ISSN 1024-7548

ICIMOD
International Centre for Integrated Mountain Development

Discussion Paper
Series No. MFS 95/3

On Farm Management of Biodiversity and Genetic Resources

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International Centre for Integrated Mountain Development
Kathmandu, Nepal
1995

Published by

International Centre for Integrated Mountain Development
G.P.O. Box 3226,
Kathmandu, Nepal

Typesetting at ICIMOD Publications' Unit

ISSN 1024-7548

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August 1995
International Centre for Integrated Mountain Development
Kathmandu, Nepal

Preface

This current discussion paper in the Mountain Farming Series, "On Farm Management of Biodiversity and Genetic Resources," is one of a number of papers delivered at the "Regional Conference on the Sustainable Development of Fragile Mountain Areas of Asia" which took place from December 13th to 16th 1994 in Kathmandu, Nepal. Support for this Conference came from the Swiss Development Cooperation, FAO, UNDP, UNEP, and the UNU.

The unanimous concern expressed at this conference was for the deteriorating conditions of both the environments and livelihoods of mountain people. Mountain development had not been geared to the people nor the environment it purported to serve.

One of the achievements of the Conference was a wider sharing of knowledge amongst the mountain countries of Asia and insight into the constraints that confronted them and the opportunities offered by the wide diversity of their special mountain environments. Another significant achievement was the formulation of a Call to Action on the Sustainable Development of Mountain Areas of Asia, or SUDEMAA recommendations.

By publishing the conference papers in its various discussion paper series, ICIMOD seeks to share the knowledge gained with a wider audience. This current paper should be of interest to all those who are working with on-farm genetic resources and their management.

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Introduction

Today there is global awareness concerning the urgency and importance of preservation of biodiversity and of genetic resources and their roles in the survival of the human species, in general, and for food security in particular. It is, however, beyond the scope of this paper to discuss the broader issues of biodiversity. This presentation is limited to the management of biodiversity and genetic resources at the farm level using examples of mountain farming systems from the Himalayas and adjoining regions.

Compared to specialised market-oriented agricultural production systems found in areas with easy access to markets, farming in mountainous regions has remained largely at the subsistence level. In order to satisfy their basic needs for food and fibres, hill farmers have maintained a highly diversified farming system integrating forest, agricultural, and livestock resources. Another important characteristic typical of mountain areas is their tremendous diversity in terms of environmental conditions. The need to maintain high levels of self reliance and the variations dictated by climate and other environmental factors will ensure a wide biodiversity in present and future farming systems.

Although changes may occur at a comparatively slower pace, mountain systems nevertheless are dynamic, and concerns over the loss of genetic resources and traditional knowledge are certainly justified. Furthermore, the ecological balance in mountain systems is often extremely delicate and the slightest changes in land use systems can easily trigger off irreparable damage.

While there is a consensus about the need for preservation of genetic resources, opinions differ as to what would be the best method. Gene banks and botanical gardens have been the main agents of germplasm collectibn and preservation in the past. In the last few decades, the preservation on farmers' fields or *in situ* preservation has received increasing support from conservationists.

This presentation neither attempts to treat the subject exhaustively nor provides a recipe for on-farm conservation, it is simply intended to 1) stimulate discussions and 2) draw attention to the complexity of the subject.

Preserving Genetic Resources at the Farm Level-Potentials and Limitations

The use of biodiversity by the farmer to counter risks in the form of pests, diseases, and climate and market fluctuations is widely accepted and supported by examples beginning from prehistoric times and extending to the present day (Plucknett et al. 1987). Prominent examples cited by Plucknett et al. (1987) include the collapse of the Mayan civilisation due to the exclusive planting of maize and the Irish potato famine in the last century.

A typical hill farmer depends on a wide number of different plant and animal species and their interactions (Table 1). The best approach to conserving these resources varies with the species. The preservation of genetic resources in the original environment, or *in situ* preservation, has received considerable support over the last decade (Meyers 1983; Plucknett et al. 1987; Brush 1991; WRI et al. 1992). Supporters of *in situ* preservation argue that gene banks arrest the evolution of plants. Most discussions are, however, limited to plant genetic resources and specifically to so called 'land races' of annual crops. Many may argue that the emphasis on annual crops is justified because they are by far the most important food source and are, at the same time, the ones that are most threatened by the introduction of higher yielding varieties. Yet, this may also be the group of species with the most limited scope for on-farm preservation (Table 1). Although the debate on *in situ* preservation of major annual crops may have resulted in a better understanding of the possibilities and limitations of this form of preservation, it is unfortunate that other genetic resources have often not been included in these discussions. Most scientists do agree that *in situ* preservation of vegetatively multiplied perennials, such as fruit trees and plantation crops, is the most practical approach. Domesticated animals may require a combination of gene bank and *in situ* preservation to ensure the survival of traditional breeds.

Plucknett et al. (1987) acknowledge the merits of *in situ* preservation of crop species but, at the same time, give a list of pragmatic considerations that may make its application unrealistic.

1. Survival of resources in any system will depend on people.
2. The task and cost of monitoring farmers and administering a subsidy system may be impossible (imagine how it would be possible to maintain over 1,000 rice varieties in Nepal, or 10,000 varieties in Laos).
3. In spite of subsidies, farmers may not be motivated to maintain the 'museum land races'.
4. Maintenance of low-yielding traditional varieties may further reduce food availability in countries with high population densities (Bangladesh)
5. The material would not be readily available for the breeder
6. Another important factor to be considered is the need for a long-term commitment. A programme going for three years will definitely not suffice, we need preservation over 100s of years.

Table 1: Components of biodiversity in hill farming systems[1]

Category	Major properties	Major threat to diversity	Methods of conservation	
			On-farm	*Ex situ*
Plant species, annual crops	Major source of food, wide range of different populations for individual species	New varieties	Compl e- mentary	Main
Perennial crops	Often multiplied vegetatively, difficult to maintain with long-term storage facilities	New varieties, market demand, disease problems of old varieties	Main	Comple- mentary
Semi- domestica ted	Genetics poorly understood, often only limited local importance	Change in farming system, deterioration of resource	Main	Free species
Wild	Selection process without human intervention	Shift in vegetation by: erosion, introduction of new species, conversion to agricultural land	Main	Relatives of major crop species
Animal species, domestica ted	Farmer direct control in selection process, problems of in-breeding	New breeds, narrow population base	Main	Comple- mentary
Wild	Many species	Estimation of species	Main	

1 Refers only to species and varieties used by farmers (wild species mostly from grazing and fallow land)

7. According to Brush (1991) *in situ* conservation of crop resources will only work if it is:

i) complementary to *ex situ* methods, and

ii) politically viable and accepted by scientists, conservationists, farmers, consumers, and government officials.

During a recent discussion at IRRI, involving scientists from 15 Asian and African countries, representatives from the Southern African Development Council and five International Agricultural Research Centres (CIAT, ITA, WARDA, IPGRI, IRRI), no consensus could be reached for a research agenda for on-farm germplasm preservation for rice (IRRI 1994). It was, however, decided that further studies will be necessary to better understand 1) why some farmers retain traditional varieties, 2) the genetic consequences of on-farm conservation.

The same forum made the following points.

1. On-farm conservation cannot be achieved through subsidies and 'museum' strategies
2. Strategies that may enhance the success of on-farm conservation include:

   i) pathogen elimination in traditional varieties (potatoes, fruit trees),

   ii) stimulation of marketing (green marketing of specialist crops), and

   iii) price incentives

Management of Biodiversity and Germplasm Resources in Three Mountain Farming Systems

The examples of three farming systems, representing climates ranging from tropical to sub-alpine, are used here to discuss the existing biodiversity and genetic resources and how they will be affected by present and future management interventions (Tables 2 and 3). There is a strong tendency to an increase in biodiversity with a shift to warmer environments. The wide diversity in warmer climates perhaps influences the expectations of agronomists with initial field experience in temperate environments.

Yak Production Systems (Himalayan Region)

The resource base for yak herders consists of the extensive rangelands at elevations of from 2,500-5,000m. Yaks are unique for their adaptation to high elevations and cold climates. The yak herders migrate with their animals following the cycles of the season. They may grow a few vegetables and some barley for their own consumption at their winter camp locations.

Due to the availability of basic veterinary assistance, the mortality rate of young animals has declined sharply. Greater yak populations, combined with increased population densities of wild animals, have greatly increased the grazing pressure in some areas resulting in erosion damage and a shift in species' composition. Largely due to the limited options, no other sensational changes have occurred in the yak production system.

The Buckwheat Production System in Central Bhutan

According to the Tibetan Buddhist genesis, five kinds of grains were received as a gift of the Buddha Avalokitesvara (Aris 1988). These grains included buckwheat, barley, wheat, peas, and *soba* (probably a special barley variety according to Aris). These same species are still the main crops in the highlands of Bhutan (Table 2) and among them, buckwheat (*Fagopyrum tartaricum*), is the main traditional staple crop for farmers at elevations above 2,500m (Roder et al. 1992a). The importance of biodiversity in cultivated species is deeply imbedded in the Bhutanese culture. The seeds of 'the nine essential species' (*Du na gu*), including rice, wheat, barley, buckwheat, millet, maize, mustard, and two interchangeable pulses, are used in many important ceremonies. A location is often considered as very fortunate if all the essential species can be grown there. Both rice and millets need warmer climates, and many of the farming areas in Bhutan are, therefore, not capable of producing all the nine species.

Grass-fallow shifting cultivation is the traditional method for buckwheat production. Prior to cultivation, the topsoil layer is cut with a hoe at about five to seven centimetres/in depth and allowed to dry for several months. Dry soil is collected in conical mounds about two to three metres apart. After burning most of the organic material, the mounds are spread again shortly before planting. The burning results in loose, nice friable soil conditions and an almost complete destruction of vegetation and weed seeds, and the potential for erosion is very high. Although labour inputs for field preparation are extremely high, the method used is probably the only possible way for the farmer to obtain a crop under the given conditions without phosphate inputs.

Table 2: Biodiversity in Three Different Farming Systems

Elevation range	Yak herder (Himalayan Region)	Buckwheat grower (Bhutan)	Slash-and-burn farmer (Laos)
	3,000-5,000	2,800-3,500	300-800
Major species	1 Barley (1)[1]	3 Bitter buck-wheat (1) Sweet buck-wheat (2) Wheat (1)	2 Rice (3) Maize (3)
Pulses	1 Peas	3 Peas, Scarlet beans Phascolus beans	8 Cowpeas, Mung beans Soybeans, Peanuts, Winged beans, Pigeon peas, Phascolus beans
Minor food species		2 Barley, Potatoes	8 Taro, Sweet potatoes, Cassava, Yams, Finger millet, Sorghum, Job's tears, Potatoes
Vegetables and spices	5	15	30
Perennial species	-	4	15
Species collected from forest or fallow land	-	4	30
Example of species which may merit *in situ* preser-vation	Yak	Buckwheat, Pears, Vegetables, Sheep	Rice, Bananas, Taro, Teak

[1] Average number of varieties planted by individual farmers

Overall, road accession was the most important factor behind these changes, Thanks to road access, farmers could produce potatoes for the Indian market and import rice to replace the buckwheat in their diets. Introduction of white clover, the availability of phosphate, improved cattle breeds, and a local market for milk products have resulted in a stronger emphasis on livestock production.

Table 3: Trends Affecting Biodiversity and Germplasm Resources at Farm Level

	Yak herder (Bhutan)	Buckwheat grower (Bhutan)	Slash-and-burn farmer (Laos)
Current negative trends	Increasing grazing pressure	Shift to white clover Loss of potato varieties Loss of wheat varieties	Reduced fallow period
Major cause	Animal health care	Subsidies for seed and fertiliser- introduction of wheat and potato varieties Access to market due to road construction, cross-breeding programmes	Population pressure Legislation
Expected positive trends	Awareness for the need of conser-vation	Increased species' diversity in farming system - Reduced pressure on forest	Increased species' diversity in rice production system - Soil conservation measures - shift to perennial species Gradual reforestation

Considerable areas are now covered by white clover and potatoes, but rather than contributing to the erosion of biodiversity, the change has resulted in higher species' diversity. Wheat and potato varieties were lost before the major changes occurred. Buckwheat production has not disappeared. Although rice is socially preferable in rural areas, buckwheat has now become a valuable food for the urban elite. This not only provides for a growing market but also gradually influences the farmers to re-evaluate their traditional food habits.

Slash-and-Burn Rice Production

Farmers in the hills of Northern Laos use a slash-and-burn fallow rotation system for rice production. The fallow vegetation is cut during the dry season and burned shortly before planting rice at the onset of the monsoon. Labour inputs are high because of the heavy weeding requirements. Laos has a very rich diversity in traditional rice varieties, and an individual slash-and-burn farmer plants about three different varieties, on an average, to spread risk and labour requirements (Roder et al. 1992b). Farmers also plant a large variety of different crops and vegetables in the same field.

The combined effects of environmental concerns, expectations for higher productivity, increased population densities, and the resulting reduction in fallow periods are exerting considerable pressure on the slash-and-burn farmers to change to other production systems. Rapid changes are likely to occur over the next few decades, but, except for the loss of some rice varieties, the changes are not expected to cause a reduction in biodiversity. The rice-fallow system will probably be replaced by a rice-rotation system with several other crops, fodder plants, or trees as integral parts of the new system that evolves. The change from slash-and-burn systems to more permanent agricultural systems is also expected to reduce the pressure on primary forests and result in fallow areas reverting to forests, both important systems in the preservation of genetic resources. Sanchez (1993) postulated that each hectare of slash-and-burn area converted to higher production and a continuous cropping system would result in a saving of five to 10 hectares of tropical rain forest.

Commonalties in the Three Systems

- The most serious threat to agricultural production in hilly areas is undoubtedly soil erosion. Present farming systems and their biodiversity and genetic resources can be maintained or improved only as long as the soil fertility is maintained. Soil conservation must therefore be the first consideration in any attempt to maintain and improve the existing farming systems.
- All three systems are dynamic. Farmers are constantly adapting to changes such as population pressure, land resources, inputs available, market opportunities, and eating habits. Changes may result in the loss of know-how, experience, and genetic resources, but they may, at the same time, generate new information and genetic resources.
- All three production systems integrate the use of forest, livestock, and agricultural resources. They represent an adaptation by the farmer to the existing conditions. To date, nobody has convincingly demonstrated better production systems for the high Himalayan regions or the traditional buckwheat growing areas in Bhutan without external inputs.
- A wide range of different species is used as fodder for various types of

livestock. Since the grazing land is generally considered to be part of the farm resources, its management should certainly be included in the discussion. It is impossible to do justice to the importance of different fodder species, not only because of the tremendous number of species involved but also because of the dearth of documentation available on them.

How Real Is the Biodiversity in a Particular System?

Although the farming population is familiar with and may cultivate a large number of different crop species, apart from the large variety of crops used for grazing, the biodiversity in all three systems is not as high as it may appear on the surface. Many families in Bumthang may have had 95 per cent of their area covered with two crop species only (*P. tariaricum* and *P. esculentum*). Similarly, most farmers in the hills of Northern Laos almost exclusively plant rice. *Chromolaena odorata*, a weed species which originated from South America, is almost always the dominant plant in the first years of the fallow period. The acclaimed 'biodiversity' is then often limited to a very small area of the farm. Likewise, the average Swiss farm woman may cultivate 30 different species in her vegetable garden but nobody would consider this to be a special achievement in maintaining biodiversity! When discussing the importance of biodiversity at the farm level, we may therefore have to be more specific and differentiate between:

i) diversity in overall species/varieties used and
ii) diversity in the main production system.

The diversity in overall species and varieties can contain important genetic resources but may not help much in providing stability to the production system. The historical examples cited from Mexico and Ireland refer to the lack of diversity in the production system. The collapse of the Mayan civilisation or the horrors of the Irish famine could not have been avoided by a wider diversity of other species planted on a small vegetable patch or used in combinations with maize or potatoes.

Strategies to Maintain Biodiversity and Preserve Genetic Resources at the Farm Level

Past and Present

The most important factors that motivated farmers to maintain high biodiversity in the past were probably

i) the need for high self sufficiency levels due to communication problems,
ii) reduction of risk factors,
iii) labour considerations,
iv) unavailability of suitable 'improved varieties',
v) market fluctuations,
vi) traditional food preferences, and
vii) special requirements for ceremonies/rituals.

Depending on the speed of development the same considerations will remain important in many remote hill areas. Yet, many of us may argue that subsistence farming systems and the absence of high-yielding food crops will perpetuate poverty, dependence on food imports, and the general backwardness associated with hilly regions. Therefore, most governments provide subsidies in one form or another as incentives to farmers aimed at introducing new crop species/varieties and new livestock breeds, or as incentives for adopting 'improved' techniques. In other words, the activities of most national extension programmes, if successful, may in fact be the main cause for the loss in biodiversity.

In the Future

Most conservationists agree that systems that rely on subsidies and/or result in low production levels will not be successful in preserving existing biodiversity and genetic resources at the farm level. Factors that will contribute are as follow:

1. policies that enhance soil conservation;
2. policies that favour the maintenance of traditional systems;
3. policies that facilitate changes in farming systems but are cautious not to overemphasise the need to replace existing species, varieties, and/or techniques with improved or scientific varieties or techniques;
4. awareness of the importance of biodiversity and genetic resource conservation;
5. respect for traditional crops and food habits;
6. support to maintain traditional germplasm (eliminate viruses from vegetatively-multiplied species); and
7 market opportunities for traditional crops and varieties.

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ICIMOD

ICIMOD is the first international centre in the field of mountain development. Founded out of widespread recognition of environmental degradation of mountain habitats and the increasing poverty of mountain communities, ICIMOD is concerned with the search for more effective development responses to promote the sustained well being of mountain people.

The Centre was established in 1983 and commenced professional activities in 1984. Though international in its concerns, ICIMOD focusses on the specific, complex, and practical problems of the Hindu Kush-Himalayan Region which covers all or part of eight Sovereign States.

ICIMOD serves as a multidisciplinary documentation centre on integrated mountain development; a focal point for the mobilisation, conduct, and coordination of applied and problem-solving research activities; a focal point for training on integrated mountain development, with special emphasis on the assessment of training needs and the development of relevant training materials based directly on field case studies; and a consultative centre providing expert services on mountain development and resource management.

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Mountain Farming Systems constitutes one of the thematic research and development programmes at ICIMOD. The main goals of the programme include i) Technologies and Management Practices - Soil Fertility and Water Management; Integrating Indigenous Knowledge; ii) Strengthening Mountain Agriculture; iii) Integragion of Gender Concerns in the Development of Sustainable Mountain Agrculture; iv) Agricultural Research Networking; and v) Agricultural Extension and Training.

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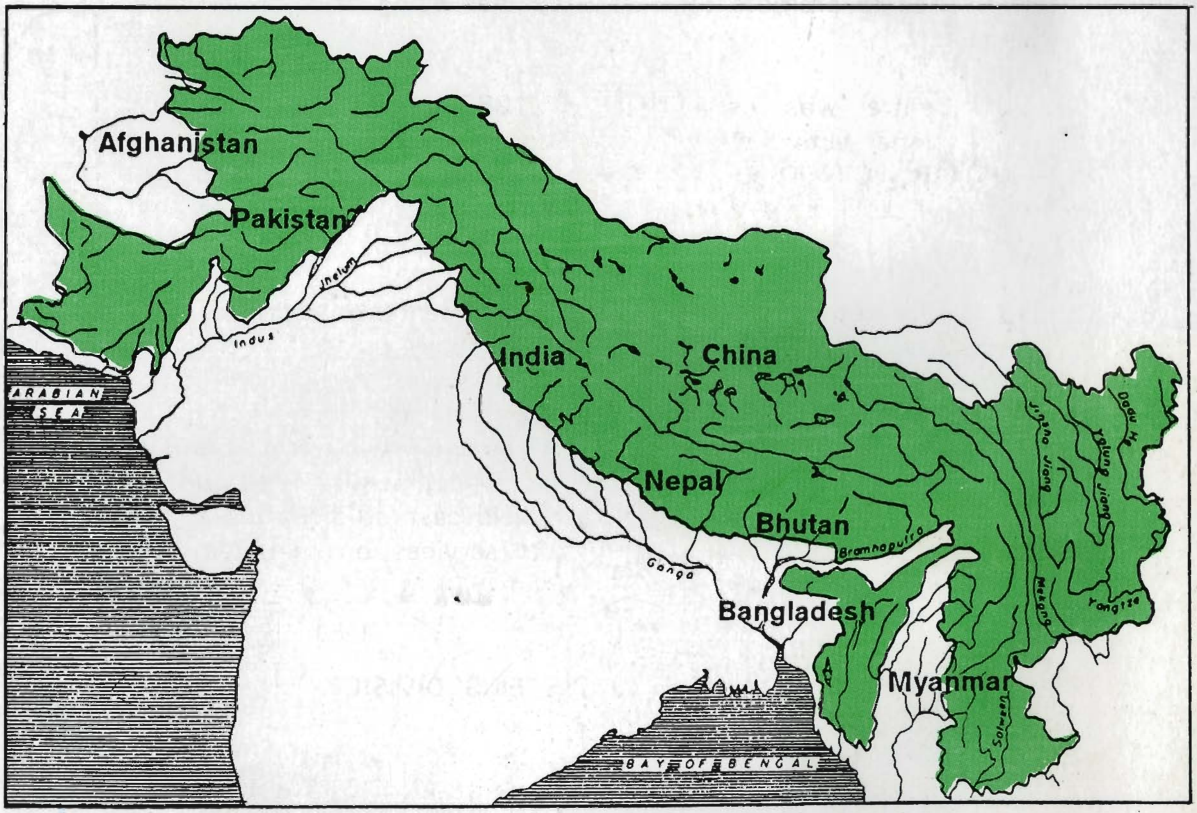

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