Communities and their agrobiodiversity

Priorities for agriculture in Uttarakhand Himalaya, India

Nehal A. Farooquee and R.K. Maikhuri

Abstract: *Poor scientific understanding of traditional farming systems and related socioeconomic issues seriously impede the identification of solutions for sustainable agricultural development in the Himalayan region. Traditional agrobiodiversity management plays a key role in coping with the uncertainties prevailing in the Himalaya. There is an urgent need to bring desirable changes in agricultural policy, research and development, land use and breeding approaches to mountainous regions. This paper describes the general characteristics of agrobiodiversity, its significance, status, rate of change and causal factors, ecological, social and policy dimensions and their impacts on agrobiodiversity loss and strategies for management of the Himalayan agroecosystems.*

Keywords: *agrobiodiversity; agriculture; conservation; Himalaya; India*

Nehal Farooquee is an Associate Professor in the School of Extension and Development Studies, Indira Gandhi National Open University, Maidan Garhi, New Delhi 110068, India. E-mail: nafarooquee@ignou.ac.in. R.K. Maikhuri is with the G.B. Pant Institute of Himalayan Environment and Development, Bhaktiyana, Srinagar 246174, Uttarakhand, India.

Plant genetic diversity is being eroded worldwide at a faster rate than researchers had predicted. Many locally adapted crop cultivars are becoming extinct, or are losing the distinct identity to which they had evolved in a particular geographical situation. Many valley areas in the Uttarakhand Himalayan highlands provide unique opportunities for *in situ* (on-farm) management of agrobiodiversity because of the preponderance of locally developed traditional crop varieties (and associated wild and weed species) in cultivation systems based on traditional knowledge and skills, high agroclimatic heterogeneity and local socio-cultural integration. The Uttarakhand Himalaya is renowned for about 40 crop species, and farmers spread throughout the different regions have selected landraces of about six types of cereals, five types of pseudo-cereals, six types of millets, 16 types of pulses, four types of oilseeds, five types of condiments and eight types of vegetable. Because the Himalaya's food-yielding plants are not exhaustively documented, 'new' varieties and types are still being discovered and reported. Recent additions to this inventory include *Cleome viscosa* L. and *Capparidaceae*, whose seeds are used as condiments (Maikhuri *et al*, 2001a). Further research involving knowledgeable local people will certainly identify additional varieties of food-yielding plants. For instance, few wild vegetables used in the remote high altitude villages of Uttarakhand have been scientifically described. However, over the last two decades, the diversity of traditional agricultural crops and vegetables in the Himalayan region has suffered as a consequence of erosion, which has led to the extinction of some of the most useful varieties of crops considered to be part of the cultural heritage of traditional societies of Uttarakhand.

In the Himalayan region, the identification of certain traditional cultivars has remained largely a specialized activity practised by elderly women in the agricultural communities. This contrasts with the situation in the plains and foothills where all varieties of crops and seeds are readily available and easily recognized in the markets. The difference in familiarity with the crops is explained by the fact that in the plains the land available for agriculture is stable, and regular irrigation provides a steady availability of seeds that can be stored for the next cropping year. In the Himalaya, the rainfall is highly erratic and hence there is no continuity of a particular variety in a particular area or on a certain piece of land. As a result, each ecological niche supports its own varieties/cultivars of plants that are suited to local conditions, and accordingly, many of them succumb in difficult seasons and may become extinct unnoticed.

General features, status and major issues

Agriculture and allied activities not only provide livelihoods to large sections of the Himalayan population, but also form a pivotal part of their way of living. Environmental, biological, socio-cultural and economic factors prevailing in the Indian Central Himalayan region have resulted in the evolution of diverse agroecosystems. Traditional agroecosystems in the Himalayan region combine crop husbandry, animal husbandry and forest utilization, constituting complex and interlinked production systems. Inaccessibility, environmental heterogeneity, ecological fragility and marginality have favoured the evolution of subsistence production systems sustained with organic matter and nutrients derived from the forests, with the emphasis on optimizing productivity in the long term (Maikhuri *et al*, 1997, 2001b; Palni *et al*, 1998). Whilst the Himalayan region is a known natural centre of crop diversity, different crop plants were also introduced into the region by the early settlers. The even greater resulting diversity has been maintained through a variety of crop choices, favoured by the variations in the edaphic, topographic and climatic conditions. The introduction of horticultural crops is a recent phenomenon that has penetrated the traditional farming systems in states such as Himachal Pradesh, Jammu, Kashmir and Uttarakhand. Invariably, the importance of horticultural crops is ascribed to their commercial value rather than to the value of their availability for local consumption. In recent times, cultivation of off-season vegetables and floriculture have also made significant inroads. Increased population pressure from within the mountain region, further exacerbated by external pressures from the relatively industrialized societies down in the plains, has resulted in major changes to the agroecosystems of the Himalayan region, and especially in the rapid depletion of agrobiodiversity, which is one of the greatest expressions of collaboration between people and nature (Maikhuri *et al*, 2001a).

About 80% of people in the Central Himalaya practise subsistence agriculture. Landholdings are small and fragmented; per capita cultivated land is 0.2 ha. Terraced slopes, covering 85% of total agricultural land, are largely rainfed, while the remaining 15% in the valleys is irrigated. Mixed cropping is common under rainfed conditions. The cropping patterns are built around two major cropping seasons: namely, the *Kharif* (April–October) and *Rabi* (October–April), generally up to 1,800 m above mean sea level (amsl) and up to 2,000 m amsl in some places. At higher altitudes (>2,000 m amsl), only summer season crops (April–October) are raised. Over 40 crop species, often erroneously termed 'lesser known crops' comprising cereals, millets, pseudo-cereals, pulses, oilseeds, tubers, bulbs and spices, are cultivated.

A variety of changes in the traditional Himalayan agroecosystems has emerged in response to a multitude of pressures including population, market forces, migration of able-bodied young people, ineffective technological innovation, land tenure policies, economic growth, inappropriate social welfare and environmental conservation policies. Negative trends in agroecosystems, such as declining crop yields, expansion of agriculture on marginal land, declining carrying capacity of the rangelands, weed infestation, loss of crop genetic diversity, soil erosion, hydrological imbalances and social disintegration, dominate the debate on sustainable development in Himalaya. But because of the diversity and complexity of agroecosystems, there are serious limitations on how strategies for sustainable development can be devised if there are only generalizations on which to base them, for the realities vary from one ecological situation to another and from one traditional society to another.

Diversity plays a significant role in maintaining the long-term stability of traditional agroecosystems in a variety of ways. The contribution of diversity has been characterized in the following ways (Altieri, 1991):

- it helps to minimize crop loss due to insect pests;
- it improves soil fertility by incorporating legumes in the crop mixture;
- it minimizes losses from plant diseases and nematodes;
- it contributes to sound below ground biodiversity management;
- it reduces dependency on external inputs;
- it helps maximize effective use of resources and the environment;
- it inhibits or suppresses weed growth;
- it increases productivity per unit area;
- it produces a varied diet;
- it preserves soil from erosion on steep slopes; and
- it insures against crop failure.

The modern approaches involving monocropping of high-yielding varieties neither recognize the value of mixed cropping for risk avoidance, nor realize the difficulty in maintaining a continuous supply of necessary inputs such as fertilizers, improved seed, pesticides, etc under hilly conditions. Unfortunately, they displace traditional cultivars and may result in the elimination of centuries of accumulated experiences and knowledge of cultivation and uses of these crops. Once a local traditional crop is displaced, its unique germplasm is lost forever.

Traditional farming: its worth to farmers

In surveys conducted in selected villages in the Kedarnath, Bhyundhar, Pinder and Uargam valleys in the Garhwal Himalayan region to understand farmers' perceptions of diversity, it was observed that the farmers felt most secure with their traditional diversified agricultural practice. In the rainfed agricultural systems, the diversified local landraces are regarded as a means to secure production, where quantity of product is not the critical criterion. In the traditional systems, the farmers were more or less self-reliant and most of the inputs were drawn from their own farmland and surrounding forests, not technological inputs. The traditional agricultural systems, apart from maintaining a balance of crop

Table 1. Traditional criteria for nomenclature for various landraces of crop plants.

Category	Possible agromorphological criteria	Percentage of the total landraces grown and assigned folk names
Origin/source of the material	Region, village, farmer	8.3
Morphology	Seed characteristics, leaf shape, plant height	50.0
Agronomic performances	Flowering time, earliness, growth habit, yield	4.2
Environmental adaptation	Tolerance to biotic/abiotic stresses, type of soil	8.3
Use	Taste, nutritional value, type of preparation, ethnomedical value, religious ceremony value	29.2

Source: After Bisht *et al*, 2006.

diversity, also supported an array of weeds, a number of non-crop species, innumerable species of micro-organisms, insects, birds and some small mammals. In most countries, with the possible exception of Ethiopia, crop biodiversity levels are higher when the production decision makers are older or more experienced. In Uttarakhand, such decisions are made by the elderly women, who have learnt from their experiences rather than from any formal training. Thus, crop diversity could be placed at risk as older generations fail to pass on their knowledge or values to a younger generation of farmers.

The scientific methods involved in the traditional nomenclature of local landraces in almost all the valleys of Garhwal Himalaya are of particular interest. The local farmers have, since time immemorial, developed criteria for naming particular varieties, and these criteria are almost universally applied in all traditional farming systems. The detailed inventory of predominant landraces of the various traditional crop species grown in different valleys revealed that the nomenclature is based on the sources of material, morphology, agronomic performance, environmental adaptation and use. Morphology and traits related to use were the predominant criteria for naming the variety. Based on a similar study conducted by Bisht *et al*, 2006 in the Urgam valley (Table 1), it was found that the nomenclature method of local landraces was the same in the Kedarnath, Bhyundhar and Pinder valleys, apart from a little local modification. However, the elderly womenfolk of the region were the most expert in this and needed to communicate only a few catchwords to identify a particular landrace.

Under rainfed agriculture, farmers practise low input agriculture in marginal areas where they have been conserving significant amounts of both specific and intraspecific crop diversity. They depend on vertical mixtures, multiple crops, intercropping, home gardens and polyculture as well as genetically diverse landraces of individual crops. Table 2 gives the areas under cultivation of different crops grown in the Urgam valley, and it is interesting to note that rice and wheat, the two main food crops, had the maximum number of landraces and area under cultivation.

The farmer's perception of agrobiodiversity

It is extremely important to understand agrobiodiversity from the farmer's angle, along with the value of crop and variety diversity to the farmers who manage it. The diversity of crops and crop varieties is a consequence of human choice in close interaction with natural selection. Crop diversity in the Himalaya is accredited to the ingenuity and skills of the traditional farmers, particularly the elderly women of the household. Moreover, because of the scarcity of options, traditional farming communities have evolved sophisticated and complex agricultural systems and practices. These include practices such as mixed cropping and intercropping, crop rotation, maintaining fallow periods, incorporating wild and weedy relatives of crops, experimental and deliberate selection for a variety of traits, and interspersing of trees and other non-crop species, all of which have helped to conserve their systems. Farmers choose to grow particular crop varieties for the specific qualities they seek, which include traits such as crop yield and tolerance to pests and diseases, as well as consumption-related attributes such as taste and processing qualities. Farmers in mid-altitude regions grow more varieties of millet, barley, lentils, maize and local pulses and accordingly consume them differently as compared with farmers at low altitudes and in valley areas.

The economic value of increasing crop productivity through the diffusion of improved, modern varieties has been extensively documented. Costs and benefits have also been estimated for plant genetic resources conserved in gene banks, destined principally for use by commercial farmers (Koo *et al*, 2004). In contrast, there has been scant economic research seeking to understand the value of increasingly scarce, local varieties to the farmers who grow them. This is partly because such varieties are typically found in marginal, isolated environments of the remote Himalayan areas, where they are traded outside of formal markets. In addition, economists have only recently challenged the commonly held assumption that local varieties will inevitably be replaced by modern varieties over time (Brush *et al*, 1992; Brush, 1995, 1999; Meng, 1997). Moreover, it is the case that few studies have discovered the continued production and consumption of a number of local varieties of food crops in Uttarakhand (Maikhuri *et al*, 2001a; Palni *et al*, 1998). Local varieties, often called landraces, generally exhibit high degrees of local adaptation with particular properties or characteristics that are valuable to the communities in which they are grown. *Fagopyrum esculentum, Fagopyrum tataricum, Amaranthus frumentaceus* and *Setaria italica*,

Table 2. Traditional crops grown in the Urgam valley during *Kharif* and *Rabi* seasons with available landraces.

Crops	No of landraces	Area (ha)	% of total cultivated area	Mean area per household (ha)	% decline in traditional crops during last three decades*	Replacement crops
Kharif (rainy) season crops						
Oryza sativa	12	52.4	21.9	0.05	No change	High-yielding
Amaranthus spp.	3	30.1	12.6	0.03	–	–
Phaseolus vulgaris	5	30.1	12.6	0.03	–	–
Eleusine coracana	4	9.1	3.8	0.01	45.0	*Amaranthus*
Echinochloa frunentacea	4	9.2	3.8	0.01	63.0	*Amaranthus*
Vigna mungo	2	9.1	3.8	0.01	28.0	*Phaseolus vul.*
Fagopyrum spp.	4	7.2	2.9	0.007	63.0	*Amaranthus*
Glycine max	3	3.1	1.3	0.003	33.0	*Phaseolus vul.*
Setaria italica	2	2.2	0.8	0.002	65.0	*Amaranthus*
Macrotyloma uniflorum	3	2.1	0.8	0.002	42.0	*Phaseolus vul.*
Vigna umbellate	2	1.1	0.4	0.001	72.0	*Phaseolus vul.*
Sesamum indicum	1	1.1	0.4	0.001	35.0	*Amaranthus*
Perilla frutescens	1	1.1	0.4	0.001	92.0	*Amaranthus*
Panicum miliaceum	1	1.1	0.4	0.001	62.0	*Amaranthus*
Rabi (winter) season crops						
Triticum aestivum	5	49.1	20.6	0.05	No change	–
Hordeum vulgare	3	12.2	5.0	0.01	72.0	*Brassica rapa*
Brassica rapa	2	8.1	3.4	0.008	No change	High-yielding
Lens culinaris	2	3.1	1.3	0.003	No change	*Brassica rapa*

*Area under cultivation of *Amaranthus* spp. and *Phaseolus vulgaris* has increased substantially during the last 2–3 decades.
Source: After Bisht *et al*, 2006.

grown in high altitude regions of Uttarakhand, are good examples that are potentially valuable for crop improvement elsewhere, where they may be scarce.

Agrobiodiversity erosion: threat to Himalayan food and nutritional security

Agrobiodiversity encompasses an enormous array of biological resources tied to agriculture such as crops, livestock, soil biota, rangelands, etc. How much of the genetic base has already been eroded is hard to say, but state-driven 'green revolution' impacts (that is, supply of high-yielding varieties, inorganic fertilizers, pesticides and irrigation – free of cost initially and then highly subsidized, particularly from the 1970s – have squeezed out the native landraces. A survey of 150 villages located along an altitude gradient in the Alaknanda catchment of the Garhwal hills revealed a shocking decline in the diversity of traditional crops during a short period of two decades (1974–94). The area under a variety of traditional crops had declined by 72–95% (Maikhuri *et al*, 1996, 1997, 2001a). These crops have mostly been replaced by cash crops such as potato, soya bean, kidney bean, pigeon pea, mustard and amaranths. Although the area under rice has not changed much, the farmer-selected cultivars grown until the 1970s have been completely replaced by hybrid high-yielding varieties such as China-4, Taichung, Govinda and Saket-7. Similarly in the case of wheat, traditional varieties have been replaced by high-yielding varieties such as Sonalika 5. In the Himalayan Gazetteers of 1882, Atkinson listed 48 varieties of rice and stated that there were thousands of other non-descriptive varieties. Today only seven or eight traditional cultivars including Ramjawan, Thapachini, Lalmati, Rikhva in irrigated areas, and Ghyasu in rainfed areas, are observed. The recent decline in agrobiodiversity is due to the cumulative effect of social, ecological and policy factors, which have significantly influenced Himalayan agroecosystems and altered cropping patterns and agrobiodiversity loss (Tables 3, 4 and 5). In short, the loss of agrobiodiversity costs the producers heavily, adds social costs to the farming communities, induces long-term effects on agricultural productivity and jeopardizes food security. The decline in the variety of foods and loss of high-protein legumes is replaced by monoculture production of crops that are less nutritious, adversely affecting the nutrition of rural Himalayan societies.

Strategy for sustainable management of Himalayan agrobiodiversity

Agricultural production has a great deal to contribute to the short- and long-term reduction of poverty. Careful analysis and evaluation are required so that agriculture and related developmental strategies can be reoriented towards better use of local resources so as to contribute more effectively to improving the living standards of the rural poor and ensuring sustainable agriculture together with the conservation of genetic diversity of crops, cultivars, agroecosystems and landscapes (Maikhuri *et al*, 2001b). The logical unifying principles of inducing sustainable agriculture development in the Himalaya should include the following priority interventions:

Table 3. Ecological dimensions of agrobiodiversity loss; indicators from the Central Himalayan agroecosystems.

Indicators	Process of change and implications
Decline in carrying capacity of forests and rangelands	The problems of land degradation in the Himalayan forests and rangelands are very serious and have a direct bearing on Himalayan traditional agroecosystem productivity and sustainability (6 ha of good quality forest are required to support one ha of agricultural land on a sustainable basis). The carrying capacity of this land has declined recently, as a result of which traditional agrodiversity is fast declining.
Abandoned land	Scarcity of natural resources (to support animal populations, which can provide manure for the agricultural land) and migration of people to the plains in search of jobs, are responsible for the abandonment of agricultural land (particularly in the lower and middle Himalayan regions).
Weed infestation	Many exotic weeds (eg *Lantana camara, Eupatorium* spp. and *Parthenium* spp.) have invaded traditional rainfed agricultural areas. Heavy labour inputs are thereby involved and the interest of farmers in agriculture is declining rapidly.
Soil erosion	Large amounts of topsoil, rich in nutrients (7–9 t $ha^{-1}yr^{-1}$) are washed away from terraced rainfed agriculture areas during the rainy season, with consequent effects on overall productivity; this is, therefore, directly or indirectly responsible for agrobiodiversity loss.
Hydrological imbalances	Drying-up of natural springs and streams; decline in the moisture retention and water holding capacity of soil have been linked to deforestation, resulting in loss of agrobiodiversity.
Cropping patterns	A significant proportion of traditional agricultural land has been brought under cash crops or off-season vegetables. This has adverse implications for traditional agroecosystems; the agrobiodiversity of the region has shrunk over time.
Crop yields	The yields of traditional crops have not reduced over time, but they are low when compared with common crops or high-yielding varieties, primarily because of the increased use of modern inputs.

Source: After Maikhuri *et al*, 2001a.

Table 4. Social dimensions of agrobiodiversity loss-indicators from Central Himalayan agroecosystems.

Indicators	Process of change and implications
Population growth	The human population has increased over time. Insufficient crop yield due to a high population density and low output–input ratio of crops compels farmers to consider other options for livelihood.
Migration	Migration of people to the plain areas in search of employment leads to a money-based economy reducing interest in traditional agriculture; richer agrobiodiversity results.
Change in food habits	Crop yield data at two points of time support the belief that yields of most traditional crops have remained relatively stable. Thus, the food insecurity or shortage problems seem largely due to changes in food habits (increasing preference for wheat and rice as staples). Shortages relate to reduction in crop diversity and net sown area, plus population growth, rather than decline in the yield of traditional crops.
Social values	Due to the changing environment, social values have tended to alter; social disintegration is increasing; people have become more individualistic in outlook. Social institutions such as community participation in natural resource management for agriculture, seed and labour exchange systems are disappearing, leading to weakening of agricultural management.
Female literacy	Agriculture of this region was usually managed and operated by the women; increase in female literacy over time has reduced interest in agriculture.
Socioeconomic development	In the Himalayan region, farmers are involved in diverse livelihood options such as cultivation of crops, livestock, forestry, etc. Many of these options provide low yields and extremely low income, forcing the farmers to adopt other activities; eg, replacement of mixed cropping – rich in agrobiodiversity with monocropping, which increases the uniformity of crops, resulting in insect/pest attacks, thereby reducing agrobiodiversity.

Source: After Maikhuri *et al*, 2001a.

Table 5. Policy dimension of agrobiodiversity loss – indicators from the Central Himalayan agroecosystems.

Indicators	Process of change and implications
Research bias	So far no emphasis has been given to improving the yield potential of traditional crops. Agricultural research has concentrated on major crops such as wheat, maize and rice and on increasing their production through technology input.
Subsidies on food imports and credit policies	A mechanism was developed by the government for subsidizing and pricing of food imports, which provided cheap food through a public distribution system (PDS). This has resulted in changed food habits and encouraged locals to abandon the cultivation of traditional crops and varieties.
Land use policies	Encouraged farmers with large landholding, especially those devoted to production of hybrid crops. Thus crop diversity has been reduced.
Subsidies on agricultural inputs	The cost of inputs such as chemical fertilizers, water, pesticides and seeds was reduced through subsidies in order to promote modern agriculture involving high-yielding varieties, at the expense of diverse traditional agriculture.

Source: After Maikhuri *et al*, 2001a.

- improvement of scientific knowledge on the ecological and socioeconomic functions of biodiversity;
- improvement of traditional technologies of soil fertility management and agronomic practices to enhance yields in natural habitats;
- drastic reorientation of agricultural policies with provision for maintaining marginal societies and accommodating the rainfed conditions of the Himalaya;
- empowerment and benefit sharing for women, who are the main conservers and managers of agrobiodiversity;
- preparation of a status report on agrobiodiversity and the weeds and wild relatives of crop plants and soil biota of the Himalaya;
- strengthening of traditional agroforestry through cost-effective water harvesting technology;
- promotion of organic recycling for soil fertility, integrated pest management, nutrient management, and of organic foods;
- promotion of wild edibles and searching for new crops and crop species;
- promotion of the cultivation of herbs and medicinal plants;
- promotion of village marketing cooperatives through appropriate policies to avoid exploitation by middle-men;
- exploration of avenues of value addition to traditional crops/produce; and
- integration of agrobiodiversity with protected areas, ecotourism and sacred landscapes for long-term *in situ* conservation.

Future research directions and policy implications

While the studies described have made significant advances in terms of reaffirming the importance of specific factors for the continued improvement of crop biodiversity, other factors still require further investigation. For example, the exact nature of market failure remains a mystery. As researchers begin to disentangle specific components of markets, the fundamental hypothesis that market isolation drives on-farm conservation appears less and less appropriate. Understanding the role of seed systems, and particularly supply interventions, is critical for researchers involved in raising agricultural productivity without sacrificing crop biodiversity. Another important issue related to studies of crop biodiversity is the geographical 'scale' or level of analysis. Although this was treated in some studies by examining variables measured at the household farm, village, settlement or community level, future work should continue to focus on how diversity measures, conceptual approaches and variable measurements should be adapted to new methods of observation and analysis. The neglect of traditional mountain crops and cropping systems in agricultural research and development has been largely due to the relatively minor role of mountain agriculture in the aggregate economy. There is an urgent need to reorient agricultural policies to benefit the small and marginal farmers in the Himalayan mountains; this might include: (a) ensuring people's participation in agricultural development and the formulation of natural resource use policies, (b) reductions in subsidies and credit policies for high-yielding varieties and high inputs, and (c) incentives to poor and marginal farmers for the conservation and management of agrobiodiversity (Table 5).

Conservation of traditional crops and cultivars could succeed when these crops are strongly linked with the economic development of hill farmers. Pragmatic multidisciplinary research efforts are needed to evolve farming systems that can provide enough quality food and economic security for the people of the region together with conservation of the traditional agrobiodiversity, sustainability of the production systems and environmental conservation. There is a strong need to bring changes in agricultural research and development, land use and breeding approaches. Adoption of the appropriate practices and policies is urgently required to provide solutions and opportunities to overcome threats and to halt the continuing erosion of genetic resources. Farmers possess considerable knowledge of resource availability and resource management in these traditional agroecosystems, and *in situ* conservation will be most effective when targeted towards specific areas with significant plant genetic resources and with communities who are willing to participate in conservation programmes.

Acknowledgments

The authors are grateful to the Director of the G.B. Pant Institute of Himalayan Environment and Development, Kosi-Katarmal, Almora for the facilities to undertake the study.

References

Altieri, M. A. (1991), 'Traditional farming in Latin America', *The Ecologist*, Vol 21, pp 93–96.

Bisht, I. S., Rao, K. S., Bhandari, D. C., Nautiyal, S., Maikhuri, R. K., and Dhillon, B. S. (2006), 'A suitable site for in situ (on farm) management of plant diversity in traditional agroecosystems of Western Himalaya in Uttaranchal state: a case study', *Genetic Resources and Crop Evolution*, Vol 52, pp 1333–1350.

Brush, S. B. (1995), '*In situ* conservation of landraces in centres of crop diversity', *Crop Science*, Vol 35, pp 346–354.

Brush, S. B. (1999), *Genes in the Field: On-Farm Conservation of Crop Diversity*, Lewis Publishers, Boca Raton, FL.

Brush, S. B., Taylor, J. E., and Bellon, M. R. (1992), 'Technology adoption and biological diversity in Andean potato agriculture', *Journal of Development Economics*, Vol 2, pp 365–387.

Koo, B., Pardey, P. G., and Wright, B. D. (2004), *Saving Seeds: The Economics of Conserving Crop Genetic Resources Ex Situ in the Future Harvest Centers of the CGIAR*, CABI Publishing, Wallingford.

Maikhuri, R. K., Rao, K. S., and Saxena, K. G. (1996), 'Traditional crop diversity for sustainable development of Central Himalayan agroecosystems', *International Journal of Sustainable Development and World Ecology*, Vol 2, pp 1–24.

Maikhuri, R. K., Rao, K. S., and Semwal, R. L. (2001a), 'Changing scenario of Himalayan agroecosystems: loss of agrobiodiversity, an indicator of environmental change in Central Himalaya, India', *The Environmentalist*, Vol 21, pp 23–39.

Maikhuri, R. K., Semwal, R. L., Rao, K. S., and Saxena, K. G. (1997), 'Eroding traditional crop diversity imperils the sustainability of agriculture systems in Central Himalaya', *Current Science*, Vol 73, No 9, pp 777–782.

Maikhuri, R. K., Semwal, R. L., Rao, K. S., Saxena, K. G., and Das, A. K. (2001b), 'Indigenous techniques of agricultural soil fertility maintenance in the Central Himalaya', *Ecology, Environment and Conservation*, Vol 7, pp 15–20.

Meng, E. C. H. (1997), 'Land allocation decisions and *in situ* conservation of crop genetic resources: the case of wheat landraces in Turkey', PhD dissertation, University of California at Davis, CA.

Palni, L. M. S., Maikhuri, R. K., and Rao, K. S. (1998), *Conservation of the Himalayan Agroecosystems: Issues and Priorities*, Technical Paper III, Himalayan Eco-Regional Cooperation Meeting, 16–18 February, Kathmandu, Nepal.