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Genetic conservation: a role for rice farmers

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17.1 INTRODUCTION

The genetic resources of rice have been well utilized in efforts to solve today's food problems. Rice land races, collected over several decades, have become 'parents' of the high-yielding, pest-resistant and well-adapted varieties which resulted in unprecedented increases in rice yields. The cost of rice to millions of consumers is now approximately half what it was in 1960 because of these gains in productivity.

The diversity of the rice crop has evolved over thousands of years, as Asian and African peasant farmers – mostly women – selected different types to suit local cultivation practices and needs. This process of selection has led to numerous rice varieties adapted to a wide range of agro-ecological conditions, and with resistance to insect pests and diseases. The number of varieties of Asian rice, *Oryza sativa*, is impossible to estimate, although claims of more than 100 000 have been made (Chang, 1985, 1995). Asian rice varieties show an impressive range of variation in many characters, such as plant height, tillering ability, maturity and size of panicles, among others. Variation in grain characters such as size, shape and colour is most useful for distinguishing different varieties. Some wild species occur as weeds in and around rice fields, and even hybridize naturally with the cultivated forms. This complex association between cultivated and wild forms has enhanced the diversity of the rice crop in traditional agricultural systems, where farmers often grow mixtures of varieties to provide a buffer against the risk of complete loss

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of the crop due to biotic and abiotic stresses.

Rice farmers in Asia continue to grow thousands of different varieties for specific traits, such as aroma or cooking quality, or because of a particular cultural aspect (Figure 17.1). However, there is widespread concern over the loss of the genetic diversity represented by these varieties, particularly as they are replaced more and more by a few genetically uniform, high-yielding varieties in many farming systems (Hawkes, 1983; Plucknett *et al.*, 1987; Brush, 1991a; Harlan, 1992; National Research Council, 1993). The need to conserve the diversity found in crop land races has been recognized as important for many decades. *Ex situ* conservation – the storage of seeds in gene banks – has been the principal strategy for the preservation of crop genetic resources, and this applies especially to rice. *Ex situ* conservation is static conservation that aims to retain as far as possible the structure of the original population (Guldager, 1975). Seed storage is a safe and efficient way of conserving rice genetic resources, and has the advantage of making the germplasm readily available for use by breeders and for study by other researchers (Ford-Lloyd and Jackson, 1986). Rice has so-called orthodox seeds that can be dried to a relatively low moisture content (± 6%), and stored at subzero temperatures. Under these conditions, the viability of rice seeds can be assured for many years – certainly decades, if not considerably longer. Therefore, this strategy has been favoured for the conservation of cultivated rices.

Lately, on-farm conservation (Altieri and Merrick, 1987; Oldfield and Alcorn, 1987; Brush, 1991a; IPGRI, 1993) has been advocated to complement *ex situ* conservation. For more than two decades, on-farm conservation of crop land races was considered as impractical and inappropriate (Arnold *et al.*, 1986). However, concern in developing countries about the concentration of genetic resources in gene banks in the industrialized countries and the fact that static conservation halts evolutionary processes have opened a debate concerning the value and objectives of on-farm conservation methods. Rural societies maintain agricultural biodiversity because it is essential to their survival. They select and breed new varieties for the same reason. There is no useful distinction for them between conservation and development. Indeed, conservation as such may not be a concept known to farmers. On-farm conservation of local varieties is an existing strategy for food security. It is a potential strategy for genetic conservation. By its very nature, on-farm conservation is dynamic because the varieties that farmers manage continue to evolve in response to natural and human selection. It is believed that in this way crop populations retain adaptive potential for the future.

In south and south-east Asia, the community of non-governmental organizations (NGOs) has been particularly active in support of farmer and community groups that have begun to conserve traditional rice varieties in community seed banks, or in dynamic on-farm management systems (Salazar, 1992). The Thai-based Technology for Rural and Ecological Enrichment (TREE) and the Philippine-based South East Asia Regional Institute for Community Education (SEARICE), Farmer–Scientist Participation for Development (MASIPAG), and the Sustainable Agriculture Coalition have been working with farmers and community groups to collect and manage traditional rice varieties as part of farming systems. However, their work has not been well documented, and we are unable to comment on the nature and scope of their activities.

Brush (1995) has suggested that, besides directly providing genes for crop improvement, on-farm conservation should be seen as satisfying four other needs:

- It preserves evolutionary processes that generate new germplasm under conditions of natural selection.
- It maintains important field laboratories for crop biology and biogeography.
- It provides a continuing source of germplasm for *ex situ* collections.
- It provides a means for wider participation in conservation, allowing for a more equitable role for nations with abundant crop germplasm resources.

In this context, therefore, on-farm conservation of crop genetic resources can be defined as the continued cultivation and management of a diverse

Figure 17.1 Surveying rice land race in Indonesia.

set of crop populations by farmers in the agroecosystems where a crop has evolved. This set may include the weedy and wild relatives of the crop that may be present together with it, and in many instances tolerated. It is based on the recognition that, historically, farmers have developed and nurtured crop genetic diversity, and that this process continues in spite of socio-economic and technological changes. It emphasizes the role of farmers for two reasons:

- Crops are not only the result of natural factors, such as mutation and natural selection, but also and particularly of human selection and management.
- In the last instance, farmers' decisions define whether these populations are maintained or disappear.

In spite of increasing interest in on-farm conservation, which is even addressed in the Convention on Biological Diversity, there is still limited knowledge about what this approach means, and even less understanding of its various social, economic, cultural and genetic aspects. There have been only a few studies aimed specifically at documenting and understanding the conservation and management of crop genetic resources among small farmers (e.g., Brush *et al.*, 1981, 1992; Dennis, 1987; Quiros *et al.*, 1990, 1992; Bellon, 1991; Zimmerer and Douches, 1991; Bellon and Brush, 1994; Brush, 1995;).

Many questions remain to be answered about the viability of on-farm conservation for genetic conservation. In what way do varieties change over time? Do farmers conserve varieties or do they conserve traits, such as aroma, plant architecture, or disease resistance, for example? What is the importance of seed exchange among farmers for enriching their germplasm? Why do some farmers continue to grow their local varieties and yet others have abandoned them in favour of improved varieties? What is the degree of outcrossing between varieties in farmers' fields, and so on?

In rice there are several studies on the adoption of modern varieties (e.g. Huke *et al.*, 1982; Herdt and Capule, 1983; David and Otsuka, 1994) and some studies, among them several ethnographies, that give detailed accounts of the management and use of traditional varieties (Conklin, 1957; Rerkasem and Rerkasem, 1984; Lambert, 1985; Richards, 1986; Lando and Mak, 1994a,b,c). There are few studies, however, aimed at describing and understanding the way farmers maintain and manage rice diversity, as well as the factors that influence these (Dennis, 1987). The lack of such studies on rice contrasts with its importance as a world crop, and with the impact that modern varieties have had on farmers.

This chapter discusses some important issues related to the on-farm conservation of rice, namely: the nature of on-farm conservation; the genetic and evolutionary implications of farmers' management of diversity; the role of institutions in on-farm conservation, and some of the research needs in this area.

17.2 THE NATURE OF ON-FARM CONSERVATION: FARMERS' MANAGEMENT OF DIVERSITY

There is increasing evidence that small-scale farmers throughout the world, and especially in areas of crop domestication and diversity, continue to maintain a diverse set of crop varieties (Boster, 1983; Hames, 1983; Bellon, 1991; Zimmerer and Douches, 1991; Brush, 1992, 1995; Bellon and Taylor, 1993). These varieties are crop populations that farmers identify and name as units (farmers' varieties). In rice, a few studies have shown this as well (Conklin, 1957; Rerkasem and Rerkasem, 1984; Lambert, 1985; Richards, 1986; Dennis, 1987; Lando and Mak, 1994a,b).

The number of varieties found in these studies and other information on the associated farming systems are presented in Table 17.1. However, we need to distinguish between the total number of varieties reported, many of which may not have been planted during the time of the research, and those that were actually planted. This distinction is important because the first category is an indicator of the cumulative number of varieties present in a location, based to a great extent on farmers' memories. The second may be more important because it actually refers to what was happening during the time of the research. To report these numbers without qualification may give the wrong impression about a given level of diversity. For example, Lambert (1985) reported 45 varieties, of which only 32 were actually planted.

In any case the important conclusion is that for both numbers there is variation across studies. The number of varieties reported is larger than the number of those planted. Most of the varieties planted are traditional, but in many cases modern varieties are already present. The number of modern varieties is low, in general, but they may cover a large area and be planted by most farmers. The data do not permit an assessment of the relative importance of modern versus traditional varieties in area or number of farmers.

The average number of varieties per farmer is much lower than the number of varieties present per village or cluster of villages. This suggests that there is a low overlap in the sets of varieties each farmer is planting. Even the maximum number of varieties per farmer falls short of the village or cluster total. Therefore, even if only studying villages, one needs to sample several farmers to capture village diversity. This suggests that, while the farmer is the basic unit of decision-making in terms of variety selection and maintenance, the village is the minimum unit of analysis for diversity. There is a need to explain the variation

Table 17.1 Indicators of farmers' management of diversity from studies of rice in Asi

Study	Country	Level[1]	Unit[2]	Sample size (no. farmers)	Rice ecosystem[3]	Varieties: No. requested[4]	Varieties: No. planted[5]	Varieties: Traditional	Varieties: Modern	Varieties: Average/ farmer	Varieties: Max/ Farmer	Farm size[5] (ha/household)	Ave yield[6] (t/ha palay)	Purpose production	Other economic activities	Ethnicity
(a)	Cambodia	Cluster of villages	Kandal		RL	14							1.9	S/MGY	Off-farm labour, palm-sugar	Cambodian
(a	Cambodia	Cluster of villages	Kompong Speu	14	RL					2.14		1.1	1.7	S/MGY	Palm-sugar	Cambodian
(a)	ambodia	Cluster of villages	Takeo		RL	15		11		2.36			.3	S/MGY	Palm-sugar, cattle	Cambodian
(b)	Cambodia	Cluster of villages	Prey Kabas		DWR +RL+IR	23[8]		8		NS	NS	1.8	2.1	S/M	Garden crops, pigs, off-farm labour	Cambodian
(b)	Cambodia	Cluster of villages	Piam Montia	36	DWR +RL+IR	18						3.2	1.1	/M	Little off-farm labour	Cambodian
(c)	Malaysia	Village	Pesagi	28	Swamp	45	32	32		3 to 4[9]	6[9]	0.534	0.45[1]	OS	Rubber	Malay
(d)	Thailand	Village	Pa Laan	22	IR	18	9[11]	6[12]		1.4	NS	0.85	NS	NS	Fruit orchards, vegetables	Thai
(d)	Thailand	Village	Mae Salap	20	IR					1.6	NS	1.3	NS	N:	Off-farm labour	Thai
(d	Thailand	Village	Tha Mon	20	IR+UP	19		10[12]								

(d)	Thailand	Village	PaNgiw	27	IR+UP	30	24[11]	23[12]		2.9	NS	0.6	NS	NS	No cash crops	Karen
(d)	Thailand	Village	Gong Hae	22	IR+UP	17	11[11]	11[12]		1.3	NS	0.33	NS	NS	Tea	Thai
(d)	Thailand	Village	Buak Jan	19	UP	13	12[11]	12[12]		.4	NS	0.7	NS	NS	Vegetables, UN program[13]	Hmong
(d)	Thailand	Village	San Pa Hiang	20	RL	9	3[11]	2[12]		1.3	NS	0.86	NS	NS	NS	Thai
(d)	Thailand	Village	Pa Daeng	19	RL	8	4[10]	2	2	2	NS	2.9	NS	NS	NS	Thai

(a) Lando and Mak, 1994a.
(b) Lando and Mak, 1994b.
(c) Lambert 1985.
(d) Dennis, 1987.

RL= rainfed lowland; UP= upland ; IR= irrigated; DWR= deep water ; TV= traditional varieties; MV= modern varieties; S= subsistence; OS= only subsistence; MGY= marketed only in good years; M= marketed; NS= not specified.

Notes

1. A **village** means that the sample of farmers used to generate the data was taken from one village. A **cluster of villages** means that the sample was taken from a cluster of villages within a region.
2. **Unit** is the name the authors gave to either the villages or clusters of villages used in their studies.
3. **Rice ecosystem** is the classification of the rice production systems sampled. It is reported as the authors did, e.g. Rainfed lowland, Swamp.
4. **Varieties** refer to farmers' varieties – crop populations named and identified as units by a group of farmers. The **number of varieties** used here refers to the number of variety names. Using this number can slightly under- or overestimate the actual number of populations present, i.e. two different populations having the same name, or one population having two different names. Nevertheless, usually within a village names give an accurate representation of the number of populations present (Dennis, 1987; Quiros *et al.*, 1990). In a cluster of villages, this may be less precise. The '**number of varieties reported**' means all the varieties listed by farmers, whether currently or previously planted, or simply declared.
5. The information on **farm size** was not precise across studies. It was not clear whether it was actual farm size or only area planted to rice. In any case area planted to rice was equal to or smaller than the number reported.
6. The data on **yield** sometimes referred to average yield for a village reported by informants, or to cuttings in some sampled farmers' fields. This information just provides a rough idea of the level of productivity in these sites.
7. **Other economic activities** may actually be underestimated because reporting of them was not consistent across studies, and they were taken from different sections of the studies.
8. Including 15 varieties lost during Pol-Pot times.
9. Lambert (1985) provided a range of the average number of varieties only, but not specific information. In terms of the maximum number of varieties, he just reported that it was not uncommon to observe up to five or six varieties planted per household.
10. The yield reported by Lambert (1985) was for a poor year (1976) when he did his study. According to him the average normal yield is 0.89 t/ha
11. The data for the villages surveyed by Dennis refers to 1984. He presented data from 1979 to 1984, but here only the last year is presented.
12. Traditional varieties in the case of Dennis (1987) included what he defined as Locally Improved Varieties and Local Varieties.
13. This is a United Nations Opium Replacement Project.

among farmers and among villages. It is important also to point out that there are farmers who maintain a much larger number of varieties than the average. As Dennis (1987) has shown, there are contrarians (his term), i.e. farmers who maintain more varieties and who exhibit a contrasting behaviour with respect to the rest. They either adopt new varieties early on (not necessarily modern ones) or maintain varieties that have been discarded by the rest. They have a better than average knowledge of varieties and ability to explain decisions concerning them.

In terms of other factors that may explain the variation observed, these studies comprise all types of rice ecosystems and some combinations of them (e.g. irrigated and upland). They show that the average farm size, or at least the area planted to rice, is relatively small. The yields are also low, but not atypical of the levels observed for traditional varieties; however, one must be cautious about this comparison (see Table 17.1, footnote 6). In general, rice production is undertaken for subsistence purposes, although surpluses may be sold in good years. Nevertheless, subsistence should not be confused with market isolation. In almost all cases, these farmers engaged in market activities such as cash cropping or off-farm labour. Subsistence indicates that the rice produced is consumed by the farm family, but this does not preclude that the farmer may have to purchase some rice or that the farmer may sell it as well. It is not clear what the relationship is between diversity and increased rice production for the market while maintaining subsistence. There is variation in ethnicity of the studies reported, but these emphasize ethnic majorities. Only Dennis (1987) compared an ethnic majority with ethnic minorities.

Infraspecific crop diversity maintained by farmers is not just the set of varieties they plant, but also the management processes these varieties are subject to and the knowledge that guides these processes. In fact, the specific varieties in the set may change over time (Dennis, 1987). Hence, the diversity observed in farming systems is a process rather than a state. We can refer to this process as farmers' management of diversity, which can be characterized as one in which farmers cultivate a diverse set of more or less specialized crop populations. These populations are named and recognized as units by the farmers (farmers' varieties). They are usually segregated in space, time and/or use. The set of varieties is formed through a constant process of experimentation, evaluation and selection of existing and new varieties. There are two levels of selection: choosing the varieties to be maintained; and then for each one, choosing the seed stock that will be planted the next season. The selection process is dynamic and is influenced by the supply of populations from other farmers, villages, regions, or even countries. This supply may involve new populations, as well as existing ones that a particular farmer may have lost and wishes to replant. Four components of farmers' diversity management can be identified: seed flows, variety selection, variety adaptation, and seed selection and storage.

17.2.1 Seed flows

The exchange and transport of germplasm form a common historical pattern throughout the world that currently continues, particularly with the introduction of modern varieties. Several studies have documented the flow of seed of different varieties among small-scale farmers (Dennis, 1987; Cromwell, 1990; Sperling and Loevinsohn, 1993; Louette, 1994). These flows can happen within a village, a region, a country, or even between countries. They take place as farmers exchange or market seed among themselves, purchase seed from commercial or government outlets, receive seed as a gift, or collect it from other farmers while travelling. The increasing importance of migration as an economic activity for many farmers may foster these flows.

In rice, Dennis (1987) documented an active exchange of rice germplasm among farmers of northern Thailand across village, district and provincial lines. This means that a variety does not need to stay in the same village to persist successfully within a region. He distinguished three categories of varieties: local, which have been grown in an area for many years or have been bred or selected from varieties long used in the area; locally improved, which were developed from traditional ones by pure-line selection; and modern, which have been released since 1965, have high-yielding potential, and are generally short-stemmed and fertilizer-responsive. Here, the first two categories are lumped together and referred to as traditional.

Dennis found that variety flows were mostly from north to south. Most of the varieties adopted were traditional ones: from 40 instances of village-level adoption between 1976 and 1984, 29 were traditional varieties and only 11 were modern varieties. However, almost all of the discarded ones were traditional. The largest diversity and the lowest level of variety replacement were found among the Karen and Hmong ethnic minorities. Nevertheless, even among the Thai ethnic majority, the more isolated villages had lower replacement rates than those that were more integrated. Some farmers among the two ethnic minorities planted seed plots, while this was not the case among the ethnic majority. Surprisingly, the villages with fewer varieties and a greater percentage of varieties discarded were not located in the irrigated but in the rainfed system. In both cases, these were Thai farmers relatively close to the city.

Seed flows are important in understanding the diversity in a given location because they are the basis of incorporating new varieties and obtaining materials that have been lost but are desirable. It is not uncommon for a farmer to lose a desired variety by accident, or even purposely discard one, and then wish to recover it (Dennis, 1987; Sperling and Loevinsohn, 1993). Furthermore, these flows may have major genetic implications because they may be an important mechanism for the migration of genes, and may counter genetic drift in varieties planted over very small areas (Louette, 1994). In theory, a network of seed exchange coupled with a rigorous and consistent seed selection method, which produces high-quality seed, may allow farmers to abandon poorer lines whenever there is access to better ones, eventually creating a cumulative effect of generating and maintaining highly adapted and productive cultivars (Lambert, 1985).

The collection of land races, their use for the development of modern varieties and their introduction into the farming systems themselves have expanded the scope of these flows and the level of diversity. Modern varieties incorporate germplasm that originated from many different countries. It is common to observe modern and traditional varieties being grown by the same farmers. For example, Dennis (1987) used analysis of isozymes to sort the different rice varieties collected in northern Thailand into different genotypes. He found that, while most of the traditional varieties in his sample belonged to one genotype, the collected modern varieties established a new isozyme group. He concluded that, in his area of study, the introduction of modern varieties was more likely to broaden genetic diversity in the landscape than the introduction of a traditional variety brought from another area in northern Thailand.

17.2.2 Variety selection

The process of variety selection can be seen as a farmer's decision to maintain, incorporate or discard a variety to be planted in a particular growing season. The diversity of varieties present in a farmer's field is the outcome of this decision. If the number of varieties incorporated and maintained is larger than that of the ones discarded, then diversity increases, and vice versa. The varieties maintained or incorporated are either kept from the previous agricultural cycle or obtained through exchange or purchase.

Farmers continually evaluate each variety, and the process has two components. One is to find out how a variety performs with respect to each concern or selection criterion, such as its performance under drought or flood conditions. The second is to rank the performance of the varieties in terms of different stresses, such as drought resistance. Farmers constantly try to match their crop populations or varieties to these concerns, which in turn reflect the conditions in which they farm. In describing the management of traditional rice varieties in Pesagi, a Malay village, Lambert (1985) observed that farmers constantly experiment with rice cultivars. Even with well-known cultivars individual households test one variety against another, a process of matching varietal performance to small but significant differences in localized habitats.

The fact that farmers have multiple criteria for selecting what varieties and where, when and how to plant them has been well established (e.g. Brush *et al.*, 1981; Lambert, 1985; Bellon, 1991; Brush, 1992; Sperling *et al.*, 1993; Lando and Mak, 1994c), and those criteria reflect their concerns. Bellon (1991) grouped them in three major types of concerns:

- agro-ecological, which refers to the performance of a variety with respect to agro-ecological conditions, such as rainfall, temperature, soil quality and topography;
- technological, which pertains to the performance of a variety with respect to management and inputs – for example, the response to the amount of fertilizer applied, to delays in weeding and to association with other crops;
- use, which relates to the performance of a variety with respect to the purposes and uses of the output, such as taste, texture, yield, quality, production for subsistence or for the market, and production of straw or fodder.

Rice studies report different selection criteria by farmers (Table 17.2), but many are common to most of them. In terms of agro-ecological concerns, common ones include maturity and adaptation to different water level regimes such as drought and submergence. In terms of use concerns, yield and texture are very common. Texture is associated with different purposes such as subsistence or market production, or different uses such as direct consumption or elaboration of cosmetics or cakes. Certain categories manifested by the farmers were not well defined by them, such as 'good field adaptation'. This category may be a combination of factors specific to a habitat (e.g. Lando and Mak, 1994c). Reliability is only mentioned by one author (Lambert, 1985), although it may be very important for all subsistence farmers. In terms of technological concerns, the ability to 'fit' with other crops and to avoid labour bottlenecks, factors that are related to maturity, are reported as well. Only Lando and Mak (1994c) provide some quantitative data on the percentage of farmers who declared each of the concerns. An interesting finding for all varieties is that, while yield was cited as the most frequent reason to plant a variety, this trait was mentioned as frequently as field adaptation and maturity for early-maturing varieties, and as often as flood tolerance for late-maturing ones when data were desegregated by maturity. Unfortunately, in these studies the association of farmers' selection concerns with the varieties they planted is not systematically reported: for example, how each variety performed with respect to drought or floods. It is not clear whether different farmers have different selection concerns or how they even rank their concerns. For example,

Table 17.2 Farmers' selection concerns

Source	*Agroecological*	*Use*	*Technological*
Lando and Mak, 1994c	Field adaptation Maturity Drought tolerance Flood tolerance Lodging resistance	Yield Eating quality Price Volume expansion	Not reported
Lambert, 1985	Performance under different levels of water depth Drought tolerance Dependability: production on adverse conditions	Texture (glutinous, vitreous, viscous), related to use for subsistence or market Yield Price Colour of husk	Resistance to weeds, insects and disease
Rerkasem and Rerkasem, 1984	Drought tolerance Flood tolerance Maturity (earliness) Lodging resistance	Texture (glutinous subsistence, non-glutinous market) Quality Price Production of straw for mulch	Fit with multiple cropping patterns Fit with patterns of off-labour

poor farmers may have different concerns from rich ones, as may be the case of female farmers versus male farmers, or an ethnic majority [illegible] minorities.

Farmers' selection concerns are not homogeneous, and may vary with the different agro-ecological, socio-economic and cultural conditions they face. Rich and poor farmers in a productive region probably have very different concerns, as may be those of two poor farmers in a marginal area. Even within a farming household, there may be differences between male and female concerns. In many rice farming systems, there may be a clear sexual division of labour (Lambert, 1985) that [illegible] the possibility [illegible] This area merits further research, given the increasing [illegible] role of women in rice farming.

Since farmers' concerns are varied, and a good performance with respect to certain concerns often implies poorer performance with respect to others, several varieties are maintained. Diversity may sometimes be maintained as an option because farmers may not know the future benefit or availability of particular varieties, or because humans can value diversity for its own sake, with no ulterior purpose. However, in the case of diversity that is directly useful, it is important to underline that, in order to explain its development and maintenance, there should be trade-offs among the varieties. For example, Harlan (1992) points out that alleles for disease resistance generally have negative effects on yield in the absence of the disease, and sometimes even in its presence. Hence, there are costs associated with resistance. Therefore, it is important to know and understand not only the positive traits of a variety, but also its negative ones, as those relate to the trade-offs among different farmers' concerns. The combination of two types of traits defines the opportunities for complementation among varieties.

Variety selection is a process of continual experimentation and evaluation. Much of this information is transmitted from farmer to farmer. Experimentation and communication have two important roles in the management of diversity, since they are the basis of the development of farmers' crop knowledge and they allow farmers to know and evaluate new and unproved germplasm without jeopardizing their livelihood or scarce resources. The fact that many small-scale farmers have a well-developed knowledge of their crops and crop varieties has been well documented by human ecologists, anthropologists and ethnobiologists (Conklin, 1957; Berlin *et al.*, 1974; Brush *et al.*, 1981; Boster, 1983; Hames, 1983; Bellon, 1991). This knowledge includes ecological, agronomic and consumption characteristics of the crops and crop varieties they plant. In many instances, this knowledge is systematized in a regular system of nomenclature, organized in a taxonomic manner, i.e. folk taxonomies (Brush *et al.*, 1981). It may be used to make decisions regarding management, use, storage, culinary aspects and rituals (Boster, 1983; Hames, 1983; Bellon, 1991).

17.2.3 Variety adaptation

Whenever a farmer finds a variety that is superior for whatever reason, it will be cultivated under the conditions or for the purposes for which it is superior. This process contributes to the development of increasingly adapted crop populations. The stronger and more distinct the selective pressures, the more specialized populations are likely to be. It has been observed that traditional and modern varieties are usually segregated in different areas of the farm, subject to different management and aimed at different uses (Brush, 1991a). The fact that many rice farmers match different varieties to different field levels, that in turn reflect different regimes of water availability, is well documented (Lambert, 1985; Lando and Mak, 1994a,b). Certain varieties have been maintained only for very specialized uses such as making rice-starch cosmetics, medicinal preparations, or traditional snack foods and cakes (Lambert, 1985).

17.2.4 Seed selection and storage

Farmers not only choose which varieties to plant, or where and how to manage them, but also the seed that will be planted the next season. Variety selection and management are reinforced by a careful and rigorous selection of the seed that will be planted the next season. Seed selection procedures vary by crop and its reproductive system. In open pollinated crops such as maize, seed selection may be fundamental to maintain the integrity of a variety (at least from the point of view of the farmer), but this can be easily lost due to hybridization (Bellon and Brush, 1994; Louette, 1994). This may not be such a problem in the case of a self-pollinated crop such as rice. Nevertheless, rice farmers may decide to keep varieties separate to facilitate their identification and allocation to specific niches. Even if mixtures are planted, in general, they are not a random collection of varieties, but specific combinations. For example, in Uttar Pradesh, India, a popular variety in drought-prone areas, called *gora*, is a mixture of brown, black and straw-coloured genotypes that differ in drought resistance and grain quality (Vaughan and Chang, 1992).

The seed selection and storage methods reported in the studies analysed here are shown in Table 17.3. Although all of them recognize that seed selection is an important component of farming, the level of detail of their descriptions of it is variable. Some have detailed descriptions (e.g. Lando and Mak, 1994c), while for others it is minimal (e.g. Lambert, 1985). Nevertheless, different methods are reported. Particularly, they differ in the timing and place of seed selection. These two aspects are important because they define whether plant characteristics can be taken into account (special harvest of areas with a good standing crop), or only panicle traits (selection during threshing at home). In general, farmers are reported to maintain segregation of their varieties, and in some cases to go to great lengths to accomplish this (e.g. Lando and Mak, 1994c). Careful seed selection may not happen at the end of every season, but every three or four seasons, with a bulk selection of seeds in the intervening ones (Dennis, 1987).

Seed selection may also be important to identify a new population or variety that may arise due to hybridization or mutation. At harvest, a farmer may single out seed from one or more plants that are perceived as being entirely different from a known cultivar, in an attempt to develop a new strain (Lambert, 1985). Richards (1986) pointed out that harvesting rice with a knife, panicle by panicle, as done by farmers in Sierra Leone, West Africa, permits the careful roguing of off-types. Frequently, this material is kept for experiment, and in some cases leads to the selection of new varieties. Therefore, this process may be important to increase diversity in self-pollinated crops, where hybrids between varieties occur at low rates. Nevertheless, the introduction of modern varieties may modify the systems of seed selection because farmers may purchase seed

Table 17.3 Seed selection and storage of rice

Aspects of selection	*Dennis, 1987*	*Lando and Mak, 1994a*	*Lambert, 1985*
General comments	One method, in two cycles: (a) one careful selection every three to four years (b) simple bulk selection in the intervening years	Two methods: (1) after harvest at threshing (2) identify area with standing crop with desirable characteristics and harvest it	Recognized as important, but poorly described Underlie the importance of appropriate training of seed selectors
Time and place	(a) before general harvest in the field (b) after harvest at threshing	(1) after harvest at threshing in the house (2) before general harvest, in the field	Not specified
Plant parts used	(a) panicles and other plant characteristics observed in the field (b) seed from threshing mat	(1) panicles (2) panicles and plant characteristics. If varietal mixing occurs in the field, one person (usually a women) must separate seed stock panicle by panicle	Portion of best grain from mature crop
Frequency	(a) every three to four years (b) every year in the intervening ones	Every year in both methods	Not specified
Criteria	(a) large healthy panicles true to type (b) disease-free sheaves of grain	(1) and (2) full panicles with well–filled seeds (2) area in the field with standing crop, with desirable characteristics	Colour, size and shape of grains
Storage method	Not specified	Sun dried for 3–4 days, stored separately by variety; use home-made bags called *khbong*, or gunny bags. Non-glutinous varieties under house or separate granary. Glutinous varieties and seed stock stored separately	

instead. Dennis (1987) noted that the practice of on-farm seed selection was declining as improved seed supplies became more available from government agencies. It is also important to emphasize the role of women as seed selectors in rice. Their knowledge and expertise in this respect are increasingly being documented (Conklin, 1986).

It is clear that there is variation in the management of diversity among farmers. There are different numbers and types of varieties maintained, selection concerns, seed selection methods and different rates of seed flows. The variables that describe farmers' management of diversity can be seen as a set of dependent variables. On the one hand, they are affected by the environmental, socio-economic and cultural factors that influence the farmers' decision-making. These factors operate at different scales. Some have to do with farmers' characteristics such as socio-economic status, access to resources and knowledge; others with village level characteristics such as local institutions (e.g. patterns of labour exchange, land tenure, social obligations); and others are related to processes that occur at the regional or national levels, such as availability of infrastructure (irrigation, roads, telecommunications), degree of development of markets and government policies. On the other hand, farmers' diversity management has consequences for the genetic structure and diversity of the crop. Nevertheless, genetic structure of the crop is also influenced by environmental factors through natural selection. Furthermore, although farmers cannot observe or appreciate the genetic structure of the crop, they gain knowledge of morphological traits expressed (e.g. yield, plant stature, resistance to drought, insects). This knowledge is in turn used in their decision-making processes regarding their management of diversity (Figure 17.2).

Government policies, particularly those aimed at increasing the food supply for a growing urban population, also affect diversity. Governments have provided infrastructure, modern inputs and subsidies to farmers, favouring and sometimes forcing specialization. In many cases, they have imposed restrictions on what farmers can and cannot do, either through a legal process, or by imposing conditions on the access to desirable inputs (e.g. conditioning credit to the compulsory planting of modern varieties, in the belief that it will increase food production). Government policies vary from country to country, even by region, and from time to time. It is difficult to predict their impact on diversity, except that usually there has been a bias against diversity.

17.3 GENETIC AND EVOLUTIONARY IMPLICATIONS OF FARMERS' MANAGEMENT OF RICE DIVERSITY

Considerable progress has been made during the last 10 years in the study of the rice genome. There is a strong contrast between our knowl-

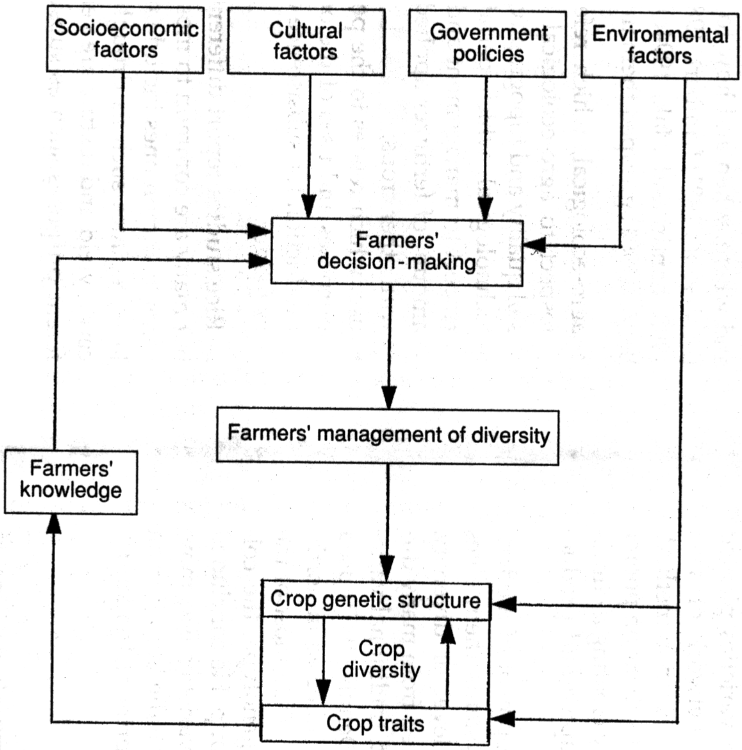

Figure 17.2 Conceptual model of the factors that influence farmers' management of diversity.

edge of diversity at the molecular level and our ignorance about the role of genetic diversity in farmers' fields. This is not really surprising. Studying the diversity in farmers' fields implies analysis of an evolutionary process involving a triple interaction between genetic diversity *per se*, natural selection and farmers' management. From a specific point of view of conservation of genetic resources (and one that initially excludes the important question of a farmer's well-being), on-farm conservation of genetic resources aims to use this evolutionary process to promote the adaptation of these resources to environmental conditions. It is essential, therefore, to increase our knowledge of this process in farmers' fields in order to define the potential outputs from on-farm conservation of rice genetic resources.

Several important questions must be posed. Firstly, why can we assume that farmers' management of rice diversity is an evolutionary process? Secondly, what are the genetic components of this process? Thirdly, to what extent can on-farm conservation of rice genetic resources be expanded towards utilization? Lastly, what are or should be the relationships between on-farm conservation and *ex situ* conservation ?

17.3.1 Farmers' management of rice diversity as an evolutionary process

To be convinced that farmers' management is an evolutionary process that has produced diversity, there is no better way than to consider the overall diversity of *O. sativa*. It results from several thousands of years of farmers' management and natural selection. Useful lessons for the genetic and evolutionary implications of on-farm conservation can be drawn from studies on the structure of this diversity.

On the basis of isozyme studies, Second (1982) interpreted the diversity of *O. sativa* as resulting from a continuous recombination process between two independently domesticated subspecies, so-called *indica* and *japonica*. This hypothesis is supported by Glaszmann (1987), who classified Asian varieties of *O. sativa*. Highland rices from Madagascar also offer clear examples of reciprocal introgression between *indica* and *japonica* varieties (Ahmadi *et al.*, 1991). More recently, Second and Ghesquière (1995) have used RFLP markers to demonstrate that the genome in some *O. sativa* varieties consists of 'pieces' of genetic material originating from both subspecies.

Studies on the diversity of *O. sativa* varieties have also demonstrated the important input of wild species having the same AA genome. Marker studies have highlighted the contribution of *O. rufipogon* and *O. longistaminata* to the diversity of *O. sativa*, in Asia and Africa, respectively (Ghesquière, 1988). In contrast, the species complex of African rice, which consists of the cultivated species *O. glaberrima* and its wild progenitor *O. barthii*, is strongly isolated from other AA genome species by strong reproductive barriers.

17.3.2 Components of the evolutionary process in farmers' fields

Let us suppose here that rice varieties are not pure lines but polymorphic populations, as might be expected in land races. Like other crops, rice varieties have continued to evolve under two kinds of selection pressure: environmental and human. These act on genetic polymorphism by discarding the less adapted genotypes. It is the role of genetic recombination to create new material to be exposed to selection. Therefore, to be adaptable (i.e. to be able to respond to changes in selection pressures), a variety must be genetically polymorphic. Selection will act on gene frequencies in the variety. Another factor of change in gene frequencies is genetic drift, a random process of loss of genes, and one that depends in particular on population size. Within-variety polymorphism is generated through both rare mutation events and, to a much greater extent, gene flows from other varieties. However, gene flows will enhance polymorphism only if they come from genetically different varieties. In other words, research into on-farm conservation must deals both with the polymorphism within rice varieties and with the genetic diversity of cultivated varieties (including the modern ones) as the source of this within-variety polymorphism.

17.3.3 Within-variety polymorphism

Numerous germplasm collecting reports detail the occurrence of morphological polymorphism within traditional varieties. The strongest evidence obviously relates to grain and panicle traits, which are most easily observed in the field. However, few studies have been carried out to assess the genetic components of this polymorphism. Ghesquière and Miézan (1982) studied the genetic structure of West African traditional rice varieties as revealed by isozymes (40 loci). They studied 44 *O. sativa* varieties including 19 from Guinea and 25 from Côte d'Ivoire. The within-variety polymorphism accounted for 12% of the *O. sativa* variety diversity. It was higher for *indica* varieties than for *japonica* varieties (37% versus 16%), as also observed for the genetic diversity of these sets of varieties (0.090 versus 0.077). Six *O. glaberrima* varieties were also studied. High within-variety polymorphism was observed (32%), particularly in contrast to the low genetic diversity of this sample of varieties (0.0269). Miézan and Ghesquière (1985) obtained the same overall picture of the genetic structure by studying a subset of these varieties for several agromorphological traits. Morishima (1989) studied the isozyme polymorphism of 15 land races from India, Nepal and Thailand. Six land races showed a gene diversity less than 5%. The gene diversity of the nine other land races ranged from 10 to 25%. In some cases (Oka, 1991), land race populations were found to be more heterogeneous than annual wild populations of *O. rufipogon*.

Gene flows are the main factor to increase diversity. They are achieved if cross-pollination occurs between different genotypes, and if more or less fertile progeny are produced. The two cultivated rice species are predominantly self-pollinated crops. At anther dehiscence, pollen grains preferentially deposit on stigmas of the same panicle because of proximity. Nevertheless, when flowering, both stamens and stigmas are exerted outside the spikelets. Pollen grains are dispersed by wind, and stigmas are receptive to pollen coming from other plants. Natural outcrossing is therefore possible in rice. The actual outcrossing rate of rice in farmers' fields and the migration distance of rice pollen are poorly known. Outcrossing rates could be increased in the case of products of hybridization between genetically distant *O. sativa* varieties. F1 hybrids within *O.*

sativa, especially intersubspecific hybrids between *indica* and *japonica*, often show partial pollen sterility, leading to lower seed fertility (Oka, 1988; Pham, 1991), and may result in increased cross-pollination, since female fertility of F1 hybrids is more rarely affected (Oka, 1988). Morishima (1989) reported the occurrence of *indica–japonica* hybrids in an upland rice population from Yunnan.

In West Africa, there are several reports of *O. sativa* and *O. glaberrima* growing together (Borgel and Second, 1978; Sano *et al.*, 1984), and presumed hybrid plants between the two cultivated species have been observed *in situ* (Borgel and Second, 1978; Pham and de Kochko, 1983). However, little evidence of gene flow has been found, except for the single study by Second (1982) who identified a plant of the weedy form of *O. barthii* that could have resulted from the introgression of *O. sativa* genes into *O. glaberrima*. The absence of gene flow can be explained by the strong reproductive barriers isolating the two species (Sano *et al.*, 1979, 1980; Pham and Bougerol, 1993), including phenological ones (Oka, 1988).

The management of fields and varieties by farmers is a potential cause of variation in the rate of gene flow between varieties. Coincidence in flowering dates (which depends on sowing date and earliness) and proximity (adjacent varieties are likely to exchange more genes than varieties in distant fields) are factors that influence gene flows. However, bearing in mind the expected low level of gene flow due to the mating system of rice, accurate studies would be time-consuming in terms of their potential impact. More attention should be given to particular situations, such as mixtures of varieties, accidental or controlled, that seem the most efficient way to promote gene flow between two varieties, as Dennis (1987) has reported for traditional rice varieties in northern Thailand.

17.3.4 Genetic diversity of rice varieties

The study of genetic diversity at the farm, village and regional level is a key aspect of research on farmers' practices and on-farm conservation. The aim should be to quantify the diversity in each of these units, and in particular, the impact of modern varieties must be evaluated. Many modern varieties have been bred using germplasm from traditional ones, and their impact on diversity may vary, depending on the region where they are released.

Any genetic approach to the study of on-farm conservation must have strong links to the social, economic and cultural aspects of farmers' diversity management. It is indeed important to study the relation between the level of diversity perceived by farmers and the actual level of genetic diversity. Dennis (1987) suggested that Karen farmers retained colourful varieties because colours are a useful indicator of genetic diversity. However, such morphological traits are governed by few genes and generally are not useful indicators of genetic diversity *per se*.

The rate of turnover of varieties is also an important factor. If a traditional farming system is a closed system, the adaptability of the set of varieties cultivated will depend on its level of genetic diversity. If new varieties are introduced, it can be enhanced. But if the turnover is too fast, the time of co-occurrence between varieties will be too short to allow significant gene exchange. Nothing new would be produced in the extreme case where, at every cultivation cycle, a set of genetically diverse varieties would be replaced by another set of genetically diverse varieties. In other words, we have to distinguish between the adaptation of the farming system and the adaptation of the germplasm.

17.3.5 The role of diversity

The adaptation to changes in different biotic and abiotic pressures, particularly pests and diseases, is perhaps the principal objective of dynamic conservation of genetic resources. Future changes in climate are predicted to affect agriculture world wide (Ford-Lloyd *et al.*, 1990; Jackson and Ford-Lloyd, 1990), but changes in pest pressures have actually been documented in rice culture in recent decades, and have widely affected the orientation of rice research programmes.

Several approaches have been proposed to manage the coevolution of pathogens with host plants to prolong resistance (Mundt, 1994). However, few data have been obtained to assess their actual efficiency. Some are based on dynamic management of resistance genes, that aim to avoid rapid selection for pathogen races virulent to the varieties. These approaches are analogous to what happens or could happen in farmers' fields. Among the examples are the following:

- **Gene rotation.** A set of cultivars, each with a single race-specific resistance gene, is cultivated in rotation. This approach was implemented in Indonesia for the control of rice tungro disease (Mundt, 1994). A reduction of tungro disease was observed, which is linked to gene rotation or to changes in practices induced by rotation. It would be interesting to see if such a rotation in varieties is *de facto* observed in traditional fields.
- **Gene combinations.** Two or more race-specific resistance genes are combined into a single host genotype. To know if such combinations can occur naturally in farmers' fields is an important issue. Situations where both traditional and modern varieties are cultivated would be of particular interest.
- **Cultivar mixtures.** Mixtures of cultivars with different resistance genes are another strategy employed against diseases; for example,

against barley powdery mildew in Germany (Wolfe, 1992). The cases of intentional mixtures of traditional varieties of rice reported in northern Thailand by Dennis (1987) are not related to disease management. However, more situations must be investigated.

- **Gene deployment**. The strategy is to distribute resistance genes among different fields or regions. The pattern of distribution of genetic diversity at the field, village and regional level should provide valuable information in relation to this strategy.

It is unlikely that each of these different strategies will be found separately in farmers' fields. Mixed variety situations are more likely, with variation in both space and time. Methodologies will have to be developed to assess the potential relation between genetic diversity in fields and conscious or unconscious management of pest pressures.

More generally, an issue of great interest is to know whether a farmer's management of diversity leads to the selection of specialist varieties, generalist varieties, or both. Strong local selection pressures would be likely to select specialist varieties, that fit particular farmers' needs or particular agronomic conditions. Generalist varieties could be related to what is perceived by farmers as the 'reliability' of some varieties. David (1992) used simulations to show that, in certain conditions, gene flows can maintain generalist abilities in populations submitted to strong directional selection. Therefore, the role of within-varietal polymorphism could be to maintain an overall generalist ability in rice varieties.

17.3.6 Demonstrating genetic changes in farmers' fields

On-farm conservation is dynamic. Nevertheless, it will be difficult to demonstrate genetic changes in varieties and changes in the amount of cultivated diversity over a short time frame. However, a 'historical' approach comparing the present with past situations could provide such evidence. Changes of within-variety diversity could be studied through: sampling cultivated varieties and comparing them with samples of the 'same' varieties cultivated 10–20 years ago, by using the gene bank collections; comparing varieties that were released as unique 10–20 years ago; and comparing different samples of widespread traditional varieties, such as *Azucena* in the Philippines.

Changes in the total amount of diversity could be approached by comparing at the village or regional level the diversity cultivated nowadays and the diversity cultivated in the past, evaluated by using collecting reports and gene bank collections.

17.4 LINKS BETWEEN ON-FARM CONSERVATION AND RICE GENE BANKS

It seems that on-farm conservation of traditional rice varieties is something that farmers choose to do individually. On-farm conservation is not the same sort of strategy as *ex situ* conservation, in terms of the way that public sector institutions can decide to establish a gene bank, for instance. We believe that institutions, including NGOs, cannot do 'on-farm conservation', but they can identify the opportunities – social, economic and cultural – under which the cultivation of land race varieties of rice may continue to thrive. They may also be able to facilitate farmer access to a broad range of rice genetic diversity, and establish the links between farmers and gene banks.

This view should not remain a theoretical one. Recent experiments on participatory breeding support the idea that farmers can be efficiently involved in processes previously managed by institutions only. In Rwanda, farmers who are bean experts have been identified and invited to the research station to assess cultivars and select those they prefer for their plots (Sperling *et al.*, 1993). Compared with cultivars selected by the breeders, those chosen by farmers were often higher yielding on-farm. Moreover, they were retained longer by farmers. Participatory breeding therefore seems to be a useful approach in promoting the adoption of new cultivars by farmers. This was also the conclusion reached by British plant breeder John Witcombe (personal communication) about an experiment of participatory breeding of rice varieties in India and Nepal. In Nepal, the farmer participation was extended to include breeding of segregating material that was supplied to farmers for on-farm selection.

17.4.1 Management by farmers of 'foreign' diversity

The strategy proposed here is to involve farmers in managing a sample of genetic diversity in addition to their own varieties. There are two reasons for this strategy. Firstly, if the farmers' management of diversity does produce changes with adaptive significance, why not artificially increase the amount of diversity exposed to this process? Secondly, genetic polymorphism is required to permit adaptation to evolving selection pressures. This condition is necessary but not sufficient alone. Indeed, being polymorphic does not necessarily mean being adaptable when the available polymorphism does not permit an appropriate response to selection. Even if the polymorphism may be sufficient to permit a slight adaptation under selection pressures, it may be insufficient for the variety to reach an optimal adaptation. This means that cultivated land races are not necessarily the ones best adapted to the local conditions where they are grown.

Three complementary ways may be proposed for this strategy: reintroduction of varieties, introduction of alien varieties, and introduction of composite populations. Besides its interest for the conservation of genetic resources, this approach would provide useful information on the consequences of farmers' management. This would complement the descriptive part of any research with an experimental, controlled approach.

The most promising approach is likely to be the management of composite populations. It is essential to bear in mind that traditional varieties have resulted from several thousand years of cultivation. Managing artificial populations should permit changes to be observed over a far shorter time scale. The idea of conserving bulk populations is not recent (Suneson, 1956; Simmonds, 1962). One important experiment has been conducted on barley in which a composite population has been cultivated since 1928. The main results relate to changes in disease resistance (Allard, 1988, 1990). More recently, an experiment on the dynamic management of composite populations of winter wheat has been carried out in France (Henry *et al.*, 1991), based on the so-called metapopulation concept. Significant changes were observed after only six years of multiplication. The maintenance of resistance genes to mildew and the appearance of novel gene combinations (Le Boulc'h *et al.*, 1994) were among the most important results. Some guidelines for an experiment of conservation of composite populations of rice have been proposed by Pham *et al.* (1994), based on the multiplication of these populations in a multilocation network in order to promote their multidirectional differentiation through different selection pressures.

The composition of populations should have at least two objectives:

- The variability of material included in the initial population must permit evolution under various conditions. There is no interest in seeing local populations disappearing after the first year! Consequently, it will be necessary to check if traditional entries can grow under intensive conditions with completely different disease pressures. Involving modern varieties in the initial population should give time for the development of resistance gene combinations.
- Farmers must be interested in cultivation of the populations. This means that farmers now growing only dwarf varieties are unlikely to accept populations with only traditional traits (tall plants, lodging susceptibility, low yield potential). Introducing dwarfing genes in the initial population could be a critical point to make the genetic material more attractive for farmers.

The choice of initial material will require consideration and the following ideas should be considered:

- The initial population could be made by mixing a great number of traditional varieties. Some of them will be eliminated very quickly in local populations. Others will contribute to the future generations. Hybrid sterility will favour outcrossing, particularly if *indica* and *japonica* varieties are mixed.
- Another way to compose the populations would be to limit the number of entries to popular and widely cultivated land races. Traditional varieties that are well known by breeders or good donors for particular traits (tolerance to drought or blast, for instance) could also be used. There is no need to use completely evaluated varieties. A pyramidal cross could then lead to the initial population, as in the experiment with wheat (Henry *et al.*, 1991). Utilization of genic male sterility will favour intercrossing and introduce dwarfness if necessary.

Management should be as simple as possible. After dispatching the initial population in the network, farmers should cultivate each local population every year. They would store the harvested seeds for sowing the next season. Two modes of management could be compared: normal management, and no conscious selection on panicles and seeds while harvesting, storing and sowing.

Use of molecular markers should permit the monitoring of the populations in terms of specific marker frequencies based on samples of appropriate size. Furthermore, modelling effects on population structure could be demonstrated through using molecular markers like RFLPs (Resurrecion *et al.*, 1994) and RAPDs (Virk *et al.*, 1995a). They provide many different markers spread over the genome, showing allelic polymorphism similar to isozymes and closely related to *indica–japonica* differentiation. More recently, the identification of micro-satellites in rice has provided many allelic differences coming from small repeat units (Wu and Tanksley, 1993) and these sequences can provide more successful markers for following genetic changes. Adaptive variation of biotic and abiotic factors in relation to environmental heterogeneity should also be monitored.

Finally, the composite population approach may be the most appropriate one for dynamic conservation of *O. glaberrima*, given the genetic isolation of this species from *O. sativa*, and the decrease in its cultivation area.

17.4.2 Wild and weedy species

The genetic contribution of wild species to the diversity of cultivated rice has been significant, but little is known about this over short timeframes. *O. longistaminata* is an outbreeder, and the outbreeding rate of *O. rufipogon* ranges from 7 to 56% (Oka, 1988). However, because of the autogamous mating system of *O. sativa*, and also because of the reproductive barriers between *O. sativa* and these two wild species, gene flow is probably low. The wild–cultivated species relationship in rice cannot be compared with the frequent exchanges expected between maize and teosinte (Wilkes, 1967), for instance, or between wild and cultivated pearl millet (Pernès, 1984). Does this mean that on-farm conservation of rice genetic resources should not consider the wild–cultivated species relationships? We suggest that this issue should be addressed by considering both on-farm conservation of cultivated rice and *in situ* conservation of wild rice populations.

17.4.3 Complementarity between *ex situ* and on-farm conservation

The complementarity of on-farm conservation and *ex situ* conservation clearly exists at the level of objectives. *Ex situ* conservation aims to capture and maintain the genetic diversity at a given instant, whereas on-farm conservation aims to promote the adaptation of this diversity by using an evolutionary process. This complementarity does not mean that these genetic conservation strategies should remain isolated from each other. On the contrary, it should be enhanced through reciprocal flows of genetic material. The proposed flows are summarized in Figure 17.3.

If adapted varieties are produced by on-farm conservation, the question is whether useful changes can be detected and used. On-farm conservation does not only deal with the conservation of allelic diversity; it also deals with the occurrence of adapted combinations of alleles. Epistatic relationships are expected in selfing species. The criteria for the evaluation of the products of on-farm conservation must be defined, and must take into account the heterogeneity of the material.

Release of modern improved varieties, bred thanks to genetic resources collected from farmers' fields, can be considered as a feedback from the institutional sector to farmers. The development of original populations or genotypes through on-farm conservation and their use in plant breeding programmes or their conservation in *ex situ* collections would provide an exciting example of reciprocity in the production of improved genetic material.

The current attention that on-farm conservation is attracting and the apparent rush to implement conservation projects seem to be inversely proportional to the research effort being expended. As emphasized in this chapter, on-farm conservation is a process managed by farmers themselves, and not one imposed by institutions. The establishment of on-farm conservation reserves has been proposed where farmers would be encouraged, through a range of incentives, to continue to cultivate their local varieties. What is urgently needed is information on the circumstances and opportunities that promote on-farm conservation, or at the very least that permit farmers to make objective decisions about the

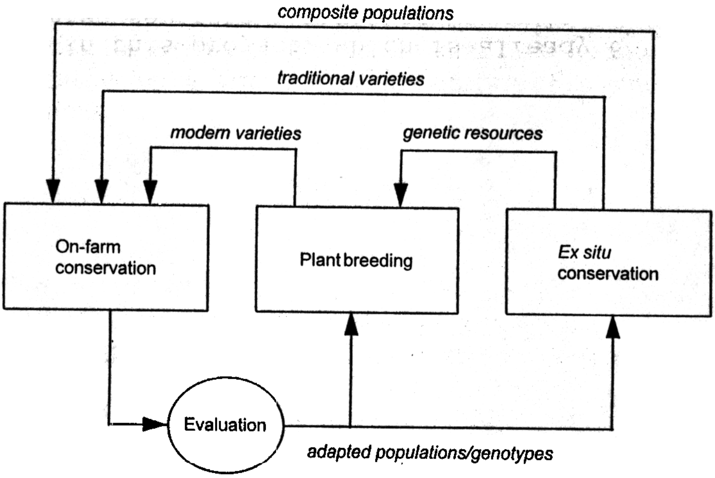

Figure 17.3 Possible exchanges of genetic material between on-farm conservation, plant breeding and *ex situ* conservation.

crop varieties (including locally adapted ones) that they choose to grow. On-farm conservation research must address these social, economic and cultural issues, and seek to determine the genetic consequences of different types of management by farmers. After all, we are seeking to preserve the adaptive potential of crop varieties in dynamic systems, while not neglecting the welfare of farmers. On-farm conservation must bring tangible benefits to the farmers who have nurtured this genetic heritage for generations.