crop varieties

1 Directive 2008/62/EC of 20 June 2008 provides for certain derogations for the acceptance of agricultural landraces and varieties which are naturally adapted to the local and regional conditions and threatened by genetic erosion and for marketing of seed and seed potatoes of those landraces and varieties.
is extremely limited (Tripp, 2001) and seeds obtained from farmers, market vendors, or seed companies are frequently reported to be accompanied by a lack of adequate information (Badstue, 2007). Farmers may also lack access to information on management methods, particularly, for example, for nursery practices for fruit trees (Oyedele et al., 2009; Shalpykov, 2008).

There is a widening recognition by the agricultural research and development community of the value of farmer knowledge, and an increasing use of new information and communication technologies to disseminate this information (Ballantyne, 2009; Kesavan and Swaminathan, 2008; Liang and Brookfield, 2009). Despite the reports that farmers often lack information (as noted above), there are also reports that farmers exchange information on individual varieties, local uses of plant parts, cropping systems, and eating qualities, along with seeds (Rijal, 2007). Farmers also share ecological information together with seeds through local networks. The technical messages derived from failures are shared among local farmers faster than those associated with success (Rijal, 2007; Rana, 2004; Shah et al., 2009). In some cases, information may be shared through cultural media, such as folksongs that characterize different traditional varieties and promote genetic enhancement in Ethiopia (Mekbib, 2009) (Table 1).

Lack of both formal and informal inter-agency and inter-ministerial (e.g., ministries and departments of the environment and of agricultural) information sharing is a barrier to successful policy formulation to support innovative land management technologies and strategies that support local crop genetic diversity in the production system (Grafström et al., 2005). Robertson and Swinton (2005) and Pretty and Smith (2004) discuss the increasing importance of new communication methods among agricultural professionals and farmers. Modern information and communication technologies in village-based knowledge centers have been used to provide timely and local-specific information that meets farmers’ demands (Kesavan and Swaminathan, 2008). Nursery growers in Central Asia and India can now access information related to scion and rootstock compatibility, and contact custodians of diversity of both mother plants (scion block) and rootstocks (Kerimova, 2008; Djavakyns, 2010; Singh, pers. Comm., 2010) (Table 1). Radio and television are also effective and easily accessible sources of agricultural information (Shah et al., 2009; Baral et al., 2006; Ballantyne, 2009; Balma et al., 2005) (Table 1). In the developed world, networks of weather stations in farming regions are becoming the norm. Farmers tap into these for real-time weather data. A relatively inexpensive weather station can be purchased for a farmer community and added to a free weather network such as Wunderground Weather (http://www.wunderground.com/weatherstation/index.asp#hardware) (Table 1).

In addition to information, access to traditional varieties may often be limited within the community, even when a sufficient quantity of seed is available (Badstue, 2006), simply because of poor access to information, weak social networks, social exclusion, and weak institutional mechanisms for collective actions (Shhapit and Joshi, 1996; Shrestha et al., 2006) (Figure 1: 3a.1). In some instances, many farmers may not be aware that useful resources are available, particularly when a variety is only grown by a few farmers within a community (Shhapit and Rao, 2009). For example, Shhapit et al. (2006d) reported that while aromatic sponge gourd was grown by only a few farmers in a mid-hills community in Nepal, the number increased significantly after a diversity fair was organized and locally multiplied seeds were distributed.

Most of the work on the evaluation and characterization of traditional varieties is undertaken in the context of the description of materials from genebank collections (Dudnik et al., 2001; Fowler and Hodgkin, 2004). It has been suggested that this may have limited value with respect to evaluation data, as many traditional varieties are specifically adapted to their abiotic and biotic environment (Budenhagen, 1983; Harlan, 1977; Teshome et al., 2001). Recently, there has been an increased interest in testing varieties collected directly from farmers and in comparing their performance with modern varieties (as checks or controls) under low input conditions, in order to have data that compares traditional varieties with other options available to farmers (Bouhassan et al., 2003; Tushmereirwe, 1996; FAO, 2010). These studies have included multi-locational trials on farm and on research stations for adaptive traits such as drought tolerance (Sadiki, 2006; Jackson et al., 2008; Magorokosho et al., 2006; Weltzien et al., 2006), salt stress (Rhouma et al., 2006; Hue et al., 2006), nitrogen fixation (Sadiki, 2006), cold tolerance (Thinlay, 1998, Thinlay et al., 2000) and disease resistance (Truett et al., 1997; Gauti et al., 2005; Finckh and Wolf, 2007). In one study, the relative performance of rice varieties was tested by reciprocal planting in different moisture regimes using upland, rain-fed and irrigated rice ecosystems. Interestingly, the results showed that some rice varieties had higher yields outside their home environments (Rijal, 2007).

While traditional knowledge (and variety names) may provide some information about the nutritional value of different varieties, specific macro- or micro-nutrient data is often not available (Woreda, 1997). Laboratory evaluations comparing nutritional levels among traditional and modern varieties for Bangladesh rice showed that some of the traditional varieties had higher iron and zinc contents than modern ones (Kennedy and Burlingame, 2003). Similar work has been done to compare protein levels across traditional and modern bean varieties (Cazarez-Sanchez, 2004; Cazarez-Sanchez and Duch, 2004) and levels of hotness in chili varieties in the Yucatan, Mexico, (Cazarez-Sanchez et al., 2005). Hotness was related also to the different dishes prepared with chili. Surprising little characterization of traditional varieties for systems that adopt certified organic agricultural practices has been done until very recently in Europe (Dawson et al., 2008; Bengtsson, 2005).

It is important that characterization and evaluation studies are done under farm conditions, in sites that are accessible to...
farmers and include appropriate modern varieties as controls or checks. Farmers often do not have sufficient capital or time to experiment with allocating their varieties to different production spaces in replicated trials. Growing varieties from different areas together in replicates on farmers’ fields offers farmers the chance to observe comparative reactions of traditional and modern varieties. Interventions, such as the establishment of diversity blocks by community seed banks, and the organization of farm walks, cross-site visits for farmers, or other community events, can act as platforms for social learning. An important aspect is to provide the platform at the community level that allows farmers and researchers to interact and learn.

B. Improving Traditional Varieties

Improving the performance of traditional varieties in participatory crop improvement programs has been undertaken in many programs over the last decade, particularly in low input systems (Table 1). Some of these programs have involved the identification of agronomic traits with molecular characterization so as to exploit the local diversity and produce varieties that are superior in marginal environments, but have a broad genetic base (Chiffoleau and Desclaix, 2006; Ceccarelli and Gando, 2007; Dawson et al., 2008; Gyawali, et al., 2007; Joshi et al., 2001; Sthapit et al., 1996; Witcombe et al., 2005; Ceccarelli et al., 2009; Danial et al., 2007; Almekinders et al., 2006; Ortiz et al., 2009; Valdivia Bernal et al., 2007; Marquez et al., 2009). Participatory or decentralized crop improvement begins with an understanding of the farmers’ preferred criteria, and often includes describing the management methods that farmers use for selecting the next generation (Smith et al., 2001; Mekbib, 2008; Nkongolo et al., 2008; Jarvis and Campilan, 2007) (Table 1). Traditional varieties may be improved by both preserving traits which are preferred by farmers and by adding additional traits (e.g., pest resistance) to a preferred traditional variety; the process can be implemented at a large number of locations (Lacy et al., 2006). The process helps to link farmer and breeder choices, and analyze tradeoffs that might differ among farmers’ and breeders’ choices (Gauchan et al., 2006). Setting collaborative breeding goals with farmers in Nepal for improving the traditional rice variety mansara, adapted to poor soils, resulted in the development of the improved variety, mansara-4. This variety is now spreading to areas where no other rice variety could be grown (Sthapit et al., 2006a; Gyawali et al., 2007).

In several countries resistance breeding procedures are integrating farmer selection and using local material and participatory breeding to improve other production and quality traits of locally-resistant varieties, as well as improving the resistance of locally adapted non-resistant varieties (Mgonja et al., 2005; FAO, 2010). Varieties that are made available from participatory programs are most likely to spread through existing seed systems. It is therefore important that methods used to improve crop material and seed quality take account of and are linked to seed supply systems (Bishaw and Turner, 2008; Gyawali et al., 2007).

A major concern for farmers is seed quality including purity, high germination rates, and reduced disease problems (Weltzien and vom Brocke, 2000; vom Brocke et al., 2003; Asfaw et al., 2007). Studies on traditional variety seed germination rates (Celis-Velazquez et al., 2008) and resistant to post-harvest pests (Teshome et al., 1999) have compared relative levels for traditional and modern varieties and found traditional varieties to perform well in many cases. Village seed systems certainly maintain the identity of varieties and, in central Mozambique, have been shown to maintain the purity of varieties and supply quality seed (Rohrbach and Kiala, 2007). On-farm seed quality for traditional sorghum varieties was found to be comparatively good by comparison to modern varieties and met national and regional West Asian and North African standards (Mekbib, 2009). Truthful labeling and declaring the source of seed is being used to ensure quality at the community level (Devkota et al., 2008). Actions such as seed sorting machines, training in seed quality improvement, seed health, and processing can improve seed quality. Seed cleaning technology for seed-borne diseases, normally recommended for certified varieties, has been used on traditional varieties to increase faba bean yield for traditional varieties by almost 50% (Sadiki et al., 2002). Recommendations have been made to expand agricultural extension packages to include traditional varieties with improved management methods (Jarvis and Hodgkin, 2008).

C. Improving the Management of Traditional Varieties

Management practices may also serve to improve the productivity and stability of traditional varieties within the farmers’ production system (Figure 1: 3c). Planting mixtures of traditional varieties, or of crop populations with high genetic variability, has the potential to reduce pests and diseases on farm (Li et al., 2009). Managing sets of varieties or crop populations with different levels of avoidance or tolerance to abiotic stress can decrease the probability of yield loss due to unpredictable rainfall and temperature regimes (Figure 1: 3c.2).

The potential negative consequences of planting large areas to single, uniform crop cultivars were recognized as early as the 1930s by agricultural scientists (Marshall, 1977). The Irish potato famine has been cited as one of the most dramatic examples of genetic uniformity leading to devastating loss of crop (Schumann, 1991). Breeding programs continue to develop new varieties and to replace varieties that have lost their resistance to diseases, but the maintenance cost, particularly in developing countries, is high (Strange and Scott, 2005). Resistant varieties may only remain so for a few cropping seasons as new pathogens emerge (de Vallavielle-Pope, 2004). When resistance in a monoculture breaks down, the whole area of the crop sown to susceptible varieties may succumb while, in a genetically diverse field or variety, it is much less likely that all the different types of resistance present will break down (Mundt, 1991).

Farmers often have local preferences for growing mixtures of cultivars that provide resistance to local pest and diseases
and enhance yield stability (Truttmann et al., 1993; Karamura and Karamura, 1995; Truttmann et al., 1993; Jarvis et al., 2007). High levels of diversity of traditional rice varieties in Bhutan has been shown to have high functional diversity against rice blast (Thinlay et al., 2000; Finckh, 2003) while high wheat diversity in Italy has been shown to provide yield stability in conditions of low pesticide application (Di Falco and Chavas, 2007). The development of varietal mixtures, or sets of varieties with non-uniform resistance and with lower new pathogens migration or mutation probability of existing pathogens, is in progress in many parts of the world (Finckh et al., 2000; Finckh and Wolfe, 2007; Jarvis et al., 2007). Such mixtures are based on the analysis of the resistance background, agronomic character, economic value, local cultivation conditions, and farmer preferences.

There is substantial genetic variation for response to water deficit within and among traditional varieties, and a growing literature on the use of a diversity of traditional varieties to minimize risks due to climatic variability (Sawadogo et al., 2006; Sadiki, 2006; Weltzien et al., 2006). Drought is a complex stress, influenced by both heat and drought, and plant response also varies according to timing in relation to the plant growth stage and stress intensity (Witcombe et al., 2008). Drought tolerance and drought avoidance seem to involve different mechanisms (Yue et al., 2006). While no unified abiotic stress resistance mechanism exists (Blum, 2004), there are certainly genes which are involved in responding to a number of different stresses. Planting a range of varieties or multiline with different drought avoidance and resistance properties could be an attractive option for low input systems. Sorghum growers in West Africa use a diversity of traditional varieties with different flowering dates to minimize risks due to climatic variability (Weltzien et al., 2006). Lipper et al. (2009), have shown that for sorghum farmers in Ethiopia the adoption of a sorghum improved variety, developed to allow drought evasion, was not an effective means of coping with drought and that landraces were more likely to provide the desired drought tolerance characteristics desired by farmers. They also noted that improving education levels among farmers might allow them access to more varieties adapted to low production conditions.

Brown and Rieseberg (2006) compared methods for managing diversity for abiotic and biotic stress that would enable farmers to cope with the stress factors in their production systems. They noted that the scale of variation of abiotic stress both in time and space was greater for abiotic than for biotic stress, that the degree of abiotic stress is less affected by the plant condition than biotic stress, and that divergence is more important that local polymorphism for abiotic versus biotic stress (Brown and Rieseberg, 2006).

Both farmer selection and natural selection can have substantial effects on the seed produced for future crops. Different farmers may have diverging perspectives and management practices in managing their seed stocks and introducing new material. This can result in differences in the time when seed can be provided and in the population structure of the next generation of seeds (Louette et al., 1997). Different farmer selection practices (or different participatory selection procedures will affect the genetic make-up and evolutionary dynamics of crop populations (Ceccarelli et al., 2009; Scarcelli et al., 2007; Barnaud et al., 2008; Sagnard et al., 2008; Gautam et al., 2009). In the case of vegetatively propagated crops, this reflects farmers’ variety-specific handling of seed tubers (Zannou, 2009; Scarcelli et al., 2006) and genetic effects are likely to result from mutation, epigenetic influences or mixing by farmers.

Marketing at a desirable price can be a problem when farmers do not have storage facilities but must sell their crop to avoid seed or tuber rot (Figure 1: 3c.1). Improved storage allows farmers to sell their seeds or grain at periods when the market price is higher (Aghajae et al., 2005). Seed storage devices and methods determine the vulnerability of seeds to pests, diseases and physiological deterioration (Gepts, 1990; Latourniere-Moreno et al., 2006; Table 1). Post-harvest losses are a serious cause of production losses in developing countries (Grum et al., 2003). Improving the air-tightness of storage containers (Wambugu et al., 2009; Thamaga-Chitija et al., 2004), heat treatment (Beckett et al., 2007), manual seed cleaning, and application of nontoxic materials, are some easily applicable methods that combine traditional and modern seed storage technology to reduce the post-harvest vulnerability of seeds (Table 1). Complementary technical solutions will be necessary to integrate the future use of agricultural strategies that include the use of diverse traditional varieties. These may also include adjustments of planting and harvesting to facilitate separation of the harvest products where the handling of mixtures is not possible or not desirable (Finckh, 2008).

D. Improving Policies to Support Farmers Using Traditional Varieties

In general, there are few incentive structures that promote: the conservation and sustainable use of agricultural biodiversity and farmers’ customary practices—the heart of Farmers’ Rights (2010); Figure 1: 3d). Current legal systems make it difficult to adequately recognize the contributions of farmers and farming communities in conserving, developing and using agricultural biodiversity. National and local governments have not yet adequately given a real content to the overused, but so far rather diffuse concept of Farmers’ Rights by translating it into practical measures that effectively support farmers who conserve and generate crop diversity (Andersen, 2005; 2007).

Intellectual property rights have been a recurrent element in the discussions around the concept of farmers’ rights. The limitations to use, save, duplicate and exchange plant varieties protected by intellectual property rights, the lack of recognition or compensation for farmers when new products based on their traditional varieties and ancestral knowledge are subject to property rights, the incapacity of the current intellectual property system to adequately protect farmers’ varieties and knowledge as well as innovations generated at the community level, are some of the issues that are commonly raised when dealing with
the protection of farmers’ rights (The Crucible Group, 1994; Leskien and Flitner, 1997; Correa, in press).

Some national laws have attempted to conciliate the different stakeholders’ interests with regard to intellectual property protection by combining UPOV-style protection of new plant varieties and a sui generis protection of farmers’ varieties. Examples of this are the Thailand Plant Varieties Protection Act 1999, the Indian Protection of Plant Varieties and Farmers’ Rights Act 2001, and the Malaysian Protection of New Plant Varieties Act 2004. However, the success of such laws in achieving crop diversity conservation and farmers’ rights protection is questionable. There is also a great deal of opposition to the belief that conferring private rights to farmer varieties would be beneficial to farmers and farmer communities (Srinivasan, 2003; Eyzaguirre and Dennis, 2007). Jaffe and Van Wijk (1995, p.76) argue that the introduction of plant variety protection causes a change of principle: “When farmers start to use protected varieties, their natural right of seed saving becomes a legal right, or even less, a “privilege.” Such a legal right is subjected to political decision-making and possibly prone to restrictions in the future.”

Registers of traditional varieties have been promoted by a few national and local governments to help advance the realization of farmers’ rights in different ways (Table 1). The registries document and perpetuate traditional knowledge related to the use of crop diversity and have been used to create a sense of ownership over traditional varieties and empower local communities with regards to local activities oriented to the conservation and sustainable use of traditional varieties (Lopez Noriega, in press; Aboagye, 2007). In addition, they have worked as defensive publications and prevent the misappropriation of farmers’ genetic resources by acting as a record of the farmer varieties found within the community together with descriptive agronomic, adaptive, quality and other use traits. Examples of local registers can be found in several communities in Nepal (Subedi et al., 2005; Sthapit and Quek, 2005). The government of Peru maintains a national register of traditional varieties of potato, and several regional governments in Italy support regional databases of ancient varieties (Lopez Noriega, in press; Ruiz, 2009). In some cases, the registers or databases constitute the basis for the government to provide direct support to the farmers who cultivate traditional varieties. In Hungary, a list of locally-grown traditional varieties targeted for protection is published as an annex to a law, with mechanisms developed for adding new varieties to the list. Farmers who grow crops from the list can receive subsidies, on the condition that they provide a prescribed quantity of seeds to others interested in the growing of the same crop (Mar, 2002, Bela et al., 2006).

Another important aspect of Farmers’ Rights, as pointed out by the International Treaty on Plant Genetic Resources for Food and Agriculture, e.g., the farmers’ involvement in

V. BENEFITING FROM THE USE OF LOCAL CROP GENETIC DIVERSITY

Benefits from the use of local crop genetic diversity may come from its current use value, derived from the consumption of a good or service by an individual or a community. Benefits may come from its options value, or the value associated with retaining an option to a good or service in the future. Finally, a resource may be valued for its existence, unrelated to any use of the resource and/or its bequest value, the altruistic value that the individual or community is concerned that the resource should be available to others in the current or future generation (Smale, 2006; Bateman et al., 2002). Enhancing the benefits for farmers of local crop diversity means enhancing the net benefits, as there also could be costs to farmers associated with any benefit generating option (Sthapit et al., 2008b). This involves ensuring that appropriate incentives for creating and sharing benefits with farmers are developed and that unnecessary or unintended barriers to the flow of benefits to the farmer are not created through the introduction of taxes and subsidies (Bragdon et al., 2009).

There are many ways which farmers can derive greater benefits from the traditional crop varieties they manage. The success of these involves inter alia supporting local institutions, enhancing collective action and property rights, and enabling farmers to participate and lead the decision making process to the appropriate action and its implementation.

A. Market-Based Actions and Incentives

Markets involve the exchange of goods and services between participants, and as such constitute one of the principal social arenas structuring farmers’ management decisions about diversity (Smale, 2006). The market value of agricultural production can be increased through development of new markets, improved marketing, value addition, high value product differentiation; improved processing equipment adapted to diversified sustainable use of plant genetic resources for food and agriculture, and the equitable sharing of the benefits arising out of their use, in harmony with the Convention on Biological Diversity. Parties to the Treaty recognize their responsibility for realizing Farmers’ Rights under Article 9 of the Treaty.
raw materials, and building trust among market chain actors (Kontoleon et al., 2007; Lipper et al., 2010; Di Falco and Perrings, 2006; Giuliani, 2007; UNORCAC, 2008; Figure 1: 4a; Table 1).

Agricultural communities interact with markets directly and indirectly on a variety of scales, from household to global. The steady integration of traditional farming regions into wider national and international market relationships is a dominant trend of the last half-century. Pascual and Perrings (2007) reviewed the influence, at the micro-scale (household, family farm) and meso- and macro-scale (national and international policies), of economic and institutional failures that have systematically distorted farm-level decisions to conserve agricultural biodiversity. These include agricultural production subsidies, tax breaks, and price controls (Tilman et al., 2002; Kontoleon et al., 2007; Kitti et al., 2009).

Several market practices have been tested and put in place to create incentives for agricultural biodiversity conservation. “Fair trade” for “free trade” are market schemes that support and advocate replacing millions of dollars in aid by paying a decent price for the products purchased from poorer countries and giving producers in those countries an opportunity to take care of their own production environment (Kitti et al. 2009; Kesavan and Swaminathan, 2008; Renard, 2003). Price premiums that represent true costs of production have been studied to understand how they can provide an incentive to conserve agricultural biodiversity and, at the same time, to create benefits for poor farmers (Kitti et al., 2009; Perfecto et al., 2005; Smith et al., 2008). Product labeling can provide consumers with important information not only on food quality, but about the conditions under which the commodity was produced (Swallow and Sedjo, 2000; Giuliani, 2007). This labeling practice includes various geographical identification procedures (Ramakrishnappa, 2006; Garcia et al., 2007; Nagarajan, 2007; Salazar et al., 2007; Ori-Gin, 2010).

Among other factors, creation of appropriate market conditions depends on the provision of accurate and credible information (Pascual and Perrings, 2007, Lipper et al., 2010; FAO, 2007; Okwu and Umoru, 2009; Bela et al., 2006). Many developing country farmers are aware of market prices before participating in the market, obtaining information most often from neighbors, followed by village traders, the mass media, and Extension agents (Nagarajan et al., 2009). The increased use of mobile and fixed phones has improved the flow of price information among markets for small scale farmers (Nagarajan et al., 2009). Groups working with rural poor communities in India are supporting local market intelligence systems for small-scale farmers in order to improve the availability of data on demand and supply, production capacity and market prices (Kesavan and Swaminathan, 2008). In some cases, creating stable markets for diverse varieties sold as raw agricultural products may not be a valid option although it may be possible to enhance the benefits to farmers of local varieties by processing them for specific markets (Kruitjesen et al., 2009). This would involve having processing equipment that can be used with diverse raw materials (Finckh, 2008).

Choice models were originally developed by economists during the 1970s to explain patterns of adoption of “green revolution” crop varieties by farmers in Asia and other regions (Smale, 2006). Subsequent researchers applied and refined revealed preference models to identify why smallholder farm households continue to grow traditional crop varieties even in the presence of agricultural development and widely available improved varieties (Brush et al., 1992; Meng et al. 1998; Smale et al., 2001; Van Dusen 2006; Gauchan et al., 2006). Recent studies have shown that although greater on-farm diversity can increase the likelihood that a household will sell traditional varieties, high levels of diversity on farm may not be reflected in local markets (Edmeades and Smale, 2009). Diversity on-farm was reported to be a necessary condition for market involvement, both in terms of the decision to participate and the richness of traditional varieties sold. But this does not guarantee that on-farm diversity will lead to market sales or diversity at the point of sale (Edmeades and Smale, 2009).

Changes in markets linked to infrastructure and rural development may trigger the erosion of traditional crop varieties, both directly and indirectly. For instance, a new paved road that reaches a previously isolated farm community can help farmers to replace local varieties with improved seeds available in more distant markets. The same road can also enable farm households to substitute newly available goods or services for those previously supplied by diverse varieties (Smale and King, 2005). However, improved access to a greater number of markets can also provide potential incentives for farmers to retain crop diversity, such as when demand for unusual heirloom or niche market varieties exists among urban residents or other consumers (Lee, 2005; Irungu et al., 2007; Giuliani, 2007; Van Dusen, 2006; Gauchan and Smale, 2003; Rana, 2004; Gruere et al., 2007; Ramirez et al., 2009; UNORCAC, 2008).

Assisting smallholder groups to produce together and expand niche markets, will include such activities as educating consumers about the values of diverse varieties, providing better packaging (Gruere et al., 2007; Devaux et al., 2006) and offering credit provisions to support transportation costs (Lee, 2005; Almekinders et al., 2010). In the best of cases, niche markets might be useful for traditional varieties that are also “best fit” to particular ecosystems, such as particular traditional varieties shown to grow well on swampy soil or on poor upland soils (Gauchan and Smale, 2003; Rana, 2004; Gruere et al., 2007). Marketing social-cultural aspects of traditional varieties for particular culinary aspects and associated ethnic identity have also been used to create niche markets (Gruere et al., 2007; Ramirez et al., 2009; Williams, 2009; Sthapit et al., 2008a).

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1OECD developed countries spend approximately US$225 billion annually on agricultural subsidies for their own producers, between one-fourth and one-third the global value of agricultural production in 2000.
Econometric methods have been used to test the effects of crop genetic diversity on expected crop yields and yield variability as well as the probability of crop failure, given levels of pesticide applied (Di Falco and Chavas, 2007). The work has shown that when pesticide use is low crop genetic diversity reduces yield variance, but when pesticide use is high the effect of the crop biodiversity on yield variance is not significant. Indicating that crop genetic diversity is acting as a substitute for pesticides.

Value chain analysis has been used by economists to identify bottlenecks to obtaining increased value from traditional varieties and to map out the relations among actors and flows of crop genetic resources (Andersen et al., 2010; Giuliani, 2007; Kruisjes et al., 2009). The analysis has shown that stakeholder meetings provide a forum for collecting crucial information about the market chain as the meetings involve as many actors as possible: producers and traders, cultivation experts, NGOs, and representatives of relevant ministries (Giuliani, 2007). These meetings help to design joint ventures with private sector entities. They also create reputation and trust in the areas of quality and prices among farmers, food manufacturers, retailers, NGOs, community-based and government organizations, important in reducing transaction costs (Lipper et al., 2010; Almekinders et al., 2010; Smith et al., 2008) (Table 1). Retailers and other intermediaries are important sources of seed inputs and credit for farmers (Almekinders et al., 2010; Giuliani, 2007; Lipper, 2010). They facilitate the flow through the chain by storing, transporting, and reselling seeds and can respond to seed demands from different regions at different planting times.

The role of local markets in seed provision, particularly of traditional varieties has been the subject of a number of important recent studies. Local markets can be more effective in promoting seed movement than specialized traders who may overlook locally sourced seed (Dalton et al., 2010). In the case of traditional crop varieties, seed and grain markets are usually the same and the availability and identification of materials that will be used as seed, with information on the desired production and consumption traits may be difficult (Lipper et al., 2010). Some studies have suggested that local seed supply channels cannot be enhanced unless they are separated from grain supply channels (Nagarajan and Smale, 2007; Smale et al., 2010; Almekinders et al., 2010). Enhancing local seed supply channels may involve, for example, developing mechanisms for production and trade of truthfully labeled or quality-declared seed by farmer organizations with building collective action groups that screen and value seed. Certifying the sellers rather than seed may also be an option. Current examples are Producer Marketing Groups (PMGs) in Kenya (Audi et al., 2010) and Quality Declared Seeds in Tanzania where small scale farmers are registered to produce seed for local sale and are provided with vendor certification (FAO, 2006b; Granquist, 2009) (Table 1). Smale et al. (2010), nevertheless, caution against the formalization of the informal markets in Mali. They suggest that this development could have negative effects on women who would lose the little control they now exert over the grain resources unless they were trained about seed and linked to seed producer groups. It might be more appropriate to develop regulations that shorten the process of certifying seeds or that focus on seed quality rather than seed purity (Lipper et al., 2010).

B. Non-Market-Based Actions and Incentives

The full value of agricultural biodiversity and its services is not captured by the market because of a failure to internalize external costs (Thiès, 2000). Crop biodiversity has socio-cultural, insurance and option values, that will be underestimated if left to the market (Pascual and Perrings, 2007; Smale, 2006). These different values of traditional varieties may to some extent be realized through non-market incentives (Figure 1: 4b; Table 1). They can be realized, for instance, by improving public awareness about sociocultural values of traditional varieties (Birol et al., 2007), by providing information on the substitution value of traditional variety diversity for fertilizer and pesticides (Di Falco and Perrings, 2007), moral suasion, regulation and planning, by preventing specific land management practices such as low input zones (Pascual and Perrings, 2007), by designing agroecological parks or agrotourism zones (Ruiz, 2009; Ramirez et al., 2009; Ceroni, et al., 2007). Other possibilities include compensating farmers for their conservation functions through payment for environmental services (FAO, 2007; Brussaard et al., 2010) or by supplying insurance functions and option values (Bragdon et al., 2009). Insofar as they exist, the enforcement of Farmers’ Rights, and the adaptation and enforcement of intellectual property law could also play a role.

Methods to assess the non-market value of public goods can be divided into two categories (Birol et al., 2007): 1) choice experiment studies (or direct methods) that use stated preference (willingness to pay/accept) to investigate the public’s valuation of agri-environmental schemes and crop genetic resources (Campbell et al., 2006; Birol and Ryan-Villalba, 2009); and, 2) hedonic analysis (or indirect methods) that use revealed preference (market information) to estimate the value of attributes of crop genetic resources (Van Dusen and Taylor, 2005; Edmeades, 2006; Edmeades and Smale, 2009). Birol et al. (2007) reviewed the different models and experimental data for obtaining non-market values of biodiversity resources. They combined choice experimental data with farm household data and concluded that welfare measures derived from non-market public goods could be more accurate when the methods are combined. Welfare measures (willingness to accept compensation) can be calculated for different agrobiodiversity attributes within the farmers’ production system and for the services provided by traditional varietal diversity. These methods have helped to identify least cost agri-environmental schemes that can encourage farmers to undertake home gardens and on-farm management practices to support the conservation and use of traditional varieties (Birol et al., 2006; 2007; 2009; Poudel and Johnsen, 2009).

Diversity, in the form of traditional varieties, has also been valued as a deliberate strategy for managing abiotic and biotic pressures in labor-intensive production systems with low levels
of chemical inputs (Edmeades et al., 2006; Waage et al., 2008). Low chemical input or organic farming with local varieties can promote agro-ecosystem stability and health (Østergård et al., 2009). Other studies have been used to account for substitution value that traditional varietal diversity may give for pesticide inputs using a damage-abatement framework. These models value the effect of crop varietal diversity not only for the yield effect but also for the damage abatement effect of crop genetic choices as a substitute for pesticide application (Oude and Carpenter, 2001). In this context, it is also worth noting that pesticide manufacturers probably do not pay the full cost of the adverse affects that pesticides have on the environment of human health (Pretty, 2008; Pingali and Roger, 1995).

There are several examples across the world of countries and institutions implementing mechanisms to capture the non-market value of local agricultural biodiversity (Table 1). Environmentally Sensitive Areas (ESAs) in Hungary are a window for promoting organic farming, which could include the use of traditional crop varieties (Bela et al., 2006). In Poland semi-subsistence farms are often regarded as a major obstacle to development. However, Siudek (2008) notes that expanding farm businesses to include agrotourism in rural areas of Poland would have the potential to reverse negative economic trends. Agricultural biodiversity for recreation (Ceroni et al., 2007; UNORCAC, 2008) includes agrotourism zones established in Peru (Ruiz, 2009) and agrobiodiversity botanical gardens in Ecuador (Williams and Ramirez, 2006). These emphasize both traditional crop diversity and cultural identity and are a means to share benefits with local farming communities.

Bela et al. (2006) have suggested that there is a need to improve communication among stakeholders to understand trade-offs between public attributes and profitability. Advertising campaigns could be used, for example, to change norms on nutrition and taste and or try to reduce the use of chemical inputs. Education on the value of increasing use of traditional varieties can be part of these campaigns. Modification of existing primary and secondary school curricula to include agricultural biodiversity as an adaptive resource in biology courses is another method of introducing new ideas into the education system (Ramirez et al., 2009; UNORCAC, 2008) (Table 1).

Case studies compiled in the context of the Convention on Biological Diversity indicate that empowerment and benefit-sharing with farmers and farming communities will only take place if additional measures accompany activities related to access and benefit-sharing (Regine, 2005; Convention on Biological Diversity, 2010). National laws on access to genetic resources, intellectual property and bio-safety need to form part of the legal landscape that supports the use of traditional varieties. This includes advocating that local and national governments integrate biodiversity, including agricultural biodiversity, into their legislation on environmental impact assessment of projects, policies, plans and programs as a method for informing decision-making with regard to agrobiodiversity maintenance and use (Slootweg et al., 2006; Wale, in press).

Participatory plant breeding has been shown to help enable farmers to influence the development of materials and technologies in ways that are informed by their specific needs, agro-ecological environments and cultural preferences (Halewood et al., 2007; Gyawali et al., 2007; in press). The Thai Plant Variety Protection Act is one example of a law that includes a benefit-sharing scheme by which those who are granted plant breeders’ rights must pay part of the monetary benefits gained through the commercialization of the variety to a common fund which will support Thai small farmers who conserve and use crop diversity. The practical implementation of the law has been very challenging and the plant variety fund is still empty (Gagne and Ratanasatien, in press). Benefit-sharing policies must combine different approaches; the reality shows that conservation of crop diversity on farm cannot rely only on levies on plant breeders’ royalties (Srinivasan, 2003).

It has been argued that true benefit-sharing involves developing mechanisms that support communities and their farming systems and thus agricultural techniques that conserve local agricultural biodiversity. Farmers’ Rights implies the development of some means of ensuring benefits flow to farmers and farming communities either through an ownership approach or a stewardship approach (Farmers’ Rights, 2010). In this context, creating incentives and removing disincentives to enable farmers to continue their work as stewards and innovators of agricultural biodiversity need to be part of any benefit-sharing mechanism (Bragon et al., 2009). Currently, disincentives to the maintenance of traditional varieties may be associated with various aspects or consequences of agricultural development strategies such as 1) alterations in land tenure systems that threaten the survival of traditional farming communities; 2) subsidy schemes that promote exclusive adoption of uniform agricultural productions; 3) research programs that neglect traditional varieties and their associated knowledge and uses; and 4) food standards that limit entry of traditional farmers’ varieties and products into markets.

C. Strengthening Local Institutions and Farmer Leadership

All approaches or activities to enhance benefits to farmers rely on building up social capital, or the ability of men and women farmers to develop and use social networks (Figure 1: 4c). Social networks help farmers to obtain access to credit as well as information and knowledge about new options and practices. Furthermore, these networks expand choices available to each household member (Pretty, 2002; Bantilan and Padmaja 2008). Building social capital includes developing appropriate

The ownership approach refers to the right of farmers to be rewarded for genetic material obtained from their fields and used in commercial varieties and/or protected through intellectual property rights. The stewardship approach refers to the rights that farmers must be granted in order to enable them to continue as stewards and as innovators of agro-biodiversity. Benefit-sharing is most promising when the point of departure is the farming communities that actually contribute to the maintenance of plant genetic diversity benefits (Regine, 2005).
collective management practices, which are understood as the voluntary action that is taken by a group to achieve common interests and property regimes (Meinzen-Dick and Eyzaguirre, 2009; Eyzaguirre and Evans, 2007). Through collective action members of the group may act directly on their own or through an organization, such as deciding on and observing rules for use or non-use of a resource through coordinated activities across individual farms. Property rights involve the “the capacity to call upon the collective to stand behind one’s claim to a benefit stream” (Bromley, 1991). Interventions to strengthen the property rights of individuals or groups to help them participate in collective activities can improve their bargaining positions (Eyzaguirre and Evans, 2007). This may involve the development of institutional mechanisms that local participants can use to organize themselves, such as through special districts, private associations, and local/regional governments (Meinzen-Dick and Eyzaguirre, 2009) and better link them to policy institutions (Pretty, 2008).

Combinations of farmer innovation and empowerment, the transformation of local government staff, and the establishment of new farmer–governed local institutions that have equitable links to the private sector have resulted in successful collective action for equitable management and use of traditional crop varieties (Friss-Hansen, 2008; Pretty 2008; Swaminathan, 2003; UNORCAC, 2008). Pimbert et al. (2010) discusses citizen juries formed by farm leaders, progressive researchers, and NGO technicians to evaluate, deliberate, and publicly address the equity and sustainability of conventional research systems and initiatives in West Africa. Collective action is important in enabling farmers to address market imperfections and transaction costs, such as in surmounting information, credit and marketing constraints. Such institutions support farmer unions and cooperatives for educating farmers in production and marketing, assisting with price negotiations, collecting land taxes, and information sharing (Caviglia and Kahn, 2001).

Diversity field fora (Smale et al., 2008), which bear some similarity to farmer field schools (see Van der Berg and Jiggins, 2007), are becoming a new institution in West Africa which can strengthen the capacity of farmers to analyze, manage and improve their own crop plant genetic resources (Bioversity International, 2008). In diversity field flora, farmers acquire both knowledge and leadership skills through experiments that are designed and conducted by the farmers with technical support from project staff, to better manage and benefit from their crop genetic resources (Bioversity International, 2009; Smale et al., 2008; Jackson et al., 2010). The community-based biodiversity management (CBM) approach, developed in Nepal and now being tested in South and Southeast Asia, is a similar multi-step process that focuses specifically on strengthening the local decision-making and governance capacity of communities to utilize agricultural biodiversity (Shapit et al., 2006a; De Boef et al., 2007). Collective action is also supported when participatory plant breeding is not limited to the development of varieties for a specific area, but becomes part of integrated community-based biodiversity management activities (Shapit et al., 2008b).

It has been argued that agricultural policies are required that build human capital (Neuchatel Group, 2007; Smale et al., 2006). Policies that support inclusive agricultural extension or advisory services need to go hand in hand with the process of strengthening local institutions. Extension services have to be more responsive to the needs of all farmers, including women and those who are poor and marginalized (Neuchatel Group, 2007; Smale et al., 2006). This is likely to involve paying increasing attention to contextual factors in the design and implementation of agricultural extension service programs. In addition to the characteristics of the local communities, the types of farming systems and the degree of market access are examples of important contextual factors that need to be taken into account (Birner et al., 2010). In the same way it has been suggested that agricultural policies need to be more gender sensitive and designed to empower women by providing knowledge and ensuring access and control of resources toward achieving food security (MEA, 2005). Women have multiple responsibilities within the household and communities but are often ignored at all levels of decision-making.

Most studies agree on the need to improve trust and mutual understanding across different actors and institutions (Kruissij et al., 2009). These studies emphasize the need for reciprocity, obligations, and mutually agreed upon rules, which are structured and connected through groups and networks (Cramb and Culasero, 2003; Pretty, 2008). Cultural institutions, such as weddings and tea houses, are places of trust where information on traditional crop diversity is exchanged and which could be linked to wider support networks (Van Dusen et al., 2006). There is potential for local institutional support and capacity building to link individuals of different networks together through a neutral party (NGO or other organization) or to both build smaller networks that could be linked to help diffuse innovations and messages (Granovetter, 1973). Resilience is built into agroecological production systems through supporting institutions and social-ecological networks that create flexibility in problem solving and that can balance power among interest groups (Folke et al., 2002; Walker et al., 2002; 2010). These many different types of networks can be strengthened by linking them to community-based seed production groups and to participatory plant breeding schemes so as to capitalize on natural pathways of seed flow. Networks can help demystify laboratory-based technologies (Kesavan and Swaminathan, 2008), provide technology empowerment, and support literacy training, to enable farmers to have more control over their resources (Swaminathan, 2003). These can be supported by knowledge empowerment actions that take advantage of the new information and communication technology (Kesavan and Swaminathan, 2008).

VI. CONCLUSIONS

Over the last two decades a substantial body of information has developed on the continuing maintenance and use of traditional varieties by small-scale farmers around the world.
Farmers appear to find that diversity, in the form of traditional varieties of both major staples and minor crops, remains important to their livelihoods, despite earlier expectations that these varieties would rapidly disappear from production systems.

No doubt the arguments about long-term trends with respect to the continued use of traditional varieties will continue. However, there are a number of reasons for thinking that these varieties will continue to play an important role for many crops in a wide variety of production systems in the future. In addition to the reasons such as adaptation to marginal and low input agriculture, stable performance, and the socioeconomic conditions of many small-scale farmers—who, as Lipton (2006) noted, make up 45–60% of the rural poor—already mentioned in the Introduction, farmers around the world are using traditional varieties to help cope with climate change (Platform for Agrobiodiversity Research, 2010). The growing concern with developing more sustainable production systems and reducing dependence on chemical inputs is also likely to favour the maintenance and use of traditional varieties.

In these circumstances it seems important not only to understand the nature and contribution of traditional varieties to the production strategies of rural communities around the world, but also ways in which they are maintained and managed. This can help in the development of ways of improving the use of these varieties and their contribution to rural livelihoods. As shown in this review, there is a rich and growing body of information on traditional varieties, and on the problems and benefits associated with their maintenance and use. The review has also demonstrated the importance of work that adopts a multidisciplinary approach and emphasizes working with farmers in collaborative ways. There remain clear gaps in our knowledge. There is still a need to develop better indicators and ways of monitoring diversity that are adapted for the use of farmers, communities, and scientists. Molecular methods, which can now provide significant additional insights into the extent and distribution of diversity and on the ways in which it is correlated with important social, environmental, and management variables have yet to be undertaken on the scale needed except perhaps for sorghum and pearl millet in Africa (e.g. Barnard et al., 2008; Bezancon et al., 2009; Busso et al., 2000; Deu et al., 2008; Sagnard et al., 2008; Allinme et al., 2008). With the rapid improvements in methods over the last decades this is now possible on the required scale.

While each situation may appear to be unique with respect to the amount of diversity present in the system, its distribution and the associated biological, environmental, socioeconomic, and cultural characteristics, it is possible to recognize general properties which can be used to ascertain the sorts of activities that farmers, and those working with them, may find useful in identifying ways in which traditional varieties can both be maintained and contribute to improved livelihoods. The heuristic framework presented here provides a number of overlapping approaches and entry points for such activities. At present this probably should be regarded very much as “work in process” as it is likely to be amended as further information becomes available. However, even at this stage, it is possible to draw some general conclusions based on its application. Firstly, it is essential to develop an appropriate understanding of the extent and distribution of diversity in a system and of how it is maintained through local institutions and practices. Secondly, the analysis is likely to lead to the identification of a number of complementary supporting actions. Thirdly, the success of any actions will depend centrally on local knowledge, the strength of local institutions and the leadership of farmers and communities.

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