A Suitable Site for in situ (On-farm) Management of Plant Diversity in Traditional Agroecosystems of Western Himalaya in Uttaranchal State: A Case Study

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A suitable site for *in situ* (on-farm) management of plant diversity in traditional agroecosystems of western Himalaya in Uttaranchal state: a case study

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Abstract

There is a growing realisation world over that the introduction of modern agriculture has to be supplemented with measures to conserve biodiversity *in situ* if yield gains are to be stabilized. Hence, there is a growing interest from agricultural development specialists and conservation biologists for understanding the socioeconomic factors determining the conservation of biodiversity *in situ*. The present study was conducted with the objective of understanding the *in situ* (on-farm) conservation of agrobiodiversity in traditional agroecosystems taking the Urgam valley in north-western Himalaya of India, as a case study. An inventory was made of traditional crops and wild economic species for subsistence, and the structure of forest resource base, traditional knowledge related to resource management and use. Institutional and scientific challenges for *in situ* (on-farm) management of crop diversity were studied and are discussed in this paper. Complementarity of *in situ* (on-farm) conservation with *ex situ* conservation together with crop improvement in such marginal areas are suggested.

Introduction

In situ and *ex situ* conservation of biodiversity for agriculture and forestry are complementary approaches. The emphasis on *in situ* and *ex situ* approaches will, however, depend on the conservation context- the object, aims and location of conservation. For each situation, an understanding of the genetic diversity is fundamental (Iwanaga 1995; Jarvis and Hodgkin 1998; Jarvis et al. 2000b). *In situ* conservation is concerned with maintaining species populations in habitats in which they occur and has been reviewed in greater details by several authors (Oldfield and Alcorn 1987; Iwanaga 1995; Maxted et al. 1997a, b; Brush and Meng 1998; Brush 1999). Conservation *in situ*, with local communities and farmers ensures that resources remain directly in the hands of the primary users.

Iltis (1974) proposed the *in situ* conservation model for the first time. This required no change in farming systems nor introduction of foreign material. For socio-economic reasons such 'freezing' of the genetic landscape is not possible, nor necessary (Louette and Smale 1996). Thus, Louette (1994) and Long et al. (2000) proposed a model based around the idea that *in situ* conservation means preserving in their original agro-ecosystem varieties cultivated by farmers using their own selection methods and criteria. There is however lot of literature available now on various activities involved and generalized models for the conservation of genetic diversity on-farm (Altieri et al. 1987; Bellon 1991, 1996; Brush 1991, 1995, 1999; Worede 1992; 1993, 1997; Worede and Hailu 1993; Eyzaguirre and Iwanaga 1996; Bellon et al. 1997; Maxted et al. 1997a, b, 2002; Jarvis and Hodgkin 1998; Jarvis et al. 2000a).

The traditional farming in the Central Himalaya (part of North-Western Himalaya) is complex in that crop husbandry, animal husbandry and forests constitute interlinked systems (Maikhuri et al. 1996). The traditional agriculture of the region is value based which has been evolved over centuries through the process of trial and error. To keep the traditional agro-ecosystems at optimum level of productivity it requires resources from 16 units of surrounding forests as inputs (Ashish 1979; Singh et al. 1984; Hrabovzsky and Miyan 1987; Ashish 1993; Rao and Saxena 1994; Maikhuri et al. 2001). Many valley areas in the Himalayan highlands provide unique opportunity for *in situ* (on-farm) management of agrobiodiversity because of the preponderance of locally developed traditional crop varieties (and associated wild and weedy species) in traditional cultivation based on traditional knowledge and skills; high agro-climatic heterogeneity and local socio-cultural integration. However, Maikhuri et al. (1996), have shown that substantial reduction of traditional crop diversity has taken place in this region during the last two to three decades.

The present study was therefore initiated in the Urgam valley in Chamoli district of Uttaranchal state with a view to select a suitable site for developing a model on *in situ* (on-farm) conservation of diversity in traditional crop species in Himalayan agroecosystem with the following objectives:

(i) To understand the value of crop diversity to farmers including inventory of traditional crops, wild economic species for subsistence and structure of forest resource base supporting farmlands.
(ii) Economic efficiency of agro-ecosystems.
(iii) Documentation of traditional knowledge related to resource use and management for value addition to local resources.
(iv) Scientific and institutional challenges for on-farm management of crop diversity in view of complementing *in situ* (on-farm) conservation with *ex situ* conservation and crop improvement in marginal areas.

Study area and climate

The Urgam valley was selected for the present study as it is a representative site of traditional landrace-based cultivation of Uttaranchal Himalaya. A total of eleven villages are located in Urgam valley and the rural settlements are spread within the altitudinal limits of 1700–2000 m a.s.l. The farmland in these villages are not separate units distinguished by village boundaries but are overlapping with each other as one close-knit unit. There is high degree of land fragmentation and fields are highly scattered as there is no land consolidation system existing as per the prevailing land tenure system in the region. The elevational range represents the middle altitude zones and almost all the traditional crops are largely grown along traditional lines with seasonality in cropping seasons and cropping patterns. At higher altitudes, particularly above 2000 m a.s.l., the cropping patterns do not follow such cropping seasons and only summer season crops (April–October) are grown owing to cold climatic conditions. This valley had also shown maximum species richness for traditional crops with least area under modern high yielding varieties (HYVs) of common food crops in an earlier survey of the region (Maikhuri et al. 1996). The main characteristic features of the agroecosystems of this region are the use of bullocks for draught power and humans for labour, the use of crop residues to feed livestock during winter months and the use of cow dung and forest litter as a source of farmyard manure. Human labour, particularly women, play a crucial role in almost all the agricultural activities. Crop rotation is another important feature of rainfed agroecosystems to preserve the fertility of the soil, as well as to enhance or maintain crop productivity. The

Table 1. General structure of the villages situated in Urgam Valley.

Parameters	Baraginda (Malla)	Banso	Salna	Lyari	Geera	Devgram	Baraginda (Talla)	Bharki	Gwana	Pilkhi	Bhenta
Total no. of households	67	23	22	37	22	69	94	29	25	12	16
Total population	402	141	97	210	111	358	671	145	130	37	104
Male	140	53	44	64	38	96	195	48	50	13	29
Female	173	64	24	66	39	133	232	52	55	10	28
Children < 15 years	89	24	29	80	34	129	244	45	25	14	47
Total Agricultural land (ha)	60.3	17.2	15.22	20	17.0	51.0	29	13	8	2	5
Irrigated (ha)	8.1	1.6	0.02	2.2	2.0	5.0	1.5	–	–	–	–
Rainfed (ha)	52.2	15.6	15.2	17.8	15	46.0	27.5	13	8	2	5
Agricultural land per household	0.90	0.75	0.69	0.54	0.77	0.74	0.31	0.45	0.32	0.16	0.31
Literacy: Male	85	90	100	96	90	92	48	82	82	92	82
Female	55	40	95	84	80	68	30	70	65	50	76
Total cultivated crops	34	16	15	16	16	34	14	16	18	11	13

structure and general characteristic features of the villages that fall in this valley are depicted in Table 1. The year consists of three distinct seasons: summer (April–June), rainy (July–September) and winter (October–March). Average rainfall is about 925 mm, of which about 51% is received in a short period of 2 months (July–August) featuring a strong monsoonic influence. Monthly maximum and minimum temperature ranges between 28–16 °C and 9.5–5.0 °C, respectively.

Average land holding size is estimated to be about 0.54 ha/household which is maximum in Baraginda Malla (0.90 ha) followed by Geera (0.77 ha), Banso (0.75 ha) and Devgram (0.74 ha) and least in Pilkhi (0.16 ha) village (Table 1). A variety of horticultural trees (apple, apricot and walnut) which provide fruits, fuel, etc. are grown on the margins of the rainfed terraces. Seasonal and off-season vegetables such as, cucurbits, ginger, cabbage, green vegetables, etc. are cultivated in the kitchen gardens. The area under kitchen garden was estimated to be about 0.0028–0.012 ha/ household.

Livestock are the important component of the traditional agroecosystems and is considered as a secondary food production system. Livestock provide draught power for farm operations including ploughing and threshing, source of organic manure for crops and the main source of protein for human beings through the supply of meat and milk and is also a source of income by sale of animals. Total livestock population was recorded to be 6142, of which 88% are out-grazers and 12% are stalled animals.

Materials and methods

The study was carried out in all 11 villages of the Urgam valley, as one unit, during October 2000–December 2002. All the households were surveyed to determine average land holding size, area under different crops, crop compositions, cropping patterns and crop rotations. The information was collected through informal discussions with knowledgeable members of the farm families, particularly the elderly women who play important role in almost all agricultural activities. To gather the above information, each household was visited at least 5–6 times during the study period. For measuring crop diversity, total land under agriculture was surveyed to assess the actual area under cultivation for different crops during two major seasons, *rabi* (October–April) and *kharif* (April–October) for over 2 years (2000–2002). A door–door survey was conducted in each village to enumerate the total land area under cultivation for individual crops. Information was also collected on the erosion and shift in landrace diversity during the past 2–3 decades by interviewing the head (elderly person) of each household. The information for current status was validated by taking observations in the field for the landrace diversity under cultivation. The extent of cultivation of the traditional crop landraces of paddy and other crops by each household is based upon sampling done in these villages during the cropping season over a 2 year period. Detailed documentation on paddy landraces, it being the major crop, is presented in this paper in greater detail.

The economic yield (grain yield kg/ha) of different landraces for all the major traditional crops was determined in different plots based on 20 quadrats (1 × 1 m) per plot, both under mono- and mixed cropping conditions from five random sites. The economic yield per plant under different cropping systems/crop combinations was determined in a plot as an average of 15 plants for a given cultivar/landrace. The economic yield per hectare in all cases was calculated on the basis of yield from the entire plot. Data of paddy landraces are presented here in a limited way.

Detailed inventory of plant resources for wild subsistence, material culture, traditional phytochemistry, etc. was also undertaken as farmers are dependent on these resources a great deal and these resources are essential to support the farmlands in traditional agroecosystems. For this purpose, the valley was divided into four resource base categories/compartments viz., Alpine pasture, Reserve forest, Civil forest and Van Panchayat forest. The Van Panchayat forests are exclusively managed by Village Panchayats (local self-government). Based on group interviews, listing of resources extracted was done for each resource zone. As per the standard vegetation analysis methods (Kershaw 1973; Saxena and Singh 1982; Mehta et al. 1997) 30 number of 10 × 10 m quadrats were laid randomly in these zones for enumerating the number of seedlings and saplings of tree species and trees of various species. While shrubs were enumerated using a 5 × 5 m quadrat, herbaceous vegetation was assessed using a 1 × 1 m quadrat. The quantity of resources extracted is based on observations made on 25 randomly selected households. It involved assessing actual amounts brought to households from the extraction visits to forests and village commons during various seasons.

The ethnobotanical knowledge pertaining to traditional crop cultivars/landraces, wild economic plants and other forestry resources was also documented by interviewing the farmers of different age group (15–30, 31–50 and > 50 years), sex (male and female) and literacy (illiterate/low, medium and high). The information was extracted from 25 randomly selected households. While recording the names of crop cultivars/landraces, visits were made with the informant for identification of the landrace in the field. Information was also obtained on crop/plant resources which have become extinct from the valley. Villagers were also asked to fill-in a questionnaire for extracting information on their knowledge regarding crops and the specific landraces, folk nomenclature of traditional landraces, distinctive properties of crop landraces; medicinal plants, their seasonal availability and specific uses; wild edibles, their seasonal availability, conservation status and mode of use; importance of forestry resources in sustaining farm lands, etc. Information obtained was authenticated from knowledgeable elderly people and other sources. The questionnaire also contained questions about farmers' perceptions on various issues and institutional challenges for sustainable management of traditional agroecosystems.

Results

General description of agroecosystems, cropping patterns and value of crop diversity to farmers

In the Urgam valley, the rainfed agriculture on steep terraces is the predominant form of land use. Farmers practice low input agriculture and in marginal areas have been conserving significant amount of crop diversity, at both the species and intraspecies level. They depend on varietal mixtures, multiple crops, intercropping, home gardens and polycultures, as well as on genetically diverse landraces of individual crops. About 20.42 ha (8.5% of the total cultivated land) area is irrigated. The rainfed agriculture in all the villages of the valley is practiced on almost two equal halves of agricultural land (locally called as 'sar' with different crop compositions). To maintain soil fertility, the tradition is to keep fallow one half of the land during one winter season for 6 months (October–March) over a period of 2 years. Therefore three crops can be harvested in 2 years period from rainfed agriculture. From irrigated land two crops, a summer and a winter crop, are harvested in a year. The cropping pattern is built around two major seasons, *kharif* (April–October) and *rabi* (October–April). The major crops of *Kharif* season include paddy (*Oryza sativa* L.), barnyard millet (*Echinochloa frumentacea* L.), ragi (*Eleusine coracana* (L.) Gaertn.), foxtail millet (*Setaria italica* L.), amaranth (*Amaranthus caudatus* L., *A. viridis* L.), buckwheat (*Fagopyrum* *esculentum* L., *F. tataricum* L.), maize (*Zea mays* L.), soybean (*Glycsine max* L.), kulthi (*Macrotyloma uniflorum* Roxb.), French bean (*Phaseolus vulgaris* L.), blackgram (*Vigna mungo* (L.) Hepper) and seasonal vegetables. The *rabi* season crops are wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), mustard (*Brassica rapa* L. em. Metzg.), lentil (*Lens culinaris* Medik.) and seasonal vegetables. Area under cultivation of various crops grown in the valley is presented in Table 2. Maximum area is covered by paddy (52 ha), followed by wheat (49 ha), potato (30 ha) and least, 1 ha each, by *Panicum miliaceum* L., *Perilla frutescens* (L.) Britton and *Vigna umbellata* (Thunb.) Ohwi et Ohashi. Some landraces of paddy, wheat and mustard are being cultivated in irrigated conditions whereas other crop cultivars are grown only in rainfed condition. Common bean, potato, pea and grain amaranth are the cash crops. The cash crops are sold to local and nearby distant markets. Amaranth is mainly exchanged with rice, in barter system, to traders from distant markets in plain areas.

Area under traditional crops, and common food and cash crops is presented in Table 3. Mixed cropping is practiced for most of the traditional crops. Wheat and paddy are normally grown in monocropping, particularly in irrigated land. During *kharif* season mixed cropping, as complete mixtures, of millets, legumes, amaranths, buckwheat, sesame, etc. is a common practice. Intercropping of common bean and grain amaranths is also common, mostly in alternate plots. Mixed cropping, as complete mixtures, of wheat with mustard and lentil is common during *rabi* season. Buckwheat is normally grown mixed with potato. The seasonal vegetables are mostly grown in backyards and kitchen gardens.

Table 2. Traditional crops grown in Urgam valley during *kharif* and *rabi* season.

Crops	No. of landraces	Area (ha)	% of the total cultivated area	Mean area per household (ha)	% decline in traditional crops during the last three decades*	Replacement crops
Kharif (rainy) season crops						
Oryza sativa	12	52.4	21.9	0.05	No change	High yielding landraces
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	Amaranths
Echinochloa frumentacea	4	9.2	3.8	0.01	63.0	Amaranths
Vigna mungo	2	9.1	3.8	0.01	28.0	*Phaseolus vulgaris*
Fagopyrum spp.	4	7.2	2.9	0.007	63.0	Amaranths
Glycine max	3	3.1	1.3	0.003	33.0	*Phaseolus vulgaris*
Setaria italica	2	2.2	0.8	0.002	65.0	Amaranths
Macrotyloma uniflorum	3	2.1	0.8	0.002	42.0	*Phaseolus vulgaris*
Vigna umbellata	2	1.1	0.4	0.001	72.0	*Phaseolus vulgaris*
Sesamum indicum	1	1.1	0.4	0.001	35.0	Amaranths
Perilla frutescens	1	1.1	0.4	0.001	92.0	Amaranths
Panicum miliaceum	1	1.1	0.4	0.001	62.0	Amaranths
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 landraces
Lens culinaris	2	3.1	1.3	0.003	No change	*Brassica rapa*
Miscellaneous vegetable and other minor crops (cucurbits, spinach, fenugreek, radish, taro, yams, onion, garlic, ginger, turmeric, etc.)	Local landraces	3.7	1.3	0.003	No change	–
Cash crops (mainly improved varieties)						
Potato	3	30.3	12.6	0.30	No change	–
Pea	2	8.2	3.4	0.008	No change	–

*Area under cultivation of *Amaranthus* spp. and *Phaseolus vulgaris* has increased substantially during the past 2–3 decades.

Table 3. Explanatory factors and variables for farmer crop and variety choices

Factor	Important variables	Impact assessment
Agroecology	Irrigation resources, land quality, soil type	About 8.5% of the total cropped area is irrigated. The high yielding paddy landraces and some other cash crops like potato and pea are monocropped under irrigated conditions. Other crops and traditional coarse grains are grown under rainfed conditions in poor soil in mixed cropping.
Market infrastructure	Distance to nearest market, price differentials	Cash crops like potato and pea grown for local market needs. *Phaseolus vulgaris* (seed types) and *Amaranthus* spp. are grown for distant market needs as these can be stored for a longer period and there has been substantial increase in total cropped area under these crops. Some local landraces of *Phaseolus vulgaris* are sold at premium prices and farmers have the market incentive in growing them. Most of the other crops are grown for self consumption needs. Not much seed is acquired from off-farm sources.
Household characteristics		
Economic status and objectives	Farm size, number of months food self-sufficient, percent of harvest sold	About 75% households have <0.5 ha land and they are self-sufficient in food requirement for only 6–7 months in a year and mainly grow coarse grains. Farmers with large holdings (>1 ha) grow more cash crops and self sufficient in their food requirement, a substantial portion of the harvest of cash crops sold in market including farm-saved seeds for sale to resource poor small farmers.
Income sources	Seasonal migration, crop share of farm income to total income, off-farm income	Small farmers largely rely on off-farm jobs for subsistence and mainly grow coarse grains under mixed cropping; the ratio of farm income to total income was 1:1 for average resource poor farmer with farm size <0.5 ha.
Human resources	Family size, household composition	Farmers with large family size invariably grow coarse grained landraces with high yield potential regardless of their wealth status and farm size. Farmers with more women members in household grow more traditional coarse grained millets as these crops require special women-related skill for processing and food preparation.
Land resources	Fragmentation	There is high degree of land fragmentation as per the existing land tenure system in the Valley. Farmers with large farm area with relatively less fragmented fields can afford to maintain more landraces per household basis for market oriented incentives and also for aesthetic reasons.

The local crops viz. *Hordeum vulgare* (6-rowed hulled and hull-less types), *Amaranthus* spp., *Fagopyrum* spp., *Panicum miliaceum*, *Echinochloa frumentacea*, *Setaria italica*, *Macrotyloma uniflorum*, *Vigna umbellata*, etc. are very rich in calorific value and minerals (Maikhuri et al. 1996). There is little dependency on market bought food in the Valley. Except common bean and grain amaranth, the local crops are not purchased but sometimes exchanged for other common food crops to meet other food requirements.

Inventory of crop diversity

Out of the 67 predominant food crop species of the north-western Himalaya (Zeven and Zhukovsky 1975; Arora 1991), about 34 species (comprising of cereals, pseudocereals, millets, pulses, oilseeds and different kinds of vegetables) are grown in the traditional agroecosystems of the Valley. Detailed inventory of traditional crops of the Valley is presented in Table 2. The major traditional crops with intra-species diversity are *Oryza sativa*, *Triticum aestivum*, *Hordeum vulgare*, *Eleusine coracana*, *Echinochloa frumentacea*, *Amaranthus* spp. (*A. viridis*, *A. caudatus*), *Vigna mungo*, *Glycine max* (local black seeded types), *Brassica rapa*, *Lens culinaris* and *Phaseolus vulgaris*. Many of the traditional underutilized crops with high heterogeneity include *Fagopyrum esculentum*, *F. tataricum*, *Macrotyloma uniflorum*, *Vigna umbellata*, *Perilla frutescens*, *Setaria italica*, *Panicum miliacium*, *Sesamum indicum* and several miscellaneous vegetable crop species (*Trigonella* spp., *Beta* spp., Cucurbits, radish, taro, yams, etc.).

A total of 12 distinct landraces of paddy, 5 of wheat, 5 of common bean, 4 of ragi, 4 of barnyard millet, 3 of kulthi, 3 of *Glycine max* were grown by the farmers of the Valley at present. High inter- and intra-specific diversity in other traditional crops viz., amaranths, buckwheat, mustard, foxtail millet were also recorded but no distinct landrace name were assigned in most of these crops.

Erosion of landraces and factors thereof

Based on the information obtained from each household, it was observed that there has been substantial loss in diversity of major traditional crops grown in the past in terms of cropped area (Table 2). Among the traditional underutilized crops, *Panicum miliaceum* and *Setaria italica* (the two fastest ripening crops), the area under cultivation has reduced to 62–65% during the last 2–3 decades. Decline in area under cultivation by 42–92% has also been recorded for many other traditional underutilized crops such as *Fagopyrum esculentum*, *F. tataricum*, *Eleusine coracana*, *Echinochloa frumentacea*, *Macrotyloma uniflorum*, *Vigna umbellata*, *Perilla frutescens*, *Glycine max* (local black seeded types) and many of the locally grown vegetable crops. Many of these crops and their traditional landraces are being replaced very fast by several of the cash crops, such as potato, common bean, pea, etc. Many of the underutilized local crops such as *Perilla*, *Fagopyrum*, *Setaria*, etc., are also being replaced by other traditional crops such as amaranths and common bean. *Perilla* has almost been replaced by amaranths. The replacement crops for most of the traditional crops are presented in Table 2. The area under cultivation of two major cereals, wheat and paddy, has however remained stable but genetic erosion remains an actual and potential threat to the landrace diversity in these major crops as well.

Explanatory factors and variables for farmer crop and variety choices are presented in Table 3. Agroecology, market structure and various household socio-economic characteristics like economic status of households, income sources, family structure, gender roles, land tenure system, etc. are important factors dictating farmers' crop/variety choices. Area under traditional and cash crops is presented in Table 4. With increasing land holding size the area under monocropping of few important staple and cash crops increases.

A detailed inventory of named paddy landraces grown in the Valley is presented in Table 5. A total of 12 landraces are grown at present. The farmers, however, recalled 23 paddy landraces with their distinctive properties grown during the past 2–3 decades, of which 12 are still continued and 11 have been abandoned. Majority of the landraces are grown by marginal farmers (land holding < 0.5%) with an average of 3 landraces grown per household. Number of traditional landraces declined with increasing land holding size but an average of 5 landraces are grown by all the farmers with landholding > 1.0 ha per household. The results, therefore, indicate that though more number of landraces are grown by marginal farmers but big farmers possess more landraces per household basis. The predominant landraces grown by majority of farmers include Bhabri, Shyudwal, Ukhri, Khullu Safed, Lal Sati, Semolal, Khullu Kala and Jolya. Two landraces, Bhabri and Shyudwal were introduced in the Valley from neighbouring areas during 1980s and occupy over 50% area under present paddy cultivation, owing to their high yield potential. Area under cultivation of the landrace Ukhri has also increased substantially during the past three decades. Other landraces like Jolya, Kalon Lal, Kalon Safed,

Table 4. Land holding size and area under traditional, and common food and cash crops.

Land holding size	% Household	Area under traditional crops	Area under common food and cash crops*	% Area of traditional crops under mixed cropping	% Area of traditional crops under monocropping
< 0.5 ha	75.3	69.3	29.7	83.3	17.7
0.5–1.0 ha	19.1	63.2	36.8	77.7	22.3
1.0–1.5 ha	4.3	52.7	47.3	60.2	39.8
>1.5 ha	1.3	47.8	52.2	37.5	62.5

*Include paddy, wheat, common bean, potato and pea.

Table 5. Paddy landraces grown in Urgam valley with area under cultivation, pattern of occurrence and ethnomedicinal uses.

S.No.	Name of landrace*	Area under cultivation (ha)	Proportion of rice cultivated area and pattern of occurrence**	Ethnomedicinal uses***
1.	Bhabri	18.0	34.4 (widespread, common)	Seeds boiled together with flowers of kesar (*Crocus sativus)* effective in curing stomachache. Fried rice (with purified butter oil) effective against shivering
2.	Jolya	2.0	3.8 (widespread, rare)	Cooked rice, fried with sesame oil, used to cure constipation
3.	Kalon Lal	1.1	2.1 (localized, rare)	Fried rice (with purified butter oil) considered effective for curing leucorrhoea
4.	Kalon Safed	1.0	1.9 (localized, rare)	Porridge of seeds considered effective in curing dysentery
5.	Khullu Kala	2.3	4.4 (localized, common)	Ointment prepared with the seeds mixed with leaves of wild *Ocimum* sp. effective cure for pimples
6.	Khullu Safed	2.8	5.3 (widespread, common)	Paste of the fresh young leaves mixed with turmeric cure wounds and internal injury
7.	Lalsati	2.4	4.6 (localized, common)	Juice of the fresh young root considered good to cure ear-ache. Cooked rice together with green vegetables effective in curing urinary infection particularly in males
8.	Safed Kholya	1.0	1.9 (widespread, rare)	Seed starch mixed with curd and applied on the head for 10–20 minutes before taking bath effective against hair loss
9.	Saro	1.4	2.7 (localized, rare)	Fried rice with butter oil and curd effective against hiccups and indigestion
10.	Semolal	2.4	4.5 (widespread, rare)	Mixture of by-product and green leaves of *Grewia optiva* (bheemal) considered nutritious for milching animals. Seed starch effective against stomachache due to constipation
11.	Shyudwal	9.0	17.2 (widespread, common)	Half boiled seeds fried with mustard oil effective to cure urinary disorders
12.	Ukhri	9.0	17.2 (widespread, common)	Fried rice with purified butter oil considered as nutritious for nursing mother
	Total area	52.4	100.00	

*10–12 landraces were grown by small and marginal farmers (landholding < 1.0 ha) with an average of 3 landraces per household whereas 6–7 landraces were grown by medium and big farmers (landholding > 1.0 ha) with an average of 5 landraces per household.
**Widespread (occurs in more than a few field), localized (restricted to a few fields), common (grown at least on some field in above average field sizes, rare (grown in small patches only) (Based on Jarvis et al. 2000a).
***Farmers also recall growing Ghyasu, Kimoli, Lalmati, Mukhmar, Nagyon, Nandini, Rajbhog, Rajmati, Ramjawan, Sukhnandi and Thapachini landraces in the past with their distinctive ethnomedicinal uses.

Safed Kholya and Saro are still popular among marginal farmers but occupy only 8.6% of the total area under paddy cultivation, much less area than they were occupying 2–3 decades ago. Based on pattern of occurrence, four landraces namely Bhabri, Shyudwal, Ukhri and Khullu Safed were ranked as widespread and common; Jolya and Safed Kholya as widespread and rare; Khullu Kala, Lalsati as localized and common, and Kalon Safed, Kalon Lal and Saro as localized and rare.

The two most popular landraces, Shyudwal and Bhabri recorded high yield potential of 3.43 and 3.25 t/ha, respectively, followed by Khullu safed, Ukhri, Kalon Lal and Lalsati, the yield ranging between 2.0 and 2.4 t/ha under farmers' traditional management. The yield potentials of these landraces are comparable with the improved HYVs recommended for the region viz. Parag, Sugandha, Terna, Ambika, VL 221 and PD 6 (the yield potential of these improved varieties range from 1.9–4.2 t/ha under improved agronomic management in institutional experimental trials). The farmers recalled growing specific landraces with distinctive properties like Ghyasu, Kimoli, Lalmati, Mukhmar, Nagyon, Nandini, Rajbhog, Rajmati, Ramjawan, Sukhnandi and Thapachini during 1970s and 1980s which are not more in cultivation in the Valley at present.

The factors that induce changes in the mix and extent of genetic diversity of crops are economic and socio-cultural, environmental and policy issues (Table 6). Among these the important fac-

Table 6. Reasons for erosion of traditional crops/landraces (in decreasing order of importance based on farmers' perceptions).

Important factors responsible for agrobiodiversity loss	Process of change and implication
Socio-economic factors	
Change in cropping patterns due to economic considerations	The farmers in the region are involved in diverse livelihood options as cultivation of crops, livestock, forestry, etc. Many of the traditional crops are grown under marginal conditions and often provide low yield and extremely low income, forcing the farmers to undertake other activities, for example, replacement of mixed cropping to monocropping, cultivation of improved strains bringing about more uniformity in crop species and switching over to cash crops. Monocropping and uniformity results in increased vulnerability to pest epidemics and consequent loss of biodiversity. Besides, a significant proportion of the traditional agricultural land has been brought under cash crops or off-season vegetables. This has adverse implications on traditional agro-ecosystems and traditional agro-biodiversity of the region has shrunk over the time.
Population growth and land fragmentation	The human population has increased over time. The land fragmentation and insufficient crop yield due to high land: man ratio and low output: input ratio of traditional crops compelled farmers to consider other options for livelihood.
Lack of traditional knowledge	Since there is no systematic documentation of ethnomedicinal uses of traditional landraces and the traditional underutilized crops, the younger generation is unaware about the distinctive properties of the landrace diversity. Lack of this knowledge often leads to discontinuation of cultivation of some of these landraces which are of high nutritional value to them. This kind of knowledge is, however, very much essential for value addition to local landrace diversity and also in IPR protection.
Out-migration	Migration of people to plain areas for off-farm jobs and reduced interest in traditional agriculture.
Change in food habits	Yield potential of most of the traditional crops has been stable for the last 2–3 decades. The food shortage problem is because of population growth, change in food habits (increasing preference for wheat and rice as staples), reduction in crop diversity and net sown area.
Social values	Local socio-cultural integration has decreased. Social institutions such as community participation in natural resource management for agriculture, and seed and labour exchange systems are disappearing fast leading to weakening of agricultural management.
Female literacy	Traditional agriculture in the region is mainly managed by the women folk; increase in female literacy over time has reduced interest towards agriculture.
Ecological factors	
Decline in carrying capacity of forests and rangelands	The problem of land degradation in the Himalayan forests and rangelands is very serious and have a direct bearing on Himalayan traditional agroecosystem productivity and sustainability (6–8 ha of good quality forest is required to support 1 ha agriculture land on a sustainable basis). The carrying capacity of these lands has declined recently causing various environmental problems. Due to unavailability of forest resources it is difficult for farmers to cultivate traditional crops which require heavy inputs of leaf litter and organic manure; as a result of this traditional agrobiodiversity is fast declining.
Hydrological imbalances	Low rainfall and 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.
Policy issues	
Lack of formal seed distribution system	It was observed that maximum landrace diversity was maintained by big farmers (land holding >1 ha). Erosion of landraces is more common with small and marginal farmers due to lack of formal seed exchange system. Farmers' loss of seeds is attributed mainly to crop failure and, in case of poor farmers, sometimes the consumption needs of the household exceed production. When they lose their seed, they may not be able to procure seed of their choice for the next planting. Improving farmers' seed management and access to crop genetic diversity will therefore contribute to possibilities of farmers to maintain *in situ* those materials that are of value to them.
Research bias and lack of market incentives	So far no emphasis has been given towards improving the yield potential of traditional crops. Agricultural research has concentrated on major crops, such as wheat, rice and maize and on increasing their production through technology input. In addition, no niche markets are available to majority of the traditional crops discouraging farmers to produce more seeds of these crops beyond subsistence level.
Subsidies on food imports and credit	A mechanism got developed for subsidizing and pricing of food imports which provides cheap food through public distribution system. This has resulted in changed food habits and encouraged locals to abandon the cultivation of traditional crops and varieties.

Table 7. Wild economic species of Urgam valley.

Category	No. of species
Medicinal and aromatic uses	92
Vegetables and related	38
Fodder plants	35
Ornamental	12
Fruit trees	12
Soil stabilization and soil erosion control	6
Oil corps	5
Other specific uses	5
Grain legumes	2
Total	207

tors are market forces creating new preferences, demographic pressures, land fragmentation, lack of traditional knowledge, out-migration, declining carrying capacity of forests to sustain farm lands, lack of formal seed distribution system, research bias and lack of market incentives.

Inventory of wild economic useful plants and forestry resources

It was recorded that 75% of the farming families collect more than 115 species from the wild for variety of purposes (Table 7). Table 8 lists the forestry resources of the Valley under different categories of forests. It was quite interesting to note that the Van Panchayat forests managed and protected by the local communities has the highest density of trees and shrubs as well as the predominant useful species. Some forestry species are on the verge of extinction. *Berberis* sp. is one such example.

Inventory of traditional knowledge

Farmers possess enough knowledge about various crop resources and wild species for subsistence and other uses. More than 73% farmers in the higher age group (> 50 years) posses reasonable knowledge about specific landraces as against 27.3% in the age group of 15–30 years. Similar trend was observed with farmers having fair knowledge about wild resources for subsistence. Womenfolk were more knowledgeable about crop landraces and their distinctive properties. More than 95% female respondents have fair knowledge of traditional landraces as against 62% in case of male respondents. The male respondents, however, were more knowledgeable about medicinal plants and other wild economic species for subsistence. Respondents with low level of literacy possess more knowledge both of crop resources and wild subsistence as compared to the respondents from high literacy group.

Many of the paddy landraces, besides being staple food, also possess specific medicinal properties and the local farmers use these landraces for curing various ailments. A documentation of the enthno-medicinal uses of paddy landraces based on farmers' knowledge is listed in Table 5. These landraces are being used to cure various ailments viz., stomach related disorders such as dysentery, constipation, hiccup, indigestion, shivering; as a tonic particularly for expectant

Table 8. Forest vegetation of Urgam valley.

Forest species	Total density (plants/ha)		
	Reserve forest	Van Panchayat forest	Civil forest
Tree + tree saplings	1380	1776	470
Tree seedlings	1470	2816	497
Shrubs	12120	14817	1612
Predominant tree species			
Quercus leucotrichophora Roxb.	370	298	12
Rhododendron arboreum Smith	550	621	22
Myrica esculenta Buch-Ham. ex D.Don	221	289	7
Pinus roxburghii Sarg.	45	38	215
Viburnum cotinifolium D.Don	70	82	58
Prunus cerasoides D.Don	38	42	–
Lyonia ovalifolia (Wall.) Diuce	29	31	–

Table 9. Criterion for farmer variety names for various landraces of crop plants.

Category	Possible agromorphological criteria	Percentage of the total landraces grown and assigned folk name
Origin/source of the material	Region, village, farmer	8.33
Morphology	Seed characteristics, leaf shape, plant height	50.00
Agronomic performance	Flowering time, earliness, growth habit, yield	4.17
Environmental adaptation	Tolerance to biotic/abiotic stresses, type of soil, cropping system	8.33
Use	Taste, nutritional value, type of preparation, association with religious ceremony, ethnomedicinal value	29.17

and nourishing mothers; cure of pimples and small pox; urinary disorders; cure of piles; for healing wounds and cuts; curing leucorrhoea; curing earache etc. Farmers still recall the distinctive properties of paddy landraces grown in the past that have become extinct now in the Valley.

Farmers also have a system of naming the traditional landraces. Farmers have several criteria for naming a variety. Detailed inventory of predominant landraces of various traditional crop species grown in the Valley revealed that traditional nomenclature is based on source of the material, morphology, agronomic performance, environmental adaptation and use. Morphology and traits related to use were the predominant criteria for naming the variety (Table 9).

Table 10 lists the predominant species used for medicinal purposes in the Valley. There is, however, a gradual loss of traditional knowledge due to several factors. The ignorance and out-migration of the new generation for off-farm jobs is an important factor.

Scientific and institutional challenges for managing crop diversity on-farm

Farmers' perception for sustainable management of crop diversity in agroecosystems is enumerated in Table 11. It is evident that conservation of traditional crops and their landraces can succeed only when they are linked with economic development of hill farmers. Creation of specialized niche markets for local crops, land consolidation and development of marketing cooperatives through policy interventions, strengthening the local seed system and farmers access to crop diversity, identification of the elite germplasm with the potential for use in food industry and multiplication of these seed types for both local and urban consumption are some of the important policy and research support that farmers require for sustainable management of crop diversity in traditional agroecosystems.

Discussion

Genetic diversity continues to meet farmers' needs and plays an important role in traditional agroecosystems. The Urgam Valley of Uttaranchal Himalaya is one such valley where people are still practicing traditional landrace-based cultivation. Farmers' dependence on varietal mixtures, multiple crops, intercropping, growing genetically diverse varieties of individual crops fits with high variability in their edaphic and biological environments and their limited access or inability to acquire purchased inputs. In the Valley, total agriculture land is 237.72 ha and more than 70% land is used only for cultivation of traditional crop cultivars/landraces. Gradual reduction in area of several traditional crops (Table 2) and farmers preferences for certain other traditional and introduced crops is induced by the economic and socio-cultural factors (Table 3 and 6). The market forces are creating new preferences. New materials were also incorporated into existing landraces, permitting the agricultural system to evolve without total replacement. The area under common bean is increasing. The local landraces are also being replaced with high yielding landraces from neighbouring areas in case of common food crops like wheat, paddy and *Brassica*. *Perilla*, a minor oilseed crop, is almost replaced by amaranths.

Energy return for energy input in traditional agriculture is quite high, approaching 20:1 in some cases (Rappaport 1972). The energy output/input pattern and energy efficiency ratio for different

Table 10. Most useful medicinal and wild economic species of Urgam valley.

Species	Vernacular name	Parts used	Uses	Mode of uses
Aconitum heterophyllum Wall.	Atis	Tuber	Stomachache, fever, diarrhea, dyspepsia	Root extract used to cure headache, decoction of tuber used to cure fever and stomach ache, diarrhea, dyspepsia and when it is boiled with water, used as a tonic
Angelica glauca Edgew	Choru	Root	Dysentery, body pain	Decoction of root is used to cure dysentery and pain due to cold; also used as a spice and condiment
Arnebia benthamii Wall. ex. D.Don) I.M. Johnston	Balchhari	Root	Hair tonic	The fresh or dried roots put into water or hair oil for 2–3 days prevents the hair loss
Berberis aristata DC.	Chotru	Bark, root	Eye diseases, headache, dysentery	Root boiled in water, decoction used to cure eye diseases; paste of fresh roots used to cure headache; bark has also a good dyeing properties
Bergenia ligulata (Wall.) Engler	Shilphori	Leaves	Traditional tea	Dried leaves grinded into powder which is used as a good substitute of tea
Betula utilis D.Don	Bhojpatra	Resin	Cold and cough	Dried resin extracted from the bole is grounded into powder and used as an important constituent of the traditional nam-keen tea used to cure cold and cough
Cedrus deodara (Roxb. ex Lambert) D. Don	Devdar	Wood	Skin disease	Oil extracted from the wood used to cure the skin disease of sheep and goat known as makku disease and also used to cure the demodectic scabies disease. Oil is also used to cure wounds and cuts in human. 1–2 drop of oil is taken orally for killing stomach worms
Hippophae rhamnoides L.	Amesh	Fruit	Cold and cough	Juice extracted from the ripe fruits is boiled with sugar and is a good medicine for cold and cough. Juice extract also used as antidote when poisonous grasses are eaten by the domestic animals. The concentrate decoction of the juice is applied externally on the neck used to cure influenza and cough
Origanum vulgare L.	Jangli tulsi	Leaves	Fever, cough	The extract of fresh leaves is used to cure fever and cough and also kills harmful intestinal worms and also used as an ointment in skin diseases
Rheum australe D. Don	Dholu	Root, shoot, above ground parts	Boils, wounds and cuts	Paste of root when mixed with water used to cure boils, wounds and cuts, young shoot used for pickle, and also used to dye the woolen cloths when bark powder mixed with acid
Rhododendron campanulatum mD. Don	Awom	Leaves	Wounds, Cold and cough	Fresh leaves are mixed with mustard oil and paste is obtained which is useful in wounds and cuts. Dried leaves grounded into powder are used to cure cold and cough when given to the patient with boiled water
Rosa webbiana Wall. ex. Royle	Sedum	Ripe fruits	Eye disease	Fruits are edible, paste of the bark used as a ointment on the eye lid to cure eye disease
Saussurea costus (Falc.) Lipsch.	Kut	Tuber	Stomach pain, fever	Decoction of tuber is used to cure stomachache, tooth ache and typhoid fever. Traditionally it is believed that snake would not enter inside the houses when a part of tuber is kept inside.

Table 11. Scientific and institutional challenges for managing crop diversity on-farm based on farmers' perceptions (listed in decreasing order of importance).

Issues	Action points
Socio-economic and policy issues	
1.	Developing niche markets for traditional crops and promoting agroprocessing industries for local produce including the wild edibles.
2.	Land consolidation and development of village marketing cooperatives through appropriate policies so as to avoid exploitation through middlemen.
3.	Improving seed management of local landraces and access of farmers to crop genetic diversity for increased use.
4.	Empowerment of women and benefit sharing by the gender which is the main conserver and manager of agrobiodiversity.
Scientific challenges	
1.	Improvement in scientific understanding on ecological and socio-economic functions of biodiversity in traditional agro-ecosystems
2.	Identification of elite germplasm with the potential for use in food industry and multiplication of these seed types for both local and urban consumption.
3.	Increased use of local crop resources for value addition based on traditional knowledge and farmer participation in crop breeding.
4.	Promotion of organic recycling for maintaining soil fertility and integrated nutrient management for promotion of organic food.
5.	Development of community seed bank and linking the community conservation with *ex situ* conservation.
6.	Promotion of wild edibles and search for new crops.

traditional crops grown in pure and mixed form at different altitudes of Central Himalaya is also quite high (Maikhuri et al. 1996; Singh et al. 1997; Nautiyal et al. 2002). Mixed cropping of *Fagopyrum esculentum* + potato, *Amaranthus* spp. + *Phaseolus vulgaris*, *Perilla frutescens* + *Vigna mungo*, *Macrotyloma uniflorum* + *Eleusine coracana* in mid and high altitude areas has shown very high energy output/input and efficiency ratio (Maikhuri et al. 1996). The energy output/input ratio for *Fagopyrum esculentum* + potato was recorded to be 16.3 and 24.5; for *Amaranthus* spp. + *Phaseolus vulgaris*, 13.1 and 64.9; for *Perilla frutescens* + *Vigna mungo*, 17.6 and 35.8; for *Macrotyloma uniflorum* + *Eleusine coracana*, 10.4 and 40.5, respectively, for grain yield and grain + by-product. The cultivation and processing of the traditional crops are simple. Diverse and versatile food items can be prepared in a variety of forms. Traditional agriculture can therefore help conserve biological diversity and maintain healthy relationships between rural people and the land.

Population structures and dynamics of landraces are relatively simple to consider when limited to a single field, or to a group of fields maintained within a community. But, in the present investigation, given the level of land fragmentation and very small land holding size per household, it was difficult to assess whether a farmer maintains a sufficiently large population for effective conservation over time (genetic drift in small populations is a common phenomenon and will definitely result in loss of diversity over time). Erosion in traditional crops is highlighted in the context of relatively small population size of most of the traditional crops grown per household. The precise inter-household and inter-village data could not be presented. It is because of this problem that a general assessment of diversity and erosion is made based on decline in total cropped area for most of the traditional crops over time. In the absence of named varieties in most of the traditional crops like ragi, barnyard millet, foxtail millet, amaranth, buckwheat, horsegram, blackgram, etc. fair assessment of level of diversity and erosion was not possible at the farm level.

In paddy, 12 named landraces are presently grown by the farmers (Table 5). The area under paddy cultivation is static during the past 2–3 decades but only 2–3 landraces with relatively high yield potential occupy most of the area and grown invariably by all medium and big farmers with >1.0 ha land area. Many of the other landraces, with relatively low yield potential, are maintained on relatively much smaller area by marginal farmers. This raises important questions regarding the size threshold and distribution of crop genetic diversity needed for effective conservation. It is surprising to note that not a single landrace of paddy is replaced by the HYVs, developed by institutional breeding efforts (and recommended for the region) in the Urgam Valley, yet the rate of the genetic loss is an indication of the severe threat to landrace diversity. Lack of formal seed exchange system of traditional landraces is one important factor as threat to continued survival of these landraces especially those grown by marginal farmers. It was observed that majority of the landrace diversity was maintained by marginal farmers. Farmers' loss of seeds is attributed mainly to crop failure and, in case of poor farmers, sometimes the consumption needs of the household exceed production. When they lose their seed, they may not be able to procure seed of their choice for the next planting. Improving seed management and access to crop genetic diversity could therefore contribute to maintenance *in situ* of those materials which are of value to farmers. Maintaining community seed banks and complementing community conservation to *ex situ* institutional conservation of the existing landrace diversity is therefore essential before more landrace diversity is lost from traditional agro-ecosystems. Ranking the existing paddy landraces as widespread-common, widespread-rare, localized-common and localized-rare based on pattern of occurrence in the Valley gives some insight into their population structure. To make rational conservation plans, it is important to test how variable are common varieties than less common varieties. Further, locally common alleles are more important for conservation and interesting to users.

Grain yield of some of the traditional landraces of paddy was comparable with the HYVs recommended for the region (Naseem and Abdullah 1998; Singh et al. 2001). It suggests that the hill agroecosystems with traditional crops are ecologically and economically viable and still have the potential to support the food requirements in the Himalayan region. There is, however, substantial evidence that the introduction of modern HYVs in agroecosystems has resulted in extinction of traditional landraces in the Himalayan region. A recent study conducted by Nautiyal et al. (2000) in the Uttaranchal Himalaya showed that a prominent scented paddy landrace, "Mukhmar" has become extinct because of the introduction of HYVs by government policy interventions in certain areas. During 1980s a programme was launched by the government through watershed management project in the region and seeds of HYVs along with fertilizers at subsidized rates were provided to the local farmers. Farmers started cultivating a scented HYV of rice in place of the local scented rice landrace Mukhmar. At initial stages the HYV showed high output in terms of grain yield under high agronomic management but later on its production declined when the government agencies stopped giving subsidy on fertilizers. The traditional landrace Mukhmar has completely disappeared from the area now. Such state sponsored policies/programmes have therefore negative implications on traditional knowledge-based agriculture.

It is also noticeable that crop yields, in general, during the past 2–3 decades of most of the traditional crops have been more stable than that of the common food crops like wheat and paddy (Maikhuri et al. 1996). Unfortunately human preferences for consumption of wheat and paddy are recent changes in food habits. The main nutritional value of traditional crops like finger millet, foxtail millet and barnyard millet, lies in their potential ability to provide one of the cheapest sources of dietary energy, in the form of proteins and carbohydrates, in the Himalayas. Majority of the traditional grain and pulse crops of the mountains viz. *Hordeum vulgare* (naked barleys), *Fagopyrum* spp., *Amaranthus* spp., *Panicum miliaceum*, *Eleusine coracana*, *Setaria italica*, *Echinochloa frumentacea*, *Macrotyloma uniflorum*, *Glycine max* (local black seeded types) and *Vigna mungo* have high calorific values (Maikhuri et al. 1996). Traditionally, in the Himalayas many of these local crops supplement the wheat and rice meal.

Wild and forestry resources play important roles in these agricultural villages of the Valley (Tables 7 and 8). *In situ* conservation and agricultural development projects need to consider all these plant resources as the farmers of the Valley have ecological relationships far beyond the village. In the Himalayan highlands, the farmlands need support of forests. In the hills of Nepal, each hectare of farmland needs 3.48 ha forest to support it (Sattaur 1987). Similarly, in north-western Himalaya in India, the literature indicates that about 6–8 ha of good forest can produce similar amounts of resources required to meet such demands (Ashish 1979; Singh et al. 1984;

Hrabovzsky and Miyan 1987; Swarup 1993; Ashish 1993; Rao and Saxena 1994; Maikhuri et al. 2001). These Himalayan forests are ecologically sensitive, requiring expert management if they are to continue providing desired inputs for agriculture beside other benefits in terms of fodder, firewood, construction materials, fruit and medicinal plants

In order to optimise food production in the low-input farming systems of the Valley, farmers possess a considerable knowledge both of the nature and characteristics of the various crop resources available, and of the methods suitable for sustainable crop production under conditions which are often marginal for agricultural activity. Besides staple food, the documented ethnomedicinal uses of the landraces described here are an important aspect that needs systematic inventorisation in the present IPR regime. The ethnomedicinal uses of traditional landraces of paddy described in the present paper (Table 5) provides a strong evidence that local farmers were dependent on traditional crops for cure of various diseases/ailments during the past due to lack or inaccessibility of modern medical facilities/allopathic medicines particularly when the wild medicinal plants are not available easily during the lean period.

It has now been well realized that in many areas farmers have developed distinct systems of classification and description of local landraces (Boster 1985; Berge et al. 1991). In the present documentation, the traditional nomenclature of landraces in the study area was based mainly on two important criteria, the morphology and use (Table 9). Although such taxonomies have been recognized for many years, renewed attempts are now being made to incorporate such indigenous knowledge with scientific knowledge. Indigenous knowledge about the location and extent of crop diversity that farmers maintain in a given area may prove to be the most effective way to locate and monitor this diversity.

The agriculture related indigenous knowledge possessed by the elderly people, mostly womenfolk, is facing series of challenges due to variety of factors and out-migration of younger generation to urban areas. Limited efforts have so far been made to document the ethnomedicinal values of agrobiodiversity of agroecosystems in the Himalaya (Maikhuri et al. 2001). However, the situation for wild biodiversity (Dobriyal et al. 1997; Maikhuri et al. 1998; Nautiyal et al. 2000, 2002a,b; Negi et al. 2003) in the Himalayan region and many other parts of the world (Anderson 1986; Begossi 1996; Siebert and Belsky 1985) is relatively better. The documentation of traditional landrace-based indigenous knowledge system would play significant role in making value addition of the traditional crops and their better management on-farm. Policy makers should not only promote planning to increase consumption of traditional crops as human and animal food but should also support research that will enhance their utilization (Maikhuri et al. 1996; Palni et al. 1998).

In situ conservation and crop improvement can complement one another in marginal areas. Breeding programmes that evaluate landraces and use them in local improvement efforts are expected to produce material of direct value for marginal agroclimatic zones as well as achieving significant local conservation (McNeely 1988; Harlan 1992; Brush 1999; Smale and Bellon 1999; Almekinders and Elings 2001). By including decentralized breeding as part of an *in situ* programme, farmers and crop biologists can become partners in local crop improvement efforts for marginal agrocilmatic zones and for crops without national breeding programmes. This 'grass-root breeding' can build upon existing knowledge and skills of farmers and link farmers from different regions through the exchange of information and landraces (Iwanaga 1995; Brush and Meng 1998; Berthaud et al. 2001; Cooper et al. 2001). *In situ* (on-farm) conservation can also be seen as a conservation strategy that is complementary to *ex situ* conservation (Visser and Engels 2000; Almekinders et al. 2000; Almekinders and Elings 2001).

Careful analysis and evaluation of various socio-economic, environmental and scientific challenges (Table 11) is essential so that agricultural activities could be reoriented towards better use of local resources and their sustainable management in Himalayan agroecosystems. Conservation of traditional crops could succeed when these crops are linked with the economic development of hill farmers. Pragmatic multi-disciplinary research and policy support are needed to evolve farming systems which can provide enough quality food and economic security for the people of the Valley and encourage them conserve and enhance crop diversity in the traditional ecosystems.

In situ (on-farm) conservation will be most effective when targeted to specific areas with significant plant genetic resources and with communities who are willing to participate in conservation programmes. Urgam valley is, therefore, a suitable site for on-farm conservation of landrace diversity of the traditional crops. Most of the traditional crops such as amaranth, barnyard millet, fingermillet, buckwheat, horsegram, blackgram, barley (the hullless types), *Perilla frutensens* still occupy substantial area under cultivation and supplement the major dietary energy in these agroecosystems with valuable intra-specific diversity. These crops can also be cultivated in different agroecological regions across altitudinal gradients in the Himalayas, to provide increased food security. The farmers possess considerable knowledge of resource availability and resource management in these traditional agroecosystems. There is ample forest resource base to support the farmland as an integral component of traditional agroecosystems. Breeding and utilization strategies for local crop, forage and forestry diversity to improve productivity without replacing local genetic diversity must be supported through policy and research interventions. Strategies to enhance local participation through marketing and education must be identified.

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