Dynamics of plant bioresources in Western Himalayan region of India – watershed based study

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The dynamics of plant bioresources including agriculture is different in the hills from those in the plains. The agriculture and forestry are the two major land use types and play an important role in providing food and livelihood security. The structure of vegetation for trees and shrubs layer was moderately instable and uneven as few species such as *Acacia catechu, Lantana camara, Carissa spinarium* in Mandhala; *Quercus leucotrichophora, Pinus roxburghii, Myrsine africana* in Moolbari, and *Salix denticulata, Pinus wallichiana* and *Picea smithiana* in Megad dominated the vegetation. Species richness was high at lower altitudes and low as we go higher. The distribution of species was mainly contiguous, however, few species showed random and regular distribution. Agricultural patterns have changed from traditional and subsistence to modern, which are primarily monoculture of high-valued cash crops. This has enhanced farm incomes but at the same time led to severe genetic erosion of traditional crops and varieties. Several development factors coupled with emerging climate change like erratic rain and snowfall patterns, flash floods, depletion of top soil and groundwater, destruction of natural habitat, wildlife menace, infestation of land through invasive alien weeds, low productivity, abandonment of agricultural lands have emerged as serious threats to the dynamics of hill agro-ecosystems.

Keywords: Bioresources, invasive weeds, species diversity, species richness, Western Himalaya.

INDIA in general and Himalayan region in particular is known for its biological richness and has always been a botanist's paradise. Its diversified landforms, relief and environmental conditions support a wide range of vegetations. Accurate assessment and understanding of the dynamics of plant resources is important for their sustainable management and utilization. It also helps to identify the threats to biodiversity from advancing anthropogenic[1–3] and climatic factors[4,5], allowing strategies to be developed and implemented in right perspective. These biotic factors regulate species recruitment and survival patterns[6,7] and have large effects on the land use/cover dynamics[8,9]. Therefore, understanding the causes and consequences of land use/cover changes, and their cascading effects on ecology are the keys for identifying negative effects on biodiversity[10,11]. Several workers[12–14] have done vegetation analysis in the Himalayan region but most of them are limited to forest vegetation. In this investigation we have studied the dynamics of both forest-vegetation and agricultural bioresources on watershed-based case studies for three watersheds, viz. Mandhala (W1), Moolbari (W2) and Megad (W3), which represent three distinct agro-climatic regions, i.e. Shivaliks or lesser Himalaya, mid-Himalaya and higher or greater Himalaya respectively (Figure 1).

Description of the state and study sites

Himachal Pradesh is a mountainous state of western Himalayan region of India and lies between lat. 30°22′40″–

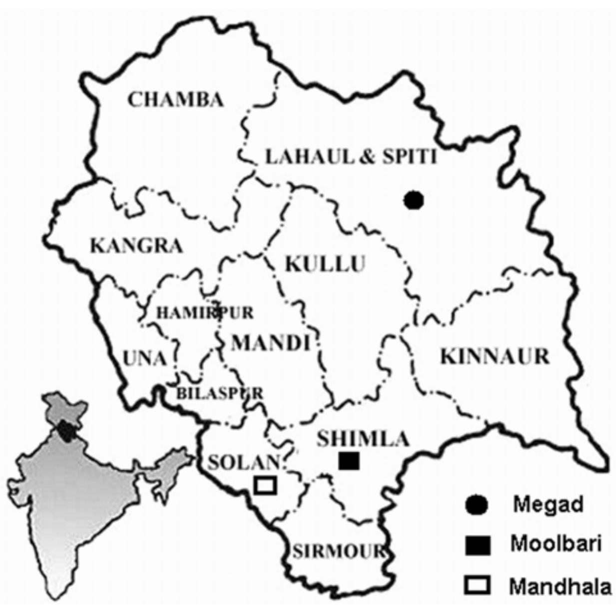

Figure 1. Location of watersheds in Himachal Pradesh.

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Table 1. Physiographic features of the watersheds

Characteristics	Mandhala (W1)	Moolbari (W2)	Megad (W3)
Total area	12.20 sq. km	10.50 sq. km	46.05 sq. km
Geographical location	30°53′–30°57′N 76°50′–76°54′E	31°07′–31°11′N 77°04′–77°12′E	32°38′–32°43′N 6°37′–76°42′E
Elevation	550–1075 m asl	1200–2000 m asl	2200–5000 m asl
Rainfall	1000 mm	1076 mm	400 mm
Mean temperature	Winter 18°C, summer 25°C	Winter 11°C, summer 16°C	Winter 3°C, summer 12°C
Climate	Foot hills with sub-humid, sub-tropical type	Mid hills with humid, sub-temperate type	High hills, temperate and cold arid type
Soil	Formed on soft sandstones, poorly bedded conglomerates, brownish clays, flood plains are developed on alluvium derived from hills, almost neutral	Moderately shallow to shallow, predominantly loam/silt loam to clay loam with varying proportion of gravels, slightly acidic to strongly acidic	Soils loose, sandy nearly neutral medium to high in organic carbon content and available nitrogen and potassium, and high in available phosphorus
Cropping season	Two with a cropping period of about 300–330 days	Two with a cropping period of about 300 days	One with a cropping period of about 160 days
Aera under agriculture	25% of the total area	22% of the total area	9% of the total area because 70% of it is under glaciers and alpine meadows
Topography	Plains, moderately steep to very steep slopes	Moderate to steep hill slopes, terraces and slopes with pasture and forest cover.	Valleys with moderate slopes along riversides followed by steep slopes above
Drainage system	Drained by number of small drainages (nallas) that finally merge in Ghagar river	Drained by *bari ka khadd*, a tributary of the Satluj river	Drained by the Chandra Bhaga river

33°12′20″N and long. 75°45′55″–79°04′20″E with elevation ranging from 350 to 6975 m above mean sea level. The climatic conditions are hot and sub-humid tropical in the southern tracts to warm and cool temperate to cold alpine and glacial in the northern and eastern mountain ranges. The average annual rainfall is 1125 mm, varies from <400 mm in Spiti to more than 3400 mm in Dharamshala while temperature varies from 25°C to –15°C. Flora is rich and diverse, and out of the 45,000 flowering plant species found in India, 3294 species occur here. Forestry and agriculture system are more diversified in the interiors and rainfed areas whereas monoculture through cash crops in irrigated areas is predominant. The physiographic features of three watersheds studied have been described in Table 1.

Methodology

Vegetation studies

The field work was done during 2002–05. Sampling strata was selected based on the differences in growth form, physiognomy and structure of the vegetation, and variation in dominant species[15,16]. Vegetation analysis was carried out by laying random quadrats of 10×10 m size for tree layers, which were determined by the species area curve method[17] and the running mean methods[18]. Each quadrat was further subdivided into $5 \text{ m} \times 5$ m and $1 \text{ m} \times 1$ m sample plots to examine the shrubs and herbs respectively. Data were analysed for species richness (SR)[19], density (D)[17,20], species diversity index (H)[21,22], concentration of dominance (CD)[22], evenness (J)[23] and abundance/frequency (A/F) ratio[24,25]. Here abundance is taken as the total number of individuals of a species while frequency as number of quadrats in which that species occurred. A/F ratio interpreted as, if <0.025 indicates regular distribution, between 0.025 and 0.050 random distribution, and >0.050 indicates contiguous distribution[25,26].

Agricultural resources

Data were recorded on major crops, weeds, cropping patterns, cropping intensities and area under different crops. The change in cropping patterns and genetic erosion was assessed over years, i.e. the scenario of 2005 was compared to 1990, which was kept as base year because most significant changes in agricultural land-use started towards the end of 80s. The increase/decrease in area under different crops was calculated as $N - (N1/N) \times 100$; where N is the area under particular crop in 1990; $N1$ the area under same crop in 2005. Percentage of increase/decrease in the area under a particular crop in relation to the total cultivated area was also calculated using the same formula. The data were recorded using both structured and unstructured questionnaire from randomly chosen 10 villages and 25 families from each village in a watershed. Few important questions asked from inter-

Table 2. Vegetation parameters

Vegetation layer	D	H	CD	J	SR	A
W1						
Tree	3.01	2.58	0.16	0.64	54	18.98
Shrub	9.33	2.12	0.26	0.61	32	25.76
Herb	4.58	2.02	0.31	0.56	36	27.03
W2						
Tree	5.86	2.30	0.20	0.59	48	20.44
Shrub	4.11	2.99	0.09	0.73	60	27.12
Herb	6.60	3.45	0.05	0.79	77	55.47
W3						
Tree	2.70	1.91	0.17	0.72	14	9.57
Shrub	2.80	2.00	0.20	0.70	17	11.67
Herb	5.70	3.82	0.03	0.90	91	63.24

viewee were: (i) name and age, (ii) size of landholdings, (iii) crops grown, (iv) name and number of the landraces grown in the base year or even before and in the years of data recording, (v) number of domestic animals, (vi) number of approximate days in a month for which a particular food crop is consumed, (vii) reasons for shifting cropping patterns and (viii) level of awareness on the importance of plant genetic resources, and efforts to conserve them. Group meetings and informal discussions were also held to collect the data.

Results

Vegetation analysis

The tree density for individual tree species ranged from 0.001 to 2.23/100 sq. m across the watersheds and it was highest in W2 followed by W1 and W3. Abundance was high for *Acacia catechu* (37.75%), followed by *Dalbergia sissoo* and *Flacourtia indica* in W1; *Quercus leucotrichophora* and *Pinus roxburghii* together constituted 58% in W2 whereas *Salix denticulata* (23.17%), *Pinus wallichiana*, *Picea smithiana* and *Abies pindrow* formed major biomass in W3. Vegetation parameters such as H, CD, J and SR showed rich tree diversity in W1 and W2 and low in W3, and tree layer was moderately stable and even as evident from high H and moderate CD and J values (Table 2). The pattern of species distribution was contiguous for a majority species; nonetheless it was random for *Azadirachta indica*, *Acacia catechu*, *Acacia arabica*, *Cassia fistula* and *Flacourtia indica* in W1; *Q. leucotrichophora*, *Prunus cerasoides*, *Punica granatum*, *Pyrus pashia*, *Pistacia integrrima*, *Celtis australis*, *Myrica esculenta* and *Morus alba* in W2, and *Juglans regia* in W3.

The shrub density for individual species ranged from 0.001 to 2.644/25 sq. m. The important shrubs were *Lantana camara* (28.31%), *Carissa spinarium*, *Murraya koenigii* in W1; *Myrsine africana* (24.91%), *Berberis asiatica*, *Rubus ellipticus* in W2, and *Juniperus communis* (37.38%) and *Rosa webbiana* in W3. The shrub diversity was medium to low and community was unstable in W1 and W3 but it was moderately equitable and stable in W2. The shrub species have contiguous distribution except for *Murraya koenigii*, *Lantana camara*, *Rubus ellipticus*, *B. asiatica* and *B. pseudoumbellata*, which showed random and it was regular for *R. webbiana*. The density of herbs ranged from 0.002 to 1.603 per sq. m with preponderance of more species (SR) in W3 followed by W2 and W1. The herbs like *Cynodon dactylon*, *Ageratum conyzoides* and *Parthenium hysterophorus* constituted 75% of the total population resulted into unevenness and instability of herbs layer in W1 whereas it was diverse, stable and evenly distributed in W2 and W3 (Table 2).

Floristic analysis (species listed in the Annexure 1–3) showed hierarchical predominance of Fabaceae, Moraceae, Combretaceae in W1; Rosaceae, Moraceae, Pinaceae in W2, and Pinaceae, Rosaceae, Salicaceae in W3 for tree layer whereas Euphorbiaceae, Verbenaceae, Apocynaceae in W1, Rosaceae, Fabaceae in W2 and W3 for shrubs. Asteraceae and Poaceae were predominant families for herbs in all the watersheds.

Agricultural analysis

Crops and weeds: The rice, maize and wheat have occupied major acreage in W1 and W2 and barley in W3 among cereals whereas tomato, onion, garlic, capsicum, potato, cabbage, okra, ginger, *Colocasia*, turmeric, mango, papaya, *Citrus*, pear and apple were important among vegetables and fruits across watershed. Some naturally occurring fruits like *Myrica esculenta* (kaphal), *Pyrus pyrifolia* (Asiatic pear), *Punica granatum* (wild form of pomegranate), few walnuts in W2 and apricots (*chuli*) and *Hippophae rhamnoides* (sea buckthorn) were found common in W3. *Bunium persicum* (locally known as *kala zeera*) is a high-valued spice (Rs 400–500/kg), grows naturally and also cultivated sporadically in W3. The cultivation of medicinal plants such as *Saussurea lappa*,

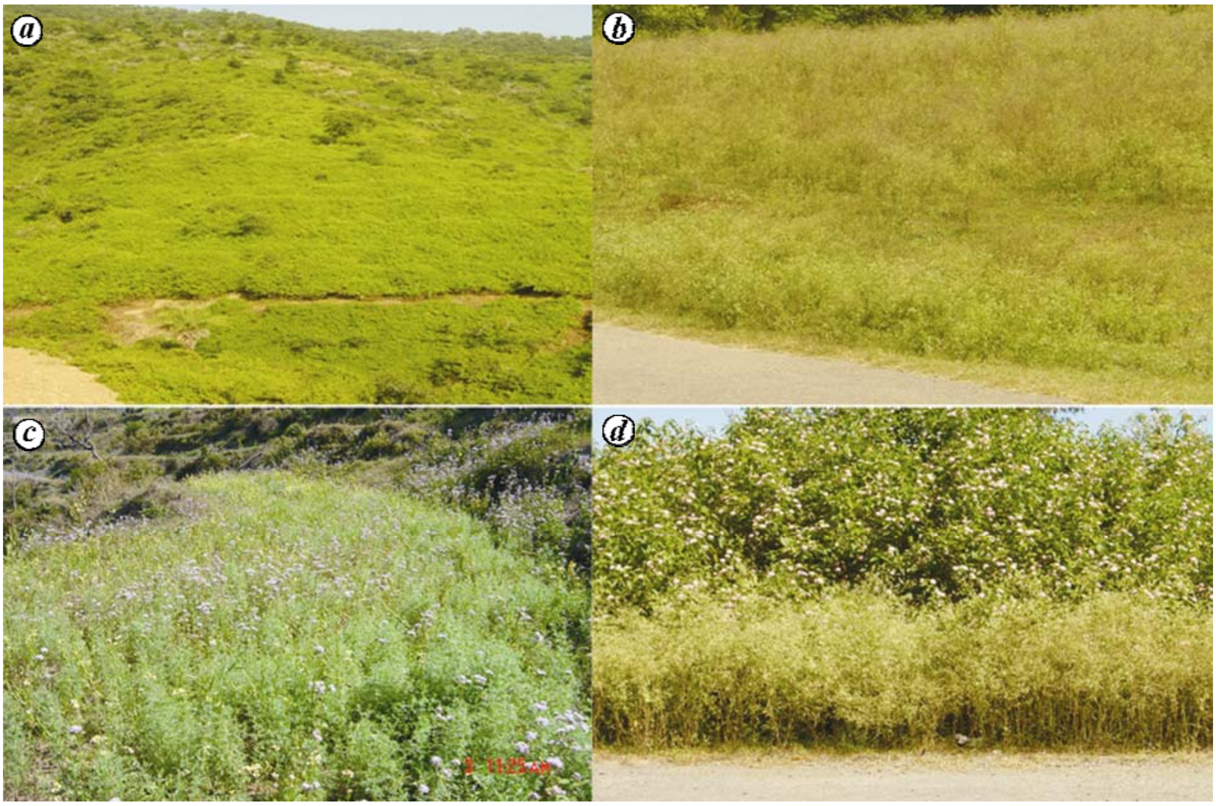

Figure 2. Dominance of invasive weeds: (***a***) *Lantana*, (***b***) *Parthenium*, (***c***) *Ageratum* and (***d***) *Lantana* and *Parthenium* together.

Inula racemosa, *Aconitum heterophyllum*, *Dactylorhiza hatagirea* and *Podophyllum hexandrum* has increased in W3. Agroforestry was also found to be an integral component of hill agriculture and agri-horti-silviculture system was predominant. The agro-forestry species such as *Azadirachta indica*, *Terminalia bellerica*, *Mangifera indica*, *Dalbergia sissoo*, *Morus alba*, *Toona ciliata* in W1; *Grewia optiva*, *Celtis australis*, *Bauhinia variegata*, *Toona ciliata* in W2, and *Salix denticulata*, *Salix alba*, and *Populus nigra* in W3 were observed as most predominant multipurpose species.

The crop–weed analysis showed *Anagalis arvensis*, *Fumaria parviflora*, *Stellaria media*, *Chenopodium album*, *Ageratum conyzoides*, *Malva parviflora*, *Convolvulus arvensis*, *Cyperus rotundus* in W1; *Stellaria media*, *Vicia hirsuta*, *Oxalis corniculata*, *Fumaria parviflora*, *Galium aparine* in W2, and *Digitaria cruciata*, *Polygonum plebejum*, *Medicago sativa* and *Poa annua* in W3 as the most predominant weeds. Alien invasive weed species *L. camara*, *P. hysterophorus* and *A. conyzoides* have severely infested the land use/cover in W1. The habitat analyses of these three species showed that they are not competing with each other for resources rather each species has chosen its own territory for infestation. *Lantana* is predominant in wastelands, forests, roadsides (3–15 m), *Parthenium* in grazing lands, lawns, roadsides (1–3 m) and *Ageratum* on the bunds and paths of cultivated fields and fallow lands. Vegetation analysis of shrub and herb layers also indicated the dominance of *Lantana camara*, *A. conyzoides* and *P. hysterophorus* (Figure 2). This has resulted in competition–resource–use type interaction where each population adversely affects the other for resources, which remained in short supply and ultimately weak competitors get eliminated, for instance, the numbers of individuals of *Carissa spinarium*, *Murraya koenigii*, *Justicia adhatoda*, *Dodonea viscosa*, *Cynodon*, *Arundinaria*, *Bothriochloa*, *Chrysopogon*, *Cymbopogon* and *Senna tora* have been reduced significantly in W1.

Shift in cropping patterns/genetic erosion: The average cropping intensity has decreased from 168% to 145% in W1, 173% to 150% in W2 and increased from 75% to 100% in W3. The area under cash crops (fruits, vegetables, medicinal plants) has increased from 4% to 8% in W1; 6% to 15% in W2 and 30% to 64% in W3. The shift in individual crop area in relation to total cultivated area showed decrease from 36.72% to 31.70% in wheat, 4.42% to 1.71% in rice, 2.44% to 0.75% in black gram and increase from 0.14% to 1.20% in tomato, 1.77% to 3.08% in mustard and 0.29% to 0.50% in mango in W1. Similar trend was observed for wheat (42.01–35.21%), maize (43.01–33.70%), rice (3.73–0.42%), amaranth (1.12–0.08%), mustard (0.47–2.15%), garden pea (1.15–

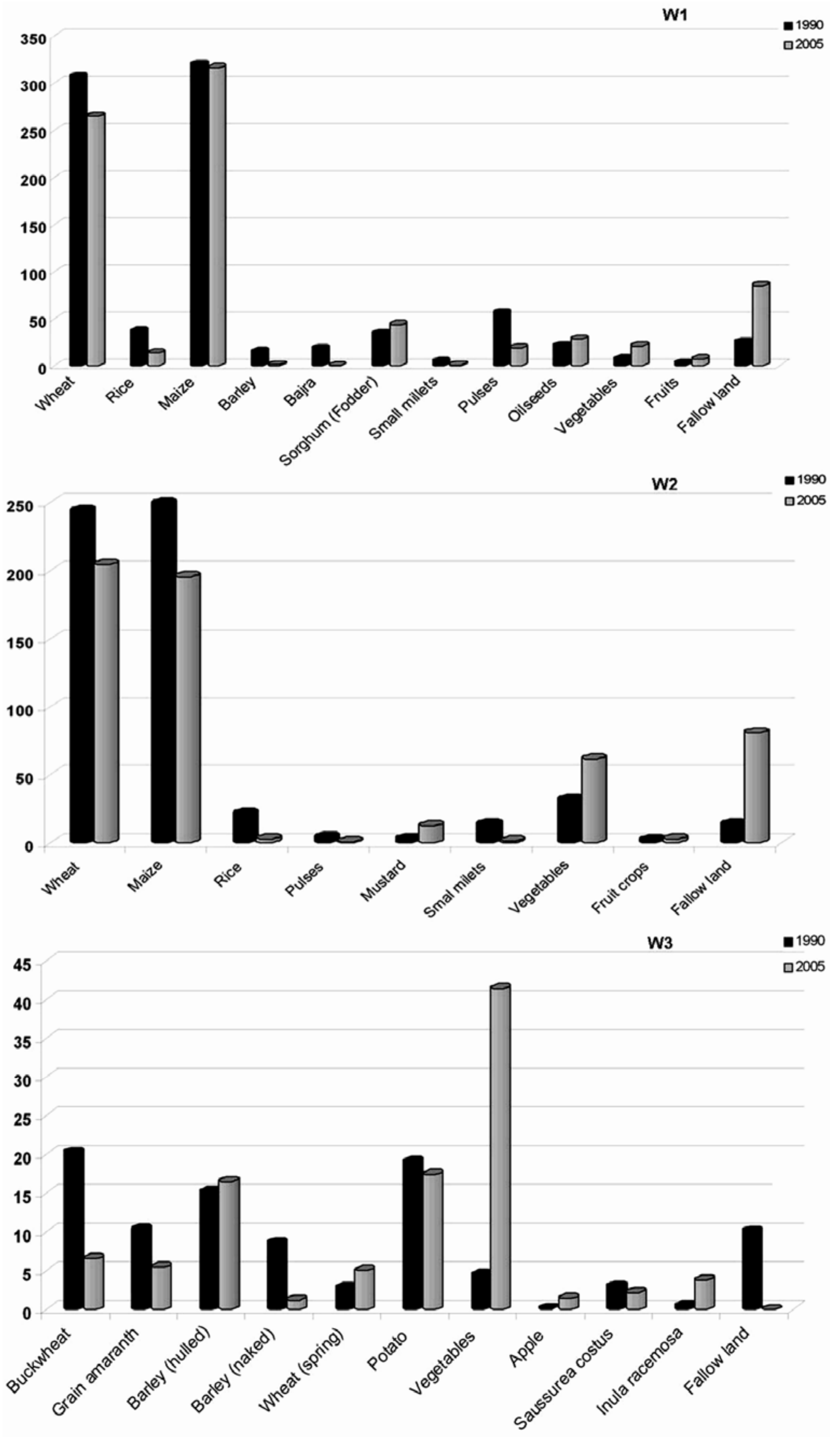

Figure 3. Shift in cropping pattern through increase/decrease in area under crops/crop groups from 1990 to 2005 in three watersheds.

2.04%) and ginger (1.59–2.73%) in W2 and from 22.23% to 7.23% in buckwheat, 11.17–6.02% in amaranth, 9.40–1.32% in barley, 2.47% to 29.30% in garden pea, 1.65–13.45% in french bean, and 0.11% to 1.54% in apple in W3. The shift in area under particular crop in relation to its own area over the same period showed similar trends (Figure 3).

Discussion

Assessing and understanding the dynamics of plant resources including agriculture is important for the management of ecosystems in general and agro-ecosystems in particular. Biological richness except for herbs was high in W1 and W2 and low in W3 which falls in high altitude and has less biotic disturbance. Roy and Behera[27] observed that high biological richness and high disturbance occurred at lower altitudes, whereas high altitude areas have low biological richness and low level of disturbance. The low SR in higher altitude could be due to the low rate of evolution and diversification of communities[23] and climate extremities, poor soil formation and stabilization as observed in W3. Under such conditions, it is difficult for a species to adapt to extremes of temperatures and moisture; the less optimal the conditions, the fewer the species that can evolve and successfully coexist. In contrast, biological richness generally increases towards lower elevations and warmer climate due to availability of more solar radiation and resources[28,29] and, therefore, more energy accumulation as noticed in W1 and W2.

The value of H and CD ranged from 1.91 to 3.82 and 0.10 to 0.99 for vegetation layers in all the watersheds and was in agreement with other studies carried out in temperate forests[13,29–31]. Contiguous distribution of species which is common in natural vegetation was predominant[1,19,32,33] while random distribution found only in uniform environments and regular distribution when tough competition exists between individuals, e.g. man-made ecosystems[17]. Species which showed random distribution have multi-purpose uses such as food, fodder, fuel and occur throughout the watershed, thus intensive management has not caused much loss to species richness[33–35]. Species overlapping (per cent) was 13.72, 12.24 and 22.12 for trees, shrubs and herbs respectively between W1 and W2, 9.67, 1.29 and 11.17 between W2 and W3. There was no commonness among three watersheds for trees and shrubs but 5.36% herbs were found common in all. This confirms the altitudinal differences in the type of vegetation. Species distribution was also varied with regard to aspect. Slopes facing north-east were rich in vegetation due to more moisture and shade than south-west which are exposed to sunlight for longer durations and therefore has less moisture.

The area and production of major cereals and pulses has decreased whereas it has increased under vegetable, fruits and other high-valued cash crops including medicinal plants. Introduction of cash crops has enhanced farm incomes, yet it has led to the loss of agro-biodiversity. Many traditional varieties and crops have eroded over the years, for instance, landraces like *Dhankri* (long tubers, good taste) and *Nambri* (round tubers) of potato; *chhamar* (bold seeded, white grains, high yielding) and *sathoo* (early maturing 60 days, small red seeded, good in taste (both flour and popping)) of maize; *shruin*, *mandaka*, *shatelia* and *jurari* (awnless) of wheat; *sherohi* of mustard and *ratua*, *rodu*, *madholu* (red grained cold tolerant) of rice have been extinct from W1 and W2. The area under crops like barley, amaranth, buckwheat, chenopod, finger millet, proso-millet, foxtail millet, barnyard millet, rice bean, horse gram and black gram has declined substantially and it ranged from 60% to 92%. Earlier studies[4,36] showed that there were about 84 crops (both cultivated and naturally occurring) people were consuming in 1975 had reduced to 39 in 2001.

Analysis of factors responsible for genetic erosion vis-à-vis shift in cropping patterns

The most crucial factors although were common across watershed, their relative contribution varied with respect to particular watershed, for instance, wild life menace, invasive weeds and inconsistent rainfall were more serious problems in W1 and W2 while introduction of cash crops in W3.

Changing lifestyles/food habits

It has affected the cultivation and consumption patterns. Access to wheat, rice through public distribution system at cheaper rate and stopping occasional collection of wild edible plants has shrunken the food basket. Farmer being aware of the change and its negative impact remained to be ignorant. Average consumption of wheat and rice has increased by 54% and 65% respectively, whereas it has decreased by 42% for maize in the last 30 years. Similarly, the consumption of minor millets and pseudocereals has decreased by 70–100% across watersheds.

Wildlife menace

This problem has emerged in the last 25 years mainly because of destruction of habitats of wild animals which is primarily due to deforestation and monoculture of forest plantation, for instance, plantation of *P. roxburghii* does not allow minor fruits or any other edible plants to grow underneath. As a result, wild animals like monkey, blue bull, wild boar, leopard, jackal and stray cattle migrate near to or into villages. They damage almost every crop, for example maize, root and tuber crops by wild boar;

Annexure 1. Plant species of Mandhala watershed

Trees

1. *Acacia catechu* Willd.
2. *Dalbergia sissoo* Roxb.
3. *Flacourtica indica* (Burm.f.) Merr
4. *Acacia arabica* Willd.
5. *Cassia fistula* L.
6. *Mangifera indica* L.
7. *Azadirachta indica* A. Juss.
8. *Anogeissus latifolia* (Roxb. ex DC) Wall. ex Guill&Perr
9. *Eucalyptus citriodora* Hook.
10. *Populus deltoides* Bartram ex Marsh.
11. *Terminalia elliptica* Willd.
12. *Lannea coromandelica* (Houtt) Merr.
13. *Zizypus mauritiana* Lamk.
14. *Acacia leucophloea* (Roxb.) Willd.
15. *Albizzia lebbek* (L) Benth.
16. *Bauhinia variegata* L.
17. *Syzygium cuminii* (L.) Skeels
18. *Carica papaya* L.
19. *Butea monosperma* (Lam) Taubert.
20. *Sterculia colorata* Roxb.
21. *Grewia optiva* J. R. Drumm. ex Burret
22. *Bombax ceiba* L.
23. *Ficus palmata* Forssk.
24. *Toona ciliata* M. Roem.
25. *Psidium guajava* L.
26. *Albizzia procera* (Roxb.) Benth.
27. *Aegle marmelos* (L.) Correa.
28. *Phoenix sylvestris* (L.) Roxb.
29. *Leucaena leucocephala* (Lam.) deWit
30. *Ficus benghalensis* L.
31. *Moringa oleifera* Lam.
32. *Ficus religiosa* L.
33. *Diospyros montana* Roxb.
34. *Pinus roxburghii* Sarg.
35. *Grevillea robusta* A.Cunn.ex R.Br.
36. *Erythrina indica* Lamk.
37. *Punica granatum* L.
38. *Celastrus paniculatus* Willd.
39. *Morus alba* L.
40. *Ficus racemosa* L.
41. *Ficus virens* (Aiton)
42. *Phyllanthus emblica* L.
43. *Terminalia bellerica* Roxb.
44. *Terminalia arjuna* (Roxb. ex DC) Wight&Arn
45. *Ficus auriculata* Lour.
46. *Prunus cerasoides* D. Don.
47. *Melia azedarach* L.
48. *Limonia acidissima* L.
49. *Parkinsonia aculeata* L.
50. *Cratavea nurvula* Frost.

Shrubs

51. *Lantana camara* L.
52. *Carissa spinarium* L.
53. *Murraya koenigii* (L.) Spreng.
54. *Dodonea viscosa* Jacq.
55. *Justicia adhatoda* L.
56. *Ipomea carnea* Jacq.
57. *Woodfordia fruticosa* Kurz.
58. *Jasminum multiflorum* (Burm.f) Andrews
59. *Helicteres isora* L.
60. *Saccharum spontaneum* L.
61. *Dendrocalamus strictus* Nees.
62. *Vitex negundo* L.
63. *Ziziphus nummularia* (Burm.f.) Wt & Arn.
64. *Saccharum bengalense* Retz.
65. *Colebrookia oppositifolia* Sm.
66. *Pogostemon benghalensis* (Burm.f.) Kuntze
67. *Nyctanthes arbor-tristis* L.
68. *Euphorbia royleana* Boiss.
69. *Zanthoxylum armatum* DC.
70. *Calotropis procera* (Aiton) W.T. Aiton
71. *Agave americana* L.
72. *Spiraea canescens* Don.
73. *Ricinus communis* L.
74. *Mallotus philippensis* (Lam.) Muell. Arg.
75. *Naringi crenulata* (Roxb.) Nicolson
76. *Datura stramonium* L.
77. *Nerium oleander* L.
78. *Asparagus adscendens* Roxb.
79. *Solanum viarum* Dunal.
80. *Hamiltonia suaveolens* Roxb.
81. *Clerodendrum viscosum* Vent.
82. *Rubus ellipticus* Smith.

Herbs and Climbers

83. *Cynodon dactylon* (L.) Pers.
84. *Ageratum conyzoides* L.
85. *Parthenium hysterophorus* L.
86. *Desmostachya bipinnata* (L.) Stapf.
87. *Oxalis corniculata* L.
88. *Blumea wightiana* DC.
89. *Tridax procumbens* L.
90. *Micromeria biflora* Benth.
91. *Drepanostachyum falcatum* (Nees) Keng f.
92. *Polygonum plebejum* R.Br.
93. *Evolvulus alsinoides* L.
94. *Bidens pilosa* L.
95. *Chrysopogon serrulatus* Trin.
96. *Dicliptera bupleuroides* Nees.
97. *Senna tora* (L.) Roxb.
98. *Bauhinia vahlii* Wight & Arn.
99. *Cissampelos pariera* L.
100. *Galinsoga parviflora* Cav.
101. *Aerva sanguinolenta* (L.) Blume
102. *Blepharis maderaspatensis* Heyne ex Roth.
103. *Boerhaavia erecta* L.
104. *Malva parviflora* L.
105. *Chamaesyce hirta* (L.) Millsp.
106. *Eupatorium reevesii* Wall.
107. *Achyranthes aspera* L.
108. *Prunella vulgaris* L.
109. *Trichodesma indicum* (L.) Sm.
110. *Bidens biternata* (Lour) Merr & Sherff.
111. *Cyanthillium cinereum* (L.) H.Rob.
112. *Xanthium strumarium* L.
113. *Rumex hastatus* Don.
114. *Gomphrena celosioides* Mart
115. *Aloe vera* (L.) Burm.f.
116. *Sida cordifolia* L.
117. *Dioscorea deltoidea* Wall.ex. Griseb
118. *Persicaria hydropiper* (L.) Delarbre.

maize, fruits and vegetables by monkey; wheat, barley, rice and pulses are grazed out at young stage by blue bull and stray cattle. The level of damage in some areas has reached to such an extent that farmers have stopped

Annexure 2. Plant species of Moolbari watershed

Trees

1. *Quercus leucotrichophora* A. Camus.
2. *Pinus roxburghii* Sarg.
3. *Quercus glauca* Thunb.
4. *Myrica esculenta* Buch-Ham.
5. *Grewia optiva* J. R. Drumm.ex Burret.
6. *Cedrus deodara* (Roxb.ex D. Don) G. Don.
7. *Celtis australis* L.
8. *Rhododendron arboreum* Smith.
9. *Pistacia integerrima* J. Stewart.
10. *Prunus cerasoides* D. Don.
11. *Pyrus pashia* Buch-Ham.ex D. Don
12. *Pinus wallichiana* A.B. Jacks.
13. *Punica granatum* L.
14. *Machilus duthiei* King.
15. *Toona ciliata* M. Roem.
16. *Bauhinia variegata* L.
17. *Lyonia ovalifolia* (Wall.) Drude.
18. *Euonymus tingens* Wall.
19. *Acacia decurrens* Willd.
20. *Juglans regia* L.
21. *Acer oblongum* Wall. ex. DC
22. *Citrus medica* L.
23. *Prunus perscica* (L.) Batsch.
24. *Zanthoxylum armatum* DC
25. *Sapium insigne* (Royle) Benth. ex. Hook
26. *Ficus palmata* Forssk.
27. *Ilex dipyrena* Wall.
28. *Rhus wallichii* Hook.f.
29. *Bombax ceiba* L.
30. *Robinia pseudoacacia* L.
31. *Ficus neriifolia* Sm.var.nemoralis (Wall.ex Miq) Corner
32. *Cupressus torulosa* D. Don.
33. *Prunus armeniaca* L.
34. *Psidium guajava* L.
35. *Litsea umbrosa* Nees
36. *Mallotus philippensis* (Lam.) Muell.Arg.
37. *Ficus roxburghii* Wall.
38. *Cornus macrophylla* Wall.
39. *Pyrus communis* L.
40. *Prunus domestica* L.
41. *Phyllanthus emblica* L.
42. *Lagerstroemia indica* L.
43. *Morus alba* L.
44. *Eriobotrya japonica* (Thunb.) Lindl
45. *Grevillea robusta* A. Cunn. ex. R. Br.
46. *Jacaranda mimosifolia* D. Don.
47. *Malus domestica* Mill.
48. *Platycladus orientalis* (L.) Franco

Shrubs

49. *Myrsine africana* L.
50. *Berberis asiatica* Roxb. ex. DC
51. *Rubus ellipticus* Smith.
52. *Berberis aristata* DC.
53. *Isodon rugosus* (Wall. ex. Benth.) Codd
54. *Cotoneaster microphylla* Wall.
55. *Sarcococca pruniformis* Lindl.
56. *Hypericum oblongifolium* Choisy.
57. *Woodfordia fruticosa* (L.) Kurz.
58. *Daphne cannabina* Lour ex. Wall.
59. *Solanum anguivi* Lam.
60. *Euphorbia royleana* Boiss.
61. *Carissa carandas* L.
62. *Osyris quadripartita* Salzm. ex. Decne.
63. *Prinsepia utilis* Royle.
64. *Debregeasia longifolia* (Burm.f.) Wedd.
65. *Rhus cotinus* L.
66. *Rosa macrophylla* Lindl.
67. *Smilax vaginata* Decne.
68. *Leptodermis lanceolata* Wall.
69. *Indigofera pulchella* Roxb.
70. *Asparagus adscendens* Roxb.
71. *Salvia coccinea* Buchoz ex. Etlinger.
72. *Inula cuspidata* C.B. Clarke.
73. *Jasminum humile* L.
74. *Vitex negundo* L.
75. *Pseudocaryopteris bicolor* (Roxb. ex. Hardw) P.D. Cantino
76. *Naringi crenulata* (Roxb). Nicolson
77. *Cotoneaster bacillaris* Wall. ex. Lindl
78. *Rubus lasiocarpus* Smith.
79. *Dodonaea merica* Jacq.
80. *Viburnum cylindricum* Buch-Ham.ex D. Don
81. *Agave mericana* L.
82. *Rosa chinensis* Jacq.
83. *Deutzia staminea* R. Br. ex. Wall
84. *Spiraea canescens* D. Don.
85. *Hamiltonia suaveolens* Roxb.
86. *Lespedeza sericea* Miq.
87. *Isodon japonicus* (Burm) Hara
88. *Lonicera quinquelocularis* Hardw.
89. *Girardinia diversifolia* (Link). Friis
90. *Murraya koenigii* (L.) Spreng.
91. *Nerium oleander* L.
92. *Opuntia stricta* (Haw) Haw.
93. *Parthenocissus semicordata* (Wall)Planch.var.roylei (King) Raizada & H.O. Saxena
94. *Ziziphus nummularia* (Burm.f.) Wt & Arn.
95. *Celastrus paniculatus* Willd.
96. *Desmodium elegans* DC.
97. *Campylotropis eriocarpa* (DC) Schindl.
98. *Berberis lycium* Royle.
99. *Clematis buchananiana* DC.
100. *Coriaria nepalensis* Wall.
101. *Indigofera heterantha* Wall.ex Brandis
102. *Pyracantha crenulata* (D. Don) Roem.
103. *Smilax aspera* L.
104. *Strobilanthes dalhousianus* C.B. Clarke
105. *Hypericum patulum* Thunb.
106. *Roylea cinerea* D. Don.
107. *Viburnum cotinifolium* D. Don.
108. *Hedera helix* L.

Herbs

109. *Chrysopogon serrulatus* Trin.
110. *Rumex hastatus* Don.
111 *Micromeria biflora* (Buch-Ham.ex.D. Don) Benth.
112. *Cynodon dactylon* (L) Pers.
113. *Cyperus niveus* Retz.
114. *Anaphalis busua* (Buch-Ham.ex.D. Don) DC
115. *Anaphalis contorta* (D. Don) Hook.f.
116. *Oxalis corniculata* L.
117. *Boenninghausenia albiflora* (Hook) Meisn
118. *Dicliptera bupleuroides* Nees.
119. *Apluda mutica* L.
120. *Thalictrum foliolosum* DC.
121. *Ajuga bracteosa* Wall.ex Benth
122. *Oxalis intermedia* A. Rich
123. *Artemisia nilagirica* (Clarke) Pamp.

(*Contd…*)

Annexure 2. (*Contd…*)

124. *Bidens pilosa* L.	155. *Bidens biternata* (Lour) Merr & Sherff.
125. *Geranium pratense* L.	156. *Goldfusia dalhousenia* Nees.
126. *Viola canescens* Wall. ex. Roxb	157. *Ageratum conyzoides* L.
127. *Urtica dioica* L.	158. *Phyllanthus niruri* L.
128. *Oplismenus undulatifolius* (Ard) Roem. & Schult	159. *Morina longifolia* Wall. ex. DC
129. *Galium aparine* L.	160. *Eupatorium reevesii* Wall.
130. *Conyza stricta* Willd.	161. *Cannabis sativa* L.
131. *Geranium nepalense* Sweet.	162. *Tridax procumbens* L.
132. *Galinsoga parviflora* Cav.	163. *Chamaesyce hirta* (L.) Millsp.
133. *Viola pilosa* Blume.	164. *Chrysopogon gryllus* Trin
134. *Euphorbia helioscopia* L.	165. *Mirabilis jalapa* L.
135. *Myosotis caespitosa* Schultz.	166. *Barleria cristata* L.
136. *Eriophorum comosum* Nees	167. *Verbascum thapsus* L.
137. *Siegesbeckia orientalis* L.	168. *Oenothera rosea* L. Her. ex. Aiton.
138. *Nepeta laevigata* (D. Don) Hand-Mazz	169. *Conyza bonariensis* (L.) Cronquist
139. *Chenopodium album* L.	170. *Pennisetum orientale* Rich.
140. *Achyranthes aspera* L.	171. *Cissampelos pariera* L.
141. *Bothriochloa pertusa* (L.) A. Camus.	172. *Poa pratensis* L.
142. *Fragaria vesca* L.	173. *Lespdeza juncea* (L.f.) Pers.
143. *Geranium wallichianum* D. Don	174. *Gerbera gossypina* (Royle.) Raizada & Saxena
144. *Taraxacum officinale* F.H. Wigg. aggr	175. *Senna tora* (L.) Roxb.
145. *Rumex nepalensis* Spreng.	176. *Drepanostachyaum falcatum* (Nees) Keng f.
146. *Vicia hirsuta* (L.) Gray.	177. *Aerva sanguinolenta* (L.) Blume.
147. *Galium rotundifolium* L.	178. *Justicia simplex* D. Don.
148. *Rubia cordifolia* L.	179. *Smilax glaucophylla* Klotzsch.
149. *Scutellaria scandens* Buch-Ham. ex. D. Don	180. *Eragrostis nigra* Nees.ex Steud
150. *Prunella vulgaris* L.	181. *Nicotiana tabacum* L.
151. *Leucas lanata* Benth.	182. *Hedychium spicatum* Sm
152. *Erigeron bellidioides* (Buch-Ham. ex. D. Don) Benth.ex C.B. Clarke	183. *Viola biflora* L.
153. *Sonchus oleraceus* L.	184. *Veronica persica* Poir
154. *Flemingia procumbens* Roxb.	185. *Impatiens balsamina* L.

growing crops in the fields particularly those away from villages or near forests. This has increased abandonment of agricultural lands which means decrease in crop diversity and increase in weeds including invasive. According to *Giyan Vigyan Samiti*, a non-governmental organization, out of 3243 *panchyat* (group of few villages may be 8–10) in Himachal Pradesh, 2301 are affected from the wildlife menace to the extent of 40–80%.

High-yielding varieties

The high-yielding varieties (HYV) are essential to increase production, but have impacted and eroded gene pool that exists in traditional varieties and landraces. The hill agriculture however, was last to come under the influence of HYV and thus few traditional varieties and landraces can still be found in remote areas. Nonetheless, the analysis of data showed that adoption of HYV has not increased the overall production of hill crops to the extent it could have been, rather adversely affected hill crops diversity. Because the varieties developed by institutions, especially those located in plains, generally respond to high inputs including irrigation which hills invariably lack. When such varieties are grown under poor inputs (rainfed, marginal and sandy soils), they perform poorly than the local varieties, which are well adapted to such conditions.

Lack of awareness

From the analysis of awareness data gathered from farmers particularly on the importance of plant genetic resources, and their conservation and genetic erosion, it appeared that 64% of the farmers are not aware about what they had and what is already lost while 36% farmers were found aware. Out of those found to be aware, 80% were not putting any efforts to conserve and 20% were putting some efforts to conserve and save genetic diversity. Their efforts include growing traditional varieties and crops, keeping own seeds, eating crops other than wheat and rice, etc. Nonetheless, the scenario which emerged shows that people by and large were not much aware about genetic erosion and its implications in agriculture.

Better price and market for off-season crops

The hill farmers have an added advantage of growing off season crops as compared to their counterparts in the plains. The prices of many crop commodities are much

Annexure 3. Plant species in Megad watershed

Trees

1. *Salix denticulata* Anders.
2. *Pinus wallichiana* A.B. Jacks
3. *Picea smithiana* (Wall) Boiss.
4. *Abies pindrow* (D. Don) Royle.
5. *Salix alba* L.
6. *Juglans regia* L.
7. *Juniperus recurva* Buch-Ham. ex. D. Don
8. *Malus domestica* Mill.
9. *Cedrus deodara* (Roxb. ex. D. Don) G. Don
10. *Betula utilis* D. Don.
11. *Prunus armeniaca* L.
12. *Crateagus rhipidophylla* Gand.
13. *Populus nigra* L.
14. *Robinia pseudoacacia* L.

Shrubs

15. *Juniperus communis* L.
16. *Rosa webbiana* Wall. ex. Royle
17. *Lonicera quinquelocularis* Hardw
18. *Echinops echinatus* Roxb.
19. *Cotoneaster falconeri* Klotz.
20. *Hippophae rhamnoides* L.
21. *Sorbaria tomentosa* (Lindl) Rehder.
22. *Fraxinus xanthoxyloides* (G. Don) Wall. ex. DC.
23. *Berberis pseudoumbellata* Parker.
24. *Ribes alpestre* Wall. ex. Decne.
25. *Viburnum cotinifolium* D. Don.
26. *Hypericum perforatum* L.
27. *Persicaria wallichii* Grente & Burdet
28. *Euphorbia elliptica* Lam.
29. *Desmodium tilaefolium* Don.
30. *Urtica hyperborea* Jacq. ex. Wedd.
31. *Lespdeza gerardiana* Grah.

Herbs

32. *Medicago sativa* L. subsp. falcata (L) Arcang
33. *Digitaria cruciata* (Nees ex, Steud.) A. Camus
34. *Trifolium repens* L.
35. *Eragrostis minor* Host.
36. *Artemisia brevifolia* Wall. ex. DC.
37. *Calamogrostis pseudophragmites* (Hall.f.) Koel
38. *Morina persica* L.
39. *Nepeta eriostachya* Benth.
40. *Bromus ramosus* Huds. subsp. ramosus
41. *Cannabis sativa* L.
42. *Bromus inermis* Leyss.
43. *Agrostis canina* L.
44. *Artemisia maritima* L.
45. *Stellaria media* (L.) Vill
46. *Mentha longifolia* (L.) Huds.
47. *Cicer microphyllum* Benth.
48. *Morina coulteriana* Royle.
49. *Agrostis pilosula* Trin.
50. *Bromus confinis* Nees ex. Steud.
51. *Fragaria nubicola* (Hook.f.) Lindley ex Lacaita.
52. *Rumex acetosa* L.
53. *Trifolium pratense* L.
54. *Impatiens sulcata* Wall.
55. *Phlomis bracteosa* Royle. ex. Benth
56. *Verbascum thapsus* L.
57. *Urtica dioica* L.
58. *Potentilla nepalensis* Hook.
59. *Polygonum plebejum* R.Br.
60. *Bothriochloa ischaemum* (L.) King.
61. *Chenopodium album* L.
62. *Erigeron alpinus* L.
63. *Chareophyllum villosum* Wall. ex. DC
64. *Taraxacum officinale* F.H. Wigg. aggr
65. *Capsella bursa-pastoris* (L.) Medik.
66. *Heracleum candicans* Wall. ex. DC
67. *Rumex nepalensis* Spreng.
68. *Cynoglossum nervosum* Benth. ex. C.B. Clarke
69. *Jaeschkea oligosperma* (Griseb.) Knobl.
70. *Persicaria hydropiper* (L.) Delarbre
71. *Rumex patientia* L.
72. *Geranium nepalense* Sweet.
73. *Astragalus grahamianus* Royle ex. Bth.
74. *Plantago major* L.
75. *Anemone polyanthes* D. Don.
76. *Equisetum arvense* L.
77. *Erigeron bellidioides* (Buch-Ham. ex. D. Don) Benth. ex. C.B. Clarke
78. *Ceratocephala falcata* (L.) Pers.
79. *Persicaria capitata* (Buch-Ham) ex. D. Don H. Grass
80. *Origanum vulgare* L.
81. *Crysopogon gryllus* (L.) Trin
82. *Melilotus albus* Medik.
83. *Achillea millefolium* L.
84. *Poa alpina* L.
85. *Pedicularis bicornuta* Klotz.
86. *Sonchus oleraceus* L.
87. *Arctium lappa* L.
88. *Festuca rubra* L.
89. *Fragaria vesca* L.
90. *Geranium collinum* Steph-ex Willd.
91. *Thymus serpyllum* L.
92. *Convolvulus arvensis* L.
93. *Thalictrum foliolosum* DC.
94. *Senecio laetus* Edgew.
95. *Anaphalis busua* Buch-Ham ex. D. Don
96. *Poa bulbosa* L.
97. *Aster falconeri* Hutch.
98. *Chamerion latifolium* (L.) Holub
99. *Thalaspi arvense* L.
100. *Lactuca orientalis* (Boiss).
101. *Silene vulgaris* (Moench) Garcke.
102. *Chesneya cuneata* (Benth) Ali
103. *Conyza canadensis* (L.) Cronquist
104. *Galium aparine* L.
105. *Geranium pratense* L.
106. *Cirsium wallichii* DC.
107. *Filipendula vestita* (Wall ex G. Don.) Maxim
108. *Oxyria digyna* Hill.
109. *Tanacetum himachalensis* Aswal & Mehrotra.
110. *Tanacetum tibeticum* Hook.f. & Thomas. ex. C.B. Clarke
111. *Thalaspi montanum* L.
112. *Echinops cornigerus* DC.
113. *Launea procumbens* (Roxb.) Ram.
114. *Veronica persica* Poir.
115. *Bunium persicum* (Boiss) Fedtsch.
116. *Chenopodium foliolosum* (Moench)
117. *Cichorium intybus* L.
118. *Malva verticillata* L.
119. *Sisymbrium irio* L.
120. *Tragopogon pratense* L.
121. *Amaranthus viridis* Hook.f.
122. *Dactylorhiza hatagirea* D. Don.

The plant species in each vegetation layer have been given in their hierarchical order, i.e. frequency of occurrence highest being the first. Herbs mentioned here represent only forest land use.

less in the main season. On the contrary, off season produce is always less in quantity and fetch attractive price in the market. With the result that traders lift the crop produce from the field itself and farmers do not even bear transport cost. For instance, garden pea costs Rs 4–5/kg and Rs 20–25/kg in plains and hills respectively. These better prices and door step market facilities have lured farmers to switch over from traditional crops to cash crops.

Other factors such as migration of people from rural to urban areas in search of jobs and better education facilities, nuclear family systems, agriculture subjected to vagaries of nature, considering agriculture as a low status and a low income profession, inconsistent rainfall and declining snowfall, invasive alien weeds, expansion of cities and establishment of new industrial hubs and townships in the cultivated lands are also threatening agriculture and its future. The genetic resources important for food and nutrition security have been lost and are being lost at a much faster rate and we consider this a disaster to agriculture especially to the regions practising subsistence agriculture and/or those who are heavily dependent on agriculture, for instance, on the mountains. Depending too much on few varieties, however, invites future catastrophe should climate change, or should the energy and chemical subsidies needed to maintain these varieties become scarce, or should new diseases and pests attack a vulnerable variety. Therefore, the management of natural resources, viz. land, water and biodiversity is crucial and calls for urgent attention and concern from every member of the society be it farmer, researcher or policy planner.

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