Quantitative analysis of tree species in two community forests of Dolpa district, mid-west Nepal

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Two community forests, Amaldapani and Juphal from Dolpa district, were selected for a study of quantitative analysis of tree flora. A total of 419 individual trees representing 16 species, 16 genera and 11 families were recorded. Total stand density and basal area were, respectively, 2100 trees ha^{-1} and 90 $m^2 \cdot ha^{-1}$ in Amaldapani and 2090 tree ha^{-1} and 152 $m^2 \cdot ha^{-1}$ in Juphal. Of the families, the Pinaceae was the most diverse, with 28 individuals representing five species and five genera, followed by the Rosaceae with three individuals representing two species and two genera. *Pinus wallichiana*, *Abies spectabilis, Quercus semecarpifolia* and *Cedrus deodara* had the highest importance value index and could therefore be considered the dominant species. Since the study area was diverse in tree population of conifers and deciduous forest tree species, it is essential to carry out further studies in order to establish conservation measures that will enhance local biodiversity.

Key words: Vegetation, tree species, *Pinus wallichiana*, community forest, Dolpa

Him J Sci 2(3): 23-28, 2004
Available online at: www.himjsci.com

Received: 25 Dec 2003
Accepted after revision: 20 Apr 2004

Human impact has, to varying degrees, led to a reduction in biodiversity in much of the forested area of Nepal (Karki 1991, Chaudhary and Kunwar 2002). Conservation of such forests requires an understanding of the composition of the particular forest, the effects of past disturbances, and the present impact of neighboring land use on that forest (Geldenhuys and Murray 1993). In order to understand the phytosociological structure of the Himalayan forests, we need studies that deal with distribution of individual plant species and of various girth classes, associations among species, patterns of dispersion and various indices of diversity (Longman and Jenik 1987). The present study therefore was designed to explain variation in vegetation composition and diversity components of tree species of Amaldapani and Juphal community forests of Dolpa district.

Materials and methods

Study area

Both Amaldapani Community Forest (ACF) and Juphal Community Forest (JCF) in Juphal Village Development Committee (VDC), Dolpa district were selected as study sites. Dolpa, in the rain shadow of northwestern Nepal, is the largest and most arid district in the country. Lying between 27°21' – 27°40' N and 84°35' – 84°41' E, it encompasses elevations between 1525 and 6883 m asl. ACF has a total area of 100 ha and 87 users, and was established in 1998 (2055 BS); JCF, with 1750 ha and has 165 users, was established in 1995 (2052 BS). Both community forests lie between 1900-2700 m asl, are situated close to agricultural lands, and are dominated by *Picea* and *Pinus* species.

Methods

Field studies were carried out in July 2001 and May 2003. Twenty plots, i.e. ten plots in each community forest, each plot measuring 10m x 10m, were randomly demarcated for study. Density, frequency, basal area and their relative values and importance value index (IVI) of tree species were calculated following Mueller-Dombois and Ellenberg (1974). Botanical name and author citation was made following DPR (2001). In addition to quantitative data, we used interviews and group discussions to collect information relating to community forest management. In order to assess the general condition and vegetation structure of the forest, we developed a density-diameter histogram. Girth of trees exceeding 10 cm diameter at breast height (dbh, at 1.37 m above the ground) was measured. The height of standing trees was measured by means of a clinometer. The species area curve of each community forests was calculated by randomly adding up the number of tree species in each quadrat. The dominance diversity curve (D-D curve) was used in order to ascertain the resource apportionment among the various species at various sites.

Jaccard's (1912) coefficient (J) was used to quantify the extent to which family and species composition overlapped between sample sites. It is defined as: J = A /(A + B + C) where A is the number of family and species found in both sites, B is the families and species in site 1 but not in site 2, and C is the families and species in site 2 but not in 1.

'S,' or species richness, was determined following Whittaker (1976) by tabulating the number of woody species in each plot. Shannon-Weiner's diversity index 'H' (Shannon and Weiner 1963), concentration of dominance 'D' (Simpson 1949) and Hill diversity numbers N0, N1 and N2 (Hill 1973) were computed.

Simpson's index 'D' was calculated using the formula

'D' = $1 - \sum pi^2$, where pi is the relative density.

Shannon-Weiner's diversity index 'H' was calculated using the formula

'H' = $- \sum pi \log pi$, where pi represents the proportional abundance of the i^{th} species in the community.

Hill diversity indices were calculated using the following formulae:

Number 0: N0 = S, where S is the total number of species;
Number 1: N1 = e^H, where 'H' is the Shannon's index;
Number 2: N2 = 1/D, where 'D' is Simpson's index

Results

Species area curve

The slope of the species area curve for each study site declined as sample area increased but did not approach an asymptote (**Figure 1**).

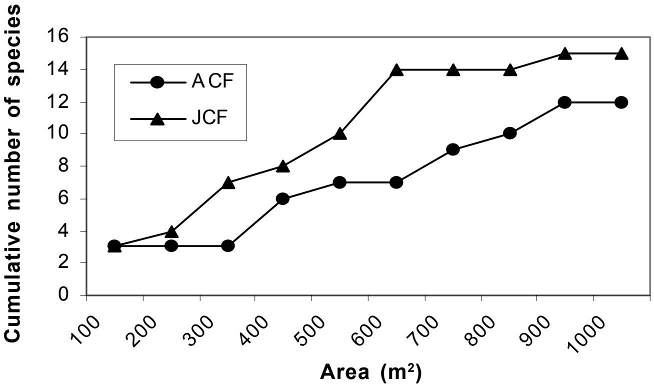

FIGURE 1. Species area curve

Vegetation composition

A total of 419 tree individuals, representing 16 species, 16 genera and 11 families, were identified within the 0.2 ha area survey (**Table 1**). *Acer caesium* (Aceraceae), *Juniperus recurva* (Cupressaceae), *Picea smithiana* (Pinaceae) and *Prunus* sp (Rosaceae) were found only in JCF and *Aesculus indica* (Hippocastanaceae) was reported only in ACF (**Table 1**).

Total stand density and basal area were, respectively, 2100 trees ha^{-1} and 90 $m^{2}\cdot ha^{-1}$ in ACF and 2090 trees ha^{-1} and 152 $m^{2}\cdot ha^{-1}$ in JCF (**Table 2 and 3**). Girth sizes of trees at breast height (gbh) ranged from 31 to 224 cm in ACF and 31 to 440 cm in JCF. The greatest gbh of *Abies spectabilis* (440 cm) was found in JCF followed by *Quercus semecarpifolia* (400 cm). The tree species attaining the greatest heights (>20 m) were *A. spectabilis, Acer caesium, Cedrus deodara, Juniperus recurva* and *Tsuga dumosa,* all in JCF.

The highest IVI value was that of *P. wallichiana* (109.58) followed by *C. deodara* (54.22) in ACF and *A. spectabilis* (75.59) followed by *Q. semecarpifolia* (57.31) in JCF. Based on IVI values, *P. wallichiana* and *A. spectabilis* were found to be the most dominant species in the study area (**Table 2 and 3**). 4.53% of the total tree individuals were stumps: 4.05% (17) in ACF and 0.5% (2) in JCF. Of the total stumps, 52.63% (10) were *P. wallichiana,* 36.84% (7) *C. deodara* and 5.26% (1) *A. spectabilis* and *Q. semecarpifolia* each.

TABLE 1. Composition and distribution of tree species in Amaldapani and Juphal community forests (CF)

Species name	Vernacular name	Family	Amaldapani CF	Juphal CF
Acer caesium Wall. ex Brandis	Tilailo	Aceraceae	□	+
Betula utilis D. Don	Bhoj patra	Betulaceae	+	+
Juniperus recurva Buch.-Ham. ex D.Don	Dhupi	Cupressaceae	□	+
Rhododendron arboreum Smith	Gurans	Ericaceae	+	+
Quercus semecarpifolia Sm.	Khasru	Fagaceae	+	+
Aesculus indica (Colebr. ex Cambess.) Hook.	Pangro	Hippocasta-naceae	+	□
Juglans regia Linn.	Okhar	Juglandaceae	+	+
Abies spectabilis (D.Don) Spach	Jhule sallo	Pinaceae	+	+
Cedrus deodara (Roxb. ex D.Don) G.Don	Deyar	Pinaceae	+	+
Picea smithiana (Wall.) Boiss.	Thingre sallo	Pinaceae	□	+
Pinus wallichiana A. B. Jackson	Khote sallo	Pinaceae	+	+
Tsuga dumosa (D.Don) Eichler	Gobre sallo	Pinaceae	+	+
Prunus species	Aare	Rosaceae	+	+
Pyrus species	Pande mel	Rosaceae	□	+
Populus ciliata Wall. ex Royle	Bhote pipal	Salicaceae	+	+
Taxus wallichiana Zucc.	Kandeloto	Taxaceae	+	+
Total			**12**	**15**

+ = presence, □ = absence

Size class distribution

The distribution of dbh classes conformed to an reverse 'J' shape curve, with 63.24% of individuals having dbh between 11-30 cm: 104 individuals of 11-20 cm dbh and 35 of 21-30 cm dbh in ACF; 82 individuals of 11-20 cm dbh and 44 of 21-30 cm dbh in JCF (**Figure 2**). The number of individuals with a diameter greater than 50 cm was 12 in ACF and 31 in JCF, totaling 10.26% of total species (**Figure 2**).

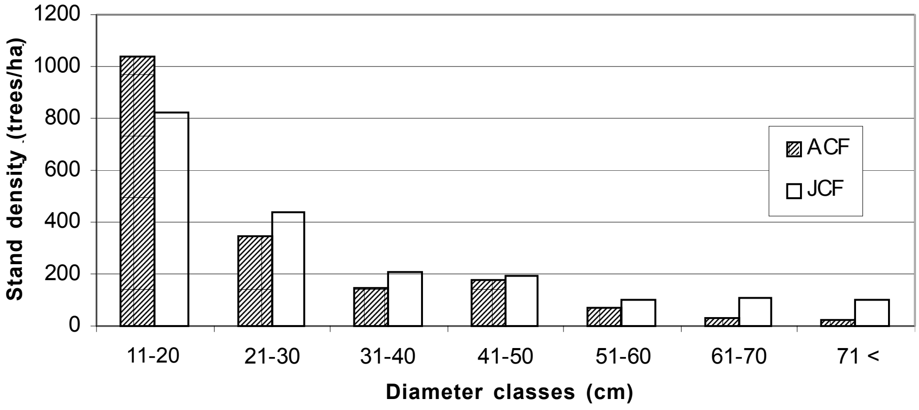

FIGURE 2. Distribution of tree in different size classes

Dominance diversity curve

Species dominance related to the availability of suitable niche and resource apportionment in a community has often been interpreted from the dominance diversity curve (D-D curve). D-D curves for ACF and JCF (**Figure 3**) were found consistent with the normal distribution model of Preston (1948), i.e., relatively few species had a high IVI. These curves illustrate resource partitioning among the various species (Verma et al. 2001).

Species diversity

Table 4 depicts the plant species richness, Shannon-Weiner diversity index, Simpson's diversity index, Jaccard's coefficient and Hill's diversity index of the two community forests. Maximum species richness (15) was observed in JCF while the minimum (12) in ACF. The Shannon-Weiner diversity index was 3.02 in JCF and 2.36 in ACF, while the concentration of dominance Simpson diversity index for JCF was 0.82 and 0.70 for ACF. Jaccard's coefficient (J) was 0.65. Hill diversity numbers N0, N1 and N2 were 12, 10.59 and 1.42 respectively in ACF.

Discussion

While square plots are usually superior for correlating plant communities with local environmental variables (Ferreira and Merona 1997), various shapes and sizes of plots have been selected for other studies (**Table 5**). In Nepal, most studies designed for the study of diversity or family/species abundance (including the present) have employed square sample plots. Comparison of quantitative data from the present study to those collected at other forest sites has been shown in **Table 5**.

For both surveyed sites, the slope of the curve relating species and area declined as sample area increased. The species area curves for ACF and JCF were more or less consistent with a gradual increase in the number of species with area, initially up to 600 m^2,

TABLE 2. Quantitative analysis of vegetation of Amaldapani community forest

Species name	D (tree/ha)	F (%)	BA (m^2 ha^{-1})	RD (%)	RF (%)	RBA (%)	Mean Ht (m)	IVI
a. *Pinus wallichiana*	1000	90	40.22	47.61	17.30	44.67	8.11	109.58
b. *Cedrus deodara*	440	90	14.38	20.95	17.30	15.97	8	54.22
c. *Abies spectabilis*	250	80	8.33	11.90	15.38	9.24	7.75	36.53
d. *Populus ciliata*	90	50	5.17	4.28	9.61	5.74	9.2	19.63
e. *Taxus wallichiana*	80	50	3.46	3.80	9.61	3.84	7.4	17.25
f. *Quercus semecarpifolia*	70	30	6.98	3.33	5.76	7.75	9	16.84
g. *Betula utilis*	60	30	3.58	2.85	5.76	3.97	9	12.58
h. *Aesculus indica*	40	40	1.48	1.90	7.69	1.64	7	11.23
i. *Tsuga dumosa*	30	20	3.55	1.42	3.84	3.94	10.5	9.20
j. *Juglans regia*	20	20	2.32	0.95	3.84	2.57	9.5	7.36
k. *Rhododendron arboreum*	10	10	0.37	0.47	1.92	0.41	6	2.80
l. *Prunus* species	10	10	0.23	0.47	1.92	0.25	7	2.64
Total	**2100**	**520**	**90.07**	**99.93**	**99.93**	**99.99**		**299.86**

D = density, F = frequency, BA = basal area, RD = relative density, RF = relative frequency, RBA = relative basal area, IVI = importance value index

TABLE 3. Quantitative analysis of vegetation of Juphal community forest

Species name	D (tree/ha)	F (%)	BA (m^2 ha^{-1})	RD (%)	RF (%)	RBA (%)	Mean Ht. (m)	IVI
a. *Abies spectabilis*	510	80	53.09	24.40	16.32	34.87	13.25	75.59
b. *Quercus semecarpifolia*	410	60	38.67	19.61	12.24	25.46	11.5	57.31
c. *Pinus wallichiana*	400	70	10.68	19.13	14.28	7.01	7.28	40.42
d. *Taxus wallichiana*	280	60	4.63	13.39	12.24	3.04	7	28.67
e. *Tsuga dumosa*	100	50	13.19	4.78	10.20	8.69	14	23.67
f. *Populus ciliata*	90	40	1.75	4.30	8.16	1.15	8.25	13.61
g. *Cedrus deodara*	60	20	8.50	2.87	4.08	5.56	14	12.51
h. *Betula utilis*	60	20	5.11	2.87	4.08	3.39	10.5	10.34
i. *Acer caesium*	50	20	6.41	2.39	4.08	4.23	14	10.07
j. *Juniperus recurva*	40	10	5.37	1.91	2.04	3.53	15	7.48
k. *Picea smithiana*	20	20	2.07	0.95	4.08	1.36	10	6.39
l. *Juglans regia*	40	10	1.88	1.91	2.04	1.23	8	5.18
m. *Pyrus* species	10	10	0.40	0.47	2.04	0.25	9	2.76
n. *Prunus* species	10	10	0.14	0.47	2.04	0.09	5	2.60
o. *Rhododendron arboreum*	10	10	0.09	0.47	2.04	0.07	4	2.58
Total	**2090**	**490**	**151.98**	**99.93**	**99.96**	**99.93**		**299.81**

and then appears to be approaching an asymptote indicating that the sampled area is adequate for this specific forest (**Figure 1**). It can be argued that, for conifer dominant forests, sample plots covering one to two hectares are adequate.

Community management of ACF was initiated in 1998, ending a period of uncontrolled exploitation; in JCF, on the other hand, management was initiated in 1995 and has been supported by the indigenous forest management. Community forest management runs under users' forest operational plan and forest act. The operational plan guides and regulates forest management. Despite the institution of community forest management, human disturbance continues in various forms, including grazing, tree felling, fuelwood collection, and encroachment on marginal land. The presence of mature trees (>50 cm dbh) is the result of prolonged forest management in JCF, while the small boles and stumps in ACF are signs of early succession and uncontrolled disturbance before 1998.

TABLE 4. Diversity indices of Amaldapani and Juphal community forests

Diversity indices	Amaldapani CF	Juphal CF	Average
Species richness (S)	12	15	13
Simpson's diversity index (D)	0.70	0.82	0.76
Shannon-Weiner's diversity index (H)	2.36	3.02	2.69
Hill's diversity number			
N0 (species richness)	12	15	13
N1	10.59	20.49	15.54
N2	1.42	1.21	1.31
Jaccard's coefficient (J)		0.65	

At the time of our survey, there were 310 mature trees ha^{-1} in JCF, as compared to 120 ha^{-1} in ACF. The reduced diversity of vegetation can be attributed to the human impact noted above, which was particularly severe due to the close proximity of agricultural lands. Disturbance has been considered an important factor structuring forest communities (Foster 1980) and different levels and types of disturbance have a differential impact on forest communities (Halpern and Spies 1995). Agricultural practices, over and premature harvesting and recreation constitute 18% of the aggregate threat to the plant diversity (Freemark et al. 2001). High human and other biotic pressures are detrimental to the vegetation structure of forests.

A total of 10 plant families were reported in JCF and nine in ACF. Among them, three families (Aceraceae, Betulaceae and Taxaceae) were identified as temperate. Pinaceae was the most diversified family with 28 individuals, five species and five genera, followed by Rosaceae, with three individuals, two species and two genera. *Pinus wallichiana* in ACF contributed the maximum stand density (1000 trees ha^{-1}), or about 50% of the total stand density. Stand density differed slightly among study sites, although there was a broad similarity in major species composition. Density is influenced by various factors, including elevation, soil type, dominant and associated species and human activities (cf. Shrestha et al. 1998). Climatic factors, environmental stability, land use and area and habitat heterogeneity are the factors often discussed as determinants of variability in species richness (Spies and Turner 1999).

In our study areas, the values for total basal area and density were higher than the values (15-60 $m^2 \cdot ha^{-1}$ and 320-2080 trees ha^{-1}) reported by Bhandari et al. (1997) in temperate forests of the Garhwal Himalaya. As vegetation matures, total stand density tends to decrease and the stand increases in height, basal area and volume. Density and dispersion are quite sensitive to size and intensity of disturbance. The remarkable differences in stand density between ACF and JCF were due to the management history. The mean height and total basal area also differed significantly i.e. 8.20 m and 90.07 $m^2 \cdot ha^{-1}$ in ACF and 10.05 m and

TABLE 5. Vegetation characteristics of various forest types

Forest type	Location	Study area (ha) / Plot size (m^2)	Girth size (cm)	T. stand density (trees ha^{-1})	T. basal area (m^2 ha^{-1})	Source
Temperate forests	Mid west Nepal	0.20 / (10x10)	≥ 30	2095	90-152	Present study
Shorea robusta forests	RBNP, Nepal	2.81 / (25x25)	≥ 30	333-385	32-36	Giri et al. (1999)
Shorea robusta forests	MBNP, Nepal	1.20 / (20x20)	≥ 10	1125-1174	32-35	Duwadee et al. (2002)
Castanopsis hystrix forests	MBNP, Nepal	0.60 / (10x10)	≥ 30	1921-3075	23-36	Shrestha et al. (2002)
Shorea-Castanopsis forests	MBNP, Nepal	3.84 / (20x20)	≥ 10	1425	59	Chaudhary and Kunwar (2002)
Riverine forests	KTWR, Nepal	1.84 / (20x20)	≥ 30	472-652	20-31	Karki et al. (2001)
Temperate forests	Kavre, Nepal	0.37 / (10 m radius)	-	5-132	8-19	Shrestha et al. (1998)
Himalayan forests	Nainital, India	0.10 / (10x10)	≥ 30	620	16.8	Khera et al. (2001)
Dry evergreen forests	Southern India	0.50 / (50x20)	≥ 20	280-1130	11-36	Visalakshi (1995)
Dry evergreen forests	Southern India	2.00 / (100x50)	≥ 10	453-819	11-20	Parthasarathy and Sethi (2001)
Himalayan forests	Garhwal, India	0.20 / (10x10)	≥ 10	792-1111	56-126	Pande (2001)
Semi evergreen forests	Eastern ghat, India	4.00 / (10x10)	≥ 30	367-667	26-42	Kadavul and Parthasarathy (1999)
Upland forests	Jau NP, Amazonia	4.00 / (40x10)	≥ 30	160-178	32-40	Ferreira and Prance (1998)

T = total, RBNP = Royal Bardiya National Park, MBNP = Makalu Barun National Park, KTWR = Koshi Tappu Wildlife Reserve, NP = National Park

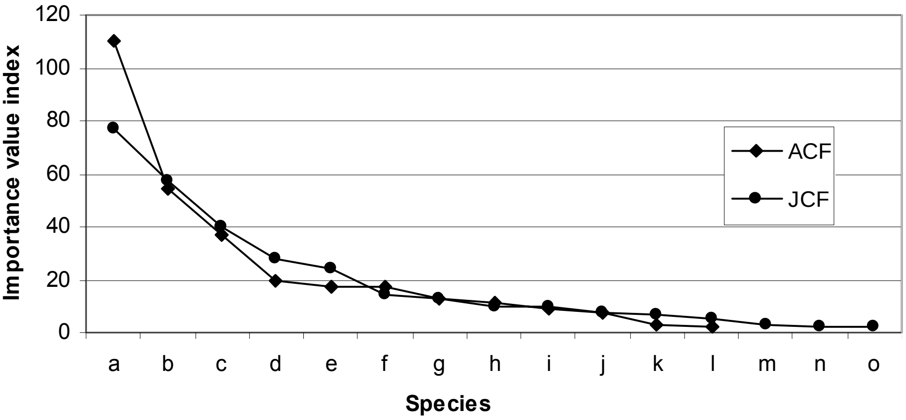

FIGURE 3. Dominance diversity curve for the tree species given in Table 2 and 3

151.98 $m^2 \cdot ha^{-1}$ in JCF, respectively. The higher total basal area in JCF was the result of the high proportion of trees of diameter greater than 50 cm (**Figure 2**). Trees with larger diameter have wider canopy cover and as canopy becomes close plant competition intensifies and slow growing trees become stunt and die. The wide range in basal area in JCF shows its heterogeneity.

The presence of a large number of trees in the 10-30 cm diameter class indicates that the study area is in mid-level succession. However, there were few trees in the small size classes (<10 cm): only 120 ha^{-1} in JCF and 260 ha^{-1} in ACF. The paucity of small trees indicates that the forest is not sustaining itself. This may be due to the recurrent human disturbance. The extent of disturbance can be attributed to easy access, inefficient management, and lack of alternative sources of forest products. Local people involved in community forestry programmes, on the other hand, generally protect their forests and access to government managed forests out of self-interest (Shrestha and Paudel 1996, Kunwar 2002). Strengthening local control and governmental oversight is urgently needed to assure long-term sustainability.

The dominance of four species (in descending order, *A. spectabilis, P. wallichiana, Q. semecarpifolia* and *C. deodara*), together with their contribution of 75% of the total stand density, 75% of frequency, 74% of total basal area and 67% of IVI, indicates that these species utilize the majority of forest space and resources (**Figure 3**). Of these four dominant species, three belongs to the Pinaceae family and one to the Fagaceae. The dominance of Pinaceae in Amaldapani and Juphal community forests of Dolpa district is one of the characteristic features of coniferous forest in temperate climate zones.

The top niches were occupied by *P. wallichiana* and *C. deodara*, in ACF, and *A. spectabilis* and *Q. semecarpifolia* in JCF. In both sites, the remaining species shared the intermediate and lower niches more or less equally. The gentle slope of D-D curve (**Figure 3**) observed in JCF indicates steady growth of trees, while sharp depression of the curve representing the small size classes of ACF trees is the result of human disturbance. The distribution pattern of tree species was similar, with the notable exceptions of *P. wallichiana* in site ACF and *A. spectabilis* in JCF. Such pattern of distribution is a general characteristic of nature (Odum 1971) while the conifer predominates the others in nutrient absorption in temperate forests (Saxena and Singh 1984).

Under severely disturbed conditions, the age class distribution of colonizers may be narrow, while individuals of diverse ages are found where disturbance is less severe (**Figure 2**). A total of seven size-classes of tree species with an interval of 10 cm dbh were recognized for each forest site; such a large number of size-classes is the result of better protection due to community forest management. The proportion of different age-classes of plant species across a landscape and over time is one of the fundamental characteristics of the vegetation mosaic (Spies and Turner 1999). The reverse 'J' shaped size-class distribution curve was obtained which is typical of all types of forests (Ferreira and Merona 1997).

If one compares the Shannon diversity values observed in the present study with the values reported (between 1.16-3.4) for temperate forests by Saxena and Singh (1982), the present study falls within the earlier reported range. Biodiversity was relatively low in ACF. The impact of human activities such as firewood collection, tree felling and cattle browsing accounts for the reduced diversity of vegetation in ACF. The similarity index of the studied sites reveals a remarkable degree of overlap in vegetation composition and structure. This may reflect the similar microclimates of the surveyed sites.

Conclusion

Differences in number of individual trees, species, families, total basal area, and vegetation composition may be due to differences in local environmental variables (disturbance gradients and vegetation characteristics). The dominance of *Pinus wallichiana, Abies spectabilis, Quercus semecarpifolia* and *Cedrus deodara,* with their major contribution to total basal area, frequency, stand density and IVI, indicates that these are frequent in the studied forests. The contribution of seven species to total species diversity and of three species to dominant species list indicated that the study area vegetation is conifer dominant. Although the forest existed in several girth classes, there was a reduced number of small tree individuals (<10 cm) which may be attributed to recurrent disturbances (marginal land encroachment, grazing and firewood collection); this dearth of immature individuals indicates impaired sustainability of the surveyed forests even though both are community managed. Better management and local control over the forests is therefore urgently needed. The present study is a modest effort focusing on a small area; large-scale studies are needed to help determine appropriate conservation and management strategies for the betterment of the existing population and biodiversity of forests. ■

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