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SAFEGUARDING AND PRESERVATION OF THE BIODIVERSITY OF THE RICE GENEPOOL

FINAL REPORT

July 2000

Introduction

This final report summarizes the activities conducted under the three main components of the project:

I. Collection and *ex situ* conservation of wild and cultivated rices.

II. On-farm management of traditional rice varieties.

III. Strengthening germplasm conservation by National Agricultural Research Systems (NARS) and Non-Governmental Organizations/Farmer Organizations (NGOs/FOs).

Annual reports for the year 1994-1999 have already been submitted to the Swiss Agency for Development and Cooperation (SDC), with the approval of the Project Steering Committee. These annual reports contain the details of activities under each of the project components, and are attached to this report for reference. The section about on-farm conservation is more detailed given the policy implications of the research.

Project Scope and Implementation

Following approval of the project by the SDC in November 1993, two planning workshops were held at IRRI in early 1994:

- Discussion Workshop on On-Farm Conservation of Crop Genetic Resources (February 24-26, 1994).
- 5-Year Action Plan Meeting (February 28-March 3, 1994).

These workshops developed the broad scope of the proposed on-farm conservation research, and the scale of germplasm collecting and training efforts that would be required to sustain the genetic conservation activities of the NARS.

Collecting rice varieties and wild species was carried out in 22 countries (Table 1). Most of the Asian countries that sent representatives to the Action Plan Meeting did develop active programs over the life of the project. Three countries – China, India, and Sri Lanka – undertook no collecting activities because these had already been largely accomplished.

In Sub-Saharan Africa, the decision was taken to support national activities in many of the Southern African Development Council (SADC) region countries through the SADC Plant Genetic Resources (SPGRC) based in Lusaka, Zambia. SPGRC provided administrative and accounting support to Botswana, Swaziland, Tanzania, Zambia, and Zimbabwe. Mozambique and Namibia received funding directly, and also accounted for expenditures independently from SPGRC. Through the Sub-Saharan Africa Regional Office of the International Plant Genetic Resources (IPGRI), collecting was supported in Uganda and Kenya, and an IPGRI staff member, Mr. Dan Kiambi, participated in collecting missions in these countries as well as some of the SADC countries.

In Latin America and the Caribbean, it was originally envisaged that collecting could be coordinated through the International Center for Tropical Agriculture (CIAT) in Colombia. This approach was never developed further. Discussions were held with officials of the National Center for Genetic Resources and Biotechnology (CENARGEN) in Brasilia, Brazil, but the necessary Memorandum of Agreement/Understanding between EMBRAPA/CENARGEN and IRRI was never concluded. It should be pointed out that the successful conclusion of these discussions was probably affected by the international negotiations over access to and use of germplasm under the Convention on Biological Diversity, and the revision of the FAO International Undertaking. However, extensive collecting was carried out in Costa Rica.

Participation by NGOs in the planning phase was limited, as has been their involvement throughout the project. A farmers' group representative did participate in the Discussion Workshop on On-Farm Conservation, but at the national level in several countries there has been more NGO participation in collecting and training, although not really significant. IRRI has assisted the Philippines-based NGO SEARICE (South East Asian Research Institute for Community Education) in the drying and packing of rice seeds for medium-term conservation in the genebank at the Philippine Rice Research Institute (PhilRice).

With the secondment to IRRI of a population geneticist, Dr. Jean-Louis Pham, from the French research organization ORSTOM (now IRD), and the recruitment of a social anthropologist, the research about on-farm conservation was initiated in 1995. Research partnerships and sites were established in three countries:

Country	Partners	Research sites
India	Indira Gandhi Agricultural University, Raipur, and National Bureau of Plant Genetic Resources (NBPGR), New Delhi	Bastar Plateau, Madhya Pradesh
Philippines	PhilRice	Cagayan Valley, northern Luzon
Vietnam	Huê University of Agriculture and Forestry	Region of Huê

The project achievements for the three components are described in separate sections, and brief analyses of impact and monitoring are also presented.

Project Component I. Collection and *ex situ* conservation of wild and cultivated rices

One hundred and sixty-five collecting missions (and additional collecting activities by extension workers in remote areas not reported as formal collecting missions) were carried out in 22 countries from 1995-2000 (Table 1). The trips lasted from just a few days to several weeks.

A total of 24,718 samples of *Oryza sativa* was collected, and 2,416 samples of 16 *Oryza* species, weedy types and mutative hybrids, and some unclassified samples; there were samples of at least four species from three related genera (Tables 2 and 3). A complete breakdown of the samples by species at the time of preparation of this final report requires further inputs from national partners.

Over 80% of the cultivated rice samples and 68% of the wild rice samples have already been sent to the International Rice Genebank (IRG) at IRRI for long-term conservation (Table 4). Cambodia and the Lao PDR also took the opportunity to send some previously-collected germplasm samples not already duplicated in the IRG, so there is not a complete congruence between the figures in Tables 2 and 4.

The collecting effort in the Lao PDR was particularly impressive, with more than 13,000 samples of cultivated and wild rice now safely conserved in the local genebank and in the IRG. The collecting activities in sub-Saharan Africa focused almost entirely on wild species, and in general the number of samples collected was not high. The resource investment to collect this material was quite high but realistic given the somewhat sparse geographical distribution of the species populations, and the difficulties in collecting. NARS observations on constraints to collecting are listed in Table 5.

Observations by national program personnel on genetic erosion and germplasm collection are presented in Appendices I and II, respectively. Some observations on indigenous knowledge are presented in Appendix III.

Project Component II. On-Farm Management of Traditional Rice Varieties

This section presents the main results and conclusions of the IRRI-coordinated research project for on farm-conservation of rice diversity in the Philippines, in Central Vietnam and in India. It presents how the project was designed, the main results it has achieved, and their implications for the on-farm conservation of rice genetic resources, as well as recommendations on the role that a research institution like IRRI can play in this area in partnership with other stakeholders.

Objectives and implementation of the project

In 1994, IRRI organized a think-tank workshop on the on-farm conservation of genetic resources. The participants agreed on the need to develop the scientific basis for on-farm conservation. The philosophy of the IRRI-coordinated project was presented in a position paper (Bellon *et al*., 1997). As with the conclusions of the workshop, we have consistently argued that although on-farm conservation of genetic resources was strongly advocated in international forums, there was limited understanding of what this approach really meant. We concluded that more research should be conducted to understand farmers' management of crop diversity and its genetic consequences. This was especially true in the case of rice for which very limited knowledge was available. Therefore, the IRRI-coordinated project was designed as a research project, not as an implementation project.

The objectives of the project were defined (Pham *et al*., 1996):

- to increase knowledge on farmers' management of rice diversity, the factors that influence it, and its genetic implications;
- to identify strategies to involve farmers' managed systems in the overall conservation of rice genetic resources.

Identification of study sites and partnerships

Rice is cultivated in four main different agroecosystems: the flood-prone ecosystem, the irrigated lowland, the rainfed-lowland and the rainfed-upland ecosystems. One of the first steps in the project was to identify the ecosystem on which to focus our efforts. The flood-prone ecosystem was too marginal to be the main focus of a project aiming at methodological outputs—although obviously not marginal for farmers who grow flood-prone rice. The irrigated system has been the main target for development of modern varieties, and these have largely displaced traditional ones. The restoration of genetic diversity in the irrigated ecosystem is a valid objective, but much beyond the purpose of on-farm conservation. We did not give priority to the upland ecosystem, although the genetic diversity of traditional upland varieties is well known. Even though traditional varieties are the most important in the upland ecosystem due to the limited impact of modern varieties, this was not chosen because the process of loss of rice diversity is not associated with the substitution of traditional by modern varieties, but by a changes in land use or the substitution of rice by other crops.

Finally, the rainfed lowland ecosystem is where we dedicated most of our efforts. This ecosystem is important in terms of area, production, and number of farmers. Rainfed lowland rice makes up 25 percent of the world's harvested rice area and 17 percent of world production. The impact of modern varieties has not been as strong as in the irrigated ecosystem—one reason being that conventional breeding is not as efficient in unfavorable and heterogeneous environments as in favorable and homogenous ones. The coexistence of traditional and modern varieties makes this ecosystem the most promising for on-farm conservation. However, we also included the upland and irrigated ecosystems for a broad assessment of farmers' management of diversity and genetic diversity among the three major rice ecosystems in the Philippines and Vietnam.

Other selection criteria were related to the possibility of comparing the effect of several factors on genetic diversity and its management, based on the theoretical planning framework shown in Fig. 1. These factors included market integration, ethnic identity and environmental heterogeneity (Table 6). Other factors were eventually incorporated into the research plan but in the planning stages only these were considered in site selection.

A general workplan was elaborated in June 1995 (Bellon and Pham, 1995), circulated within IRRI, sent for comments to the members of Project Steering Committee, and finally endorsed by that committee in December 1995. This workplan served as a framework for the three specific country-based work plans developed with national partners in the selected countries.

The identification of country and study sites came from a pragmatic combination of possible partnerships and scientific opportunities. Exploration trips were made and discussions were conducted with potential NARS partners. This resulted in the choice of three study countries and sites: India (Bastar Plateau, Madhya Pradesh), Vietnam (Huê Province, central Vietnam), and the Philippines (Cagayan Valley, northern Luzon). These sites represent a broad cross section of rainfed lowland and upland farming systems, with a wide divergence in agricultural, policy, and economic conditions.

Partnerships were developed with research institutions and also with the institutions in charge of rice genetic resources in the study countries (Fig. 2). The research partners were the Indira Gandhi Agricultural University (IGAU-IGKVV, Raipur, Madhya Pradesh) and the National Bureau of Plant Genetic Resources (New Delhi), the Huê University of Agriculture and Forestry (HUAF), and the Philippine Rice Research Institute (PhilRice). The Vietnam Agricultural Science Institute (responsible for rice genetic resources in Vietnam) did not participate in the research activities.

The Cagayan valley is in the north of the island of Luzon in the Philippines. The agroecological conditions there are generally diverse, although the overall condition is one of marginal lands within a variable environment. In our study area of the rainfed-lowland rice, the most common land types are the *drought and submergence*, *submergence prone*, or *drought prone* environments. The favorable land types are infrequent. It is a typhoon- and flood-prone region. Tuguegarao is the capital of the Cagayan province. The local network of roads is not sufficient to allow an easy access to all villages known as *barangays.* However, the region is easily accessible by road or air.

The region of Huê, in central Vietnam, is narrow walled with mountain chains to the west along the Lao border, and flushed with sandy areas on the eastern coastline. The narrow coastal plains are the food supply area of the whole region. Most of land, often irrigated, is used for rice. The coastal sandy ridge occupies a rather large area and plays an important role in agricultural production and ecosystem conservation. Because of its rainfed condition, sandy soils with poor water holding capacity, salinity and pest pressures, the yields of rice and other crops (such as sweet potato, groundnut sesame, cucumber, chili, beans) are low. In between the two major economic poles of Vietnam—Hanoi and Ho Chi Minh City—central Vietnam has not benefited from the same economic development. Its isolation is decreasing however, as air and road connections with the other parts of the country improve.

In the state of Madhya Pradesh in central eastern India, the study region of Chhatisgarh was represented by two selected districts, Raipur and Bastar. The Raipur district is very near the regional capital city of Raipur whereas Bastar is rather distant (more than 300 km). Among all our study sites, Bastar was by far the most isolated, and the least affected by Green Revolution technologies. Both areas have irrigated and rainfed rice agriculture, although in different proportions. The net sown area for rice in Raipur is 946,000 hectares, of which 425,000 ha (44.8%) are irrigated. Bastar has a total sown area of 841,000 ha, of which 25,000 ha (2.9%) are irrigated. These figures have not significantly changed in the past 10 years. The presence of irrigation also has an impact on the productivity of rice land. The average productivity in Bastar is approximately 1 t ha^{-1}, and 1.5 t ha^{-1} in Raipur. It is evident that rainfed rice agriculture is important in both the Raipur and Bastar areas, although irrigation, while critical in Raipur, is insignificant in Bastar where drought is the main constraint to rice cultivation.

Multidisciplinarity

The theoretical planning framework (Fig. 1) stressed the need to develop a multidisciplinary approach. The IRRI research team consisted of a population geneticist (Jean-Louis Pham, project team leader, seconded from IRD, formerly ORSTOM) from May 1995-July 2000, and an anthropologist (Mauricio Bellon from March 1995-February 1997, and Stephen Morin from March 1997-June 1999), supported by three assistants (seed collection and field studies, molecular markers, social sciences). This mixture of biological and social sciences was extended to the partnerships developed in the study countries, as NARS counterparts were identified in both areas (Table 7). In all, a dozen NARS scientists participated significantly in the project, and a number of others contributed at a more limited level. Also, extension personnel were largely involved in the identification of study villages and in establishing contacts with farmers and village officials. A by-product of the project was to build associations between scientists within collaborating NARS from disciplines that seldom collaborate. In May 1999, the project workshop organized at IRRI provided an additional opportunity to develop links among NARS scientists.

Methods were chosen based on the objectives of the research, their cost-effectiveness, and available personnel at IRRI and NARS to conduct the research. The methodologies used during the project included:

- socioeconomic surveys;
- questionnaires on farmers' management of diversity;
- anthropological methods, including semi-structured and unstructured interviews;
- field seed collections;
- surveys for biotic constraints;
- molecular marker analyses (isozymes, microsatellites);
- field trials.

On-farm conservation: a complement to *ex situ* conservation of rice genetic resources

Depending on which stakeholders are affected, on-farm conservation may aim at different objectives. In all cases, however, the starting point should be an assessment of the actual genetic diversity that farmers maintain, how and why a population evolves, and how diversity is perceived and managed by farmers. The ultimate aim must be a link between farmers' conceptualization and decision-making regarding diversity and the actual genetic effect of these behaviors.

Diversity assessment

Germplasm collection. The seed collecting activities led to collections of local rice germplasm which are now maintained by the national programs (Table 8). These collections are absolutely unique because of the effort made to collect a sample of all the varieties cultivated by all the households in the study. Thus, it was possible to capture the diversity at the village or region of a given variety name.

Distribution of variety names. Although it does not necessarily reflect the actual genetic diversity, the number of names is a basic indicator for on-farm conservation, as names reflect the units of seed management by farmers. The richness of variety names was obvious at all study sites in the rainfed-lowland ecosystem (Table 9). This demonstrates that farmers still maintain a sizeable diversity of rice varieties, even in agroecosystems in the midst of economic and technological changes (Philippines, Vietnam). In India, the Bastar Plateau is a much more isolated environment where farmers maintain an enormous diversity (more than 100 variety names in 8 villages).

In the Philippines and in Vietnam, the number of varieties maintained at the village level was relatively low. The consequence for genetic conservation strategies is that it would not make sense to develop projects based on a small number of villages. On-farm conservation plans in central Vietnam and in the Cagayan Valley must involve several villages distributed across the target agroecosystem.

We paid particular attention to the distributions of variety names across villages, and to methods to represent them. The categorization of varieties into local and widespread varieties, and frequent and rare varieties can help in designing the conservation priorities (Fig. 3). Also, the shape of the accumulation curves of variety names frequencies facilitates comparison of the distribution of diversity across countries (Fig. 4). While Indian sites appear immediately to be the most diverse, as well with the lowest impact of modern varieties, diversity in the Philippines appears much less balanced than in Vietnam because of the predominance of a small number of varieties. An important conclusion however, is the ability of rice agroecosystems to retain what can be called residual diversity. Besides the most frequent varieties, infrequent or rare varieties may represent an important source of *in situ* diversity.

Molecular diversity. Molecular markers are objective indicators of genetic diversity. ● As such, they can provide arguments for the conservation of particular group of varieties, and inform policy-makers on the genetic consequences of changes in the varietal landscape in agroecosystems. In this respect the respective contribution of traditional and modern varieties to genetic diversity was a key question that we illustrate with the case of Vietnam.

Table 10 shows that in a given ecosystem, the relative contributions of traditional and modern varieties are quantitatively surprisingly similar. The specific contribution of each category of varieties must considered however. Fig. 5 shows that if one considers the allelic diversity for microsatellites, traditional varieties bring alleles that are not found in the modern varieties, particularly in the case where only the most frequent varieties would be conserved by farmers. This does not mean that modern varieties should not be considered an important component of the genetic landscape. Modern varieties also contribute genetic diversity that is not contributed by traditional varieties. In particular one should pay attention to the fact that old modern varieties—almost considered traditional varieties by Vietnamese farmers—are as threatened as the local landraces.

Clearly, the debate is not about promoting modern or traditional varieties because they are modern or traditional. It is about managing and conserving diversity in agroecosystems, whether the diversity comes from traditional or modern varieties.

Not only genetic studies played a role in this assessment. In the Cagayan Valley, anthropological studies showed that farmers conceptualize and manage groups of varieties, rather than individual varieties (Morin *et al*., 1998, Fig. 6). Each of these functional groups fits a particular niche in terms of use. These groups were broadly consistent with those identified from genetic analyses:

- The group of glutinous varieties. These varieties all share the fundamental characteristic of being glutinous varieties. The grains are sticky when cooked. In the Cagayan Valley, glutinous varieties are used for special cakes and sweets.
- The group of short growth duration varieties. This group includes varieties that mature in a relatively short period, usually from between 90 to 130 days. The members of the short duration cluster are all modern varieties. Short duration is a characteristic that is valued by farmers because it allows multiple crops per season.
- The long duration group varieties. Long duration varieties mature in more than 130 days. The group is characterized by traditional varieties. It is possible to further classify the long duration group by recognizing that a major subgroup is the Wagwag types.

The conclusion from this therefore is site-specific management of diversity. Not all varieties, or sets of varieties, have the same value in terms of contribution to the overall diversity and its function. Some varieties may bring specific alleles. Others may be associated with a set of agronomic practices and local knowledge, that are more important in the long term for the conservation of diversity in agroecosystems than varieties themselves. Therefore, the role of research institutions is to assess existing diversity through different approaches and identify its components.

A good example of this approach is provided by the Wagwag varieties found in the Cagayan

Valley. First, these varieties bring a specific contribution to the genetic diversity, as shown by DNA marker analyses (Figs. 7 and 8). Second, they play a particular role in terms of functional diversity. They occupy a particular niche in the economic and agroecological environment compared to other varieties managed by farmers because of their high grain quality and their photosensitivity.

Main factors that affect genetic diversity

Agricultural intensification plays a role in the reduction of genetic diversity. In the Cagayan Valley, a differential impact of modern varieties was observed from the upland to the irrigated lowland ecosystem from a survey of 16 households (4 villages/ecosystem, 4 households/village) by ecosystem (Bellon *et al.*, 1998). The ratio of modern to traditional varieties was 24:61, 20:19 and 43:5 in the rainfed upland, rainfed lowland and irrigated ecosystems, respectively. The analysis of the genetic polymorphism at 16 isozyme loci of 149 accessions of traditional and modern varieties showed that a gradient of genetic diversity was also observed, as the Nei's heterozygosity index was 0.25 in the upland, 0.21 in the rainfed lowland and 0.15 in the irrigated ecosystem.

No clear differences were observed between market-integrated and market-isolated villages in terms of number of varieties maintained on-farm or impact of modern varieties whether in Vietnam, Philippines or India. Obviously, this does not mean that socioeconomic conditions do not matter. At the household level, farmers' economic status determines their access to land, and thus influences their range of options. As shown in Fig. 9, the landholding size of Indian farmers is a limiting condition to the use of diversity. It does not imply that farmers with large landholdings grow more varieties, but that farmers with a small landholding—which in Bastar means fewer and therefore less diverse plots—do not grow many varieties. At the other end of the scale, the low level of diversity maintained by farmers with large landholdings reflects the fact they usually own more favorable land.

At the village or district level, socioeconomic conditions matter when they have an impact on rice environment. As we will show later, the development of irrigation is a major factor that affects the use of diversity by farmers. Within a given ecosystem, environmental conditions are the basic factor that influences the level of diversity on-farm. Adverse and heterogeneous biotic and abiotic conditions (rainfed-lowland ecosystem) promote the use of a various set of varieties, most of them being traditional varieties, by farmers:

- in eastern India, our studies clearly demonstrated that farmers manage a pool of varieties to match agroecological conditions and reduce risk and optimize resource use (Morin *et al*., 1999). Most specific varieties, i.e. varieties used in a limited numbers of agronomic conditions, are found in the marginal environments; environment imposes variety choice. In marginal situations farmers reduce risk by planting low yielding varieties suited to the prevailing environmental conditions, e.g., tall varieties in *gabhar* situation and short duration varieties in *tikra* (Fig. 10). In more favorable situations farmers are more flexible in their variety choice.
- in central Vietnam, only nine varieties out of 77 are common to the inland and coastal ecosystems. The adverse conditions in the coastal ecosystem determine the continuous cultivation of local varieties tolerant to abiotic stresses (Fig. 11). Among the 54 accessions tested for salinity tolerance, two were found of equal or better tolerance than the best control lines (*Pokali*) and can be useful germplasm for breeding purposes.

Dynamic conservation

A major question about on-farm conservation is its potential to preserve the dynamic processes of genetic evolution. Although variety mixtures are not intentionally planted as often in the rainfed lowland as in the upland ecosystem, genetic polymorphism was observed in a number of the variety populations in India and the Philippines, indicating that conditions are met to promote genetic recombination, and therefore genetic changes. Indeed, controlled experiments at IRRI suggested that outcrossing occurs preferentially between plants in the same plot, rather than between plots (Reaño and Pham, 1998).

In the Cagayan Valley, genetic analyses demonstrated that some landraces include very different genotypes while other landraces are specific, well-defined genetic entities. This has important consequences both for *in situ* and *ex situ* conservation strategies, as targeted varieties may not be correctly sampled with a single accession. The analyses also showed slight genetic differences among collections with the same modern variety name (Figs. 12a and 12b). Comparison of the farmers' varieties with those derived from breeders' seed also indicated a divergence between the two samples. These results indicate a high degree of outcrossing among farmers varieties and/or the misnaming of several varieties (Sebastian *et al*., 1998).

In India, we studied the genetic variation within two popular traditional varieties *Safri* and *Sathka*. In both cases, a large intravarietal variation was observed, indicating that not all *Safri* or *Sathka* samples are identical. Several factors have brought about this variation. Misnaming of varieties by farmers is only one of the factors, that could account for extreme differences. For both *Sathka* and *Safri*, one dominant genotype or cluster can be identified, that can serve as the reference cluster. The molecular characterization of the variety group *Sathka* showed that accessions originating from the same village tend to cluster together (Fig. 13). It suggests they result from local processes of genetic differentiation. This is supported by the results from agromorphological characterization.

Thus, it appears that farmers' management of rice diversity is a dynamic process with associated genetic changes. It suggests that in some locations, even after thousands of years of cultivation, the contribution of traditional management of rice diversity to the evolution of the crop is still considerable.

Two approaches to on-farm conservation

Here, we give examples that link the reasons why farmers maintain, discard or lose diversity, and a given on-farm conservation strategy. We believe that most, if not all, on-farm conservation strategies can be categorized under two main principles.

1. Make diversity a viable option to farmers

There is general consensus that farmers are not conservationists in nature, but are conservationists through use. In other words, farmers have to be provided with the right technical and economical options, so that they see the advantages for growing the varieties targeted by the conservationists. Creating conditions that makes diversity a viable option for farmers, either through policy or market mechanisms, is a potential means to promote on-farm conservation. This includes changing existing policy, or reducing incentives for programs that may negatively affect rice diversity.

Promoting long-duration varieties. Although agroecological and socioeconomic conditions can be met where traditional and modern varieties coexist, changes in those conditions increase the tension between traditional and modern varieties. The competition between traditional and modern varieties is aggravated when their respective niches are modified. For example, in the Cagayan Valley, the predominance of high-quality traditional varieties (Wagwag ●) is affected by the increased adoption of high-yielding varieties due to the development of irrigation. The higher market price for traditional varieties does not compensate their lower yield and longer duration. Farmers will continue to grow these traditional varieties if their cultivation does not penalize them.

The idea of investigating new cropping patterns came from the observation of the practices of a farmer who was planting his traditional varieties in late October, a full 3 months after his neighbors. According to him, this practice posed no risk and he felt he achieved higher yields with his traditional varieties than his neighbors. Field trials conducted on the IRRI Experiment Station in Los Baños confirmed these observations. Not only did a late planting decrease the duration of the Wagwag varieties, but there was an increase in yield (Figs. 14a and 14b).

It is then possible to propose a new cropping pattern, that would allow farmers to do double-cropping with both modern and traditional varieties (Fig. 15). Small-scale on-farm trials were conducted in Cagayan in collaboration with the local agricultural authorities. They confirmed the potential of the approach and revealed the interest of farmers. IRRI and PhilRice are developing a project—with the possible involvement of community-based organizations—in which large-scale tests will be conducted. As for any released technology, it will be extremely important to assess the potential impact of this double-cropping pattern, its benefits as well as its possible pitfalls (e.g., occurrence of pests and diseases).

Viability does not only encompass economic aspects. In Vietnam, national researchers are conscious that local varieties play a significant role in the sustainability of the coastal ecosystem that could be potentially harmed by the introduction of high-input varieties. We believe that in central Vietnam, future work will have to address the difficult question of the ecological benefits of agrobiodiversity. Contacts with teams working on natural resources management have been initiated (IRRI-IRD, CIRAD).

Finally, the interest and potential of the diversity of rice varieties must be understood by local authorities, so that diversity management does not conflict, as far as possible, in the practices recommended by agricultural extension agents. In this respect, two workshops were held, in the Philippines and in Vietnam, to present the outputs of our research to local authorities and agricultural officers, and increase their awareness of the existing rice diversity and its value in their activity area. ● ● ●

2. Strengthen farmers' access to diversity

Understanding the external factors of genetic erosion. Our studies demonstrated how fast genetic erosion can occur at the local level. Surveys in the Cagayan Valley showed dramatic changes in the pattern of variety distribution because of two major weather phenomena. In 1997, El Niño caused a severe drought that affected the Cagayan Valley and much of the Philippines. The total amount of rain in 1997 was lower than usual and the timing of rains that did come was not good. The drought came when the rice plants were at the seedling stage, a stage when the tolerance to drought is negligible. Some farmers who had decided to wait for more rains could never plant. In September and October 1998, the typhoons Loleng and Iliang hit the valley and caused severe infrastructure damage ● and early season flooding. ● The level and intensity of these floods was devastating. Again, rice seedlings were lost and even plants at later growth stages were badly affected.

Our surveys demonstrated that these catastrophes had a major impact on the frequency of traditional and modern varieties in Cagayan. The use of traditional varieties by farmers decreased from roughly 45% in 1996 to about 25% in 1998 (Fig. 16). In several villages, the cultivation of traditional varieties was almost abandoned by farmers. Surveys and discussions with farmers and extension agents provided four main explanations for this rapid change in the varieties grown by Cagayan farmers:

- Deficient household seed storage technology: due to the humid climate conditions, the normal seed storage conditions in farming households in Cagayan do not permit farmers to conserve the germination ability of seeds more than 6-9 months. This means that farmers cannot jump a production season; if they do not produce seeds for a given variety during season *n*, they will have to find an external source to get seeds to be able to plant the variety in season *n+1*. Obviously, another option for them would be not to plant the variety.
- Lack of infrastructure for seeds of traditional varieties: in a situation where seed stocks of most farmers were affected, farmers had to rely on external sources to obtain seeds for the next planting season. The seed stores generally carry only modern varieties and certified seed growers, a part of the Department of Agriculture's system of seed procurement strategy, grow only modern varieties.
- Support to the use of modern varieties: in 1997 and 1998 the Municipal Agriculture Offices sponsored a 'plant now pay later' scheme. In this program farmers are given

seeds at no cost, but upon harvest are expected to pay for them. The seeds given in the scheme are from the certified seed growers and are always modern varieties, and sometimes only the recommended varieties. The varieties available in 1998 were IR66 and PSBRC28, the former a popular but older modern variety, and the latter is a new and currently recommended variety. Traditional varieties are not planted by certified seed growers and were not included in the scheme.

- Resilience of irrigated plots: the varieties that were planted in irrigated plots were obviously less affected by the drought than the varieties planted on rainfed plots. Therefore, irrigation sustained the use of the modern varieties, as farmers plant only modern varieties in irrigated plots (Morin *et al*., 1998).

What is remarkable here is that genetic erosion was caused by factors that 1) are external to the farmers' decision-making process, and 2) accompany the release of improved varieties, but are not related to the intrinsic qualities of improved varieties.

Improving on-farm storage. As discussed in the analysis of the consequences of the natural catastrophes in Cagayan, poor storage conditions are a cause of genetic erosion. We are developing a simple and cheap seed drying and storage device that farmers could use to store the seeds for several years. With a simple plastic drum as a container, and toasted rice seeds as a drying medium, preliminary tests show the moisture content of fresh-harvested seeds can be brought down to 10%, i.e., to a level that would permit the conservation of seeds in the closed drum for several years. A prototype of the device is currently being tested by pilot farmers in collaboration with local authorities.

Restoring diversity. In November 1998, we went to Cagayan Province to take seeds back to farmers who had participated in our project. The seeds had been collected from farmers in 1996 and planted and characterized at IRRI in 1997. A total of 28 varieties, including both modern and traditional types, were distributed to farmers in 15 villages. In all, about 1.5 t of seeds were given away. A total of 609 bags of modern variety seeds (2 kg each) and 105 bags of traditional variety seeds (1 kg each) were distributed. ● It appeared two years later that the small amount of seeds distributed to each farmer had limited the efficiency of the distribution. The small multiplication plots implemented by individual farmers were affected by localized floods, while larger plots, possibly conducted at the community level, would have been more resilient. Only 57% and 32% of the bags of modern and traditional varieties respectively, were successfully multiplied. Nevertheless, the distribution modified the on-going downward trend of farmers growing traditional varieties (175 in 1996, 110 in 1997, and 84 in 1998), as it went up to 148 in 1999.

The distribution of seeds we organized in September 1998 demonstrated the interest of farmers in getting back seeds from varieties they had lost. It provided an example of a potential link between farmers and genebanks. Although this distribution was not organized in response to the catastrophes in Cagayan, its impact illustrates the need for genebanks to develop an expertise in the restoration of local diversity. One of the activities included in the FAO Global Plan of Action that was adopted at the Leipzig conference in 1996 is assistance to farmers in disaster situations to restore agricultural systems. The example of the Cagayan Valley shows that disasters do not necessarily happen on a very large scale. The design and logistics for local operations of diversity restoration might have to be very different of those conducted at a national or regional level.

As shown by our study in Cagayan, strengthening farmers' access to diversity can be addressed through adequate policies (e.g., seed growers for local varieties), improved on-farm seed storage at the household or community level, and distribution of seeds from genebanks.

In central Vietnam, another approach has been initiated with the joint support of AUPELF (Network of Universities of Francophone Countries). Three composite populations have been created by bulking seeds from the samples collected in the region of Huê: one population made from the inland area varieties, and two populations made from the coastal area varieties (short- and mid-duration varieties, mid- and long-duration varieties). After one cycle of multiplication in the experimental station, these populations were split into sub-populations and distributed to 10 pilot farmers to be grown every year. The first on-farm multiplication cycle has just been successfully completed. The objective of this experiment is:

- to make the overall diversity of the Huê region accessible to the farming communities and scientists in an easily manageable form to compensate for the lack of storage facilities in villages as well as in the university;
- to establish the basis for dynamic management of artificial rice populations.

Recommendations

On-farm conservation of rice genetic resources, as a complement to *ex situ* conservation can be motivated:

- by the high level of genetic diversity still maintained and managed by farmers, particularly in adverse and heterogeneous environments of the rainfed-lowland ecosystem;
- by the maintenance of agronomic practices and associated local knowledge;
- by the resilience of dynamic processes of genetic evolution in particular areas.

The role of research institutions is:

- to assess existing *in situ* on-farm diversity and its structure;
- to understand the functional role of this diversity (agronomic, socio-cultural, economic, ecological);
- to understand the processes and knowledge associated to this diversity;
- to assess the potential consequences of a loss of diversity;
- to assess the potential benefits of this diversity both to farmers and conservationists;
- to provide development agencies with a framework of understanding of the on-farm diversity in their area of action.

Make diversity a viable option to farmers. On-farm conservation cannot be imposed on farmers. Farmers will maintain or increase the diversity they grow if this brings them benefits. Obtaining the right balance of incentives for farmers to maintain diversity is critical for policy makers and researchers.

The role of research institutions is:

- to identify endangered varieties or variety groups, and the threats to these varieties;
- to identify technical or policy opportunities for the continued cultivation of these varieties (or to change policies that negatively affect diversity);
- to contribute to the transfer of knowledge/technology to farmers through the appropriate channels.

Strengthen farmers' access to diversity. On-farm conservation cannot rely only on the traditional seed exchange mechanisms between farmers that have ensured the continuous cultivation of varieties over centuries. Strengthening farmers' access to diversity is an obvious mechanism to promote diversity on-farm. Farmers should be able to plant the varieties they want, when they want. Enhancing what we call the seed infrastructure is a necessary goal in the maintenance of diversity.

The role of research institutions is:

- to understand the impact of seed policies on farmers' access to genetic diversity, and warn policymakers about their consequences;

- to understand the technical constraints faced by farmers in conserving genetic resources and to improve or develop seed technologies at the local level;
- to develop channels for the reintroduction of lost varieties when needed, and develop links between farmers and genebanks;
- to develop simple approaches to conserve locally a large amount of diversity (e.g., composite 'reservoir' populations).

Conclusions

The contribution of this IRRI-coordinated project for on-farm conservation has been:

- to bring hard data and facts to the debate on the use and relevancy of on-farm conservation of rice genetic resources, and on the impact of deployment of modern varieties on biodiversity;
- to identify avenues for the implementation of on-farm conservation strategies;
- to explore the role that research institutions could play in the future;
- to develop methodologies and competencies in the assessment of rice diversity and its management by farmers through partnership with national programs;
- to increase the awareness and understanding of issues related to on-farm conservation and the value of local diversity both in NARS and local development agencies;
- to share its experience, with other researchers through the participation to various conferences and meetings, publication of papers, organization of a workshop, and collaboration with other projects.

Project Component III. Strengthening Germplasm Conservation by National Agricultural Research Systems (NARS) and Non-Governmental Organizations/Farmer Organizations (NGOs/FOs)

Support to the NARS was provided in the form of equipment to upgrade genebank facilities or facilitate germplasm collection (Table 11), and training of national personnel on the skills needed to collect and conserve rice germplasm.

Between 1995 and 1999, 48 courses or on-the-job training opportunities were offered in 14 countries and at IRRI headquarters in the Philippines (Table 12). The training encompassed field collection and conservation, characterization, wild rice species, data management and documentation, genebank management, seed health, analysis of socioeconomic data, and isozyme and molecular analysis of germplasm. More than 670 national program personnel were trained. IRRI staff were involved in the management, coordination, and presentation of almost all the training activities.

National perspectives on the benefits of training in germplasm collection, and on-the-job training at IRRI are shown in Tables 13 and 14, respectively. Training was also given to scientists participating in the on-farm conservation research (Table 15).

Project Management and Monitoring

IRRI provided overall financial management and implementation for the project. Regular financial statements were submitted to the donor. The Head of IRRI's Genetic Resources Center, Dr. Michael Jackson, was the project coordinator, assisted by Ms. Genoveva Loresto, project scientist. In several countries such as Cambodia, Lao PDR, Myanmar, Indonesia, and Vietnam, local IRRI Liaison Scientists and country program staff provided additional logistical support for accounting purposes, and the acquisition of capital items.

Project expenditure by major categories and by countries is shown in Figs. 17 and 18. Forty percent of the project funds were expended directly by the national programs to finance collecting and training, as well as purchase capital items. Expenditures for operating costs at IRRI, primarily for the on-farm conservation research, and the processing and conservation of collected germplasm accounted for 7%. Only 1% of the total budget was spent on project monitoring.

A breakdown of the on-farm conservation expenditures is shown in Fig. 19, indicating that almost equal allocations were made to institutes in the three participating countries – India, Philippines, and Vietnam. The higher expenditure at IRRI reflects primarily the genetic and field analyses of germplasm collected in this research in which molecular markers were used to assess genetic diversity.

Impact

The project has substantially met the objectives that were established at its initiation:

- Most of the projected germplasm collection activities have been completed, although some gaps do remain. Unique germplasm has been collected from previously under-explored regions in many of the countries that participated in the project.
- Much of this germplasm is safely conserved in the International Rice Genebank Collection at IRRI. Acquisition issues remain to be resolved with Bhutan, with regard to the finalization of a Material Transfer Agreement with IRRI to permit conservation of samples in the International Rice Genebank.
- Two countries, Costa Rica and Namibia, have specified some conditions for access to germplasm from these countries. Status of germplasm *vis-à-vis* IRRI's agreement with FAO (concluded in 1994) to designate the accessions also has to be clarified. Both Costa Rica and Namibia have indicated that germplasm may not be designated to FAO. Issues of access under the Convention on Biological Diversity may be affecting the rate of duplication to the IRGC from some countries, particularly those in Africa. In other cases, initial multiplication of collected samples has proved problematic and has delayed sending them to IRRI for long-term conservation.
- Genebank standards have been addressed and opportunities taken to upgrade facilities, particularly in seed drying and storage. Training in various aspects of genebank management has enhanced staff capabilities.
- IRRI staff developed data management systems for rice genetic resources for several countries (Lao PDR, Bangladesh, Cambodia, Myanmar, and Malaysia) and provided training in data management and documentation.

National staff perspectives of the benefits and impact of this rice biodiversity project on rice genetic resources conservation, on genetic resources activities more generally, and on broader biodiversity issues, are presented in Table 16.

It is clear that the on-farm conservation research has made an original contribution to the discussions about this conservation strategy, and has identified several policy options and technical issues to address. The research has also influenced other external activities by other organizations, and there have been useful linkages with a number of them as they developed their research projects (Appendix IV).

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