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Variation in floral diversity of eight agro-ecosystems along elevational gradient in north-western Himalaya

Rahul Singh[1], D.R. Bhardwaj[1*], Nazir A. Pala[2] and Bhalendra Singh Rajput[3]
[1]Dr Y. S. Parmar University of Horticulture and Forestry, Nauni-173230, India
[2]Uttar Banga Krishi Viswavidyalaya, Pundibari-736165, India
[3]Rani Lakshmi Bai Central Agricultural University, Jhansi-284003, India
[*]Corresponding author e-mail: bhardwajdr_uhf@rediffmail.com
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Abstract
The present study was conducted at two different altitudes having eight common land use/agro-ecosystems to analyze the difference in distribution pattern and diversity of existing flora by laying down plots and quadrates. A plot of 0.1 ha was laid down in all the land use systems for measuring the density and diversity of trees and within those plots, one sub plot of size 10 m × 10 m for shrubs and 1 m × 1 m for herb layer. The density and basal area of herbaceous flora was highest in agrihortisilviculture at lower elevation and silvopastoral at higher elevation. Herbage density and basal area showed a decreasing trend with increasing altitudinal range. The maximum shrub density reported under forestland uses both the altitudinal ranges. Irrespective of the land use system, shrub density enhanced with increasing altitudinal range. At higher altitudinal range, tree density (individuals ha^{-1}) was highest under forest (550) land use followed by agrisilviculture (390), agrihortisilviculture (260), horticulture (230), silvopastoral (230) and agrihorticulture (16) systems, respectively. Shannon Weiner index (H') (2.27) was observed highest for forestland use. Among agroforestry systems, agrihortisilviculture land use system showed best results with respect to density and grassland displayed least. Hence, the study recommends the introduction of more and more forest tree species in and around the orchards and other agriculture landscapes of the region to enhance and safe guard the plant richness.

Keywords: Agroforestry, Altitudinal variation, Floral density, Grassland ecosystem

Introduction

Among the global mountain system, the Himalaya is the most complex, diversified and separates the northern part of the Asian continent from South Asia (Zobel and Singh, 1997). Temporal and spatial variations caused by diversity in geological orogeny have resulted into a marked difference in climate and physiography and consequently in the distribution pattern of biotic elements. The eastern Himalaya that harbors about 8000 species of flowering plants is considered a cradle of flowering plants, whereas western Himalaya supports over 5000 species of flowering plants (Rao, 1994). The Himalayan forest vegetation ranges from tropical dry deciduous forests in the foothills to alpine meadows above timberline (Singh and Singh, 1992). Forest composition and their community structure are important ecological attributes directly influenced by prevailing environmental as well as anthropogenic variables. There is a steady shift from traditional agro ecosystems, which maintain and protect biological diversity to modern agro ecosystems, which are based on intensive cropping and have evolved basically to increase yield and economic returns (Maikhuri *et al*., 1998). Though a number of studies on Himalayan agroecosystems are available (Sharma *et al*., 1995; Semwal and Maikhuri, 1996; Singh *et al*., 1997), knowledge on ecosystem diversity within the landscape and linkages between different ecosystem types and efficiency of different land use systems is fragmentary. Productivity of any vegetation system can be affected by nature, age and other locality factors (Chaturvedi *et al*., 2016) and to analyze the changes and spatial characteristics of woodlands in mountain ecosystems can provide information for biodiversity conservation planning (Young-Joo and Keun-Ho, 2015). Various studies (Gokhale and Pala, 2011; Pala *et al*., 2015; Shah *et al*., 2014; Bhardwaj *et al*., 2016; Rajput *et al*., 2016) have either studied floristic composition of different forest ecosystems of Indian Himalayan region or their carbon related issues. However, no systematic study pertaining to variation in floral diversity has been reported on different agroecosystems along altitudinal and climatic gradient in the region. Keeping the above scenario in view, the present study was, therefore conduct in north-western Himalayan region covering seven districts of Himachal Pradesh, India to evaluate the changes in floristic diversity of eight different ecosystems and suggest the best for conservation purpose.

Materials and Methods

***Study area*:** The study was carried out in sub-montane and low hill sub-tropical zone-I of Himachal Pradesh, India. This zone covers an area of 55673 km^2 and spreads over seven districts *viz.*, Kangra, Chamba, Hamirpur, Una, Bilaspur, Solan and Sirmaur. The area is located between 32º 50' to 30º 22'' North latitude and 76º 18' to 77º 47' East longitude and lies between 365 to 914 m above sea level. This zone is affected by all three extreme climatic conditions, high temperature in summers (18-35º C), very low in winter (5-21º C) and heavy rainfall in rainy season. The average annual rainfall varies from 1400-1800 mm and 80% of which is concentrated in July- August. Dominant tree species in this zone are *Acacia catechu*, *Grewia optiva, Pinus roxburghii, Shorea robusta, Toona ciliata, Dalbergia sissoo.* The common shrubs are *Murraya koenigii, Pyrus pashia, Lantana camara, Artemisia vulgaris, Adhatoda vasica, Carrisa carandas* and common herbs are *Bidens pilosa, Xanthium strumarium, Cynodon dactylon, Cyperus rotundus, Chrysopogon montanus, Themeda anathera*.

***Methodology*:** For the selection of sites, three districts were randomly selected and further stratified into two altitudinal ranges *viz.,* A_1: 365-635 m a.s.l and A_2: 636-914 m a.s.l. The site selection at both the altitudinal ranges was done in such a manner so that both the altitudes have common land use systems *viz.,* Agriculture (T_1), Horticulture (T_2), Agrisilviculture (T_3), Silvopastoral (T_4), Agrihorticulture (T_5), Agrihortisilviculture (T_6), Forest (T_7) and Grassland (T_8). Plots and quadrate method was used to study the floristic composition in various agroecosystems under the study area (Bhardwaj *et al*., 2016; Pala *et al*., 2015). Density of trees was calculated by counting trees in each land use systems in 0.1 ha plot (Bhardwaj *et al*., 2016). The individuals having diameter at breast height (DBH) above 10 cm were considered as trees. Shrubs were studied in each land use systems by laying out two sub plots of 10 m × 10 m within each sample plot. Herbaceous vegetation was studied in the growing season (September-October) by laying down three quadrates of size 1 m × 1 m in every land use system from the sample plots of 0.1 ha. DBH was taken for all the trees in the sample plot determined by tree calliper for measurement of basal area. The vegetation from each quadrate was segregated species wise and identified with the help of herbarium in the Dr Y. S. Parmar University of Horticulture and Forestry, Nauni and by other relevant floras of the region. Each species was analysed quantitatively for various parameters *viz*., basal area, density and frequency. Values of relative density, relative basal area and relative frequency were calculated following Misra (1969). The importance value index (IVI) for each species was worked out by using formula given by Curtis and McIntosh (1950). Species diversity was determined by using Shannon Weiner (1963) Index and Simpson's Diversity Index (Simpson, 1949).

Results and Discussion

***Phytosociology of herbage layer*:** At lower altitudinal range (A_1) maximum herbage density (individuals m^{-2}) was displayed by agrihortisilviculture land use (698.66), followed by agrisilviculture (659.91) and horticulture (529.27), whereas minimum (310.67) was reported in grassland. At higher altitudinal range (A_2) maximum herbage density (individuals m^{-2}) was displayed by silvopastoral (658.67) followed by grassland (562.60), forest (425.32), agrihortisilviculture (365.33), agrisilviculture (350.34), agrihorticulture (337.34), agriculture (276.01) and horticulture (220.01) in descending order (Tables 1, 2). Land use systems *viz*., agriculture, horticulture, agrisilviculture, agrihorticulture, agrihortisilviculture and forest land use systems had higher herbage density at A_1 altitudinal range than A_2 range. Agriculture, horticulture, agrisilviculture, agrihorticulture, agrihortisilviculture and grassland displayed higher basal area at A_1 altitudinal range than A_2. At A_1 altitudinal range maximum basal area (cm^2 m^{-2}) was in agrihortisilviculture (305.39), followed by agrisilviculture (261.50), agrihorticulture (243.58) and agriculture (167.26). Basal area (cm^2 m^{-2}) was recorded quite low in forest land use (15.91), silvopastoral (16.04) and grassland (23.93) systems at A_1 altitude. Similarly at A_2 altitudinal range basal area (cm^2 m^{-2}) was quite higher in agrihortisilviculture (274.26), agrihorticulture (230.36), and agrisilviculture (212.33) land use systems than the horticulture (7.49), forest (16.73) and grassland (22.14). Among all herbaceous species *Achyranthes aspera* in agrihortisilviculture exhibited minimum (0.02 cm^2 m^{-2}) basal area besides agricultural crops. Among agriculture crops, *Triticum aestivum* accounted for higher (86.73 cm^2 m^{-2}) herbage basal area compared to other agricultural crops in land use.

Table 1. Density (individuals m-2) of different herb species in different land uses in lower altitude range (365-635 m a.s.l)

Species	Agri culture	Horti culture	Agri-silvi culture	Silvi-pastoral	Agri-horti culture	Agri horti-silvi culture	Forest	Grass-land
Achyranthes aspera Linn.	-	6.67	-	-	-	1.33	5.33	-
Ageratum conyzoides L.	-	62.67	-	18.67	-	-	18.67	12
Allium cepa L.	-		-	-	-	56	-	-
Artemisia vulgaris Linn.	-	49.33	-	-	-	-	-	8
Avena fatua	20	-	18.66	-	33.33	10.67	-	-
Barleria cristata Linn.	-	16	-	-	-	-	-	-
Brassica campestris Linn.	25.33	-	-	-	30.67	-	-	-
Cassia tora L.	-	-	-	-	-	-	9.33	-
Chenopodium album	12	-	13.33	-	-	14.67	-	-
Cynodon dactylon (L.) Pers.	34.66	118.6	48	-	93.33	80	-	48
Cyperus rotundus L.	36	54.67	-	-	52	33.33	-	32
Dactyloctenium sinidicum L.	-	-	-	-	-	-	42.67	-
Desmodium polycarpum (Poir) DC	-	-	-	-	-	-	20	-
Digitaria sanguinalis (L.) Scop.	-	-	-	-	-	-	100	40
Echinochloa colonum (L.) Link	12	-	-	8	13.33	12	69.33	113.33
Erigeron conyzoides F.Muell.	-	-	-	-	-	-	58.67	-
Hordeum vulgare L.	-	-	146.6	-	-	-	-	-
Justicia simplex Linn.	-	-	-	-	-	-	16	26.67
Licopersicum esculantum	-				45.33	-	-	-
Malvastrum tricruspidetum L.	-	-	-	-	-	-	16	-
Oryza sativa L.	-		201.33	-	-	209.33	-	-
Paspalum sanguinale Lamrk.	48	185.33	-	-	-	-	-	-
Pennisetum orientale Rich.	-	-	-	293.33	-	-	-	-
Phalaris minor	25.33	-	20	-	13.33	36	-	-
Phyllanthus amessus	-	-	-	18.67	-	-	-	-
Poligonum hydropiper L.	-	14.67	-	-	-	-	-	14.67
Rabdosia rugosa (Wall. ex Benth.)	-	-	-	9.33	-	-	-	-
Setaria glauca L.	-		-	-	-	-	69.33	-
Sida obovata Wall.	-	-	-	-	-	-	16	-
Sida veronicaefolia Lam.	-	-	-	-	-	-		12
Siegesbeckia orientalis Linn.	-	-	-	-	-	-	9.33	-
Solanum nigrum Linn.	-	-	-	-	-	-	9.33	-
Themeda anathera (Nees ex Steud)	-	-	-	30.67	-	-	-	-
Triticum aestivum L.	134.6		178.66	-	170.67	176	-	-
Urtica dioica Less.	-	21.33	-	-	-	-	-	4
Vernonia cinerea	-	-	-	-	-	-	37.33	-
Vigna radiata L. Wilczek	10.66	-	-	-	-	40	-	-
Zea mays L.	12	-	33.33	-	34.67	29.33	-	-

Among all agroforestry systems, maximum IVI was recorded by *Pennicum sanguinale* (186.01) in silvopastoral system and minimum for *Achyranth esaspera* (3.9) in agrihortisilviculture system. In agriculture land use system, the maximum value of IVI (105.96) was displayed by *Triticum aestivum* at A_1 altitudinal range. Whereas, the minimum value of IVI was recorded by *Ipomoea purpurea* (5.53) at A_2 altitudinal range. In agrisilvicultural system the maximum value (77.76) of IVI at lower elevation (A_1) was observed for *Oryza sativa* and minimum (10.01) for *Phalaris minor*. However, at higher altitude (A_2) maximum IVI was recorded for *Triticum aestivum* (79.09) followed by *Zea mays* (44.94). Whereas, at A_2 altitudinal range, the species

Table 2. Density (individuals m^{-2}) of different herb species in different land uses in upper altitude range (636-914 m a.s.l)

Species	Agri culture	Horti culture	Agri-silvi culture	Silvi-pastoral	Agri-horti culture	Agri horti-silvi culture	Forest	Grass-land
Allium sativum L.	-	-	-	-	-	48	-	-
Anthraxon lancifolius	-	6.67	-	-	-	-	-	-
Artimisia roxburghiana Bess.	-	21.33	-	-	-	-	-	-
Avena fatua	16	-	22.67	-	22.67	17.33	-	-
Barleria cristata Linn.	-	32	-	18.67	-	-	-	-
Bidens pilosa Linn.	-	10.67	-	-	-	-	8	-
Brassica campestris Linn.	-	-	-	-	20	-	-	-
Cassia mimosoides Linn.	-	-	-	-	-	-	1.33	-
Chenopodium album	-	-	8	-	17.33	-	-	-
Chrysopogon montanus Trin.	-	-	-	-	-	-	37.33	-
Crotalaria hirsute Willd.;Fl. Br. Ind.	-	-	-	-	-	-	-	16
Cynodon dactylon (L.) Pers.	26.67	-	24	-	10.67	-	-	-
Cyperus rotundus L.	28	-	22.67	-	14.67	20	-	-
Digitaria sanguinalis (L.) Scop.	-	62.67	-	-	-	-	-	-
Digiteria ciliaris L.	-	-	-	100	-	18.67	-	-
Echinochloa colonum (L.) Link	13.33	-	6.67	206.67	24	12	28	-
Eragrostis nigra Nees ex Steud.	-	-	-	293.33	-	-	-	2.67
Erigeron conyzoides F.Muell.	-	-	-	-	-	-	10.67	-
Euphorbia heterophylla L.	-	22.67	-	-	-	-	-	-
Euphorbia hirta	-	-	-	-	-	-	10.67	8
Hordeum vulgare L.	-	-	-	-	-	-	-	-
Imperata cylindrica Beauv.	-	-	-	-	-	-	-	126.67
Ipomoea purpurea Lam.	-	-	-	4	-	-	-	-
Justicia simplex Linn.	-	-	-	18.67	-	-	9.33	21.33
Lespedeza gerardiana (L.) Michx.	-	14.67	-	-	-	-	-	-
Licopersicum esculantum	-	-	-	-	16	-	-	-
Oryza sativa L.	56	-	-	-	-	52	-	-
Panicum songuinale	-	-	-	-	-	-	84	346.6
Phalaris minor	18.67	-	25.33	-	22.67	25.33	-	-
Pisum sativum	-	-	48	-	48	-	-	-
Senecio vulgaris Linn.	-	-	10.67	8	-	-	-	-
Setaria glauca L.	2.67	49.33	-	-	-	-	-	-
Siegesbeckia orientalis Linn.	-	-	-	-	-	-	25.33	-
Solanum nigrum Linn.	-	-	-	-	-	-	1.33	-
Sonchus oleraceus Linn.	-	-	-	-	-	-	2.67	-
Spermacoce pusilla L.	-	-	-	9.33	-	-	-	-
Tagetes minuta Roxb.	-	-	-	-	-	-	13.33	-
Triticum aestivum L.	100	-	137.33	-	125.33	161.33	-	-
Triumfetta pilosa Roth.	-	-	-	-	-	-	-	8
Urochloa panicoids P. Beauv	-	-	-	-	-	-	193.33	24
Vigna radiata L. Wilczek		-	30.33	-	-	-	-	-
Zea mays L.	14.67	-	14.67	-	16	10.67	-	-

having highest importance value index was *Digitarias anguinalis* (64.51), followed by *Setaria glauca* (46.76), *Barlaria cristata* (41.48) and *Euphorbia hetrophylla* (39.85) in descending order.

Oryza sativa (77.76), *Triticum aestivum* (79.09) were having maximum IVI in agrisilviculture system at the A_1 and A_2 altitudinal ranges, respectively. In the silvopastoral system, *Pennisetum orientale* (186.01) at A_1 and *Eragrostis nigra* (111.61) at A_2 altitudinal range were the herb species having maximum importance value index. Whereas, in the agrihorticulture land use system, *Triticum aestivum* displayed the highest IVI at both the altitudinal ranges. Forest land use system of the altitudinal range A_2 was represented by many herb species. But the species displaying > 30 IVI were *Echinochloa colonum* (32.41), *Erigeron conyzoides* and *Setaria glauca*. However, in the A_2 altitudinal range *Urochloa panicoids* displayed markedly higher (107.61) value of IVI than other species. In the pure grassland use system, *Echinochloa colonum* in A_1 (119.49) and *Panicum songuinale* in A_2 (153.33 IVI) altitudinal range displayed the highest value of IVI.

***Density, IVI and basal area of shrub layer*:** The land use systems *viz.,* agriculture, agrisilviculture, agrihorticulture and agrihortisilviculture had no shrub species. Maximum density of shrubs (1966.67 plants ha^{-1}) was observed in forest, followed by horticulture (1900 plants ha^{-1}) and minimum (1533 plants ha^{-1}) in silvopastoral system. Individually density of shrub species were recorded maximum for *Lantana camara* (1067 plants ha^{-1}) in grassland and minimum density for *Ziziphus nummularia* (33.33 plants ha^{-1}) in forest. The data recorded for the basal area of shrub species in different land use system at A_1 altitudinal range revealed that the maximum (0.99 m^2 ha^{-1}) total basal area of shrubs was found in horticulture and minimum (0.236 m^2 ha^{-1}) in grassland. Individually maximum (0.268 m^2 ha^{-1}) basal area of shrub was recorded for *Lantana camara* and minimum (0.0007 m^2 ha^{-1}) for *Carrissa carandas* in forest land use.

In shrub layer IVI of different land use systems varied from 15.61 to 190.20 at A_1 altitudinal range (Table 3). The maximum IVI (190.20) of *Murraya koenigii* was recorded in horticulture followed by *Lantana camara* (159.6) in grassland system. At higher elevation range (A_2) shrubs were most frequently observed in silvopastoral system followed by forest and agrisilviculture system. The maximum number of plants (2266.67 ha^{-1}) was recorded in forest followed by silvopastoral (2001 ha^{-1}), horticulture (1666.67 ha^{-1}) and grassland (1600 ha^{-1}). The minimum density of shrubs was recorded in agrisilviculture system (1233.34 plants ha^{-1}). Individually *Murraya koenigii* was recorded in all the land use systems and its maximum density (1400 plants ha^{-1}) was recorded in forest and minimum (766.67 plants ha^{-1}) in agrisilviculture system. Maximum basal area (0.265 m^2/ha) was recorded in silvopastoral system. Species wise *Murraya Koenigii* recorded maximum basal area (0.905 m^2/ha) in grassland and minimum basal area was recorded (0.006 m^2/ha) for *Lantana camara* in grassland. At A_2 altitudinal range, *Murraya koenigii* displayed maximum IVI (300) in the horticulture land use system followed by grassland (232.66), agrisilviculture (212.20), forest (145.50) and silvopastoral (87.78).

***Density, basal area and IVI of tree layer*:** Highest density (700 trees ha^{-1}) at A_1 altitudinal range was found in agrisilviculture land use followed by horticulture and forest, whereas minimum density (230 trees ha^{-1}) was recorded in agrihorticulture system. Among the tree species maximum (520 trees ha^{-1}) density was recorded for *Citrus reticulata* in horticulture and minimum (30 trees ha^{-1}) for *Acacia catechu* in forest. Maximum total basal area (41.52 m^2 ha^{-1}) of trees was found in forest and it was minimum (4.04 m^2 ha^{-1}) in agrihorticulture land use. *Shorea robusta* showed maximum (26.92 m^2 ha^{-1}) basal area in forest and minimum (0.31 m^2 ha^{-1}) by *Morus alba* in silvopastoral land use. The maximum IVI (300) was recorded for *Citrus reticulata* in agrihorticulture land use system.

Total density (individuals ha^{-1}) of tree was maximum in forest (550) at higher altitudinal range (A_2), followed by agrisilviculture (390), agrihortisilviculture (260) and silvopastoral (230), respectively. The minimum density (160 trees ha^{-1}) was recorded in agrihorticulture system. Individually *Pinus roxbughii* recorded maximum density (400 trees ha^{-1}) in forest and minimum (20 trees ha^{-1}) by *Morus alba* and *Celtis austrralis* in agrisilviculture system each. Maximum basal area (m^2 ha^{-1}) was recorded in forest (28.04) followed by agrihortisilviculture (10.94), agrisilviculture (10.78), silvopastoral (6.87), agrihorticulture (5.69) and horticulture (1.39) in descending order, respectively. *Pinus roxburghii* displayed maximum (25.49 m^2 ha^{-1}) basal area in forest land use followed by of *Toona ciliata* (7.49 m^2 ha^{-1}) in agrisilviculture. Minimum (0.20 m^2 ha^{-1}) basal area was recorded for *Grewia optiva* in silvopastoral system. The data observed for IVI of different species in land use systems revealed that the maximum IVI was recorded for *Mangifera indica* in horticulture and minimum IVI (44.93) for *Grewia optiva* in silvopastoral system (Table 4).

Table 3. Density (plants ha^{-1}), basal area ($m^2 ha^{-1}$) and IVI of shrubs in different land use systems along an altitudinal gradient

Shrub species	Horticulture			Agrisilviculture			Silvopastoral		
	D	BA	IVI	D	BA	IVI	D	BA	IVI
Altitudinal range (365-635 m a.s.l)									
Carissa carandas L.	-	-	-	-	-	-	-	-	-
Desmodium iliaefolium L	-	-	-	-	-	-	333	0.046	69.91
Flemingia fruticulosa L.	-	-	-	-	-	-	-	-	-
Lantana camara Linn.	-	-	-	-	-	-	800	0.003	86.47
Mallotus phillippensis L.	-	-	-	-	-	-	-	-	-
Murraya koenigii L.	633	0.33	190.2	-	-	-	-	-	-
Randia spinerum L.	-	-	-	-	-	-	-	-	-
Xanthium strumarium L.	467	0.24	109	-	-	-	400	0.262	143.61
Zizyphus nummularia L.	-	-	-	-	-	-	-	-	-
Total	1900	0.99	300	-	-	-	1533	0.311	300
Altitudinal range (636-914 m a.s.l)									
Adhatoda vasica Nees.	-	-	-	-	-	-	-	-	-
Carissa carandas L	-	-	-	33.33	0.039	19.23	-	-	-
Duranta erecta L.	-	-	-	-	-	-	367	0.081	77.53
Flacouurtia indica (Burm. F.) Merr.	-	-	-	-	-	-	167	0.078	52.18
Lantana camara Linn.	-	-	-	-	-	-	300	0.087	62.09
Murraya koenigii (Linn.) spreng	1067	0.357	300	766.67	0.358	212.2	1067	0.016	87.78
Pyrus pashia L.	-	-	-	66.67	0.089	59.30	-	-	-
Woodfordia floribunda (Linn.) Kurz	-	-	-	-	-	-	100	0.003	20.40

Shrub species	Forest			Grassland		
	D	BA	IVI	D	BA	IVI
Altitudinal range (365-635 m a.s.l)						
Carissa carandas L.	233.33	0.0007	15.61	-	-	-
Desmodium iliaefolium L	-	-	-	-	-	-
Flemingia fruticulosa L.	366.67	0.0065	21.13	-	-	-
Lantana camara Linn.	766.67	0.268	98.70	1067	0.090	159.6
Mallotus phillippensis L.	366.67	0.0049	20.83	-	-	-
Murraya koenigii L.	-	-	-	-	-	-
Randia spinerum L.	200.00	0.047	30.84	-	-	-
Xanthium strumarium L.	-	-	-	667	0.146	140
Zizyphus nummularia L.	33.33	0.0014	16.75	-	-	-
Total	1966.67	0.3285	300	1734	0.236	300
Altitudinal range (636-914 m a.s.l)						
Adhatoda vasica Nees.	100	0.044	27.14	-	-	-
Carissa carandas L	366.67	0.005	31.40	-	-	-
Duranta erecta L.	-	-	-	-	-	-
Flacouurtia indica (Burm. F.) Merr.	-	-	-	-	-	-
Lantana camara Linn.	400	0.262	95.97	667	0.006	67.34
Murraya koenigii (Linn.) spreng	1400	0.215	145.50	933	0.905	232.6
Pyrus pashia L.	-	-	-	-	-	-
Woodfordia floribunda (Linn.) Kurz	-	-	-	-	-	-

D = Density; BA = Basal area; IVI = Importance value index

Table 4. Density (trees ha^{-1}), basal area (m^2 ha^{-1}) and IVI of trees in different land use systems

Shrub species	**Horticulture**			**Agrisilviculture**			**Silvopastoral**		
	D	**BA**	**IVI**	**D**	**BA**	**IVI**	**D**	**BA**	**IVI**
Altitudinal range (365-635 m a.s.l)									
Albizia procera L.	-	-	-	-	-	-	-	-	-
Acacia catechu L.	-	-	-	-	-	-	-	-	-
Albizia lebbeck L.	-	-	-	-	-	-	-	-	-
Citrus reticulata L.	520	9.04	193.24	-	-	-	-	-	-
Dalbergia sissoo L.	-	-	-	70	3.77	63.92	-	-	-
Eucalyptus tereticornis L.	-	-	-	-	-	-	160	6.80	143.82
Leucaena leucocephala L	-	-	-	-	-	-	-	-	-
Mangifera indica L.	160	3.58	106.76	-	-	-	-	-	-
Morus alba L.	-	-	-	-	-	-	40	0.31	50.08
Populus deltoids Well.	-	-	-	450	1.21	104.24	-	-	-
Shorea robusta L.	-	-	-	-	-	-	-	-	-
Terminalia arjuna L	-	-	-	-	-	-	-	-	-
Toona ciliata M. Roem.	-	-	-	180	13.34	131.84	80	5.63	106.10
Altitudinal range (636-914 m a.s.l)									
Acacia catechu L.	-	-	-	-	-	-	100	1.46	98.07
Celtis australis L.	-	-	-	20	0.21	27.09	-	-	-
Dalbergia sissoo L.	-	-	-	70	1.41	51.07	110	5.21	157.01
Eucalyptus tereticornis L.	-	-	-	-	-	-	-	-	-
Grewia optiva L.	-	-	-	150	1.44	71.80	20	0.20	44.93
Mangifera indica L.	230	1.39	300	-	-	-	-	-	-
Morus alba L.	-	-	-	20	0.22	27.21	-	-	-
Pinus roxburghii Sarg.	-	-	-	-	-	-	-	-	-
Toona ciliata M. Roem.	-	-	-	130	7.49	122.82	-	-	-

Shrub species	**Agrihorticulture**			**Agrihortisilviculture**			**Forest**		
	D	**BA**	**IVI**	**D**	**BA**	**IVI**	**D**	**BA**	**IVI**
Altitudinal range (365-635 m a.s.l)									
Albizia procera L.	-	-	-	-	-	-	40	2.20	32.34
Acacia catechu L.	-	-	-	-	-	-	30	0.51	14.55
Albizia lebbeck L.	-	-	-	-	-	-	50	2.94	27.92
Citrus reticulata L.	230	4.04	300	160	2.86	58.64	-	-	-
Dalbergia sissoo L.	-	-	-	-	-	-	60	2.05	27.27
Eucalyptus tereticornis L.	-	-	-	-	-	-	-	-	-
Leucaena leucocephala L	-	-	-	-	-	-	60	1.95	27.04
Mangifera indica L.	-	-	-	150	3.59	59.40	-	-	-
Morus alba L.	-	-	-	-	-	-	-	-	-
Populus deltoids Well.	-	-	-	120	9.60	73.70	-	-	-
Shorea robusta L.	-	-	-	-	-	-	330	26.92	129.50
Terminalia arjuna L	-	-	-	-	-	-	40	2.74	25.89
Toona ciliata M. Roem.	-	-	-	220	15.68	108.26	40	2.20	24.57
Altitudinal range (636-914 m a.s.l)									
Acacia catechu L.	-	-	-	-	-	-	150	2.54	61.34
Celtis australis L.	-	-	-	-	-	-	-	-	-
Dalbergia sissoo L.	-	-	-	-	-	-	-	-	-
Eucalyptus tereticornis L.	-	-	-	80	3.39	95.14	-	-	-
Grewia optiva L.	-	-	-	-	-	-	-	-	-
Mangifera indica L.	160	5.70	300	80	5.07	110.44	-	-	-
Morus alba L.	-	-	-	-	-	-	-	-	-
Pinus roxburghii Sarg.	-	-	-	-	-	-	400	25.49	238.16
Toona ciliata M. Roem.	-	-	-	100	2.47	95.14	-	-	-

D = Density; BA = Basal area; IVI = Importance value index

A land use system constituted and structured by different type of vegetation in the community plays an important role in biodiversity conservation. Each species play a definite role and possess its structural and functional individualism in the community (Singh, 1998). The present study recorded decreased values of density and basal area for herbs and trees with the increase in elevation. The decrease in these parameters along the elevation might be due to change in environmental variables as reported earlier (Lomolino, 2001; Camarero and Gutierrez, 2002; Jamwal and Uniyal, 2008; Sevgi and Tecimen, 2008; Sharma, 2012). This study revealed that forest land use system had highest density of shrubs and this might be due to the minimum disturbance of human for fuel wood, fodder and animal grazing. Minimum density and species richness for shrubs in high disturbance stands possibly due to collection of fuel wood and fodder, and animal grazing pressure (Uniyal *et al.,* 2010). Similar results were also reported previously by other workers (Kumar and Jeet, 2005; Bhuyan *et al.,* 2003; Mishra *et al*., 2004). Maximum tree density was observed in agrisilviculture land use system at lower altitudinal range and it might be due to densely plantation of *Populus* on farmer's field, while at higher altitude forest had greater density. Similarly Deb *et al.* (2008) reported that the traditional agroforestry had greater woody plant density (1006 stem ha^{-1}) than the tropical forest due to the presence of densely planted areca nut, palms and other small woody plants.

***Diversity indices*:** Highest value (2.27) of Shannon Weiner index (H') was observed in forest land use system, followed by agrihortisilviculture (2.19), agrisilviculture (1.98). Irrespective of land use systems, Shannon Weiner Index (H') declined with increasing altitudinal range from A_1 to A_2. Forest land use system in A_1 altitudinal range and silvopastoral system in A_2 altitudinal range displayed higher values of Shannon Weiner index (H') than the other land use systems (Table 5). Similarly simpson diversity index (SDI) of vegetation at lower altitudinal range was found maximum in grassland system (0.383) followed by agrihorticulture system (0.241) and minimum (0.107) was observed for agrihortisilviculture land use system. At higher altitudinal range, SDI was maximum in horticulture system (0.521) and minimum (0.175) in agrihortisilviculture system. SDI showed increasing trend with increasing altitudinal range (Table 5). Higher Shannon Weiner index (H') of forest ecosystem could be owed to species composition and complexity in food webs and efficiency in conservation of site resources (Toky *et al.,* 1989). The diversity of these agroforestry systems was comparable with the diversity indices of agroforestry and non-agroforestry systems as reported earlier by different workers (Sharma *et al.,* 2006; Toky *et al.*, 1989; Singh and Singh, 1991). Tiwari *et al.* (1999) reported that Shannon-Weiner index values varied from 0.41 to 2.31 under natural silvopastoral systems in Thar Desert. Shannon Weiner index (H') for vegetation (trees, shrubs and herbs) of different land use systems declined with increasing altitudinal range from A_1 to A_2, which could be owed to the fact that elevation gradients create varied climates along with resultant soil differentiation that promote the diversification of plant species (Brown, 2001).

Conclusion

The agro-ecosystems of the present studied region are rich with floristic diversity and important areas for social and economic security in the region. As pressure is mounting on forest areas for timber and other uses, these agro ecosystems are conserved and managed by personal interest. The study reported decreasing trend of biodiversity with the increase in altitude. Tree density declined with increasing altitudinal range. Shannon

Table 5. Shannon Weiner index (H') and Simpson's Diversity Index of different land use systems along altitudinal gradient

Land use systems (T)	Shannon Weiner index		Simpson's Diversity index	
	(365-635 m)	(636-914 m)	(365-635 m)	(636-914 m)
T_1 (Agriculture)	2.04	1.84	0.181	0.202
T_2 (Horticulture)	1.95	1.08	0.182	0.521
T_3 (Agrisilviculture)	1.94	2.02	0.176	0.254
T_4 (Silvopastoral)	1.56	2.07	0.185	0.187
T_5 (Agrihorticulture)	1.79	2.02	0.241	0.187
T_6 (Agrihortisilviculture)	2.41	1.96	0.107	0.175
T_7 (Forest)	2.52	2.02	0.126	0.183
T_8 (Grassland)	1.28	1.39	0.383	0.310
Mean	1.94	1.80	0.198	0.252

Weiner index (H') of vegetation was found to be maximum (2.27) for forest land use. Among agroforestry systems, agrihortisilviculture land use system showed best result and grassland displayed least in terms of density and richness. Hence, in mountain ecosystems for sustainable development of land and socio economic upliftment of the local inhabitants growing of horticulture and agriculture crops with tree plantation seems to be a viable option for species conservation and economic security.

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