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Home gardens in western Nepal: opportunities and challenges for *on-farm* management of agrobiodiversity

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Abstract. Home gardens are defined as a system of production of diverse crop plant species, which can be adjacent to household or slightly further away and is easily accessible. Species composition and management systems of Nepalese home gardens are poorly known. The study was conducted to develop an inventory on composition of crop species and varietal diversity to characterise the home gardens of Rupandehi and Gulmi of western Nepal, and to observe the species change over the time for last 10–15 years. Semi-structured Interviews, Direct Observation and Focus Group Discussions were employed to collect primary data. Shannon–Weaver index (SWI) was used to determine the species richness. Principal Component Analysis (PCA) was employed to characterise the home gardens. Mid-hill SWI ($H' = 4.41$) revealed the higher species diversity (131 species) as compared to *terai* (123 species). This species richness was significantly higher ($p = 0.001$) in the mid-hill area. The vegetable species constitute the major component followed by fruits and fodder species that also contributed to the species diversity. The size of home gardens and species richness was positively correlated ($r_s = 0.29$, $p = 0.001$). Twenty crop species have been lost during the last 10–15 years and eleven species were threatened in the studied home gardens. Inaccessibility of local seed crops and deforestation were the major causes reported accounting for this trend. Self-saved seed was the major source of planting material in home gardens. There is a need to study the seed supply system for these home gardens. Therefore, a challenge is to make these home gardens self-supporting through creating a mechanism on strengthening local seed supply systems for long term sustainability of home garden in agrobiodiversity management.

Introduction

Home gardens are well-established land use systems within the larger farming systems in Nepal, maintained very close to the homestead (Shrestha et al. 2001). The history of home gardens are not well known in the Nepalese context, but previous studies from other parts of the world define home gardens as traditional farming systems which may have evolved over time from the practices of hunters/gathers and continued in the ancient civilizations up to modern times. Home gardens are therefore among the oldest agro-ecosystems that exist throughout the world (Soemarwoto 1987; Soemarwoto and Conway 1992). Species diversity that is of immediate use in the homestead is the most prominent feature of home gardens (Soemarwoto 1987; Hoogerbrugge and Fresco 1993). Home gardens are living gene banks and a reservoir of plant genetic resources that preserve landraces, cultivars, rare species and endangered species and species neglected in larger ecosystems (Eyzaguirre and Linares 2001).

The Convention on Biological Diversity (CBD 1992)[1] has given the mandate to its Parties for the *on-farm* conservation of genetic resources (Maxted et al. 2002). After the entry into force of the CBD conflicting legal issues regarding rights over genetic resource have resulted in a difficult situation regarding the exchange and flow of germplasm (Petit et al. 2001). However, in recent years many international and national plant genetic resource programmes are being implemented through increased local participation and *in-situ* conservation by initiating *on-farm* conservation projects (Sthapit and Fris-Hansen 2000.) According to Heywood (1999), home garden is one of the components of agrobiodiversity.

> *"Agrobiodiversity includes all those species and the crop varieties, animal breeds and races, and microorganism strains derived from them that are used directly or indirectly for food and agriculture both as human nutrition and as feed (including grazing) for domesticated and semi-domesticated animal. And the range of environments in which agriculture is practiced. It also includes habitats and species outside of farming systems that benefit agriculture and enhance ecosystem function".*

Wood and Linne (1997) have also proposed research to increase the diversity available to farmers and to enhance farmers' capacity to manage this diversity dynamically. Many studies on home gardens in other parts of the world have revealed that home gardens are dynamic systems and are highly acknowledged for retaining a high diversity that represents microenvironments within larger farming systems and mimics the natural, multi-layered ecosystems (Okafor and Fernandes 1987; Padoch and De Jong 1991; Soemarwoto and Conway 1992; Hoogerbrugge and Fresco 1993; Gessler et al. 1998; Agelet et al. 2000; Clerck De and Negreros 2000; Nair 2001; Vogl-Lukasser et al. 2002). Therefore, rich species diversity of the home garden system would be important for conservation of plant genetic resources. In this case, the home gardens can be an option for *on- farm* conservation strategies and contribute to *on-farm* conservation of genetic resources at ecosystem, species, and within species level (Gajaseni and Gajaseni 1999; Hodkin 2001).

[1]CBD Article 8 j of the Convention on Biological Diversity requests the States who have signed and ratified the CBD to develop national legislation to respect, preserve, and maintain the knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and promote their wider application.

The home gardens are an integral part in a typical Nepalese homestead and play a crucial role in supplying household members with a diversity of different food crops (Rana et al. 1998; Shrestha et al. 2001). These home gardens are important sources for food supply and are also important for their economical, social and cultural use values. Vegetables, fruits, multipurpose trees, herbs and spices are major components of the home gardens on the same land unit either in a spatial arrangement or in a temporal sequence. The composition of such species in a home garden is governed by many factors that make home garden a dynamic system. Ecology, local food culture, the socio-economic conditions, the farmer's interest and prevailing market forces are some of the important factors that determine the species composition present in home gardens (Jacob and Alles 1987; Soemarwoto and Conway 1992; Hoogerbrugge and Fresco 1993; Gajaseni and Gajaseni 1999; Hodel et al. 1999; De Miguel [on line]).

The developmental interventions of government and non-governmental organisations are primarily concentrated on introducing exotic species of vegetables and fruit species rather than conducting systematic studies of home gardens and improvement of this system. Hence, there is a lack of in-depth knowledge and information on species composition in Nepalese home gardens. The home gardens have received little attention from formal institutions, apart from some developmental interventions (Shrestha et al. 2001). The main aim of this study is, therefore, to understand how the home garden owners maintain and use the species at household and community level. The current study has also explored the options for *on-farm* conservation of plant species in Nepalese home gardens. The questions investigated were as followings;

- What is the average size of home gardens?
- Why do farmers grow many species of plants in variable proportion?
- What are the major crops in the different home gardens?
- Why are these species maintained in the home garden (Economic, ecological, social reasons)
- How do the home garden owners get the seeds of the species and varieties grown (Source of seed for home gardens), and
- Has there been any change in present species and varieties grown over the last 10–15 years?

The current study was conducted in home gardens of two different ecological zones i.e. Mid-hill and *terai* of western Nepal. In these two different areas, an inventory was made of the species grown and the species composition and richness was compared between the two areas. The study also investigated species changes over time during the last 10–15 years in terms of the lost species and threatened species defined by farmers with home gardens. The study categorised the composition of species into vegetables, fruits, fodder species, cereals, medicinal plants, spices, nuts for inventory. The study excluded e.g. ornamental species, which do not relate immediately to food security.

Materials and methods

Study sites

The altitudinal variation was one of the major criteria for study site selection, but the ethnicity, accessibility and community interest were also considered. Bharsa and Baikunthapur villages of Dudrakshya Village Development Committee (VDC)[2] in Rupandehi *terai*,[3] hereafter referred as *terai* ecology, *and* Darbar Devisthan VDC of Gulmi Mid-hill hereafter referred as mid-hill ecology were selected for study purpose. The farmers of Gulmi constituted a homogeneous ethnic group with Chhetri Bramins being the major inhabitants, whereas Rupandehi *terai* was more heterogeneous with different community settings of groups e.g. Chhetri Bramins, *Tharus* and some others. Within terai, *Tharus* were the indigenous dominant community in Bharsa whereas Chhetri/Bramins were the predominant dwellers in Baikunthapur (Tables 1 and 2).

Rupandehi district represents the *terai* region of western Nepal. Bharsa and Baikunthapur are the research villages within Rupandehi with an altitude of approx 100 m a.s.l. Farming is the main occupation (69.5%) and the remaining workforce is engaged with both farming cum services (17.4%) and farming cum petty business (13.1%) in the village. Rice (*Oryza sativa*), wheat (*Triticum aestivum*) and maize (*Zea mays*) are the major staple food crops. Similarly, Darbar is located in the mid-hill region of western Nepal with an altitude range of 800–1500 m a.s.l. Farming cum services (57.1%) is the major occupation followed by farming (35.7%), and farming cum petty business (7.1%) of the people in the village. Maize (*Zea mays*) is the main staple food crop for livelihood, but millet (*Eleusine corocana*) and wheat (*Triticum aestivum*) are also grown in the area. Maize is grown in an intercropping system and is mixed with a variety of summer legumes such as rice bean (*Vigna umbellata*), cowpeas (*Vigna* spp.), and soybeans (*Glycine max*).

Sampling

Individual households were the sampling units. The households were selected using a simple random sampling technique. One-hundred and thirty-four households were sampled using the following formula according to Shrestha et al. (1999);

1. $n = NZ^2\ P(1-P)/[Nd^2 + Z^2P(1-P)]$ where,
2. n = sample size,
3. N = number of households in the study village,
4. Z = the value of normal variable (1.64) for a reliability level of 0.90,
5. P = the highest possible proportion (0.5),
6. d = sampling error (0.1)

[2]The smallest geographical political units.

[3]Terai represents the extension of the fertile indo-gangetic plains extending from east to west of Nepal on the southern plains of the country. It's also known as the 'granary' of Nepal.

Table 1. Comparative ethnic composition reported in a survey of home gardens in *Terai* and mid-hill ecological region of Nepal, 2003.

Ethnicity	*Terai*		Hill Darbar
	Bharsa	Baikunthapur	
Tharu (Tibeto Burmese)	28 (65.11)[a]	–	–
Chhetri/Bramin (Indo-Aryan group)	13 (30.23)	36 (73.46)	42 (100)
Newar (Mixed of Indo-Aryan and Tibeto Burmese)	–	2 (4.08)	–
Magar (Tibeto Burmese)	–	8 (16.32)	–
Socially disadvantaged groups (DAGs) (Indo-Aryan)	2 (4.65)	3 (6.12)	–

[a]Figures in parenthesis column represent percent.
Source: Sunwar, 2003

Table 2. The sample size of the household surveyed for home garden study in *Terai* and hill sites of Nepal ($n = 134$). 2003.

Ecology	District	Study site	Population size (HH)	Sample size (HH)	Percent
Terai (approx 100 m)	Rupandehi	Bharsa	120	43	35
		Baikunthapur	140	49	35
Mid-hill (800–1200 m)	Gulmi	Darbar Devisthan	94	42	44
	Total		354	134	38

Source: Sunwar, 2003

The survey consisted of two sections, species information in one section and the demographic information in the other. Finalisation of the questionnaire was made after pre-testing in a village adjacent to the research site. Enumerators scheduled the interview with the respondents with prior informed consent of 2 days. With the interview together with the respondent the inventory of plant species grown in each home garden was carried out simultaneously. For quality control, the surveyed questionnaires were edited and revised in different tiers, first by the enumerator himself, then through peer review and editing among enumerators and final editing by the researcher on the same date.

Species and varietal inventory

Crop species diversity was measured at the household level in a household survey and validated by direct observation. Overall crop species diversity was measured from the species inventory. Varietal diversity was assessed only in the hyacinth bean, (*Dolichos lablab*). Focus Group Discussion (FGD)[4] revealed that the lablab bean is one of the most frequently grown species in both the mid-hill and *terai*. Therefore, *Dolichos lablab* was selected as a key species through FGD to study varietal diversity. Farmers defined the following criteria for selecting the key species (which were similar to Watson and Eyzaguirre 2002):

- A species of economic importance to farmers
- The species most preferred by farmers
- A species that is cultivated by the majority of farmers in both of the studied ecological regions

The varietal diversity described of *Dolichos lablab* is based on farmers' descriptors and morphological characters to know the farmers' criteria to differentiate the varieties at community level. However, in many instances farmers give local names, which are very much mixed with genetic identity or genetic distances. The study lacks a molecular study due to time and financial limitations. This limits to some extent the final statement on quality of genetic diversity in home garden studied.

Species change over time in home garden

The FGD exercise was conducted with invited farmers to see the changes in species composition in home garden over the last 10–15 years. Focus was on which species were lost and which are on the way of disappearing, and what were the major causes that farmers perceived behind the changes. For the purpose, farmers defined the lost and threatened species during FGD. Lost species were defined by farmers as species used in the past, but not known any more in the community, and where planting materials/seed is not available in the community. Similarly, threatened species are defined as species which still exist in the community but whose frequency of occurrence is low. The old aged key informants (above 45 years) were purposively invited in FGD. They were identified through informal discussions prior to FGD with people from same community. These key informants were identified with certain criteria e.g., knowledgeable, senior and progressive, cooperative and with a long experience in home gardening. Since prior informed consent in this process is essential, the key informants were consulted and respondents were invited for discussion in order to identify lost and threatened species of home gardens at community level. They also provided us permission to publish the collected information.

[4]FGD is a participatory tool (King 2000; Rana et al. 2000) to draw information on related subject matter from few (10–15 individuals) but with key informants having good knowledge on subject matter. However, there is some disadvantage of using this tool such as some individual may dominate the discussion and not all participants may contribute to the discussion. Therefore, to overcome this constraint it may be necessary to conduct personal interviews or to use questionnaires too.

Statistical analyses

SPSS for windows version 10.1 was used to produce descriptive statistics of survey data. Shannon–Weaver index was used to determine the species richness. The index is used to characterise the species diversity in community. It is calculated through the formula $H' = \sum_{i=1}^{s} p_i \ln p_i$, where s is the number of species in the community and p_i is the proportional abundance of species i (= number of species i divided by total numbers in the community). Evenness index ($J = H/ln\ s$) was used to describe the diversity in terms of evenness i.e. how equally abundant the species were. Also, Simpson's index $\left(\lambda = \sum_{i=1}^{s} (p_i)^2\right)$ was used to describe the dominance i.e. the degree that a community is dominated by one or a few very common species (Powers and McSorley 2000). Mann–Whitney U-test was carried out to see the difference in species richness in two ecologies using MINITAB version 13.31. Spearman rank correlation coefficients were estimated to explain the relationship among home garden components. Principal component analysis (PCA) was employed to characterise the home gardens of the study sites using 13 characters.

Results

Size of home gardens

The average size of the home gardens in *terai* and mid-hill were reported as 434 m^2 and 402 m^2, respectively, but the average total land holding size in the mid-hill was higher than in the *terai*. The home garden size of *terai* had shrunk over last 10–15 years ago, whereas the home garden size of the mid-hill had increased over the same time period (Table 3). The study found that the minimum average area of home garden in *terai* and mid-hill was 68 and 63 m^2, respectively.

In *terai* and mid-hill an average of 7.7% and 5.7%, respectively of the total land holding is allocated for home gardens (Figure 1).

Table 3. Mean and standard deviation of home garden area, total landholding area, and number of species reported in the study, 2003.

Ecological region			Home garden area		Total land holding, 2003 (m^2)	Total species 2003
			1988 (m^2)	2003 (m^2)		
Terai	Bharsa and Baikunthapur	Mean ± SD	467 ± 350	434 ± 287	5200 ± 4090	27.1 ± 11
		Max	1693	1693	27088	53
		Min	0.00	68	169	4
Mid-hill	Gulmi	Mean ± SD	348 ± 208	402 ± 204	6674 ± 3938	38.7 ± 11
		Max	763	763	17805	60
		Min	32	63	1526.16	15

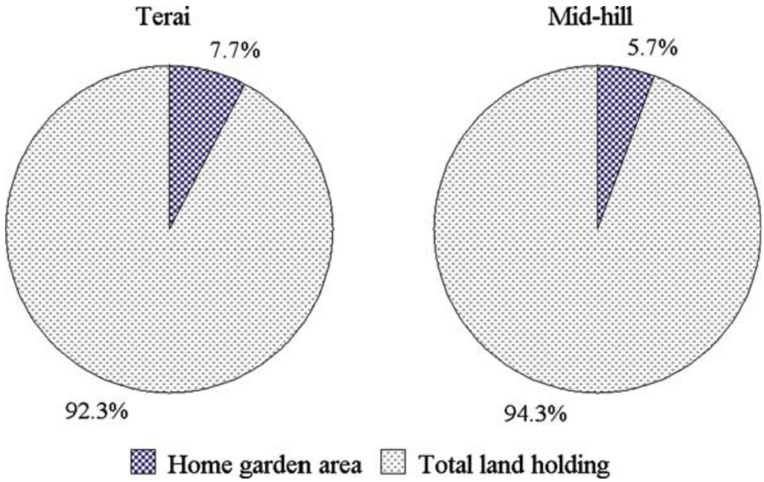

Figure 1. Proportion of home garden area over total land holding.

Species composition and species and varietal diversity

A total of 165 different crop species with a mean of 30.77 ± 11.9 from 55 plant families were recorded in 134 home gardens from two ecological study sites. The *terai* had a total of 123 crop species (27.1 ± 10.7) whereas 131 species (38.7 ± 10.5) were recorded in mid-hill. The mid-hill recorded species numbers was significantly ($p = 0.001$) higher than the *terai* ecology. Within *terai* ecology, the total species of *Baikunthapur* (116 species) was significantly higher ($p = 0.001$) than *Bharsa* (92 species). Therefore, species richness of home gardens in mid-hill was higher ($H' = 4.41$) than *terai* ($H' = 4.25$). Zaldivar et al. (2002) has reported differences in species diversity in different settlement using SWI and Evenness index. The dominance measured by Simpson's index explained the *terai* ecology ($\lambda = 0.018$) home gardens had a relatively stronger dominance of a few species as compared to mid-hill ($\lambda = 0.014$). The evenness index revealed the species in mid-hill ($J = 0.906$) were more equally abundant and evenly distributed as compared to *terai* ecology ($J = 0.880$) (Table 4).

Table 4. Shannon–Weaver, Simpson's and Evenness indices estimated for species diversity in *Terai* and mid-hill ecology, 2003.

Ecology	Study sites	Shannon–Weaver Index (H')	Simpson's index (λ)	Evenness index (J)
Terai	Bharsa (Tibeto Burmese groups)	4.03	0.022	0.891
	Baikunthapur (Indo-Aryan group)	4.25	0.016	0.896
Terai overall		4.25	0.018	0.880
Mid-hill	Gulmi (Indo-Aryan group)	4.42	0.014	0.906

The most frequently reported vegetables species were *Luffa cylindrica* L. M. Roem, *Dolichos lablab* L., *Cucurbita pepo* L. and *Brassica juncea* L., in home gardens of both regions. Similarly, *Capsicum annum* L., *Coriandrum sativum* L. *Allium sativum* L.; *Carica papaya* L. and *Mangifera indica* L., *Leucaena leucocephala* (Lamk.) de Wit. and *Morus alba* L. was frequently reported spice, fruit and fodder species in both of the study sites. *Carissa carandas*, *Cyphomandra betacea* Sendt., *Basella alba* L., *Schleichera oleosa* (Lour.) Merr. and *Trewia nudiflora* L. was the least frequently reported species in the home gardens. The varietal diversity for bean *Dolichos lablab* was reported to be highest in *terai* with 12 varieties, whereas in mid-hill seven varieties of the species were reported in FGDs by farmers (refer Appendix B.1 and B.2). These numbers were based on farmers' description from FGD and morphological characters. It was observed that the *Tharu* group in *terai* used analogies, colour and shape to differentiate among the varieties. Chhetri/Bramins including Magars and Newars from both ecologies used morphological characters such as colour, shape and the seasonal adaptation to differentiate among the varieties with in the species *Dolichos lablab*.

Home garden components

The study revealed that vegetables are the major component of the home garden followed by fruit, fodder and spices species in Nepalese home gardens. The figures below illustrate the average numbers of species for the components and the proportion for the component based on their respective frequency (Figures 2 and 3).

The majority of species grown in home gardens were annuals followed by perennials in both of the *terai* and mid-hill ecologies (Figure 4). The majority of species grown are seed propagated (Figure 5). The first preference of

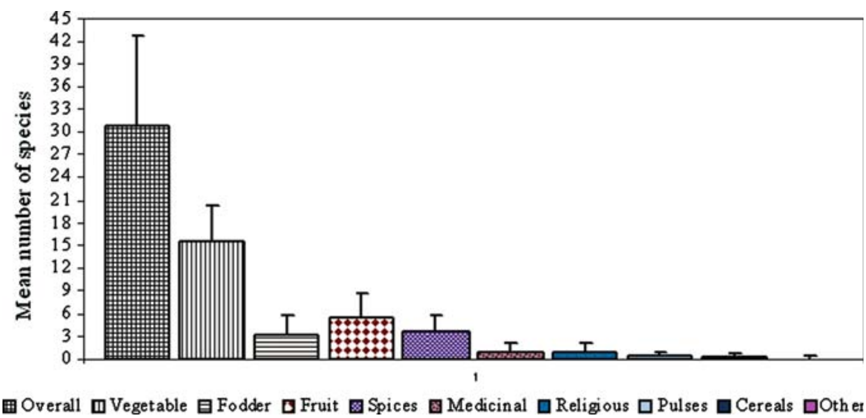

Figure 2. Mean of overall species and components species recorded in a survey conducted in Rupandehi and Gulmi study sites in 2003.

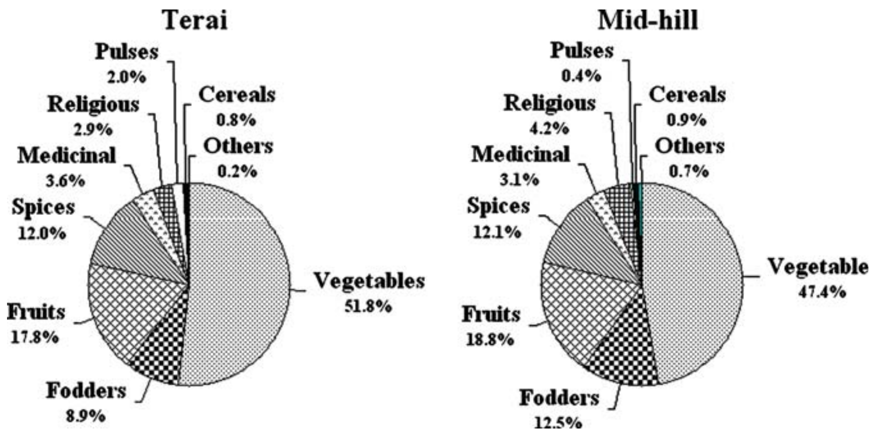

Figure 3. Home garden components based on frequency of species.

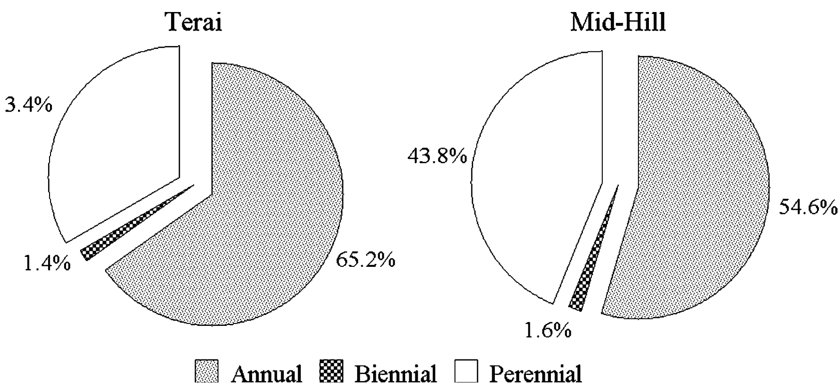

Figure 4. Growth habit of home garden species reported in *Terai* and Mid-hill ecology, 2003.

growing diverse species in home gardens is the use value of the species to the households such as of economic importance, food and nutritional and medicinal value (Figure 6). The second preference is socially and culturally valuable species such as *Ocimum sanctum* L., *Ficus religiosa* L. with religious value and *Perilla frutescens* (L.) Britton with cultural value.

Characterisation of home garden based on PCA

PCA was employed to characterise the Nepalese home gardens in terms of species used. The first four principal components of the PCA explained 64% of the variability (Table 5), in which the first principal component explained 37% of the variation, incorporating all species, vegetables, fruits, and fodder and spices. The second component explained 11% of the variability and is associated with ecology, pulses species and home garden size. The third component explained 8% and is associated with home garden size and livestock. Finally,

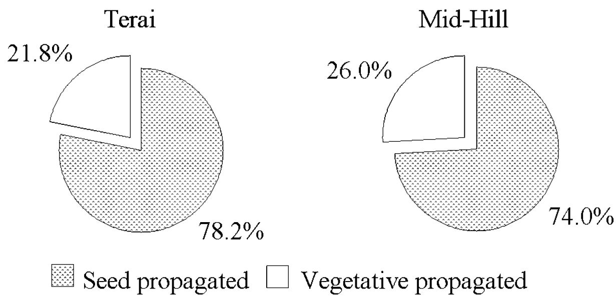

Figure 5. Propagation method in home garden species reported in *Terai* and Mid-hill ecology, 2003.

the fourth component explained 7% of variability associated with medicinal and religious species (Table 6). Thus, PCA suggests that vegetables, fruits, fodder and spices are the key components of the Nepalese home gardens.

Correlation of home garden components

There were positive correlations between home garden area and overall species. Also the spearman correlation analysis revealed that there is a positive relation between home garden size and other components (Table 7). The study found that there is a positive correlation between fodder species and livestock population ($n = 134$, $p = 0.001$). The spearman correlation for livestock and total species was also found positive and significant ($n = 134$, $p = 0.001$). According to Fowler et al. (2001) such correlations are weak but are significant. Livestock also plays an important role in the home garden for Farm Yard Manure (FYM).

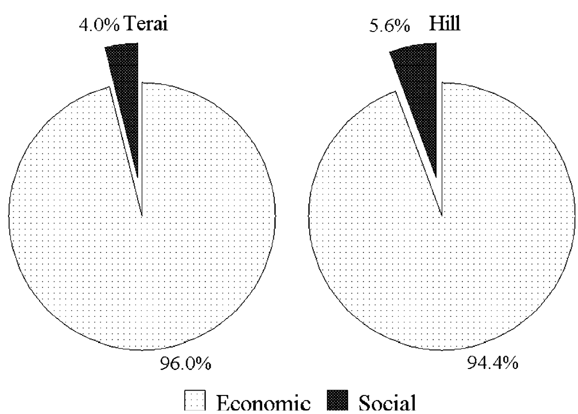

Figure 6. Use values of home garden species reported in *Terai* and Mid-hill ecology, 2003.

Table 5. Eigenvalue, percent of the variability explained by each component and accumulated variability.

Principal component (PC)	PC1	PC2	PC3	PC4
Eigenvalue	4.82	1.44	1.126	0.99
Proportion	0.37	0.11	0.08	0.07
Accumulated variability (%)	37	48.2	56.8	64

Table 6. Eigenvectors of each variable with respect to its principal component (PC).

Variables	PC1	PC2	PC3	PC4
Ecology	0.242	−0.544	0.030	0.120
Home garden area	0.119	0.347a	0.599a	0.007
Vegetable species	0.380a	0.031	0.027	0.093
Fodder species	0.320a	−0.118	−0.07	0.165
Fruit species	0.365a	0.056	0.108	−0.156
Spice species	0.319a	0.011	−0.053	0.088
Medicinal plant species	0.270	0.205	−0.114	−0.491
Religious species	0.270	−0.065	−0.277	−0.449
Pulse species	0.063	0.593[a]	−0.341	0.113
Cereal species	0.163	0.068	−0.403	0.621[a]
Nut species	0.197	−0.296	0.278	0.075
Overall species richness	0.448a	0.043	−0.048	−0.008
Livestock number	0.170	0.272	0.416[a]	0.265

[a]Important variables for explaining the respective component.

Home garden management

The study revealed that different terms were used and known for home gardens in the study sites. The tribal groups *Tharu* use the term *bera* (fenced land area), and Chhetri/Bramin groups use *Mulabari* (radish land area), *karesabari* (backyard), *gharbari* (home garden), *fulbari* (flower garden), *tarkaribari* (vegetable garden) and, *bagaincha* (fruit garden). Home gardens were near to household or within in 5–10 min walking distance in both of the two ecological regions. The home gardens were open (49%), fenced (34%) or semi-fenced (16%). Live fence, wood stakes and bamboos were the most frequently used materials for fencing for home gardens in both of the ecological regions. The majority of sources for planting materials for home garden was self-saved seed by farmers themselves (77.6%), sharing between and among farmers contributed 5.4%, and 1.4% came from the forests. On an average, 15.6% of the home garden species is obtained from market or outside the local community. However, the external dependency for the seed varies among crops (Figure 7). The proportions of self saved seed were: vegetables (58%), fruits (90.4%) and fodder species (85.0%) in home garden. This shows that for the majority of species grown in home gardens the farmers were mainly dependent on self-saved seed, although the proportion was somewhat lower for vegetables.

Table 7. Spearman correlation coefficients (r_s) measured for home garden components and home garden area, total species and fodders of Nepalese home gardens ($n = 134$).

Home garden components vs. hg area/fodder/total species		(r_s)
Total species	Home garden area	0.28 (0.00)[a]
Vegetable species	Home garden area	0.24 (0.00)
Fruit species	Home garden area	0.34 (0.00)
Fodder species	Home garden area	0.11 (0.19)
Livestock	Total species	0.29 (0.00)
Livestock	Fodder species	0.25 (0.00)

[a]Figure in parenthesis is spearman correlation *p*-value.

Species change over time in home garden

Farmers discussed the changes of species over the last 10–15 years in terms of lost and threatened species in the home gardens of the study sites. They reported that 20 species were lost from home gardens in the study sites (refer Appendix B.1 and B.2). Eleven species were perceived as threatened (refer Appendix C.1 and C.2). FGD revealed that the majority of the lost and threatened used species were local[5] vegetables, fruits and fodders. An in-depth enquiry revealed that the major causes associated with these losses and threats are; inaccessibility of seed or planting materials, lack of local seed in market, deforestation, fragmentation of home garden land, difficulty to maintain planting material, introduction of new and competitive improved[6] crop/varieties and lack of market incentives for local crops.

Discussions

Size of home garden and species

The home garden size for *terai* ecology was larger as compared to mid-hill ecology. One reason may be that there are more terraces with *bari*[7] land in the mid hill, whereas in *terai* the *khet*[8] land is predominant. But the size has shrunk as compared to10–15 years ago, mainly due to the trend of increased land fragmentation in *terai* within the family holdings. The smaller home garden size with increased altitude may be due to more terrace land in Nepalese conditions. Karyono (1981), Soemarwoto and Conway (1992) also reported a smaller home garden size with increased altitude. The overall home garden size

[5]Crop that has been cultivated in the area as long as the respondent remembered, from which the community has saved seed themselves and which has not been purchased from market, merchant or any governmental or non-governmental organisations.
[6]Crop that has been introduced recently in the area from merchant, governmental and non-governmental organisations.
[7]Unbunded and unirrigated upland.
[8]Bunded and irrigated/rainfed land mainly puddled rice is grown.

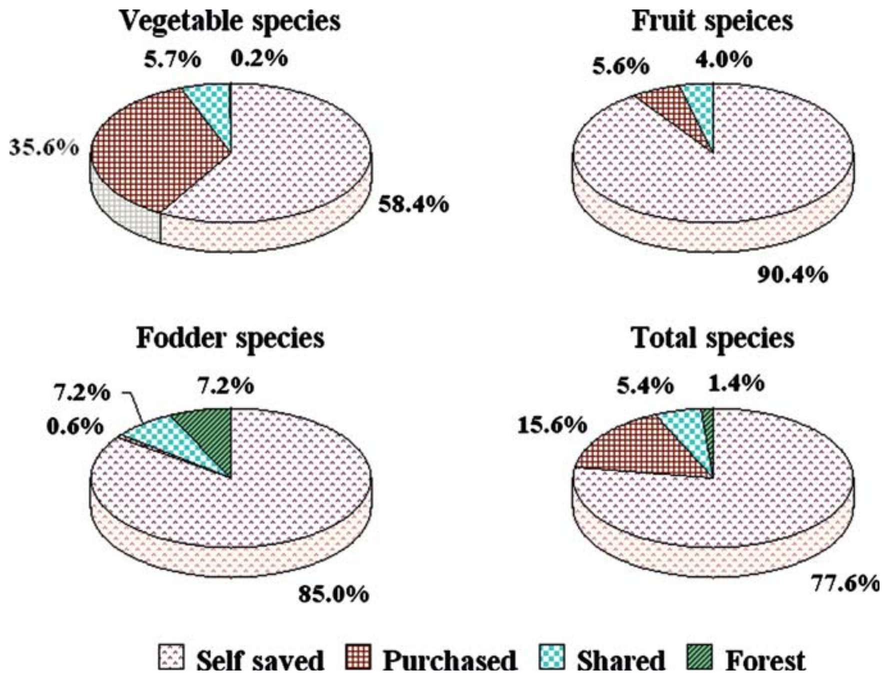

Figure 7. Planting material source for vegetables, fodder fruits and for all species.

of *terai* and mid-hill of current study sites was found to be smaller as compared to Sri Lanka (Jacob and Alles 1987), Thailand (Gajaseni and Gajaseni 1999), Nicaragua (Méndez et al. 2001) and Vietnam (Trinh et al. 2003). Rich species diversity was observed in the Nepalese home gardens, but the area allocated for each species within home garden was observed to be very small. However, the current study lacks an examination of the minimum population size that maintains a natural evolution in home gardens and/or at community level. Therefore, the study suggests the need for further examination of the population size of crop species in home gardens.

Species/varietal inventory and diversity

Higher species richness was reported in Mid-hill ecology (800–1200 m) as compared to *terai* ecology (approx. 100 m). This result differed with the findings of Hodel et al. (1999). The Mid-hill of Nepal represents a transition zones between *terai* and high hill ecology; therefore this particular region harbours the species from both *terai* and high hill. For example, temperate fruits like apple, peach, walnut as well as tropical fruits like mango, guava, litchi were reported in Mid-hill ecology. When comparing the species richness between two ethnic groups, *Chhetri/Bramins* reported more species than *Tharus*. *Chhetri/Bramin* nurtured many species of religious and cultural importance such as *Aegle marmelos*, *Gossipium arborium*, *Ocimum sanctum* and *Perilla frutescens*. Although having less species than the other ethnic groups, *Basella alba* and *Trewia nudiflora* were local and distinct to *Tharus* indicating that *Tharus* protected these species, which were not commonly grown by other groups. Shrestha et al. (2001); Hodel et al. (1999) and Soemarwoto and Conway (1992) reported that many species are maintained for sociocultural and religious importance in home gardens. The current study showed significant correlation with livestock rearing and species diversity in the Nepalese home gardens (Table 7). The livestock rearing practice was less common in Tharu farms as compared to Chhetri/Bramin farms, again supporting the result that *Tharus* had lower species diversity.

The varietal diversity of the key species *Dolichos lablab* was higher in *terai* ecology than in Mid-hill. This diversity was based on farmers' descriptor and crop morphology. The result at the genetic level may be different or may not be completely identical, and this is worth further study. The study revealed that farmers could differentiate varieties based on; seasonal adaptation, morphological traits viz. pod shape, size and colour (Appendix A.1 and A.2). This showed that farmers have their own system of varietal characterization. It was found that one reason the farmers maintained the varietal diversity of *Dolichos* was that the varieties are produced in off-season i.e. in March–April when the other vegetables are in short supply. It was evident that the market opportunity for species in the *terai* was one of the motivating factors to grow more numbers of varieties for the *Dolichos* bean, provided that the crop was produced in off-season and can fetch good price through selling the surplus production. Therefore, the market opportunity for the species in *terai* was higher, and for this reason farmers were maintaining a rich varietal diversity for the species. These crop varieties were also found to be resistant to biotic and abiotic stresses (disease and insect pest and cold injuries), and seed storage was easy. Furthermore, these varieties can fetch good prices, because of the difference in consumers' preferences and farmers strongly argued that there were no improved varieties available for *Dolichos* in the market. Mid-hill farmers maintained relatively lower varietal diversity of the species as compared to *terai*. This may be because of inaccessibility to markets. The present study suggests that home gardens retain or develop intra-varietal diversity provided that market incentives exist, the seed is easily stored or seed is easy to access, and that there exists a varietal adaptation to particular ecology and season. Rana et al. (1998) also reported that the market incentives would motivate the farmers to conserve the local crops, especially when the seed source is easy to maintain, the production cost is low and the crop has disease and pest resistance. Trinh et al. (2003) reported a similar result in Vietnamese home gardens.

Seed management in home garden

The information on informal seed management in home gardens is lacking in most technical and biological studies so far. In previous studies, the seed management mechanism for home gardens were poorly studied and considered. The current study revealed that local seed sources are important for plant genetic resource management at community level in home gardens. Self-saved seed by farmers themselves is the dominating source of planting materials for all of the major home garden components in the study sites; vegetables, fodder, fruits, and spices (Figure 7). Rana et al. (1998) has also reported that self-saved seed was the main source of planting materials for indigenous vegetables in Kaski, Nepal. Purchased seed was the second most important source. The relative contribution from purchased seed was higher for improved vegetable seeds. Vogl-Lukasser (2002) reported that purchased seed is the major source for planting materials in Austria. Sharing between and among home garden owners was the third important source of planting material. In the fodder species group, domestication of planting material collected from forest was as important as sharing (Figure 7). Subedi et al. (2003) reported that in cereal crops certain nodal farmers within a community maintain higher diversity and are instrumental in the seed flow through the farmers' network. A study of who maintains diversity of home garden species and varieties and of the seed flow in this system would be very useful. Given the losses of and threats to diversity referred to above in the studied home gardens, it seems that the local seed management through informal seed systems needs to be strengthened to manage crop diversity in home gardens. Furthermore, farmers should be recognized for their roles played in utilising, domesticating, conserving, improving and developing the crop resources to meet their needs since long time ago. However, many crop species are lost and many of them are threatened in their gardens for many reasons such as, lack of access to the seed material, deforestation, land fragmentation, etc. One conservation option would be placing threatened crop species in *ex-situ* conservation units from where the formal institution could further improve the crop quality and reintroduce them back to the community through repatriation programmes. However, most home gardens crops found in this study do not have a corresponding gene-bank/*ex-situ* facility like for example cereals, roots and tubers. Therefore, policy makers and donors ought to initiate measures towards *ex-situ* conservation for threatened home garden species in collaboration with *in-situ* conservation measures.

Home garden components

Vegetables are the major component of the home gardens in both the *terai* and mid-hill ecology followed by fruits, fodder and spices species (Figure 3). Vegetables, fruits and spices are mainly cultivated in home gardens for daily home consumption, whereas fodder species are included for livestock. Fruit trees have been reported as a major component of the home gardens in studies done in other countries (Gajaseni and Gajaseni 1999; Clerck and Negreros 2000; Méndez et al. 2001; Zaldivar et al. 2002). Farmers in this study strongly argued for the importance of livestock integration in their home gardens, since it is the only source of FYM for soil fertility management in home gardens. But it is interesting to note that livestock is not considered a home garden component by the farmers, but rather a separate component of the farming system. Cattle and goats are the major livestock reared in gardens followed by chickens, ducks and pigeons. However, livestock were reported important components of home garden in Tanzania (Fernandes et al. 1984), Kerala, India, (Nair and Sreedharan 1986), Javanese home garden (Soemarwoto and Conway 1992) and in San Jose (Levasseur and Olivier 2000). Although livestock is not considered a component of the home gardens, it played an important role in species diversity and soil fertility management in Nepalese home gardens.

Species change over time

The change of species over time in Nepalese home gardens is mainly due to inaccessibility of local seeds in the informal seed supply system and market, and to deforestation. Many of the participants in FGDs recalled and reported that they used to cultivate many more local crop species and varieties in home gardens in the past, which were no longer cultivated in the area. The species reported lost were mostly local crops and wild species, because farmers had not been able to access the seed locally and it was not possible for them to store planting material for long term. Furthermore, farmers strongly emphasised that deforestation has caused habitat destruction for both plant species and the seed disperser e.g. birds. For example, farmers explained how the birds' eye chilli was lost from their home garden in mid-hill ecology and threatened in *Terai* ecology. A certain bird species used to bring the seed of the birds' eye chilli (*Capsicum microcarpum* (L.) DC) from the forest to the home gardens. But in recent years, the farmers do not see these birds or the birds' eye chilli in their home gardens. They explained that the dispersal mechanisms have been disturbed due to deforestation. Consequently, the birds' eye chilli was lost in Gulmi mid-hill ecology and threatened in Rupandehi *Terai* ecology (refer Appendix B.2 and C.1). It was perceived that the forest was an important source for seeding material for many wild vegetables, fruit trees and fodder species. The study suggests that home gardens and forests are very much interlinked in the Nepalese context. The forest is a source of seed or saplings for home gardens and these home gardens are important avenues for utilisation of species from the forest. As previously noted, the seed supply system of home gardens species needs to be further studied in depth and should be strengthened. The current study also points to the need of linking forest conservation programme to agrobiodiversity management in home gardens. Nepal's recent experience in community forestry programmes for forest management has shown the importance of peoples' participation in sustainable use of forest resources. Today there are more than 12 thousand user groups managing thousands of hectares of living forests. These are the same community people who own home gardens and use the forest as a source of planting materials for many home garden species. The home garden is closely linked to the forest.

Thus, there should be instruments created at the policy level for linking home garden and community forestry programmes in a way which would strengthen the conservation and food security at household and community level.

Conclusions

The present study imparts information on home gardens in Rupandehi (*terai*) and Gulmi (Mid-hills) districts in western Nepal. Vegetable species constitute the most important component in Nepalese home gardens, followed by fruit, fodder and spices. The species composition and species richness of Rupandehi and Gulmi were different due to the ecological and ethnicity differences. Unlike the home garden composition of other countries, fodder species is one of the important components of Nepalese home gardens. These home gardens could be considered as potential units for maintaining species diversity and conserving plant genetic resources through utilisation. Self-saved seed was the major source of planting material in home gardens. The current study showed that there is a need to further study the seed supply system for these home gardens, since it revealed that many crop species were lost and others were threatened in the home gardens mainly due to inaccessibility of planting materials. Therefore, farmers' needs and interests along with seed security, good market incentives and risk management strategies are indispensable prior to consider home gardens as *on-farm* conservation unit.

Implications of the findings

The information on species diversity in home garden revealed that the home garden could be used as a management and conservation unit for agrobiodiversity in Nepal. Furthermore, the home garden can be a source for diversifying the nutrition of rural people that would contribute to food security at household and community level. These home gardens are fulfilling the subsistence need of farmers, which means these subsistence farmers do not maintain the diversity just for the sake of conservation; rather the value of conserving the diversity lies in its use. It is worth noting that the conservation of this diversity is not possible without using it, and also that no conservation means no utilization. These gardens also have the potential for cash production of organic products that would further benefit the subsistence farmers with market incentives. The government of Nepal is giving emphasis on cash crops as a means of income generating activities where home gardens could be an option for income generation at household level. The formal extension services are promoting only the improved varieties in home gardens, which adversely affect the agrobiodiversity of these home gardens. Therefore, emphasis should be given for the promotions and production of local species in home garden at policy level so that the use of home gardens for household food security and crop conservation could be strengthened.

The information gained in this study could be used in further participatory research to utilise the home garden for economic development and to develop together with the farmers possible strategies for the use of home gardens for agricultural biodiversity management. Agrobiodiversity managers, policy-makers, researchers and other concerned stakeholders should focus on assisting the farmers to develop the most appropriate approach through which these home gardens could be best used in managing agricultural biodiversity *on-farm* for future harvests.

Recommendations

Further in-depth studies and strengthening of local seed supply systems for home garden species are very important for long-term *on-farm* management of agricultural biodiversity in Nepal.

Study on the minimum population size that maintains natural evolutions of the crop species in home garden species is important to understand species dynamics over space and time.

It is important to regularly monitor the home gardens species which are threatened, and there is a need to identify the causes for decline of certain species. For this, links between local communities and *ex-situ* conservation agents will be important. As one of the needed conservation strategies, the species which are threatened in home gardens could be placed in an *ex-situ* conservation units i.e. gene banks such as the Asian Vegetable Research and Development Centre (AVRDC). But the AVRDC presently does not include all the crop species referred to in this study. Therefore, one may need a separate gene bank for threatened home garden species in the future, from where the formal institutions could improve the quality of the cultivars and again reintroduce back to the community for utilisation.

Exploration on value addition of home garden species and linking home garden diversity to markets should be an important part of an *in-situ* conservation strategy.

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Appendices

Appendix A.1. Name of different varieties for *Hiunde Simi* (*Dolichos lablab* L.), farmers' description, characters of varieties and morphological characters known through FGD conducted in study site Bharsa and Baikunthapur, *Terai* ecology, 2003.

Name of varieties given by farmers	Farmers' descriptor	Characters for varieties given by farmers	Morphological characters
Gaanthihawa[a]	Analogies to knot for fruiting style	Reddish purplish bean, short in size	Purplish flower, purple stem colour
Goitihawa[a]	Analogies to shape of fish	Reddish purplish bean and long size. Good culinary quality	Pinkish purple flower, purple stem
Gudrihawa[a]	Analogies to peas	Whitish green pod colour	White flower, light green leaf, light green stem
Ghiuu sim chappar[a]	Analogies to ghee colour and flat shape	Ghee colour flat bean not so good taste	White flower, light green colour
Chamra sim[a]	Analogies to taste	Greenish short, and not good taste	White flower, dark green stem and leaves
Rani sem gol[a]	Analogies to queen and round shape	Margin with pinkish colour with round shape	Purple pink flower, purple stem dark greenish leaf
Ujara simi[a]	Morphology: white colour	Bean pod is whitish colour, slightly long	White flower, light green
Seto chaite simi[b]	Morphology: white colour and seasonal adaptation	and good culinary quality	stem and leaves
Raato simi[b]	Morphology: red colour	Purplish pod and good culinary quality	Pinkish purple flower, purple stem and leaf colour
Malkihawa[a]	Analogies to fish	Fish shaped, Soft, dark greenish pod	White flower and
Hariyo simi gaadhaa[b]	Morphology: dark green colour	colour and good culinary quality	dark green stem, leaf and pod.
Rani sem chapar[a]	Analogies to queen and flat shape	Margin with pinkish colour, with flat shape	Pinkish purple flower,
Hiunde simi[b]	Seasonal adaptation		green stem and leaf
Hariyo simi fikka[b]	Morphology: light green colour	Similar to fish but light green pod colour with medium length	White flower, dark green leaf and stem
Rato dalle[b]	Morphology: red colour and small size	Small short red coloured bean, medium taste	Purple red flower, dark green leaf and stem, small red purplish small pod

[a]Reported by *Tharu* community.
[b]Reported by mixed community.

Appendix A.2. Name of different varieties for *Hiunde Simi* (*Dolichos lablab* L.), farmers' description, characters of varieties and morphological characters known through FGD conducted in study site Gulmi mid-hill ecology, 2003.

Name of varieties given by farmers	Farmers' descriptor	Characters for varieties given by farmers	Morphological characters
Hiunde hariyo lamo[a]	Seasonal adaptation/Morphology: colour and length	Winter green long bean, grow in high moisture and high fertility condition, harvest year round	White flower, green leaf and stem, pod length 9–10 cm, green and flat pod shape
Hiunde hariyo tate chepto[a]	Seasonal adaptation/morphology: colour and shape	Winter green long flat bean, grow in high fertility condition, medium culinary quality	White flower, green leaf and stem, pod length 7–8 cm, green and flat pod shape
Hiunde seto thoulo	Seasonal adaptation/Morphology: colour and size	Winter green long bean, grow in high moisture and high fertility condition, harvest whole year	White flower, green leaf with whitish vein colour, round whitish pod
Hiunde rato chepto lamo	Seasonal adaptation/morphology: colour and shape	Winter red flat long bean, soft culinary quality, high fertility demanding crop	Purplish red flower, purplish green leaf, purple leaf vein, purple stem, flat long purple pod
Hiunde rato dolo	Seasonal adaptation/morphology: colour and shape	Winter red round bean, high fertility and moisture demanding	Purple flower, green leaf/leaf margin/stem/, purplish green flat round pod
Hiunde seto sano	Seasonal adaptation/morphology: colour and shape	Winter white small bean, fertile soil demanding	Whitish flower, greenish leaf/leaf margin/stem, whitish small round pod
Cheringo hariyo seto	Seasonal adaptation/morphology: colour and shape	Green bean, fertile soil demanding	White flower, green leaf/leaf margin/stem, flat green pod

[a]Similar morphology except for pod length.

Appendix B.1. Scientific name, local name, use value and perceived reason for lost species of home garden identified through FGD conducted in a study in Bharsa and Baikunthapur villages, Rupandehi, *Terai* ecology 2003.

Scientific name	English name	Local name	Family	Use value	Perceived reasons
Psidium guajava L.	*Guava*	*Amba*	Myrtaceae	Fruit	Disease infestation Prone to dieing back disease
Zizyphus incurba Roxb.	Bead plum	Local *Bayer*	Rhamnaceae	Fruit	Land fragmentation Inaccess to sapling
Schleichera oleosa (Lour.) Merr.	*Honey tree*	*Kusum*	Sapindaceae	Fruit	Deforestation, Land fragmentation
Mangifera spp.		Local *aanp*	Anacardiaceae	Fruit, fuel	Inaccess to sapling
Musa paradiciaca	*Banana*	Local *kera*	Musaceae	Fruit	Inaccess to sapling
Terminalia chebula Retz	*Chebuli Myrobalan*	*Harro*	Combretaceae	Medicine/fodder/fuel	Deforestation Inaccess to sapling
Terminalia bellirica (Gaerth.) Roxb.	*Belliric Myrobalan*	*Barro*	Combretaceae	Fodder	Deforestation
Lindera pulcherrima (Nees) Benth. Ex Hook.f		*Phurso*	Lauraceae	Good fodder	Inaccess to sapling/seeds difficult to maintain seed deforestation
		Bidelno			
Litsea monopelata (Roxb.) Korth.		*Kutmiro*			
Ficus clavate		*Bedulo*	Moraceae		
Zingiber officinale Rosc.	*Ginger*	*Aduwa*	Zingerbaceae	Spice, medicine	Low production Storage problem
Momordica cochinchinensis Spreng.	*Chatel gourd*	*Chathail*[a]	Cucrubitaceae	Vegetable	Deforestation Inaccess to seed and sapling
Solanum tuberosom L.	*Potato*	Local *aalu*	Solanaceae	Vegetable	Inaccess to planting materials
Brassica oleracea L.	*Cauliflower*	*Fulkopi*	Cruciferae		
Trichosanthes anguina L.	*Snakegourd*	Local *chichinda*	Cucurbitaceae		

[a]Wild vegetable reported by *Tharu* communities in Bharsa, *Rupandehi Terai* ecology.

Appendix B.2. Scientific name, English name, local name, family, use value and perceived reason for lost species of home garden identified through FGD conducted in a study in Gulmi mid-hill ecology, 2003.

Scientific name	English name	Local name	Family	Use value	Perceived reasons
Solanum tuberosum L.	Potato	Local *aalu*	Solanaceae	Good cooking quality	Inaccess to planting material
Raphanus sativus L.	Radhish	Local *mula*	Cruciferae	Vegetable	Inaccess to sapling, Low yield/degraded quality, Storage problem
Capsicum microcarpum (L.) DC.	*Birds eye chilly*	*Jire khursaani*	*Solanaceae*	Spice, very pungent	Deforestation and habitat destruction of the disperser birds
Moringa oleifera Lam.	*Horse radish tree*	*Sitalchini*	*Moringaceae*	Sweetening agent	Less interest in growing the species among young generation

Appendix C.1. Scientific name, English name, local name, family, specific use value and perceived reason for threatened species of home garden identified through FGD conducted in a study in Bharsa and Baikunthapur villages Rupandehi, *Terai* ecology, 2003.

Scientific name	English name	Local name	Family	Use value	Perceived reasons
Aloe vera	Indian aloe	*Ghiukumari*	Liliaceae	Medicinal (e.g. burning)	Lack of knowledge, less interest among young people
Spondias cytheria Sonm	Golden apple	*Annwara*	Anacardiaceae	Fruit (e.g.) making pickle	Inaccess to planting materials, deforestation, propagation problem
Lycopersicon pimpineliumfolium	Cherry tomato	Local *tamatar*	Solanaceae	Vegetable, good taste	Inaccess to seed and sapling
Luffa cylindrica Roem	Sponge gourd	Local *lauka*	Cururbitaceae	Vegetable, good taste	Inaccess to seed sapling
Colocasia esculenta L.	Taro	*Pindaalu*	Araceae	Vegetable and good to prepare *maseura*[a]	Lack of market incentives, poor quality such as high irritation
Moringa oleifeera Lam.	Horse radish tree	*Sital chini*	Moringaceae	Vegetable	Prone to insect infestation
Capsicum microcarpum (L.) DC.	Birds eye chilly	*Jire khursani*	Solanaceae	Spice, pungent chilly	Deforestation and habitat destruction of dispersers the birds

[a]*Maseura* a kind of product made through drying leaves, stem and rhizome of taro and mixed with black gram.

Appendix C.2. Scientific name, local name, use value and perceived reason for threatened species of home garden identified through FGD conducted in a study in Gulmi, mid-hill ecology, 2003.

Scientific name	English name	Local name	Family	Specific use value	Perceived reasons
Jatropa curcas L.	Physic nut	*Satyajivan*	Euphorbiaceae	Medicinal (e.g. cure fever and cough)	Less interest among young people
Brassica junceae (L.) Czern.	Indian mustard	Local *rayo*	Cruciferae	Good leafy vegetable with good culinary quality	Inaccess to seed, difficult to preserve seed
Brassica oleraceae var. *Botrytis* L.	Cauliflower	Local *cauli*	Cruciferae	Vegetable with good culinary quality	Inaccess to seed and sapling, difficult to preserve seed
Cajanus cajan Mill.	Pigeon pea	*Arhar*	Leguminoseae	Pulse crop	Insect pest infestation, unfit to cropping pattern
Colocasia esculenta L.	Taro	*Pindaalu*	Araceae	Vegetable and good crop to make *maseura*[a]	Prone to insect infestation, inaccess to planting material, allergic to some persons

[a] *Maseura* a kind of product made through drying leaves, stem and rhizome of taro and mixed with black gram.

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