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# Maintenance and Management of Agrobiodiversity in Small-scale Agriculture

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## ABSTRACT

This review addresses issues of interest for understanding small-scale agricultural systems, particularly the maintenance and management of crop diversity. Following a general presentation of theses systems, some aspects related to the structure and dynamics of intra-specific diversity are discussed with respect to: their organization in space and time; the supply and circulation of propagules and seeds; and locally-developed knowledge regarding crop varieties. Some of the impacts resulting from changes in traditional farmers' ways of life, when they begin to experience a more profound influence of the urban-industrial society, are cited, since the maintenance of these phytogenetic resources depends on the cultural value of diversity and the importance attributed to its survival.

**Keywords:** maize, manioc, on-farm conservation, seed systems, traditional agriculture

## CONTENTS



## GENERAL OVERVIEW OF MANAGEMENT OF PLANT DIVERSITY BY SUBSISTENCE OR SMALL-SCALE FARMERS

The objective of this review is to focus on topics that are important for understanding the maintenance and management of phytogenetic resource diversity in small-scale farming systems. With this aim, references considered illustrative of the aspects to be addressed, and that adopt mainly an ethnobotanical approach or integrate ethnobotany with other approaches, were selected, concentrating mainly on the period from the 1980s to the present. We sought to focus mainly, but not exclusively, on studies carried out in the neotropics with two of the most important domesticated crops raised there, manioc (*Manihot esculenta* Crantz) and maize (*Zea mays* L.). This choice was influenced by the fact that they are contrasting crops with respect to various biological aspects (vegetative vs. sexual propagation, among others), agricultural management, ecological conditions and production, thus making it possible to compare strategies adopted by farmers in each case, highlighting differences and similarities. Based on the large number of studies involving these two species, a framework of biodiversity maintenance and management by subsistence farmers can be outlined.

After presenting a general overview of these farming systems, important aspects related to the structure and dynamic of intra-specific diversity are addressed, as well as the supply and circulation of planting material, and locally developed knowledge about crop varieties. Some of the impacts resulting from changes in the lives of these farming populations when they begin to experience more profound influences of urban-industrial society are discussed, as well as aspects of *in situ* conservation of these phytogenetic resources.

Small-scale farming, i.e. subsistence or traditional farming[1], can be defined as that which is practiced by a group of farmers using characteristic technologies of low environmental impact whose organizational base is the family and community, and whose main emphasis is on the material and social reproduction of the group, although surplus may

[1] In this text, the three terms are used interchangeably; the term "traditional" is used here in a broad sense to designate groups of farmers with differing levels of ethnic and cultural differentiation and isolation with respect to the national society, and degrees of insertion in the market (see Diegues and Arruda 2001).

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be produced and sold on local markets (Diegues and Arruda 2001).

One of the remarkable characteristics of this type of agriculture is its autonomy in relation to external inputs and resources, to which traditional farmers have historically had very limited access. This is a result of their isolation as well as the lack of availability of monetary capital, in the case of inputs used in modern agriculture. The isolation of traditional farmers should be understood in the geographical as well as the political-economic sense, as they generally occupy marginal positions in relation to the dominant segments of the national population, as can be easily seen in the scarcity of public policies aimed at this type of agriculture. This marginalization, however, provides the space for development of local solutions to local problems. Thus, traditional farmers continually develop practices and techniques for production based on what they encounter in their life situations. Their deeper knowledge of their environment and their strategic choices allow them to exploit locally available resources in a very efficient manner. It should be noted that traditional peoples often establish complex life strategies that include other forms of management of the plant environment, in addition to the cultivation of crops (Posey 1986). The exploitation and management of populations of native plants, depending on their intensity and purpose, can modify the structure of these populations and begin the process of domestication of a species (Casas and Caballero 1996; Casas *et al.* 1996, 1999; Clement 1999).

A traditional farming system is generally composed, in its ecological and spatial dimensions, of an environmental mosaic where natural areas that have undergone little or no alteration are interwoven with areas of varying intensities of management that reflect the basic characteristics of the environmental matrix, for example: fields of slash and burn agriculture in wooded areas, fields of short-cycle crops in floodable areas of floodplains, backyards, fruit tree orchards, etc. These farmers often occupy unstable or markedly seasonal environments with high stress levels (for example, regions that are mountainous, very dry, or floodable, and environments with large biological diversity, which are likely to harbor a large number of potential pathogens and plagues, etc.), and consequently develop ways of adapting to them (Pinedo-Vasquez *et al.* 2002).

Key elements of successful adaptation to the environment are the species and varieties of plants cultivated by the farmers. As they cultivate various species and varieties of plants, they increase the chances of exploiting the heterogeneity of the environments they occupy more efficiently, as well as having better conditions for meeting the diverse needs for their survival (Richards 1985; Bellon and Brush 1994; Louette 1999, among others). A diversified set of plants also provides greater security to deal with unexpected events, whether climatic, biological, or social, and to respond adequately to transformations in life conditions and conditions for production.

This maintenance of a set of species and varieties is common among traditional and subsistence farmers of different ethnicities and backgrounds occupying different ecosystems and cultivating different sets of plants. To some degree, it is also common among small-scale farmers who are more inserted into a market economy. There is constant interest in and attention to seeking new materials, which are then tested in the farmer's specific conditions.

## Diversity of germplasm sources

In the tropics, farmers combine species and varieties with differing habits and ecological preferences in their fields and yards in such a way that complex agro-ecosystems are established, occupying various strata, above as well as below ground. These diverse systems allow the entry and assimilation of new species originating from local/regional exchanges. As these tropical peoples came into contact with European colonizers, possibilities for the introduction of new species increased, and plants from other continents were also introduced into the set of species cultivated locally. For example, in fields cultivated by *caboclos*, *caiçaras*[2] and traditional farmers in various parts of Brazil, one finds plants of African, European, and Asian origins (such as watermelon, honey dew melon, okra, bananas etc.) cultivated alongside plants domesticated in Brazil, such as manioc, pineapple, and peanuts (Amorozo 1996; Peroni 2004; Martins 2005).

## Cultural criteria for selection

Every human group develops their own ways of satisfying their life needs, and in this sense, in no other domain is the maintenance of biological diversity so profoundly linked to the maintenance of cultural diversity than that of phytogenetic resources of cultivated plants. Aspects related to symbolic representations, as well as culinary and aesthetic preferences, have an important role in the maintenance of agricultural diversity. For example, the Kanaks of New Caledonia recognize two groups of species and varieties of bananas: the "true" or "ancient" bananas, which were probably introduced over 3000 years ago by the first colonizers, and "the others", which were introduced with the first contacts with Europeans. The former, which are still cultivated today, have sacred value and play a social role, whereas the others have a more commercial value. The "true" bananas represent the reincarnation of their ancestors; thus, each clan has various clones with recognized morphological identity, considered to be equivalent to their own identity and that of their ancestors (Kagy and Carreel 2004).

Different culinary uses may also contribute to the maintenance of plant diversity. In the Peruvian Andes, in areas where commercially-improved as well as native varieties of potatoes are cultivated, reasons given for the maintenance of the latter include important characteristics associated with their flavor and storage. They are preferred for their floury consistency and high content of dry material, and are recognized for retaining their palatability after months of storage, without becoming bitter (Brush *et al* 1981). In Mexico, each traditional recipe based on maize calls for a variety with distinct characteristics with respect to the consistency and texture of the kernel, pointing to an association between maize diversity and uses by different ethnic groups in various regions (Hernández 1985). Matthews (2004) examined culinary uses of taro (*Colocasia esculenta* (L.) Schott) in some locales where it has been cultivated for centuries. In southern Japan, for example, some recipes call exclusively for taro cultivated in wetlands, whereas others employ groups of varieties cultivated in dry soils. This distinction between dry-land and wetland varieties is important throughout most of the tropical Pacific, as are distinctions among types that mature early or late.

Nazarea (2006) highlights the affective dimension and the cultural memory imbedded in foods and locales. She argues that this helps small-scale farmers resist the assault of commercial agriculture and monoculture and continue planting a wide range of species and varieties in their fields and yards, "sustained by sensory recollections regarding the plants' aesthetic appeal, culinary qualities, ritual significance, and connection to the past" (p 325). Emperaire *et al.* (2001) identified, among other criteria for selection of manioc varieties used by a multi-ethnic indigenous community in the mid Rio Negro, in Amazonas, one of an affective order linked to its social origin. A variety may be appreciated for having been cultivated by the farmer's mother or grandmother, thus expressing continuity of lineage; or because it was offered or exchanged with someone, and thus symbolizes a relationship of alliance.

[2] In a broad sense, people of mixed European, Amerindian and to some extent African ancestry, living in Amazonia (*caboclos*) or in the Atlantic Rainforest (*caiçaras*).

## INTRA-SPECIFIC DIVERSITY

Innumerable studies have demonstrated the richness of varieties[3] maintained by traditional farmers, for most of the species cultivated and in all tropical regions of the world (e.g., Conklin 1954, 1963; Boster 1984a; Chernela 1986; Louette and Smale 2000; Elias *et al.* 2001; Emperaire 2002; Alvarez *et al.* 2005). The composition of the set of varieties is a result of constant processes of creation/introduction, experimentation, maintenance, or loss/discard. The manner of structuring the collection, with respect to the frequency and the cultivated area of each variety, the origin of the material, and the time of introduction, shows similarities in distinct communities of traditional farmers (Boster 1984a, 1984b; Chernela 1986; Bellon and Brush 1994; Amorozo 1996; Louette *et al.* 1997; Amorozo 2000; Alvarez *et al.* 2005). Below, some examples are presented from indigenous and mestizo farming communities whose main crop is either manioc or corn, two of the most important domesticated plants on the American continent (**Table 1**).

In the examples presented, some varieties have a high frequency of occurrence and occupy large total cultivated area, whereas a variable, sometimes large number of varieties have low frequency and are planted in a small area. Emperaire and Peroni (2007), in a compilation of data about manioc varieties cultivated by farmers in areas of the Atlantic Forest in southeastern Brazil (mestizos) and in the Amazon (mestizos and indigenous), reported that from 30 to 65% of the varieties in the locales studies in the Rio Negro (Amazonia), and between 38 and 53% of those studied in the Atlantic Forest, were planted by a single farmer. In four of the seven cases reported, no varieties were found that were cultivated by all the farmers. In the Brazilian state of Mato Grosso, in a case study carried out in Santo Antonio do Leverger, it was found that 45% of the 60 manioc varieties were planted by only one farmer (Amorozo 2000). Regarding communities with stronger links to the market, varieties planted in more extensive areas may be those that fulfill commercial objectives, whereas those occupying more limited cultivated area may be important for satisfying personal and local consumption preferences (e.g., Brush 1992; Amorozo 2000). The "rare" varieties sometimes do not even present characteristics of immediate interest, but function as a diversity "reserve" to be used in case of need. The set of varieties thus established allows the farmer to satisfy immediate requirements of consumption and/or commercialization, considering local environmental and economic restraints and, at the same time, helps farmers to maintain the flexibility necessary for dealing with uncertainties that they may have to confront with their own resources alone. It should be noted that, due to the restricted distribution of many of the varieties, each farmer's contribution to the set may present unique characteristics (Amorozo 1996, among others).

### Dynamic aspects

Various studies of small-scale farming suggest that the set of varieties available is not static over time. In most situations, there is an influx of varieties into the community and a certain degree of loss of existing varieties and substitution by others that are newly-created, recently introduced, or already existed in the set but at a very low level (Boster 1984a, 1984b; Chernela 1986; Amorozo 1996; Louette 1999; Brush and Perales 2007). The deliberate exclusion of varieties tends to be rare (Boster 1984a, 1984b; Amorozo 1996; Alvarez *et al.* 2005). In the case of manioc cultivated by the Aguaruna-Jívaro Indians, less interesting varieties are maintained at a low density as opposed to being simply discarded. Boster pointed out that the effort required to maintain a variety is small compared to the cost of abandoning it, because recovering it may be very difficult (Boster 1984a, 1984b). Also, the rarer varieties, or those planted in smaller quantities, are more subject to loss than those that are more common and abundant.

The length of time a plant is cultivated can vary. The degree of substitution may be smaller in more isolated communities than in more open populations, and there may be greater tendency to retain old varieties. In one of the Tukâno Indian villages studied by Chernela (1986), in the upper Rio Negro, in the Brazilian Amazon, close to one third of the 59 manioc varieties had been cultivated for over 40 years, whereas the others had been introduced more recently. The myth of the Desana Indians regarding the origin of food (*História de Baaribo*) cites 19 names of manioc varieties, most of which have been in continuous usage (Galvão and Galvão 2004; Emperaire and Peroni 2007). It would be necessary to know, in this case, whether the names maintained by the Desana have continued to refer to the same varieties over time. Among farmers in Cuzalapa, Mexico, inhabiting a still relatively isolated region, with characteristics of an indigenous society but gradually becoming more market-oriented, out of 26 varieties of maize planted, only six had been continually cultivated by at least one generation of farmers; only one variety was estimated to have been introduced about 40 years ago (Louette 1999).

The level of economic integration can influence the dynamic of substitution of varieties. For example, Brush and Perales (2007) compare populations of indigenous and mestizo farmers in Chiapas, Mexico. Although both groups produce maize for the market, the proportion of mestizos engaged in commercial production is greater; they push maize populations toward the more commercial types and are more dynamic with respect to trading their seeds. The indigenous populations maintain the maize seed lots, in the average, for a longer period of time than the mestizos. The older seed lots, which are found at higher altitudes (between 2000 and 2500 m above sea level), varied in age from 60 to 70 years. In less isolated farming communities in Santo Antonio do Leverger, in the Brazilian state of Mato Grosso, where farming is for subsistence as well as the market, only three of the 60 varieties of manioc had been cultivated for more than 40 years (Amorozo 1996). These cases suggest that, in general, in different situations, along with the dependence on plant materials maintained or created locally, these systems also depend on the introduction of allochthonous varieties, which extend beyond the borders of the communities to acquire regional dimensions.

### The keepers of diversity

Traditional farmers have a sharp perception of the importance of maintaining a significant set of varieties, and are attentive to every opportunity to renew their collection. Certainly this interest varies and may be dictated by cultural or individual reasons. Among the Amuesha Indians, for example, the shamans are the guardians of manioc diversity; they maintain a significantly greater number of varieties than other members of the tribe, and also cultivate varieties originating from hybridization (Salick *et al.* 1997). Age can be an important factor in determining the diversity of the stock maintained; Alvarez *et al*. (2005) showed, in a farming community in Cameroon, that the elders (in part because they possess larger fields) maintain a significantly greater number of sorghum varieties than the younger farmers, and serve as a source of material for the latter. Posey (1986)

[3] Defining the term "variety" is difficult, as it may have different meanings depending on the context (Emperaire 2000-2004). Different authors have different understandings of the concepts "local varieties", "ethnovarieties", "farm varieties" or "landraces", names given to refer to varieties maintained by traditional farmers (for a review, see Zeven 1998). Clement (1999) defines "landrace", as opposed to "modern cultivar", as "a domesticated (or occasionally semi-domesticated) population selected in a cultivated landscape, within a restricted geographical region with high phenotypic variability and relatively high genetic variability" (p 191). The articles cited in this review do not always clarify their definition of variety. For our purposes, in general, the varieties maintained by traditional farmers are those varieties that they recognize and identify.

**Table 1** Aspects related to the structure of sets of crop varieties maintained by traditional farmers. Relative importance: percentage of cultivated area and of farmers/fields (range of frequency variation refers to the most-planted varieties).

| Social group/locale Produced for: S=subsistence/M=market | Main crop/ approximate no. of varieties | Composition of the group of varieties | | References |
|---|---|---|---|---|
| | | Relative importance | Origin/time of introduction | |
| *mestizo*, *ejido*[a] Vicente Guerrero, **Chiapas, México** (97 farmers) **(**S,M) | Maize 15 | **4** varieties: ~82% of cultivated area; frequency from 40 to 80% of farmers | - ancient local varieties; - improved varieties (≤ 30 years); - hybrids of local and improved varieties | Bellon and Brush 1994 |
| *mestizo*/indigenous Cuzalapa, **Jalisco, México** (39 farmers) (S,M) | Maize 26 (six harvests) | **3** varieties: (local); 71% of cultivated area; frequency from 23 to 59% of farmers | - 23% local (> 30 years); - 77% regional (local and improved) | Louette *et al*. 1997 |
| Aguaruna/Jívaro Indians, Amazon Basin, **Peru** (62 farmers – 74 fields) (S) | Manioc > 100 (50 more common) | **4** varieties: ~69% of cultivated area; frequency from 59 to 71% of fields | ---- local/ some regional | Boster 1984a, 1984b |
| Tukâno Indians, Upper Uaupés River, **Amazonas, Brazil** (4 villages – unspecified no. of farmers) (S) | Manioc 59 and 75 in the 2 villages studied more closely (~137 total) | ---- | ~30% local (between 35 and 45 years); ~65% regional (introduced at various times) | Chernela 1986 |
| Small-scale farmers (‘peasants’), Santo Antonio do Leverger, **Mato Grosso, Brazil** (27 farmers) (S/M) | Manioc ~60 | **3** varieties: 79% of cultivated area; frequency from 44 to 93% of farmers | -15% local (10% autochthonous–hybridization at various times; 5%> 40 years); 78% regional (introduced at various times) | Amorozo 1996 |
| Kuikuro Indians, Upper Xingu River, **Brazil** ---- | Manioc 50 | **6** varieties: 96% of cultivated area | ---- | Carneiro 1983; *apud* Chernela 1986 |

[a] *Ejido* – communal land shared by the people of a community.

also reports that, among the Kayapó Indians in the southern part of the state of Pará, Brazil, a particular type of field of tubers (including Araceae, Zingiberaceae, and Marantaceae species) cared for exclusively by the elderly women, represents a source of diversity of these plants. Individual variations in interest in maintaining plant diversity are found in many situations studied, where key individuals are located who have fundamental importance not only in the maintenance of diversity, but also in the dissemination of species and varieties in farming communities (Boster 1984a, 1984b; Amorozo 1996, 2000; Alvarez *et al.* 2005).

## SUPPLY AND CIRCULATION OF PROPAGULES AND SEEDS

An essential aspect of the operation of any farming system is the guaranteed supply of material for planting the next crop. The term “seed” is commonly used in the literature to refer to any type of material for planting, including vegetable parts such as tubercles, bulbs, offsets, and pieces of stem, as well as seeds themselves (Hodgkin and Jarvis 2004). The term will be used here with this meaning.

The understanding of some authors is that the various processes involved in the provision, selection, and storage of seeds can be considered as a system (McGuire 2001, *apud* Hodgkin and Jarvis 2004). The concept of a “seed system” generally takes into account the actors (farmers, local institutions, and institutions of the formal sector), the components (different types of planting material), and the processes (Hodgkin and Jarvis 2004). In addition, one can distinguish between a formal and an informal seed supply sector. The formal sector, administered by government institutions and private companies focused on seed improvement, offers commercial crop material aimed at greater productivity and meeting market demands, generally with the objective of making a profit; these have penetrated traditional farming areas since the dissemination of the “Green Revolution” in developing countries in the 1960s. The informal seed sector, on the other hand, includes farming communities and local seed circulation networks, and supplies planting material developed locally or regionally. It plays a much more important role in the supply of seeds for traditional or subsistence farmers. In the case of locally important crops with no significant market value, it is the only possible source for acquiring seeds.

Clear distinctions can be discerned between the two sectors with respect to their objectives, the groups that control them, their knowledge base, and their culture (Gonzáles 1999; Baniya *et al.* 2004; Riesco 2004); when dependence on the formal sector increases in traditional farming areas, this can lead to a loss of autonomy for farmers and entanglement with an expensive technological package, as well as genetic erosion. However, farmers’ capacity to experiment with and adopt innovations to their own context (Johnson 1972; Bellon and Risopoulos 2001; Pinedo-Vasquez *et al.* 2004; Brush and Perales 2007, among others) has made it possible, in some situations, for farmers to adopt some varieties offered by the formal sector, integrating them into the local farming system and maintaining their fundamental characteristics (Brush 1992; Bellon and Brush 1994; Louette 1999; Latournerie *et al.* 2004, Pinedo-Vasquez *et al.* 2004; Brush and Perales 2007, among others). In some cases like this, although the diversity of local varieties may be maintained, the area where they are planted may be diminished, leading to changes in the population structure and loss of intra-varietal diversity (Brush 1992).

The adoption of commercially improved varieties can lead, in the case of open pollination species, to the appearance of “creole” races resulting from their hybridization with local varieties, accidental or otherwise. Bellon and Risopoulos (2001) discuss the modification of a commercial variety of maize by farmers in Chiapas, México, and its implications for the local farming system. The commercial variety had desirable characteristics but required intensive use of agricultural inputs, which limited its use only to the farmers who were better off. The alterations made by the local farmers, despite causing a decrease in performance with respect to production and maturation, allowed greater adaptation and stability, making it more appropriate for planting by the poorer farmers, as well. The management practices of the farmers in Chiapas combine varieties with contrasting, albeit complementary, characteristics of three different groups: local varieties, commercial varieties, and the “creoles”, which in various aspects, have characteristics that are intermediary between the first two groups. The result is a set that performs in such a way as to compensate for the occasional variations in local environmental conditions.

In rural communities of the Peruvian Amazon, Pinedo-Vasquez *et al.* (2004) analyzed how farmers and other local actors took advantage of knowledge and technologies of short-term seed quality improvement programs provided by governmental agencies and NGOs, integrating them into their own traditional system through complex networks of relations between farmers, travelers, businessmen, rural technicians, teachers, and urban entrepreneurs, thus creating a hybrid system between the formal and informal sectors. Their study showed that, in this case, differentiation between the formal and informal sectors proved to be difficult, because complex patterns emerged from both.

The set of varieties that each farmer plants each season is composed of those that he/she already planted and those with which he/she has come into contact as a result of everyday opportunities that arise, depending on the circumstances and events of his/her life. The diversity found at any given moment in a community of traditional farmers has basically three sources: a) the stock already established by the farmers; b) the recombination of different varieties/ introgression with related species and the opportunity for local emergence of new varieties promoted by the very dynamic of small-scale farming itself – shifting cultivation, polyvarietal cultivation, etc.; and c) provision of material from inside or outside the community, on a local or regional scale, channeled by social and/or commercial relations. The recently-created or recently-introduced variety, after the first crop cycle, will be evaluated by the farmer, and may or may not be integrated into the stock of varieties for a period of time and disseminated through social networks.

In general, the farmers' main source of seeds is the material originating from their own fields. When dealing with the cultivation of grains, the seeds gathered from the harvest are stored using different techniques (i.e., in hermetically sealed clay pots buried upside down (Worede *et al.* 1999), in containers with sand, lard, or other medium to prevent weevils, etc.), and there is little flexibility with respect to planting and harvest times. On the other hand, for many vegetatively-propagated plants in the humid American tropics, such as manioc, sweet potatoes, taro and yams, it is not necessary to collect the roots and tubercles in a specific season, as they can be stored in the soil as live plants (Martins 2005). Some ways of conserving propagules, which are branches, stem cuttings, or segments of tubercles, and whose viability can be rapidly lost, depending on the climate, include: alternation of different planting areas – for example, in many regions where fields are located in floodable areas, along river banks, sweet potatoes and manioc are cultivated in the field during the low water season, and in the backyard during high water (Amorozo 1996); simultaneous cultivation of plants of differing ages and staggering of the harvest, leaving part of the crop to be harvested closer to the time of the next planting, or planting continuously, right after the harvest, when the weather permits. In addition, in the case of manioc and sweet potato[4], the organ of propagation is not the same as that consumed, resulting in an "*agronomic disjunction* between production and reproduction" (Martins 2005, p 212). It is not necessary for the farmer to avoid consuming part of what is produced in order to use the seed in the next planting, as occurs with grains (Martins 2005). This can affect availability, circulation, and dissemination of these materials.

## Sources of germplasm

When a farmer cultivates a field for the first time, suffers total loss of his/her own planting material for some reason (environmental stress, family problems, changes in land use), or needs seeds to finish planting the area to be cultivated, he/she seeks planting material from other farmers or turns to sources outside the community to obtain propagules. In these situations, the choice of varieties for planting may be restricted.

However, even if the farmer has enough seeds, his/her interest in trying new varieties will make him/her sensitive to new materials that he/she may come into contact with. For example, in a study of small manioc farmers in rural communities in Mato Grosso, in midwestern Brazilian, it was found that 58% (in two different crops) had obtained material for planting from outside of their own fields with the sole intention of trying new varieties (Amorozo 2006).

There is yet another reason for the entry of planting material from external sources. The farmers often note that varieties become "tired" and need to be substituted (Quiros *et al.* 1992, *apud* Wood and Lenné 1997). One explanation given by the farmers is that, as one plants the same material year after year in the same location, it "loses strength" and produces less (Amorozo 1996). The change may involve substitution of the seed of one variety for the seed of another variety, or may involve material of the same variety from another locale. It may be obtained from the fields of other farmers or purchased, and may occur relatively regularly. Zeven (1999) presented a history of this practice, based on sources consulted going back to Biblical times[5]. Modern-day examples are still very common – maize in Mexico (Louette 1999), potatoes in the Andes (Quiros *et al.* 1992, *apud* Wood and Lenné 1997), manioc in Brazil (Amorozo 1996), and various crops in Nepal (Baniya *et al.* 2004), among others. Swanson and Goeschl (1999) discuss the question of the depreciation of existing varieties, referring to agricultural systems in general; citing Evans (1993), they point out that, in many cultures studied, "yields of the most intensely cultivated varieties decline over time due to evolution in pests and diseases" (p 175). This decrease is not due to the depreciation of the germplasm itself, but to changes in the environment that render characteristics formerly appropriate for previous conditions inappropriate under the altered conditions. This problem can only be overcome if the genetic composition of a crop is continually altered (Swanson and Goeschl 1999). This observation can aid in understanding the behavior of traditional farmers when they substitute material from a local variety with material from the same variety acquired from another farmer or another area (Amorozo 1996; Louette 1999). Local or traditional varieties have high genetic variability and are composed, in many cases, of a relatively wide range of genotypes. Thus, one could advance the hypothesis that the same local variety, derived from various origins, could contain a different combination of genotypes, and substitution would serve to revitalize local germplasm – for example, introducing genes that confer greater resistance to pathogens or improved adaptation to the climate.

Non-institutionalized circulation networks are very efficient for maintaining and supplying germplasm in small-scale farming systems, providing them great resilience (Emperaire 2006). There are cases in which this circulation is strongly based on the social structure of the group, with exchanges occurring via well-defined channels. For example, among indigenous groups in the upper Rio Negro, in the Amazon, the circulation of manioc varieties occurs among female family members, via networks established through exogamous marriages between members of villages from different groups. The wife goes to live in the husband's village and receives the first stock of varieties from the mother-in-law. During visits to her native village or to family and allies in other villages, she takes new varieties to bring home and distributes them to other women who request them. According to the rules of reciprocity, they will return the favor. Such exchanges are very active, and the varieties are rapidly disseminated over a radius of hundreds of kilometers (Chernela 1986; Emperaire 2002). On the other hand, in some cases, such networks are looser, and the circulation is more opportunistic. This can occur where the exchange of germplasm carries a weaker cultural weight, and is simply utilitarian, as pointed out by Pinton and Emperaire (1999) in a study among migrant settlers in the region of Altamira, PA, Brazil.

More than one type of circulation may occur via the social network. The most common situation is when a variety is solicited by someone and the keeper of the seeds res-

[4] In the tropics, sweet potatoes are propagated by stem cuttings (Purseglove 1987).

[5] One can speculate that it is as old as agriculture!

ponds positively to the request, obeying rules of collective solidarity and reciprocity common among traditional farmers (Amorozo 1996; Emperaire *et al.* 2001). In crops where the organs of consumption and of propagation do not coincide, one can expect fewer restrictions on the free donation of significant quantities of propagules if the farmer receiving the request has an extra supply that he/she does not intend to use (Amorozo 1996; Emperaire *et al.* 2001). On the other hand, in crops where the organs of consumption and of propagation do coincide, such donations can be expected to be more rare, and the provision of seeds more often associated with conditions of an immediate, equal exchange or some type of payment – such as a product, labor, or cash. This opens the door for the trading or purchase of seeds in local markets, which can be very relevant in some situations (Worede *et al.* 1999; Latournerie *et al.* 2004; McGuire 2007).

### The social significance of diversity

In many cases, maintaining the diversity of crops has value in itself that is culturally-recognized. Possession of an assorted set of varieties, and the ability to comply with the requests of other farmers when solicited to do so, is a sign of the farmer's prestige and reinforces his/her social position. Inversely, those who have a tendency to ask systematically can have weaker social status and greater dependence (Emperaire *et al.* 2001; Alvarez *et al.* 2005). Offering a variety to someone can be a gesture to please him/her. In this situation, it may serve to strengthen alliances, and the varieties offered are generally of private stock, not disseminated very much, and have well-defined characteristics (Emperaire *et al.* 2001).

In addition to following local rules of social conduct, the provision of seeds to other farmers, upon request or spontaneously offered, functions to protect against farmers' occasional losses, since they can rely on the network to which they belong to replace this material. A recently-acquired variety for which planting material is limited can also enter into the circulation network as a way to guarantee its propagation in different situations, but in this case, the recipients will be a restricted group, selected in accordance with the level of trust placed in them by the donor – generally family and friends, or close neighbors (Amorozo 1996).

When traditional communities become more subject to external influences, the size and composition of the networks can undergo changes, as well as the nature of the material that circulates through them. The opening of and greater dependence on the market economy have various consequences for the circulation of germplasm and maintenance of agricultural diversity. Often the market begins to define what should be planted, resulting in specialization and simplification of the farming systems. To meet external demands, the most-planted varieties will tend to obey criteria of productivity (greater yields, earlier maturity) or specific characteristics of the product to be commercialized. Those that are not appropriate may be planted in smaller quantities and run the risk of loss, or may simply be discarded. On the other hand, greater contact of traditional communities with the national society also provides opportunities to broaden the networks through which varieties are circulated, with the inclusion of elements from other areas or even regions (Amorozo 1996, among others).

## CLASSIFICATION, PERCEPTION, AND MANAGEMENT OF INTRA-SPECIFIC DIVERSITY BY THE FARMER

The management of agricultural diversity presupposes the existence of conceptual frameworks to organize knowledge about agricultural and ecological processes and about varieties themselves. Many studies have been carried out regarding the important role played by folk taxonomy in the maintenance of crop diversity. The rich nomenclature and systematic classification of varieties is evidence, for some authors, of the intentionality of the maintenance of agricultural diversity by local farmers (Brush 1992).

The naming of a variety usually tells something important about it. Some examples of references used to name manioc varieties are presented below. An initial broad classification distinguishes between bitter (*brava*) and sweet (*mansa*) manioc. Farmers generally differentiate them by associating a bitter flavor with the varieties that are *brava*, which in many cases is a reflection of the cyanogenic glycoside content of the roots (Chiwona-Karltun 2004), and which will influence the way they are processed. Although there is no unequivocal relation between morphological characteristics and toxicity, farmers also develop, in certain cases, criteria that more or less serve to identify locally maintained varieties. In Santo Antonio, Mato Grosso, Brazil, for example, farmers generally classify the varieties that have white root skins as *brava* and those that have red root skins as *mansa*, although they recognize some exceptions (Amorozo 2000). Among the criteria used to name varieties, it is worth noting references that are based on analogies between plants and animals, morphological or behavioral[6], and those that are based on morphological aspects of the varieties with descriptive names (Amorozo 1996; Emperaire *et al.* 2001; Emperaire and Peroni 2007); these criteria directly aid in their identification. When the name of a person is attributed to a variety, it generally indicates the farmer who first appeared with it or provided the seed. In this case, the reference serves to identify the source of a given variety and can be useful for obtaining it (**Table 2**).

On the other hand, manioc originating from sexual reproduction may be generically named for its lack of filiation – *sem nome* (no name), *sem pai* (no parent), *de semente* (from seed), *achada* (found) (Emperaire *et al.* 2001), *aparecida* (appeared) (Amorozo 2000). As it is disseminated among farmers, it may acquire a name based on its distinctive characteristics or after the farmer in whose field it appeared – for example, *de Joãozinho*, *de Dimas* (Amorozo 1996). Or it may be assimilated to an existing variety, when there are no perceived differences between the newly appeared individual and a variety the farmer already has. There are individual differences with respect to precision in the identification of varieties; some farmers establish finer distinctions within the same variety, recognizing sub-varieties, based on alterations of a particular character, such as the color of the stem, architecture of the plant, etc. Generally these are the older and more experienced farmers (Amorozo 1996; Sambatti *et al.* 2001).

In his classic studies of manioc varieties among Aguaruna-Jívaro Indians in the Peruvian Amazon, Boster (1984a, 1984b, 1985, 1986) analyzed, among other themes, the role of cultural consensus and perception of morphological differences in shaping the stock of varieties maintained by the community, establishing a relationship between the pattern of transmission of knowledge about manioc and the pattern of exchange of manioc varieties; for the more common varieties, the identification pattern was found to fit the cultural consensus model (Romney *et al.* 1986, *apud* Boster 1986), whereas for the less planted varieties, a pattern of agreement was detected related to kinship ties, which was interpreted as being due to the fact that a variety, or name of a variety, was restricted to a particular kinship group (Boster 1986). Evidence is also presented that manioc varieties were selected for combinations of characteristics that make it possible to distinguish them perceptually, which could explain why they are so variable with respect to salient taxonomic traits (for example, color of the stem and the petiole, shape of the leaf), which are unrelated to their use or the survival of the plant (Boster 1985). Sambatti *et al.* (2001) found this same pattern for manioc varieties cultivated by

[6] Behavioral analogies are rarer. Valle (2002) gives the examples of the *tatu* (armadillo) manioc, which was given this name because its root goes deep into the ground, like the animal, making it difficult to pull out.

**Table 2** Some examples of referential frameworks for naming manioc varieties ([a] Amorozo 2000; [b] Emperaire *et al.* 2001; [c] Valle 2002).

| Referential framework | Variety name | Meaning |
|---|---|---|
| **Donor, introducer** | *De Joãozinho* [a], *de Dimas* [a], *de Chefe* [a], *Marcolina* [a] | First farmer who appeared with the variety or disseminated it |
| **Similarity with plants or animals** | | |
| Plants | *Seringueira* [a] (rubber tree -*Hevea brasiliensis*), *embaúba* [a] (cecropia - *Cecropia* sp.), *inajá* [b] (inaja palm - *Maximiliana regia*), *abóbora* [a] (pumpkin - *Cucurbita* sp.) | The general aspect of the plant, or part of it, reminds one of another plant or an animal |
| Animals | *Jabuti* [b] (land turtle), *pé-de-paca* [a] (paca's foot), *juruti* [a] (a kind of bird), *matrinchã* [a], *surubim* [b] (kinds of fish), *tatu* [c] (armadillo) | |
| **Architecture or size of the plant** | *Gaiadeira* [a] (branchy), *baixinha* [a b] (small), *pinheirinho* [c] (little pine), *bambu* [c] (bamboo) | Branching or lack of branching |
| **Color** | *Branquinha* [a] (little white), *vermelha* [a] (red), *pretinha* [a] (little black), *manteiga* [c] (butter), *ouro* [c] (gold) | Predominant color of the plant or a part of it |
| **Toxicity** | *Amarguenta* [a] (bittery), *gaiadeira-mansa* [a] (sweet-branchy), *gaiadeira braba* [a] (bitter-branchy) | Toxicity perceived through the bitter taste |
| **Others** | | |
| Culinary | *Cinco-minutos* [c] (five-minutes), *apronta-a-mesa* [c] (set-the-table) | Cooks rapidly |
| Agricultural | *Ligeirinha* [c] (fast), *seis-meses* [b] (six-months) | Early maturity |

traditional farmers in the Atlantic Forest in southeastern Brazil. Evidence of this type of strategy can be found for other crops, as well. Mathews (2004) cites the diversity of color patterns of corms and leaves of taro varieties in the Pacific Islands, suggesting that selection for ornamental and attractive color patterns may serve to facilitate the distinction and maintenance of plants with other less visible characteristics. Hernández (1985) also reported use of maize kernel color as an indicator of varieties with certain ecological, dietetic, and medicinal characteristics by farmers in various regions of Mexico.

## Evolutionary aspects

Accuracy in taxonomic identification plays a relevant role in the determination of evolutionary pressures on the plant, since the selection carried out by the farmer affects the varieties he/she identifies and recognizes (Elias *et al.* 2000; Sambatti *et al.* 2001). Therefore, one may ask how accurate and discriminatory is the identification demonstrated by the traditional farmer and the implications of this for the morpho-agricultural and genetic structure of a variety, and for the local maintenance of agro-biodiversity. In the following, examples from studies of manioc and maize are presented.

Manioc, which is propagated vegetatively, nevertheless retains its capacity for sexual reproduction, so that it can cross-breed with individuals of the same or different varieties in the farmers' fields, which may result in a new variety. Farmers normally plant these recombinants to learn about their properties, and occasionally include them among the varieties they cultivate. Elias *et al.* (2001) studied morphological and genetic diversity of manioc planted by the Makushi Indians of Guyana. Phenotypic diversity was evaluated by comparing agronomical features and 14 morphological characters that were important in the farmers' identification of the varieties. Genetic diversity was characterized by AFLP[7] primers and the Mantel test was used to compare matrixes of genetic distance and morphology. They found that morphological and agronomical characteristics were highly variable **among** the varieties, in such a way that they could be differentiated. However, they also detected high variability **within** the varieties, which could lead to confusion among phenotypically similar varieties. Individuals originating from sexual reproduction, on the average, differed from the set of varieties studied, but 67% resembled one of the varieties closely enough to be assimilated to it. Thus, the genetic variability within the varieties is likely to be related to the lack of discrimination among very similar varieties and the attribution of an individual originated from seed to an existing variety. The authors concluded that "diversifying selection, exchanges of varieties between farmers, and incorporation of sexually produced volunteer plants are key mechanisms responsible for the high diversity observed" (Elias *et al.* 2001, p 143).

Along these same lines, Peroni (1998) and Peroni *et al.* (1999) used morphometric and genetic tools to study the local taxonomy of manioc varieties among *caiçara* farmers in southern São Paulo State, Brazil. They found coherence in identification with respect to morphological discontinuities, but underestimation of intra-varietal variability in relation to genetic characteristics (Peroni 2004). They posited that this could be related to inter- or intra-varietal cross-breeding, which may or may not result in individuals that are morphologically similar to the parent plants. If the differences are small, and do not drastically affect morphological characteristics that are important for their identification, the new individuals, which can later be multiplied through clonal reproduction, are given the name of the existing varieties. Thus, they suggest that a local manioc variety may, in fact, constitute a "family of genotypes", with individuals that have great morphological resemblance but genetic divergences (Peroni 2004).

Maize is an open-pollination species, and hybridization occurs among cultivated varieties as well as other species of *Zea*. The maintenance of distinct varieties depends on human intervention. For Bellon and Brush (1994), one of the great feats of Meso-American farmers was the development of knowledge for the maintenance of varieties capable of meeting different cultural and agronomical criteria. In the region of Chiapas, Mexico, where they conducted their studies, farmers plant varieties that are appropriate for different soil types and different uses, in very small fields. There is no spatial isolation among them, and temporal isolation only for some, so that cross-breeding occurs among varieties. Distinct varieties of maize are maintained through seed selection, which is not done in the field, but from the ears of maize that are harvested, taken home, and separated according to the variety. The best ears are opened and examined, selecting those that have the ideal type for the variety, based on color and size of the grain, density and shape, length of the corncob, and number of rows of grains.

Louette and other authors suggest that farming communities should not be understood as closed or isolated with respect to the introduction of germplasm. She and collaborators analyzed the cultivation of maize in Cuzalapa, Mexico, where a complex combination of hybridization resulting from cross-breeding of plants grown from local variety seed lots and plants grown from introduced seed lots, from varieties that were equal to or different from the local ones, together with the selection carried out by the farmer based on characteristics of the corn-cob and the grain, allow a delicate balance that prevents, on the one hand, genetic drift (since the number of grains of each variety planted is very small), and, on the other hand, maintains the distinctive cha-

[7] Amplified Fragment Length Polymorphism.

racteristics of the varieties. It is clear that the agricultural system that maintains the local varieties depends on the circulation of planting material within and among the communities to function (Louette *et al.* 1997; Louette 1999; Louette and Smale 2000; Perales *et al.* 2003; Louette 2004).

Thus, it can be said that the diversity of varieties maintained by traditional farmers is, in general, greater than they are aware of. Their level of identification and discrimination is sufficient to maintain enough diversity for the traditional farming system to function well. However, it may not be sufficient for *in situ*[8] conservation programs aimed at the conservation of genes or specific genotypes (Louette 1999). Traditional farming systems would be efficient for maintaining characteristics or adaptations of a plant population for generations, but the subjacent genotypes would change, which does not make them efficient for the preservation of all the existing biodiversity at the genetic level (Brown 1999). The nature of these changes has been studied little as of yet; they may occur as a result of various types of events, including stochastic events, like bottlenecks in the size of the population, sporadic migration, and variation in the cross-breeding system, as well as systematic events, such as selection by the farmer, deliberate as well as inadvertent, and mixture and hybridization (Brown 1999). However, it may be more important to maintain a high level of genetic and phenotypic diversity, a fact which is inherent to small scale farming systems, than to conserve individual varieties (Louette 1999).

## CONCLUSIONS – PERSPECTIVES ON *IN SITU* ON-FARM CONSERVATION AND TRADITIONAL FARMING

Maintaining the diversity of plant species and varieties cultivated in traditional farming systems is, as we have seen, a highly dynamic and complex process, inseparable from the culture and social organization of the farmers. It takes place inside the social fabric, with the circulation of seeds being one of the crucial points for its continuity. The knowledge and know-how passed within and among generations orally and through experience – local ecological knowledge, knowledge about the characteristics of each plant – as well as cultural aspects – preferences, motives related to prestige, identity, affect, etc., that give meaning to the existence of a society as an individualized group – will provide the basis and the meaning for this maintenance.

Currently, scientists and plant breeders around the world are interested in the conservation of local agricultural diversity by traditional farmers, considering their importance as a source of material for commercial genetic improvement and for the stability of the world food system. Brown (1999) observes that these farmers are crucial partners in the process of *in situ* conservation of cultivated plants, pointing to the importance of local knowledge regarding traditional management systems for the maintenance of diversity. Farmers' knowledge about the varieties he/she plants is also key to the *ex situ* conservation of genetic material (Valle 2002). At the same time, it should be noted that little information is available regarding the dynamic of this type of knowledge (Brown 1999).

The future of many of these traditional farming systems throughout the world is uncertain, however. The advance of large-scale mechanized farming, on the one hand, and the influence of urban-industrial society and integration with the market, on the other, have had consequences that profoundly affect them and place the maintenance of agricultural diversity at risk. In Brazil, the dominance of the agribusiness industry oriented toward export and energy production in areas that were originally occupied by traditional farmers has created land tenure situations that are unfavorable for them, resulting in a decrease or even total loss of their land for sustaining their livelihood. The low wages paid to rural workers, the lack of opportunities and incentives for younger generations to remain in their communities, and the dissemination of the urban ideology of consumerism, increase rural exodus, making it difficult to replace family workers, with pernicious consequences for the continuity of farming activities. Even where small-scale farming systems have been maintained, the farmer's access to other forms of risk minimization (monetary, for example) can result in diversity no longer having the same survival value as before, and may affect the social mechanisms that gave it priority. When part of the traditional farming families migrate to urban areas, at least some of the agricultural diversity may be maintained in this new environment. However, this depends on the continuation of rural habits by the migrating members, and the articulation and intensity of exchange between rural and urban zones. Urban yards on the outskirts of cities can act as spaces for this maintenance (Winklerprins 2002), where some resources may prosper while others dwindle. In the case of manioc, for example, the preferred varieties for planting near domestic units in general are the sweet varieties (*mansa*), which have lower levels of cyanogenic glycoside, and in this situation, the bitter varieties (*bravas*) run greater risk of being abandoned (Peroni and Hanazaki 2002).

For Brush (1999), the continuity of traditional farming systems and the conservation of phytogenetic resources through their use, as has been done for thousands of years, are threatened by the advent of a globalized society. To mitigate this problem, programs promoting on-farm conservation subsidized by governments and private organizations, with the farmer's participation, have been encouraged and established in certain conditions. Given the dynamic of farming systems, it is a fairly complex task, and such programs have often been conceived to fulfill objectives that are not always shared by the farmers, and using techniques that may not be local. Emperaire and Peroni (2007) observe that conservation programs, whether they be *ex situ* or on-farm, are focused on "finalized biological objects"; i.e., they attribute much more emphasis to the species and varieties cultivated than to the process of local construction and perception of the "objects" by the traditional farmers. They point to the need to make "conservation and valorization models compatible with the local construction of agrobiodiversity" (p 761).

In this sense, it is essential to discern the farmers who are behind the great agricultural diversity maintained by them. Gonzáles (1999) emphasizes the importance of recognizing the different epistemologies reflected in the maintenance of agricultural diversity by indigenous peoples and in the efforts of the urban-industrial society to promote *in situ* conservation. In relation to this point, it is also worth observing that research efforts are mainly concentrated on agricultural crops that are important commodities, such as maize and rice (Clement *et al.* 2007). More research is needed that focuses on important local crops and semi-domesticated plants or plants in the process of being domesticated by traditional farmers.

Understanding the dynamic of agro-biodiversity maintenance by traditional farmers requires an integrated approach that takes into consideration the sociocultural and biological aspects involved, as well as those related to management, that operate at different levels, from the local to the regional (Peroni 2004). Because of its interdisciplinary nature, characterized by the use of methods from the natural as well as the social sciences, the field of ethnobotany is well-equipped to contribute to this understanding. The study of local knowledge related to agricultural practices and management and regarding the varieties planted provides impor-

[8] According to Brown (1999), "*in situ* conservation of agricultural biodiversity is the maintenance of the diversity present in and among populations of the many species used directly in agriculture or used as sources of genes in the habitats where such diversity arose and continues to grow" (p 29). On-farm conservation is a term applied to conservation, in agricultural systems, of the cultivated species, whereas conservation *ex situ* is that done outside natural habitats or productive systems (Bioversity International 2008).

tant contributions to the understanding of farming systems from the perspective of farming populations. In this sense, ethnobotanical studies have the potential to establish bases for guiding research efforts related not only to *in situ* and *ex situ* conservation (Brown 1999; Valle 2002), but above all, to consider what is in the interest of the farming populations themselves. Only in this way will it be possible to implement public policies aimed at on-farm conservation that are compatible with the local reality and therefore more likely to have permanent and lasting effects.

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