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Traditional crop diversity and its conservation on-farm for sustainable agricultural production in Kumaon Himalaya of Uttaranchal state: a case study

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Abstract

Farming communities in traditional agroecosystems have been playing an important role in conserving agricultural diversity. They are not only the custodians but also managers of the crop diversity and maintain the dynamic processes of crop evolution and adaptation, the key elements of sustainable agricultural productions. The Himalayan highlands are important centres of crop plant diversity due to high ecological heterogeneity and high local socio-cultural integrations. The crop genetic diversity of Kumaon Himalaya in Uttarachal State of India has been documented in the present study. Existing crop genetic diversity at inter- and intra-species level was assessed and factors for changes in crop compositions and farming systems during the recent past were studied. Farmer management of rice landrace populations were studied in greater detail. Various benefit enhancing options for farmers from local crop diversity were scrutinized based on farmer perceptions and priorities for efficient management of local crop diversity on-farm and its sustainable utilization for agricultural production.

Introduction

The 20th century has seen an enormous transition in our appreciation of plant genetic diversity. By the mid-1970s, concern for plant genetic resources was widespread and efforts to conserve them underway as such diversity was viewed as threatened with the spread of agricultural development worldwide (Brown and Brubaker 2002). Individual farmers and farming communities have been playing an important role in conserving agricultural diversity. They are not only the custodians but also managers of the crop diversity and they maintain the dynamic processes of crop evolution and adaptation, the key elements of sustainability of traditional agricultural production systems.

The Himalayan highlands are the reservoir for a large number of crop genetic resources because of the preponderance of locally developed traditional crop varieties owing to high agro-climatic heterogeneity and local socio-cultural diversity. Valleys in general are intensively cropped than the hilly slopes. Traditional agroecosystems in the Himalayan region are very diverse and crop husbandry, animal husbandry and forests constitute complex and interlinked production systems. However, there has been gradual reduction of traditional crop diversity in this region during the last three to four decades which requires adequate attention of researchers and policy makers for its safe conservation on-farm and sustainable utilization for agricultural production (Singh et al. 1984; Maikhuri et al. 1996, 1997, 2001; Palni et al. 1998; Bisht et al. 2005).

The Kumaon Himalaya in Uttaranchal State of India is part of north-western Himalaya falling between 28°29′ to 30°41′ N latitude and 79°32′ to 81°11′ E longitude. It is bordered by river Kali in the east adjoining Nepal and the districts Pauri and Chamoli of Garhwal region of Uttaranchal State in the west. Tibet lies on the north and the parts of Terai region (plains adjoining foot hills) of Uttar Pradesh on the south. Physiographically, the Kumaon region can be divided into four prominent regions, the Terai region (plains), the Sub-Himalaya (the Siwaliks or foot hills), the lower Himalaya and the Higher Himalaya. The higher Himalayan ranges (> 2500 masl) has a glaciated topography with many moraines. The lower Himalaya extending from west to east is composed of granite and crystalline rocks. The sub-Himalaya with an average height of 1225 masl is the chain of small hills. The Terai region ranges between 300 and 600 masl with elevations increasing from south to north.

Total geographic area of Kumaon Himalaya is 21,038 km^2 of which about 64% is under forest cover followed by agricultural crops (11.34%), meadows (4.67%) and horticultural crops (4.36%). The rest is under agricultural and other wastelands (Joshi et al. 1983). The average agricultural land holding per household is very small in Kumaon Himalaya (0.19 ha/capita). Around 21% area is irrigated and remaining 79% is rainfed.

In the present investigation, the traditional crop diversity in Kumaon Himalaya has been documented with a view to pinpoint strategies for an action plan to manage and conserve the traditional crop genetic resources for sustainable agricultural development of the region.

Materials and methods

Data on crop genetic diversity were collected from primary sources with the help of planned structured and unstructured questionnaire/interview schedules at individual farm households level 2002 and 2003 cropping seasons. Sample households were randomly selected from all the 33 development blocks of five districts of Kumaon region of Uttaranchal state. Three to four villages were selected from each development block representing the distinct agroecological niches. In each selected village 5% households were randomly selected for interview. Lottery system was adopted for randomization. Thus, a total of 298 respondent households were interviewed for documenting crop diversity and their distinct landraces. The district-wise details of development blocks, total number of villages, total households, number of villages surveyed and respondent households are presented in Table 1. During the survey of the region, a non-participant observation method was also used while recording the crop genetic diversity.

Using participatory rural appraisal, information was obtained on the total land area under cultivation for individual crops. Information was also collected on the erosion and shift in landrace diversity and changes in farming systems during the past 2–3 decades from each household. The information for current crop status was validated by taking observations in the field for the landrace diversity under cultivation. Respondent households 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 etc. Documentation on rice landraces, it being the major crop, is presented in this paper in greater detail. Information on farmer management of population structure, pattern of rice landrace occurrence and geneflow was obtained following Jarvis et al. (2000). All possible care was taken to determine the consistency in farmers' naming and describing rice landraces by comparing information from farmer households and different social groups. The information on farmers' decision on crop/variety choice was also documented disaggregating the same based on age group, sex, literacy and wealth status. While recording the names of crop cultivars/landraces, visits were made with the informant farmer for identification of the landrace in the field. Information obtained was authenticated from knowledgeable elderly farmers and other

Table 1. Number of districts, development blocks, villages and households surveyed for crop genetic diversity in Kumaon Himalaya.

District	Development blocks	Total no. of villages	Total no. of households	No. of villages selected for the study	No. of households surveyed	No. of households surveyed in each farm-size class	No. of households surveyed in different altitude category
Almora	11	937	36480	33	100	<0.5 ha: 62 0.5–1.0 ha: 20 1.0–1.5 ha: 13 >1.5 ha: 5	<500 masl: – 500–1000 masl: 27 1000–1500 masl: 39 1500–2000 masl: 32 >2000 masl: 2
Bageshwar	3	302	12182	9	32	<0.5 ha: 18 0.5–1.0 ha: 10 1.0–1.5 ha: 3 >1.5 ha: 1	<500 masl: – 500–1000 masl: 6 1000–1500 masl: 20 1500–2000 masl: 6 >2000 masl: –
Champawat	4	297	11981	12	31	<0.5 ha: 24 0.5–1.0 ha: 5 1.0–1.5 ha: 1 >1.5 ha: 1	<500 masl: – 500–1000 masl: 3 1000–1500 masl: 17 1500–2000 masl: 8 >2000 masl: 3
Nainital	7	698	26822	21	63	<0.5 ha: 44 0.5–1.0 ha: 13 1.0–1.5 ha: 3 >1.5 ha: 3	<500 masl: 8 500–1000 masl: 24 1000–1500 masl: 25 1500–2000 masl: 6 >2000 masl: –
Pithoragarh	8	720	23604	24	72	<0.5 ha: 49 0.5–1.0 ha: 21 1.0–1.5 ha: 1 >1.5 ha: 1	<500 masl: – 500–1000 masl: 14 1000–1500 masl: 42 1500–2000 masl: 10 >2000 masl: 6
Total	33	2954	111069	99	298	<0.5 ha: 197 0.5–1.0 ha: 69 1.0–1.5 ha: 21 >1.5 ha: 11	<500 masl: 8 500–1000 masl: 74 1000–1500 masl: 143 1500–2000 masl: 62 >2000 masl: 11

secondary sources. Information was also recorded on ranking the varieties in terms of gender preferences, and area covered by each landrace/variety. The source of seed, whether self, from within the family, between farmers in communities and distant markets was also determined. The questionnaire also contained questions about farmers' perceptions on various benefit enhancing options for farmers from local crop diversity for sustainable management and use in agricultural production.

Results

General description of agroecosystem, cropping patterns and crops grown

It was revealed that more than 66% household in the present study are marginal farmers with average landholding < 0.5 ha. About 80% of the agriculture is rainfed. Agriculture, in general, is practiced in steep terraces on highly fragmented landholdings as there is no system of land consolidation based on the existing land tenure laws in the region. Except in the plain areas in Terai region and few valleys in Higher Himalayan ranges, farmers practice low input agriculture. In the Himalayas, agriculture requires a great deal of support from forestry resources in the form of leaf litter and other desired inputs. Farmers in marginal areas have been conserving significant amount of crop diversity, at both the species and intraspecies level. They depend on landrace mixtures, multiple crops, intercropping and home gardens. Irrigated and intensive agriculture is practiced only in valleys and at lower elevational ranges in Terai region and two crops, a summer and a winter crop, are harvested in a year. The rainfed agriculture in all the villages at relatively higher elevational ranges 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 to March) over a period of 2 years. Therefore three crops can be harvested in 2 years period from rainfed agriculture. The cropping pattern is built around two major seasons, *kharif* (April to October) and *rabi* (October to April). The major crops of *kharif* season include rice (*Oryza sativa*), barnyard millet (*Echinochloa frumentacea*), ragi (*Eleusine coracana*), foxtail millet (*Setaria italica*), amaranth (*Amaranthus caudatus*, *A. viridis*), buckwheat (*Fagopyrum esculentum*, *F. tataricum*), soybean (*Glysine max*, local black seeded types), kulthi (*Macrotyloma uniflorum*), French bean (*Phaseolus vulgaris*), blackgram (*Vigna mungo*) and seasonal vegetables. The main *rabi* season crops are wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), mustard (*Brassica campestris*), lentil (*Lens culinaris*) and other seasonal vegetables. A total of 76 agricultural crops are grown in the region (Table 2). The vegetables constitute the largest number of traditional crops followed by food legumes, cereals and pseudocereals, minor millets, oilseeds and spices and condiments. Except potato and pea, being the cash crops, most of the other local seasonal vegetables are grown in backyards and home gardens of the households in relatively very smaller area. It is apparent from Table 2 that higher number of crops are grown in mid elevational zones ranging between 500 and 2000 masl.

Mixed cropping is practiced for most of the traditional crops. Wheat and rice are however,

Table 2. Agricultural crops grown in Kumaon Himalaya.

Crop group	No. of crops	No. of crops grown at different altitudes (masl)				
		Upto 500	500–1000	1000–1500	1500–2000	> 2000
Cereals and pseudocereals	8	4	5	6	7	7
Minor millets	7	1	5	5	6	3
Food legumes	12	5	9	9	9	5
Oilseeds	6	3	6	6	6	2
Vegetables	37	26	33	36	32	17
Spices and condiments	6	5	6	6	6	5
Total	76	44	64	67	66	39

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. 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.

Common bean, pea, improved varieties of soybean, maize, off-season vegetables like cauliflower, cabbage, capsicum and tomato are the late introductions in the farming systems of Kumaon region.

Landrace diversity of traditional crops and changes in cropping patterns

Table 3 presents the landrace diversity of some important traditional crops at different elevational ranges. There are many named rice landraces occurring largely in mid elevational ranges between 1000 and 2000 masl. Other traditional crops with substantial intra-species diversity but a few named landraces include wheat, ragi and barnyard millet. Many of the traditional crops with high heterogeneity, but without named landraces, include *Amaranthus* spp., *Fagopyrum* spp., *Macrotyloma uniflorum, Vigna umbellata, Perilla frutescens, Setaria italica, Panicum miliaceum, Sesamum indicum* and several minor vegetable crop species (*Trigonella* spp., *Beta* spp., cucurbits, radish, taro, yams, etc.).

Rice and wheat occupy maximum area under cultivation among the agricultural crops followed by ragi and barnyard millet. There has been no change in total cropped area in rice and wheat during the past 3–4 decades. However, substantial decline in area under cultivation of many other traditional crops has been recorded (Table 3). The yield levels of most of these traditional crops have however been stable for the last 2–3 decades. There has been substantial increase in area under cultivation for some of the crops like amaranths and common bean owing to better market incentives to farmers. Hull-less or naked barley landraces have been replaced by wheat from entire higher Himalayan ranges, where it was occupying substantial area 3–4 decades ago. Among the traditional underutilized crops, *Panicum miliaceum* and *Setaria italica* (the two fastest ripening millets), the area under cultivation has reduced to 40–50% during the last 2–3 decades. Decline in area under cultivation by 20–40% has also been recorded for many other traditional crops such as *Fagopyrum* spp., ragi, barnyard millet, horsegram, ricebean, *Perilla* spp. and soybean (local black seeded types) and many of the locally grown vegetable crops. Area under many of these crops and their traditional landraces is being replaced very fast by several of the cash crops, such as off-season vegetables, 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*, a minor oilseed crop, has almost been replaced by amaranths. The off-season vegetables such as cauliflower, cabbage, bell-pepper and tomato are also replacing the local crops very fast in many areas due to market incentives. The replacement crops for most of the major local crops are shown in Table 3.

Explanatory factors and variables for farmer crop and variety choices are presented in Table 4. Agroecology, market structure and various household socio-economic characteristics like economic status of households, income sources, family structure, gender roles, land tenure system, local seed system, etc. are important factors dictating farmers' crop/variety choices.

Detailed inventorization of rice landraces and the local seed systems

A detailed inventory of named rice landraces grown in the Kumaon region is presented in Table 5. A total of 117 landraces have been documented in the present study, of which 74 were categorized as rare landraces (47 widespread rare and 27 localized rare) and 43 as common landraces (17 as widespread common and 26 as localized common). Most of the rare landraces (58) are grown under rainfed conditions as against only 17 rare landraces grown under irrigated

Table 3. Landraces of important traditional crops grown at different altitudes and area under cultivation.

Crops	Altitude (masl)					Average cropped area under cultivation in a season (%)	Change in area under cultivation during the last 3–4 decades[a]	Replacement crops
	Upto 500	500–1000	1000–1500	1500–2000	>2000			
Oryza sativa L.	3	21	53	69	27	25 (*Kharif*)	No change	High yielding landraces/cultivars
Triticum asetivum L.	2	5	10	14	13	30 (*Rabi*)	No change	High yielding landraces/cultivars
Eleusine coracana (L.) Gaertn.	–	5	12	14	14	15 (*Kharif*)	20–30% decline	Off-season vegetables, *Amaranthus* spp.
Echinochloa frumentacea L.	–	5	12	14	15	20 (*Kharif*)	20–30% decline	Off-season vegetables, *Amaranthus* spp.
Phaseolus vulgaris L.	–	3	5	12	12	5 (*Kharif*)	30–40% increase	High yielding landraces
Amaranthus spp.	–	3	10	15	15	4 (*Kharif*)	20–30% increase	High yielding landraces
Hordeum vulgare L.	1	3	4	5	6	4 (*Rabi*)	10–20% decline	*Triticum aestivum*
Brassica spp.	4	3	4	4	2	3 (*Rabi*)	10–20% increase	High yielding landraces/cultivars
Fagopyrum spp.	–	–	3	5	13	2 (*Kharif*)	10–20%	*Amaranthus* spp.
Vigna mungo (L.) Hepper	1	2	3	4	4	2 (*Kharif*)	20–30% decline	*Phaseolus vulgaris*
Glycine max L.	–	2	5	6	6	2 (*Kharif*)	20–30% decline	*Phaseolus vulgaris*
Macrotyloma uniflorum Roxb.	–	–	4	6	7	2 (*Kharif*)	20–30% decline	*Phaseolus vulgaris*
Setaria italica L.	–	–	3	4	5	0.5 (*Kharif*)	40–50% decline	*Amaranthus* spp.
Vigna umbellata (Thunb.) Ohwi et Ohashi	–	–	2	3	3	0.5 (*Kharif*)	20–30% decline	*Phaseolus vulgaris*
Sesamum indicum L.	1	1	3	3	3	0.5 (*Kharif*)	10–15% decline	Off-season vegetables, *Amaranthus* spp.
Perilla frutescens (L.) Britton	–	–	–	3	4	0.5 (*Kharif*)	20–30% decline	*Amaranthus* spp.
Panicum miliaceum L.	1	1	1	1	1	0.3 (*Kharif*)	40–50% decline	Off-season vegetables, *Amaranthus* spp.

[a]No substantial change in area under cultivation of miscellaneous vegetable crops (cucurbits, spinach, fenugreek, radish, taro, yams, onion, garlic, ginger, turmeric etc.) observed but in some cases the local landraces have been replaced by improved cultivars; area under cash crops like off-season vegetables has increased substantially (15–20%).

Table 4. Explanatory factors and variables for farmer crop and variety choices.

Factor	Important variables	Impact assessment
Agroecology	Irrigation resources, land quality, soil type	About 15–20% of the total cropped study area is irrigated. The high yielding rice and wheat landraces are monocropped under irrigated conditions. Most of the traditional coarse grains are grown under rainfed conditions in poor soil as complete mixtures or intercropped. Many of the rare rice landraces under rainfed conditions are grown in very small patches adapted to specific soil types and microclimatic niches
Market infrastructure	Distance to nearest market, price differentials	Cash crops like off-season vegetables, potato and pea are grown for both local and distant 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 considerable 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 local 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 66% households are marginal farmers ($<$ 0.5 ha land holding) 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 marginal farmers. Only big farmers can afford to maintain locally rare landraces mainly for aesthetic reasons
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 marginal farmer
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 Kumaon Himalaya. Farmers with large farm area can afford to maintain more landraces per household basis for market incentives and also for aesthetic reasons

Methodology adopted from Jarvis et al. (2000).

Table 5. Relationship between landholding size and rice landraces maintained per household.

Land holding size	No. of household	No. of named rice landraces grown	Patterns of landrace diversity[a]				Average no. of landraces/household		
			Widespread common	Locally common	Widespread rare	Locally rare	Common	Rare	Total
< 0.5 ha	197 (66.1%)	87	13 (14.9%)	27 (31.0%)	37 (42.5%)	10 (11.5%)	1	2	3
0.5–1.0 ha	69 (23.2%)	46	10 (21.7%)	17 (37.0%)	10 (21.7%)	9 (19.6%)	2	2	4
1.0–1.5 ha	21 (7.0%)	35	8 (22.8%)	13 (37.1%)	5 (14.3%)	9 (25.7%)	3	2	5
> 1.5 ha	11 (3.7%)	17	3 (17.6%)	7 (41.2%)	2 (11.8%)	5 (29.4%)	3	2	5

[a]Widespread (occurs in more than a few fields), localized (restricted to a few fields), common (grown at least on some fields in above average field sizes), rare (grown in small patches only). Of the 117 named landraces 74 were categorized as rare landraces (47 as widespread rare and 27 as localized rare) and 43 as common landraces (17 as widespread common and 26 as localized common).

conditions. It was revealed that marginal farmers grow more number of landraces with an average of 3 landraces per household. Number of traditional landraces declined with increasing land holding size but an average of 5 landraces are grown by farmers with landholding > 1.0 ha per household. The results, therefore, indicate that though more number of landraces are grown by marginal farmers but farmers with larger holdings possess more landraces per household basis. Further, farmers with larger land holdings grow more common landraces occupying greater area owing to their high yield potential. Big farmers also grow more common and rare localized landraces which fetch premium prices or are important for aesthetic reasons. On the other hand small farmers cultivate more rare widespread landraces. The farmers also recalled many rice landraces with their distinctive properties grown during the past two to three decades, which have now been abandoned from the present study area. Types of rice landraces grown approximately on different-sized farms of the sampled villages (Table 6). There was no consistency in landrace names and often it was difficult to ascertain that all the farmer-named varieties are genetically distinct. All care was however, taken to record only distinct landraces based on farmer description of their varieties using distinct naming criteria as listed in Table 7. The important common and rare landraces with their frequency of occurrence are listed in Table 8. It was analysed that women farmer preferred the common (localized) landraces more than men farmer (based on relative ranking), and also play a major role in variety choice decisions at farm level. The most frequent common landraces Thapachini and Jolya occupy substantial area under rice cultivation in Kumaon region and are in continued cultivation for the last several decades.

The local level seed supply system is the major limiting factor for farmers' variety choice (Table 9). The small farmers use either their own-saved seed or are dependent on neighbours' landraces, whereas the big and wealthy farmers largely use their own-saved seed. The improved varieties are mainly grown by big farmers thereby permitting geneflow through introduction of new diversity into the traditional production systems.

Table 6. Types of rice landraces grown approximately on different-sized farms of the sampled villages.

Land holding size (ha)	Total area of the sampled villages (ha)	Total area occupied by rice landraces (ha)	Pattern of different type of rice landraces occupying the cropped area (ha)			
			Widespread common	Locally common	Widespread rare	Locally rare
< 0.5	85.0	17.0	3.0	5.0	7.0	2.0
0.5–1.0	48.0	12.0	2.0	3.0	5.0	2.0
1.0–1.5	24.0	10.0	3.0	5.0	1.0	1.0
> 1.5	18.0	8.0	2.0	4.0	1.0	1.0
Total	175.0	47.0	10.0	17.0	14.0	6.0

Table 7. Criterion for farmer landrace names for various rice landraces.

Category	Possible agromorphological criteria	No. of landraces
Origin/source of the material	Region, village, farmer	6 (5.13%)
Morphology	Seed characteristics, plant height, vegetative characters	61 (52.14%)
Agronomic performance	Flowering time, earliness, growth habit, yield	5 (4.27%)
Environmental adaptation	Tolerance to biotic/abiotic stresses, type of soil, cropping system	8 (6.84%)
Use	Taste, nutritional value, type of preparation, association with religious ceremony, ethnomedicinal value	37 (31.62%)

Table 8. Some important rice landraces with their frequency of occurrence.

Common landraces[a]		Rare landraces[b]	
Name of landrace	Frequency (%)	Grown under rainfed conditions	Grown under irrigated conditions
Thapachini	73	Chamari	Ghesu
Jolya	56	Bhuria	Thai
Nandhani	46	Jhusia	Bhadgar
Dudh	34	Matiya	Musia
Lalsal	33	Syudwal	Kalajamali
Anjan	27	Parvati	Simodia
Banbasa	27	Jhumaria	Dhaulia
Chhotia	26	Rokhiyal	Lumodia
Kalthudia	23	Timasia	Jumudi
Naulia	22	Khardudh	Rajula
Jiruli	20	Makhur	Lali
Dalbadal	19	Masur	Lahangi
Boran	19	Mangraj	Suntola
Kalisal	17	Akadi	Sito
Jamoli	12	Bakul	Kumiti
Binduli	11	Rokhiyal	Uskau
Chinbhuri	10	Jhadua	Cheuria

[a]These landraces are preferred more by women farmers which play a major role in variety choice decisions at farm level.
[b]The frequency of occurrence varies from 10 to 30%.

Benefit enhancing options for farmers from local crop diversity

A range of options are available for enhancing the benefits for farmers of maintaining diversity on-farm. Various 'add-value' options based on farmers' perceptions and priorities are presented in Table 10.

Discussion

Farmers of Kumaon Himalaya largely practice 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. Of the total agricultural land, about 60% land is used for cultivation of traditional crop cultivars/landraces. Gradual reduction in area of several traditional crops (Table 3) and farmers preferences for certain other traditional and introduced crops is induced by the economic and socio-cultural factors (Table 4). The market forces are creating new preferences. New materials were also incorporated into existing landraces, permitting the agricultural system to evolve without total replacement.

Erosion of diversity in traditional crops could be anticipated owing to relatively small population size of most of the traditional crops grown per household. The precise inter-household and

Table 9. Relationships between land holding size and seed system of rice landraces.

Land holding size	Own landraces (%)	Neighbour's landraces (%)	Improved varieties (%)
<0.5 ha	68.0	30.0	2.0
0.5–1.0 ha	85.0	10.0	5.0
1.0–1.5 ha	85.0	–	15.0
<0.5 ha	80.0	–	20.0
Average (%)	79.5	10.0	10.5

Table 10. Benefit enhancing options for farmers from local crop diversity (based on farmers' perceptions in decreasing order of priority).

S. No.	'Add value' options	Probable actions
1.	Increasing consumer demand	Many traditional landraces of rice, millets, food legumes and local vegetables have great potential for processing, packaging and marketing. Potential consumers need to be made aware of the range of available crops and the positive features (taste, nutrition, etc.) of particular varieties
		Marketing of products made from local crops that have a special value for local food culture and a market niche for tourism. Local products from rare medicinal rice landraces, buckwheat, amaranths, horsegram, millets may be processed and marketed. Chefs in hotels and restaurants need to be sensitized to use local products in daily cuisines and local recipes making best use of the new products
		The Himalayan agriculture with very little use of purchased inputs has a great potential for organic farming. Public awareness through media campaign initiatives to educate consumers about the value of agrobiodiversity and linking it with a greater demand for organic produce can add value to the local crop diversity. Organic farming shares many of the goals of on-farm conservation such as agroecosystem health, sustainable production and low input and locally adapted farming systems
2.	Increasing farmers' access to genetic materials	Strengthening seed exchange networks and linking farmers' seed supply to the formal sector could serve to broaden farmers' option regarding variety choice while fostering diversity conservation
		Farmers' access to new and diverse varieties can be improved through community genebanks and community biodiversity registers
		Incorporation of landraces into agricultural extension packages and training extension personnel to recognize the importance of local landraces for conservation and local livelihood
		Organising community-level diversity fairs on regular basis as an important forum for public recognition of farmers and their crop diversity
3.	Improving the material itself	'Grassroot breeding' or participatory plant breeding can improve diverse crop populations or the production systems in which they are grown according to farmers' interests
		Seed storage practices could be strengthened to prevent loss due to diseases, pests and deterioration
		Particular agroecological management practices may also serve to support production of crop diversity. Low chemical input or organic farming with local varieties can serve to promote agroecosystem stability and health. Such improvement strategies must necessarily be local in order to be used for a diversity of landrace materials
4.	Policy support	Farming systems maintaining very high genetic diversity may be supported through government subsidies if the opportunity cost of conservation becomes too high for farmers' to continue cultivating diverse landraces. Further, integrated and expert forest management in the region has to be strengthened as 6–8 ha of well managed forests are required to support 1 ha of farm land in Himalayan agroecosystems

Methodology adopted from Jarvis et al. (2000).

inter-village data could not be presented due to high degree of land fragmentation and the absence of named varieties in most of the traditional crops. 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 local 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. 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 (Barrett and Kohn 1991).

It is also noticeable that crop yields, in general, during the past two to three decades for most of the traditional crops have been more stable than that of the common food crops like wheat and rice (Maikhuri et al. 1996; Bisht et al. 2005). Unfortunately human preferences for consumption of wheat and rice are recent changes in food habits in the region. 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. Mixed cropping of *Fagopyrum* spp. + potato, *Amaranthus* spp. + *Phaseolus vulgaris*, *Perilla frutescense* + *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; Bisht et al. 2005). The cultivation and processing of the traditional crops are simple. Traditional agriculture can therefore help conserve biological diversity and maintain healthy relationships between rural people and the land.

In rice, 117 named landraces are presently grown by the farmers (Table 5). About 15–20 landraces (categorized as common widespread) with relatively high yield potential occupy about 20% area under rice cultivation. Many of the other landraces, with relatively low yield potential (rare widespread), are maintained by marginal farmers in about 25–30% area under rice cultivation. Landraces under the common localized and rare localized category are invariably grown by big and wealthy farmers in specific microclimatic niches, sometimes for premium prices (in case of common localized) and aesthetic reasons (in case of rare localized) and together occupy the remaining 40–45% area under rice cultivation. The rare landraces grown in relatively small patches with highly fragmented landholdings in the Himalayas raises important questions regarding the size threshold and distribution of crop genetic diversity needed for effective conservation. The High Yielding Varieties (HYVs) are grown mainly in valleys and Terai region under irrigated conditions. The HYVs are not posing any serious threats to local landrace diversity, as no complete replacement of local landraces by HYVs has been observed in the present study. As farmers recall growing many other named landraces in the past but abandoned locally at present, a metapopulation study would be interesting as these landrace populations may be extinct locally but be founded again in the network (Hanski and Gilpin 1996; Louette 2000).

Lack of formal seed exchange system of traditional landraces is one important limiting factor to continued survival of these landraces especially those grown by marginal farmers. Farmers' loss of seeds is attributed mainly to crop failure (particularly under rainfed agriculture) and, in case of poor farmers, sometimes the consumption needs of the household exceed production (Tripp 2000). 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. Categorising the existing rice landraces as widespread-common, widespread-rare, localized-common and localized-rare based on pattern of occurrence in the region gives some insight into their population structure (Khatiwada et al. 2000). 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. Determining whether farmers are consistent in naming and describing a variety, examining the extent of farmer-named varieties and determining whether and/or at what level farmer-named varieties are genetically distinct, determining whether diversity increases with field size, determining whether rare varieties are selected from common varieties and determining whether locally common varieties have the greatest locally common alleles are the important scientific interventions required to be addressed at the national Plant Genetic Resources (PGR) institutions (Jarvis et al. 2000).

Documenting information on the amount and distribution of genetic diversity being maintained on-farm; the processes being used to maintain this diversity; the social, economic, cultural and environmental factors influencing farmers to maintain diversity on-farm; the people maintaining this diversity in terms of gender, age, ethnic and social or economic status in the community are the important parameters for developing an action plan for on-farm management of local crop populations (Jarvis et al. 2000). The social, cultural and economic factors shape farmers' decision regarding crop diversity (Brush 1995; Zimmerer 1996). The decision to conserve a given crop population should however, be made on factors such as the amount of diversity, the uniqueness of diversity, the usefulness of diversity, the threat faced by the diversity, and other national priorities. The needs of community will also factor into this decision. The collection and analysis of this information gives conservation managers and development workers the tools to develop conservation plan and make interventions.

As is evident from the detailed documentation of rice landraces in the present study that information collected at the level of household or farmers' plot may not be appropriate scale for analyzing diversity or for crop diversity conservation. Even one single village may not maintain a sufficiently large population for effective conservation over time. More likely it will be the network of villages or even a region that will be the approximate level for understanding the maintenance of crop genetic diversity on-farm in the Himalayan highlands. Documentation of rice landraces suggests that many of the rice landraces are adapted to marginal niche environments (common or rare localized landraces), the conservation strategy must therefore target these regions. Understanding farmers' system of classification for the different features of their agroecosystems may yield insights into the processes fostering conservation of diverse landraces (Martin 1995). Further, it is apparent that seed supply is the limiting factor for farmers' maintenance of diversity (Table 9), support may be targeted to local seed supplies. All interventions need to be designed and implemented through collaboration between the community and the national PGR system.

The potential 'add-value' options as stated in Table 10 need to be considered to support local farming systems. Once an option has been proposed for adding value to crop populations that are identified as targets for on-farm conservation, it will be important to design a mechanism for monitoring its progress and assessing its impact. The add-value options listed in Table 10 remains to be tested for their association with the maintenance of high genetic diversity over time. A mandate of future on-farm conservation research would therefore be to test these relationships.

Careful analysis and evaluation of various socio-economic, environmental and scientific challenges (Bisht et al. 2005) 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 Himalaya and encourage them conserve and enhance local crop diversity in the traditional ecosystems.

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