ASSESSMENT OF PLANT DIVERSITY AND PRIORITIZATION OF COMMUNITIES FOR CONSERVATION IN MORNAULA RESERVE FOREST

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Abstract. Assessment of plant diversity of the Reserve Forests of the west Himalaya and prioritization of communities for conservation have not been given much attention. Therefore, the study has been conducted in a biodiversity rich Mornaula Reserve Forest between 1500-2200m to analyse the structure, composition of the forest communities including richness of economically important, native, endemic and rare-endangered species, and prioritize communities for conservation. A total of 123 sites were sampled. For each site, habitat characteristics, altitude and dominant species have been given. From the sampled sites, 289 species (37 trees; 37 shrubs; and 215 herbs) and 31 forest communities have been recorded. The density of trees ranged from 340-2438 Ind ha^{-1} and TBA from 19.52-234.31 Ind m^2. The densities of saplings ranged from 340.00-2277.00 Ind ha^{-1} and seedlings 266.00-1571.00 Ind ha^{-1}; shrubs 357-1156 Ind ha^{-1} and herbs 21.73-431.04 Ind m^{-2}. The richness of the trees ranged from 3-27, shrubs, 8-36, herbs, 17-145, seedlings, 3-22, and saplings, 2-21. Species diversity for trees ranged from 0.99-2.93, seedlings, 0.86-2.65, saplings, 0.44-2.78, shrubs, 1.94-4.43 and herbs, 1.42-4.66. These recorded values were almost comparable with the studies conducted in sub-tropical, temperate and sub-alpine regions of the west Himalaya. In some cases the values were slightly higher than the reported values. The communities have been prioritized for conservation based on the species richness, nativity, endemism, economically important and rare-endangered species. Among, all the prioritized communities, *Rhododendron arboreum* community supports maximum species including native, endemic, economically important and rare-endangered species. In view of the high socio-economic and conservation values of the identified communities, monitoring of these communities at least for a period of five years and development of appropriate strategy and action plan for the conservation and management have been suggested.

Keywords: *Reserve Forest, communities, diversity, native, rare-endangered, socioeconomic, prioritization, conservation*

Introduction

The Indian Himalayan Region (IHR) is very well known throughout the globe due to its representative, unique, natural, and socio-economically important flora and fauna [1]. Due to this peculiar feature, the eastern Himalaya has been identifies one of the biodiversity Hot Spots [2]. This rich biodiversity is being utilized by the inhabitants of the region for medicine, as wild edible (food), fodder, fuel, timber, in making agriculture tools, religious and various other purposes [3, 4, 1]. With the increasing human population, the demand of the economically important biodiversity is increasing fast. Collection of fodder and fuel species from the forests has been identified one of the chronic problems in the IHR for the degradation of forest [5]. The anthropogenic pressures including heavy grazing coupled with the natural calamities have lead the degradation of natural habitats of many species to a great extent. Such practices are discoursing the moisture loving species and promoting the hardy and spiny species having least value for the society. This loss of biodiversity and changing pattern of

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vegetation has necessitated assess the biodiversity of the region and prioritize habitats, communities and species for conservation.

In general, structural and functional diversity of the some parts of the IHR have been evaluated by various workers [6-33]. However, the protected areas of the IHR including Reserve Forests have been very poorly evaluated for the structural and functional diversity [34] except a few studies carried out in Nanda Devi Biosphere Reserve (NDBR) and Askot Wildlife Sanctuary (AWLS) [35-39]. Further, studies integrating compositional, structural and functional diversity, native, endemic, economically important and rare-endangered species, and prioritization of community for conservation have been attempted in a few protected areas [37, 38]. Therefore, the attempt has been made to; (i) study the site/habitat characteristics; (ii) assess the diversity and distribution pattern of the species; (iii) delineate forest communities; (iv) study the distribution pattern of economically important, native, endemic and rare-endangered species within the identified communities; and (v) prioritize communities for conservation.

Materials and methods

Identification and selection of transects, sites and habitats

Four transacts *i.e.,* (i) Harinagar to Nartola; (ii) Bercheula-Lohanigaon-Mornaula; (iii) Khakar-Bheutania-Tarani; (iv) Dole-Damar-Mornaula were selected along the trails of the villages on account of typical topography and inaccessibility of the area. The sites were selected on each and every accessible aspect along transacts between 1500-2200m. The habitats were identified on the basis of physical characters and dominance of the vegetation. Sites having closed canopy with high percent of humus and moisture were considered as moist habitats whereas low percent of the same as dry habitats. The sites having >50% boulders of the ground cover had been considered as bouldary habitat, and the sites facing high anthropogenic pressures considered as degraded habitats.

Survey, sampling, identification and analysis of data

The field surveys and samplings were conducted between 2002 and 2004 within the selected sites along the transacts. In each site, a plot of 50x50m was laid. Trees, saplings and seedlings were sampled by randomly placed 10, 10x10m quadrates; shrubs by 10, 5x5m quadrates; herbs by 20, 1x1m quadrates in each plot. The size and number of quadrates was determined following [40]. For the collection of data from these quadrates standard ecological methods [41, 42, 40, 43, 35, 39, 38] were followed. From each site, samples of each species were collected and identified in the Institute with the help of florulas and research papers [44, 45, 46, 29].

For trees, basal area and Importance Value Index (IVI) have also been computed. IVI has been calculated as the sum of relative frequency, relative density and relative basal area. The abundance data of different sites were pooled to get community averages in terms of density, total basal area and IVI. Communities were identified based on the IVI. A species contributing 50 % or >50 % of the total IVI in a particular site/habitat is considered as a single species dominated community, <50 % of the total IVI is named as a mixed community.

Species diversity (H') and Concentration of dominance (Cd)

Species richness is the total number of species in a particular community. Species diversity was determined by Shannon Wiener's information statistic (H') [47] and concentration of dominance by [48]

Identification of native, endemic and rare-endangered species

Native species were identified following [49, 1, 50, 28, 29]. The species having their origin in the Himalayan region have been considered as natives. Endemism is based on the distribution range of the species [51, 1, 36]. The species restricted to the IHR have been considered as endemic whereas those with extended distribution to neighbouring countries/States as near endemic. Rare-Endangered species has been identified based on habitat specificity, population size, distribution range and anthropogenic pressures [52, 53, 36].

Prioritization of communities

Based on the occurrence of number of species (species richness), economically important, native, endemic and rare-endangered species, within the communities, prioritization of the communities for conservation has been done.

Results and discussion

Site and habitat characteristics

Site/habitat characteristic, dominant species, altitude, slope and aspect of all four transects are presented *(Table 1)*. The altitude ranged between 1500-2200m and majority of the study sites fall in northeast aspect. In all five habitats *i.e.*, shady moist, dry, riverine, bouldary, and degraded were represented in the area *(Table 1)*.

Community diversity and distribution pattern

Thirty-one forest communities have been identified between 1500-2200m in the Mornaula Reserve Forest (MRF). The community types, altitudinal distribution, sites and habitat representation and major tree associates are presented in *(Table 2)*. *Rhododendron arboreum* community represented maximum sites (26), followed by *Quercus leucotrichophora* (18 sites), and *Pinus roxburghii* (16 sites), and the remaining communities showed less representation of sites. Among the communities *Rhododendron arboreum*, *Quercus leucotrichophora*, *Pinus roxburghii*, *Quercus floribunda*, *Cupressus torulosa*, and *Quercus leucotrichophora*-*Rhododendron arboreum* mixed, showed comparatively wide altitudinal range of distribution.

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Table 1. *Physical characteristics of sites in the MRF*

Transact 1: Nartola to Harinagar

S.No.	Altitude (m)	Slope (°)	Habitat (s)	Aspect	Dominant Species
1	2130	10	D	E	*Quercus floribunda* & *Quercus leucotrichophora*
2	2130	20	B	E	*Quercus leucotrichophora* & *Quercus floribunda*
3	2130	5	B	SW	*Quercus floribunda* & *Quercus leucotrichophora*
4	2130	15	B	S	*Rhododendron arboreum* & *Quercus floribunda*
5	2130	20	B	N	*Rhododendron arboreum* & *Quercus floribunda*
6	2130	25	B	NE	*Quercus floribunda* & *Betula alnoides*
7	2120	20	B	SE	*Betula alnoides*, *Quercus floribunda*, *Lyonia ovalifolia*
8	2120	25	B	SE	*Rhododendron arboreum*, *Quercus floribunda*, *Alnus nepalensis*
9	2120	45	B	NE	*Quercus leucotrichophora*, *Rhododendron arboreum*, *Betula alnoides*
10	2125	25	D	S	*Quercus leucotrichophora*
11	2120	15	B	NE	*Quercus leucotrichophora* & *Quercus floribunda*
12	2115	10	C	NE	*Quercus floribunda*
13	2115	30	B	NE	*Quercus floribunda*
14	2120	30	B	NW	*Rhododendron arboreum*
15	2125	15	B	SE	*Rhododendron arboreum*
16	2125	20	B	E	*Quercus leucotrichophora* & *Rhododendron arboreum*
17	2125	35	B	SE	*Rhododendron arboreum* & *Quercus leucotrichophora*
18	2070	45	B	NE	*Abies pindrow*
19	2070	40	B	NW	*Abies pindrow* & *Quercus leucotrichophora*
20	2125	40	B	NW	*Quercus leucotrichophora* & *Rhododendron arboreum*
21	2125	40	B	E	*Rhododendron arboreum* & *Quercus leucotrichophora*
22	2120	35	B	SW	*Abies pindrow*
23	2125	5	D	NW	*Rhododendron arboreum* & *Quercus leucotrichophora*
24	2120	20	C	SE	*Persea duthiei* & *Rhododendron arboreum*

Transact 2: Bercheula – Lohanigaon-Mornaula

S.No.	Altitude (m)	Slope (°)	Habitat (s)	Aspect	Dominant Species
1	1900	40	A	S	*Pinus roxburghii*
2	1860	10	C	E	*Rhododendron arboreum*, *Daphniphyllum himalayense*
3	1870	40	B	N	*Rhododendron arboreum*, *Aesculus indica*, *Quercus floribunda*
4	1870	40	A	NE	*Pinus roxburghii*
5	1890	20	C	NE	*Rhododendron arboreum*
6	1900	40	A	NE	*Pinus roxburghii*
7	1890	20	C	NW	*Alnus nepalensis*
8	1970	45	B	NE	*Rhododendron arboreum*
9	1970	40	B	NE	Rhododendron arboreum
10	1960	40	D	NW	*Pinus roxburghii*
11	1960	40	B	W	*Cedrus deodara*
12	1950	50	B	E	*Cupressus torulosa*
13	2050	20	B	S	*Cedrus deodara*
14	2060	30	C	SE	*Rhododendron arboreum*
15	2040	20	C	SE	*Alnus nepalensis*
16	2070	40	A	S	*Quercus leucotrichophora*
17	2090	35	A	S	*Pinus roxburghii*
18	2095	45	B	NW	*Rhododendron arboreum*

Transact 2: Bercheula – Lohanigaon-Mornaula

S.No.	Altitude (m)	Slope (°)	Habitat (s)	Aspect	Dominant Species
19	2090	40	E	SW	*Pinus roxburghii*
20	2090	40	A	W	*Pinus roxburghii*
21	2100	20	B	W	*Rhododendron arboreum*
22	2090	35	B	N	*Rhododendron arboreum* & *Myrica esculenta*
23	2095	35	B	SE	*Cupressus torulosa*
24	2070	35	C	NW	*Rhododendron arboreum* & *Alnus nepalensis*
25	2070	35	A	W	*Pinus roxburghii*
26	2095	45	B	E	*Myrica esculenta*
27	2095	25	B	SW	*Cupressus torulosa*
28	2095	35	B	SE	*Myrica esculenta*
29	2080	45	B	SW	*Cupressus torulosa*
30	2105	60	B	N	*Rhododendron arboreum*
31	2105	50	B	NW	*Rhododendron arboreum*
32	2110	40	B	NE	*Rhododendron arboreum*
33	2110	25	B	W	*Rhododendron arboreum*
34	2120	35	C	SE	*Persea duthiei* & *Litsea umbrosa*
35	2115	20	C	NE	*Betula alnoides* & *Rhododendron arboreum*
36	2115	20	B	N	*Rhododendron arboreum* & *Lyonia ovalifolia*
37	2105	25	B	NE	*Betula alnoides* & *Rhododendron arboreum*
38	2105	20	B	NE	*Rhododendron arboreum*
39	2100	5	C	SE	*Acer cappadocicum* & *Persea duthiei*
40	1990	10	C	SE	*Quercus floribunda*
41	1985	40	B	NE	*Quercus leucotrichophora*
42	1990	15	B	S	*Rhododendron arboreum*
43	2105	15	B	E	*Quercus floribunda* & *Quercus leucotrichophora*
44	2110	15	D	SW	*Quercus floribunda*

Transact 3: Khakar-Bheutania-Tarani

S.No.	Altitude (m)	Slope (°)	Habitat (s)	Aspect	Dominant Species
1	2010	15	C	E	*Quercus floribunda*
2	2020	45	A	S	*Quercus floribunda*
3	2030	35	A	E	*Quercus floribunda* & *Quercus leucotrichophora*
4	2060	45	B	NE	*Rhododendron arboreum*
5	2080	35	C	E	*Rhododendron arboreum* & *Betula alnoides*
6	2100	35	A	SE	*Quercus floribunda*
7	2100	50	B	NE	*Rhododendron arboreum*
8	2075	35	C	NE	*Rhododendron arboreum*
9	2100	25	D	N	*Rhododendron arboreum*
10	2100	45	C	NE	*Rhododendron arboreum*
11	2100	40	B	NW	*Rhododendron arboreum*
12	2110	25	B	NW	*Quercus leucotrichophora*
13	2115	25	B	NW	*Quercus leucotrichophora*
14	2110	5	B	E	*Persea duthiei* & *Rhododendron arboreum*
15	2015	50	A	S	*Rhododendron arboreum* & *Quercus floribunda*
16	2010	40	C	N	*Rhododendron arboreum*
17	2030	40	A	E	*Pinus roxburghii*
18	1940	30	B	N	*Quercus floribunda*
19	1960	45	D	N	*Pinus roxburghii*
20	1960	50	D	SW	*Pinus roxburghii*
21	1940	35	D	E	*Quercus floribunda*

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Transact 3: Khakar-Bheutania-Tarani

S.No.	Altitude (m)	Slope (°)	Habitat (s)	Aspect	Dominant Species
22	1960	55	A	SW	*Pinus roxburghii*
23	1950	50	A	E	*Pinus roxburghii*
24	1940	10	C	SE	*Daphniphyllum himalayense*
25	1650	50	B	N	*Quercus leucotrichophora*
26	1650	70	B	SW	*Quercus leucotrichophora*
27	1720	40	A	SW	*Quercus leucotrichophora*
28	1790	45	B	NW	*Quercus leucotrichophora*
29	1790	60	B	SW	*Myrica esculenta* & *Quercus leucotrichophora*
30	1790	30	C	NE	*Quercus leucotrichophora* & *Rhododendron arboreum*
31	1800	65	B	NW	*Quercus leucotrichophora*
32	1840	50	B	W	*Quercus leucotrichophora*
33	1860	70	A	S	*Pinus roxburghii*

Transact 4: Dol-Damar-Mornaula

S.No.	Altitude (m)	Slope (°)	Habitat (s)	Aspect	Dominant Species
1	1960	15	A	E	*Quercus leucotrichophora*
2	1950	50	B	N	*Cedrus deodara*
3	1910	15	C	N	*Cedrus deodara*
4	2030	30	A	S	*Pinus roxburghii*
5	2030	65	B	SE	*Cupressus torulosa*
6	2025	40	C	SE	*Quercus leucotrichophora*
7	2025	35	A	SE	*Quercus leucotrichophora*
8	2070	50	B	S	*Quercus leucotrichophora*
9	2060	70	A	SW	*Quercus leucotrichophora*
10	2080	50	B	SW	*Rhododendron arboreum*
11	2080	50	B	NW	*Myrica esculenta*
12	2085	45	A	SW	*Pinus roxburghii*
13	2100	40	B	N	*Rhododendron arboreum*
14	2100	10	B	N	*Quercus leucotrichophora* & *Rhododendron arboreum*
15	2105	15	D	NE	*Quercus leucotrichophora* & *Rhododendron arboreum*
16	2110	30	B	NE	*Rhododendron arboreum*
17	2120	15	C	NE	*Rhododendron arboreum*
18	2110	20	C	NE	*Persea odoratissima*
19	2110	15	B	E	*Litsea umbrosa* & *Rhododendron arboreum*
20	2110	15	B	E	*Rhododendron arboreum* & *Quercus floribunda*
21	2110	10	C	SE	*Persea odoratissima*
22	2110	45	B	E	*Rhododendron arboreum*

Abbreviations used: SR= Site representation; A= Dry habitat; B= Moist habitat; C= Riverine habitat; D= Degraded habitat; and E= Bouldary habitat; E=East; N=North; W=West; S=South; NE=North east; SE=South east; NW=North west; SW=South west; and SE=South east

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Table 2. *Community types, distribution and major tree associates*

Community types	SR	Altitud. range (m)	Habitat (s)	Density (Ind/ha)					TBA (Ind m^2)	Major associate species
				Trees	Seedlings	Saplings	Shrubs	Herbs		
Abies pindrow	3	2120-2200	B	1128	964	1644	9522	72.19	135.49	*Litsea umbrosa*, *Quercus floribunda*
Acer cappadocicum-Persea duthiei-Quercus floribunda mixed	1	2100	C	1100	1348	1290	9240	51.54	125.20	*Symplocos chinensis*, *Aesculus indica*, *Rhododendron arboreum*
Aesculus indica-Litsea umbrosa-Quercus leucotrichophora mixed	1	1985	B	710	1285	1310	8100	38.83	46.21	*Quercus floribunda*, *Acer cappadocicum Carpinus viminea*
Alnus nepalensis	2	1890-2040	C	1215	693	1265	4525	131.65	229.76	*Rhododendron arboreum*, *Lyonia ovalifolia*, *Litsea umbrosa*, *Daphniphyllum himalayense*, *Carpinus viminea*
Betula alnoides	3	2105-2115	B, C	1282	1556	1470	10528	55.47	155.71	*Persea odoratissima, Quercus floribunda, Daphniphyllum himalayense, Ulmus wallichiana, Rhododendron arboreum*
Cedrus deodara	4	1910-2050	B, C, D	1033	712	758	8863	103.65	122.89	*Quercus leucotrichophora*, *Ilex dipyrena*, *Myrica esculenta*
Cupressus torulosa	5	1695-2095	B, C	973	947	692	8710	181.23	112.83	*Quercus leucotrichophora, Rhododendron arboreum*
Daphniphyllum himalayense	1	1940	C	1010	710	690	5630	75.35	82.52	*Litsea umbrosa*, *Aesculus indica*, *Ilex dipyrena*
Litsea umbrosa-Rhododendron arboreum-Quercus leucotrichophora mixed	1	2110	B	1010	837	370	8500	61.85	124.27	*Stranvaessia naussia*, *Acer cappadocicum*, *Quercus floribunda*
Myrica esculenta	1	2080	B	760	697	1580	9490	21.73	81.78	*Rhododendron arboreum*, *Quercus leucotrichophora*
Myrica esculenta-Quercus leucotrichophora-Rhododendron arboreum mixed	1	1790	B	590	635	860	5300	32.30	35.33	*Myrica esculenta*, *Quercus leucotrichophora*, *Rhododendron arboreum*
Myrica esculenta-Rhododendron arboreum mixed	3	2060-2095	B, C	1543	884	1125	5315	102.80	189.54	*Quercus leucotrichophora*, *Quercus floribunda*
Persea duthiei	2	2120	C	1055	983	2120	8515	94.55	99.67	*Persea odoratissima*, *Daphniphyllum himalayense, Litsea umbrosa, Quercus leucotrichophora*
Persea duthiei-Rhododendron arboreum mixed	1	2110	B	1060	960	777	2070	40.05	109.69	*Ilex dipyrena*, *Viburnum mullaha*, *Pyrus pashia*
Persea odoratissima	3	2110	B, C	846	914	2277	5807	109.18	132.42	*Litsea umbrosa*, *Quercus floribunda*, *Meliosma pungens*

Community types	SR	Altitud. range (m)	Habitat (s)	Density (Ind/ha)					TBA (Ind m^2)	Major associate species
				Trees	Seedlings	Saplings	Shrubs	Herbs		
Pinus roxburghii	16	1840-2090	A, B, C, D, E	1453	1488	625	8930	243.78	138.73	*Rhododendron arboreum*, *Quercus leucotrichophora*, *Acer oblongum*, *Quercus floribunda*
Pinus roxburghii-Quercus leucotrichophora mixed	1	2070	A	1200	732	830	357	76.48	142.39	*Rhododendron arboreum*, *Symplocos chinensis*
Quercus floribunda	9	1940-2130	A, B, C, D	1907	983	2242	9856	431.04	190.35	*Quercus leucotrichophora*, *Myrica esculenta*, *Daphniphyllum himalayense*
Quercus floribunda-Quercus leucotrichophora mixed	2	1990-2130	B	1240	572	1378	4265	36.20	127.57	*Rhododendron arboreum*, *Lyonia ovalifolia*
Quercus floribunda-Rhododendron arboreum mixed	3	1940-2105	B, D	1222	747	747	7263	128.18	117.75	*Quercus leucotrichophora*, *Persea duthiei*, *Symplocos chinensis*, *Lyonia ovalifolia*
Quercus leucotrichchophora-Quercus floribunda mixed	1	2130	B	1250	960	960	704	28.88	133.89	*Lyonia ovalifolia*, *Symplocos chinensis*, *Pyrus pashia*
Quercus leucotrichophora	18	1650-2130	A, B, C, D	1930	1371	722	10153	182.79	158.31	*Pinus roxburghii*, *Quercus floribunda*, *Myrica esculenta*, *Rhododendron arboreum*
Quercus leucotrichophora-Rhododendron arboreum mixed	3	1790-2125	B, C	1607	1571	1078	6603	61.75	156.76	*Myrica esculenta*, *Betula alnoides*, *Quercus floribunda*, *Litsea umbrosa*
Rhododendron arboreum	26	1860-2125	B, C, D	2438	1171	657	11056	264.25	234.31	*Pinus roxburghii*, *Myrica esculenta*, *Acer oblongum*, *Aesculus indica*, *Quercus floribunda*
Rhododendron arboreum - Quercus floribunda mixed	6	1990-2130	B	1977	1362	1003	10580	110.99	175.43	*Lyonia ovalifolia*, *Persea odoratissima*, *Quercus leucotrichophora*
Rhododendron arboreum-Alnus nepalensis mixed	1	2070	C	1080	674	830	4630	43.28	195.35	*Quercus floribunda*, *Persea duthiei*, *Betula alnoides*
Rhododendron arboreum-Betula alnoides mixed	1	2080	C	1420	910	350	9310	69.50	221.66	*Persea duthiei*, *Alnus nepalensis*, *Stranvaessia naussia*, *Quercus leucotrichophora*
Rhododendron arboreum-Myrica esculenta mixed	1	2090-2100	B	1290	1066	888	4460	330.75	154.12	*Quercus floribunda*, *Cedrus deodara*, *Cupressus torulosa*, *Quercus leucotrichophora*
Rhododendron arboreum-Persea odoratissima mixed	1	2110	B	920	1319	1880	5450	42.03	104.69	*Quercus leucotrichophora*, *Litsea umbrosa*
Quercus floribunda-Rhododendron arboreum- Pinus roxburghii-Quercus leucotrichophora mixed	1	2015	A	1110	266	340	4530	91.95	85.64	*Ilex dipyrena*, *Lyonia ovalifolia*
Rhododendron arboreum-Quercus leucotrichophora mixed	1	2125-2160	C, D	340	557	1510	6710	43.48	19.52	*Pinus roxburghii*, *Symplocos chinensis*

Abbreviations used: SR= Site representation; A= Dry habitat; B= Moist habitat; C= Riverine habitat; D= Degraded habitat; and E= Bouldary habitat

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Vegetation composition

Species richness

In all, 289 species (37 trees; 37 shrubs; and 215 herbs) were recorded. Richness of trees ranged from 3-27; shrubs from 8-36, herbs from 17-145, seedlings from 3-22, and saplings from 2-21. The values for trees were higher than the earlier reported values [54, 20, 22] but comparable to the values reported by [36, 38, 39] from high altitude areas, and also comparable to the sub-tropical and temperate regions (*i.e.,* 9-28) [14, 33]. For shrubs, the values were slightly higher than earlier records, (4-22) from subtropical and temperate forests [22, 23, 15]. For herb layer, the values were higher than previous records [54]. The high richness of trees and shrubs may be due to diverse habitats and suitable edaphic and climatic factors supporting growth and survival of the species.

Richness of native and endemic species

Of the total 289 species, 206 species were native to the Himalayan Region; 83 species were non-natives; 117 species were near endemic; and only two species *i.e., Goldfussia dalhoussiana*, and *Onychium fragile* were endemic. Of the natives, 29 species were trees, 26 species were shrubs and 151 species were herbs. The high percentage of native species in the area may be due to unique topography, inaccessibility and distance from road heads.

Among all the communities, *Rhododendron arboreum* community supports maximum, native and endemic species, followed by *Quercus leucotrichophora*, *Quercus leucotrichophora*, *Quercus floribunda*, *Rhododendron arboreum*-*Quercus floribunda* mixed, *Pinus roxburghii*, *Quercus floribunda*-*Rhododendron arboreum*, *Cupressus torulosa*, *Betula alnoides*, *Persea duthiei*, *Cedrus deodara*, *Myrica esculenta*-*Rhododendron arboreum* mixed, and *Alnus nepalensis*, communities *(Table 3).*

Table 3. *Richness of economically important, native, endemic, near endemic and rare endangered species in prioritized communities*

Community types	**No. of Species**				
	Native	Economically important	Endemic	Near endemic	Rare endangered
Rhododendron arboreum	119	127	2	33	6
Quercus leucotrichophora	97	98	2	25	6
Quercus floribunda	73	85	1	21	5
Rhododendron arboreum-Quercus floribunda mixed	70	90	1	18	4
Pinus roxburghii	67	59	1	16	3
Quercus floribunda-Rhododendron arboreum mixed	55	104	1	14	5
Cupressus torulosa	55	69	1	19	2
Betula alnoides	51	67	1	20	2
Persea duthiei	51	52	1	18	4
Cedrus deodara	46	59	1	11	1
Myrica esculenta-Rhododendron arboreum mixed	45	68	1	18	2
Alnus nepalensis	43	58	1	10	4

Structural pattern

In general, density, TBA, and IVI of trees and density of saplings, seedlings, shrubs and herbs have been presented *(Table 2).* The tree density in the communities ranged from 340-2438 Ind ha^{-1}, TBA ranged from 19.52-234.31 Ind m^2, sapling density from 340.00-2277.00 Ind ha^{-1} and seedling density from 266.00-1571.00 Ind ha^{-1}; shrub density ranged from 357-1156 Ind ha^{-1} and herb density from 21.73-431.04 Ind ha^{-1}; Tree density and TBA were slightly higher than the earlier reported values (320-1670 Ind ha^{-1} and 360-1787.50 Ind ha^{-1}) from low and high altitude forests of west Himalaya [10, 8, 11, 16, 54, 22, 36]. The total shrub density for MRF is lower than the reported range for the Pindari area [20], Kedarnath Wildlife Sanctuary [30] from sub-tropical and temperate zone in Kumaun Himalaya [18]. Total herb density was ranged from (21.73-431.04 Ind m^{-2}) for MRF, which was higher than from the reported value (0.3-17.70 tiller m^{-2}) [55] but lower when compared to the Pindari and NDBR [36]. This may be due to the diversity in habitats and mild climatic conditions supporting diversity of herbaceous species and also high density of trees in the MRF. A positive correlation between and the total basal area and richness ($r=0.34$, $p<0.05$, $n=31$) (*Fig. 1*) was observed. This indicates that the increase in the species number increases the total basal cover.

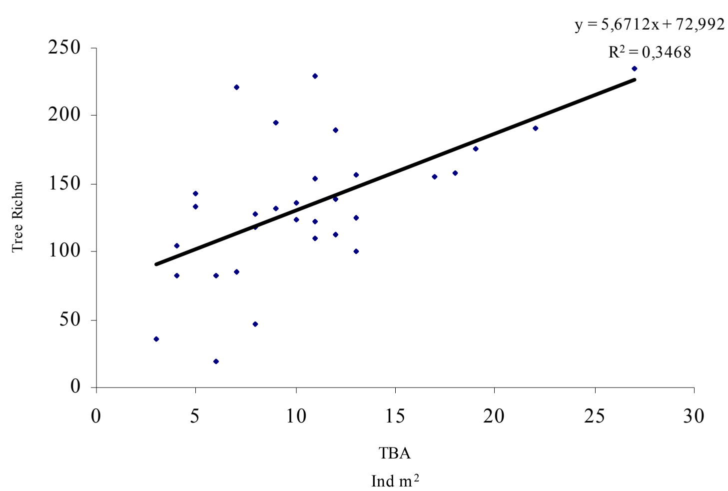

Figure 1. *Correlation between Total Basal Area and Richness*

Species diversity (H')

Species diversity of trees ranged from 0.99-2.93, seedlings from 0.86-2.65, saplings from 0.44-2.78, shrubs from 1.94-4.43 and herbs from 1.42-4.66. The diversity of trees was highest in the *Rhododendron arboreum* community (2.93), followed by *Quercus floribunda* (2.90), *Rhododendron arboreum-Quercus floribunda* mixed (2.68), and *Quercus leucotrichophora* (2.65), communities. The diversity of shrubs was highest in *Quercus leucotrichophora* community (4.43), followed by *Rhododendron arboreum* (3.49) and *Pinus roxburghii* (3.37), communities. The diversity of saplings was highest in *Rhododendron arboreum* (2.78), followed by *Quercus floribunda* (2.74), *Rhododendron arboreum -Quercus floribunda* mixed (2.73), communities. Diversity of

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seedlings was highest is *Betula alnoides* (2.65) communities, followed by *Rhododendron arboreum* -*Quercus floribunda* mixed (2.33), and *Pinus roxburghii* (2.21). Herb diversity was highest in *Rhododendron arboreum* (4.66), followed by *Quercus leucotrichophora* (4.48), and *Pinus roxburghii* (4.08). These values were comparable to the previous records for various regions of west Himalaya [8, 54, 20, 39, 38].

Concentration of dominance (Cd)

Concentration of dominance of trees ranged from 0.06-0.49, seedlings from 0.08-0.45, saplings from 0.07-0.68, shrubs from 0.03-1.00 and herbs from 0.01-0.52. Concentration of dominance of trees was highest in *Myrica esculenta* community (0.49), followed by *Pinus roxburghii* (0.46), *Daphniphyllum himalayense* (0.44) and *Quercus leucotrichophora*-*Quercus floribunda* mixed *and Abies pindrow* (0.41), communities, it was lowest in *Quercus floribunda* community (0.06). For shrubs, it was highest for *Abies pindrow* community (1.00), followed by *Pinus roxburghii-Quercus leucotrichophora* mixed (0.15), *Persea duthiei-Rhododendron arboreum* mixed (0.11), communities, and lowest for *Rhododendron arboreum* community (0.03). For herbs, it was highest for *Rhododendron arboreum-Myrica esculenta* mixed community (0.52), followed by *Quercus floribunda* (0.31), *Persea duthiei-Rhododendron arboreum* mixed (0.12) communities. These values were comparable to the previous records [8, 9].

Socio economic and conservation values of the forest communities

Among all the communities, *Rhododendron arboreum* community (208 species; 127 economically important, 119 native, 2 endemic, 33 near endemic, and 6 rare-endangered species), followed by *Quercus floribunda*-*Rhododendron arboreum* mixed (98 species, 104 economically important species, 55 native, 1 endemic, 14 near endemic, and 5 rare endangered species); *Quercus leucotrichophora* (179 species, 98 economically important, 97 native, 2 endemic, 25 near endemic, and 6 rare endangered species); *Rhododendron arboreum*-*Quercus floribunda* mixed (127 species, 90 economically important, 70 native, 1 endemic, 18 near endemic, and 4 rare endangered species); *Quercus floribunda* (150 species, 85 economically important, 73 native, 1 endemic, 21 near endemic, and 5 rare endangered species); *Cupressus torulosa* (116 species, 69 economically important, 55 native, 1 endemic, 19 near endemic, and 2 rare endangered species), *Myrica esculenta*-*Rhododendron arboreum* mixed (97 species, 68 economically important, 45 native, 1 endemic, 18 near endemic, and 2 rare endangered species), *Betula alnoides* (93 species, 67 economically important, 51 native, 1 endemic, 20 near endemic, and 2 rare endangered species), *Cedrus deodara* (80 species, 59 economically important, 46 native, 1 endemic, 11 near endemic, and 1 rare endangered species), *Pinus roxburghii* (144 species, 59 economically important, 67 native, 1 endemic, 16 near endemic, and 3 rare-endangered species); *Alnus nepalensis* (77 species, 58 economically important, 43 native, 1 endemic, 10 near endemic, and 4 rare endangered species); and *Persea duthiei* (92 species, 52 economically important, 51 native, 1 endemic, 18 near endemic, and 4 rare endangered species), communities (*Table 3*). This clearly indicates the high socio-economic and conservation values of these communities, hence, need prioritization for conservation. The key species of the prioritized communities are *Rhododendron arboreum*, *Myrica esculenta*, *Selinium tenuifolium*, *Heracleum candicans, Buplerum longicaule, Berberis aristata, Sarcococa*

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saligna, Viburnum cotinifolium, Quercus leucotrichophora, *Q. floribunda, Hypericum oblongifolium, Salvia lanata, Artemisia nilagarica*, *Acorus calamus, Origanum vulgare, Melothria heterophylla, Persea duthiei, P. odoratissima, Carpinus viminea, Pyrus pashia, Michelia kisopa, Zanthoxylum armatum, Cypripedium cordigerum, Cedrus deodara, Cupressus torulosa, Taxus baccata* subsp. *wallichiana, Habenaria edgeworthii, H. intermedia, Prinsepia utilis, Delphinium denudatum, Skimmia laureola, Bergenia ligulata, Ulmus wallichiana, Hedychium spicatum, Pimpinella acuminata, Goldfussia dalhoussiana, Onychium fragile,* and *Lepisorus excavatus*. The richness of economically important species in these communities indicates high anthropogenic pressure, which may lead to habitat degradation and extirpation of the species in near future. A significant positive relationship ($r= 0.50$, $p< 0.01$, $n=31$) has been found between the number of useful species and number of rare-endangered species, indicating that the use pattern of the species is directly proportional to the rarity of the species (*Fig. 2*.). If the rate of exploitation of the economically important species from these communities continues, there is much probability of extinction of these species from their natural habitats in near future and may lead to ecosystem imbalance. Therefore, there is an urgent need to initiate steps for the conservation of high value communities.

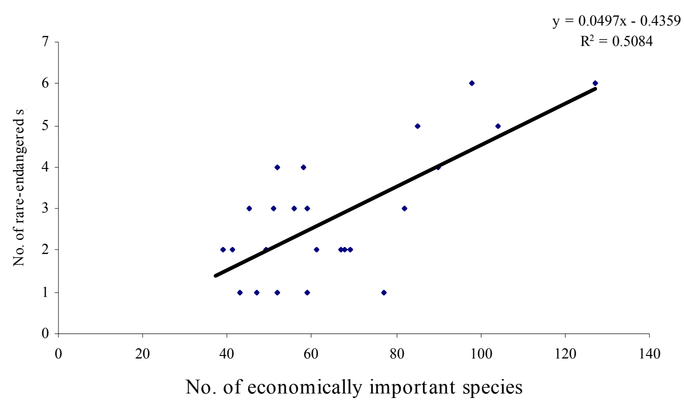

Figure 2. *Correlation between Economically Important and Rare-Endangered Species*

Prioritization of the forest communities for conservation and management

The conservation values of the communities are presented in (*Fig. 3*.) Amongst the communities, the *Rhododendron arboreum* community was ranked first, followed by *Quercus leucotrichophora, Quercus floribunda, Rhododendron arboreum-Quercus floribunda* mixed, *Quercus floribunda-Rhododendron arboreum* mixed, *Pinus roxburghii, Cupressus torulosa, Betula alnoides, Myrica esculenta-Rhododendron arboreum* mixed, *Persea duthiei, Cedrus deodara,* and *Alnus nepalensis*, communities. The prioritized communities represent the maximum numbers of economically important as well as native, endemic and rare-endangered species.

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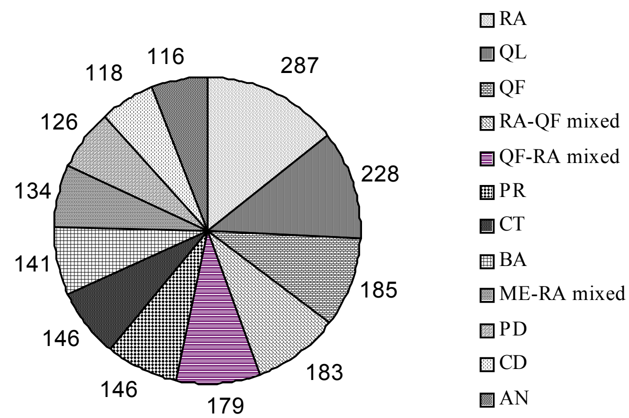

Figure 3. *Prioritization of Forest communities with their Conservation Values*
RA= *Rhododendron arboreum*; QL=*Quercus leucotrichophora*; QF=Quercus floribunda; RA-QF= *Rhododendron arboreum-Quercus floribunda* mixed; QF-RA= *Quercus floribunda-Rhododendron arboreum* mixed; PR=*Pinus roxburghii*; CT=*Cupressus torulosa*; BA=*Betula alnoides*; ME-RA mixed= *Myrica esculenta-Rhododendron arboreum* mixed; PD=*Persea duthiei*; CD=*Cedrus deodara*; and AN=*Alnus nepalensis*

Conclusions

The present study provides comprehensive information on site characteristic, habitats, community diversity, vegetation distribution pattern and forest composition of the species including richness of economically important, native, endemic and rare-endangered species, prioritization of communities for conservation. Based on the results, it can be concluded that the area has high potential in terms of number of species and communities. The occurrence of high number of native, endemic, economically important and rare-endangered species enhance the conservation as well as socio-economic values of the MRF. The day to day need of forest resources particularly fuel and fodder species has increased the pressure on forest trees and shrubs to a great extent. Furthermore, the over-exploitation of species for fuel, fodder, medicine, food (wild edibles), and house building may lead to the extirpation of these species from the area. Therefore, there is a need to develop adequate strategy and action plan for the conservation and management of habitats, species, and communities, so that sustainable utilization of the species could be ensured.

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