International Journal of Geology, Earth & Environmental Sciences ISSN: 2277-2081 (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jgee.htm
2017 Vol. 7 (2) May-August, pp.39-50/Pandey et al.
Research Article

PROTECTION FROM ANTHROPOGENIC DISTURBANCES CONTRIBUTED TO THE RECOVERY OF VEGETATION IN THE KUMAON HIMALAYA: A CASE STUDY

***Alok K Pandey[1,2], Ranbeer S Rawal[1], Sanjay Gairola[1], Indra D Bhatt[1], Ram P Kumar[2], Nivedita Priyadarshini[3] and Ashutosh Kumar[4]**
[1]G.B. Pant National Institute of Himalayan Environment & Sustainable Development, Kosi - Katarmal, Almora, India
[2]School of Environmental Science, Jawaharlal Nehru University, New Delhi, India
[3]Department of Zoology, D. A. V. College, J. P. University, Chhapra, India
[4]Department of Biosciences and Bioengineering, India Institute of Technology, Guwahati, India
**Author for Correspondence*

ABSTRACT
The protection of ecological regions is one of the principal means for the conservation of biological diversity. The current study describes species composition, biodiversity pattern and phytosociological composition of G.B. Pant National Institute of Himalayan Environment & Sustainable Development (GBPNIHED) a protected area located in the Kumaon Himalaya. The whole area is divided into three transects and three stratified plots in each transect. During sampling a total of 154 plant species were recorded from the studied area, out of which 36 are tree, 16 are shrubs 102 are herbs. Maximum IVI is reported for *Pinus roxburghii* showing its great impact on the whole ecosystem. *Pyracantha crenulata* was the dominant shrub species. An increase in the herbaceous diversity is also observed after protection. The diversity of many tree species in sapling and seedling stage is indicative that the planted stands have started regeneration naturally. It clearly shows the positive effect of protection on vegetation diversity and the recovery of an area.

Keywords: *Diversity, Himalaya; Protection, Chir-pine Forest, IVI*

INTRODUCTION
The plant community in a region is a function of many parameters such as altitude, slope, latitude, soil, aspect, rainfall and humidity. All these variables play an important role in the formation of plant communities and their composition. Himalayan mountain ecosystems usually have distinct biological communities and reflect a high level of endemism, due to their unique topography and climatic features. As such, the existence of distinct forest types and biological diversity is indicative of diversity in c limatic and edaphic factors. However, ever growing population has resulted in a diverse level of disturbances in Himalayan forests in the form of lopping, grazing, surface burning and litter removal, etc. These disturbances cause a reduction in the diversity of ecosystems and arrest the succession of the communities. Therefore, quantification of spatiotemporal changes in biodiversity by considering community composition and trends in species abundances (Convention on Biological Diversity in Rio 1992) is considered an integral task in conservation biology. Young (2000) suggested that the biodiversity crisis represents the greatest challenge humans have ever faced, and its restoration is necessary for civilization sustainability.
Protected areas are one of the most important resource allocations on the Earth. Protected area coverage was approved by the seventh Conference of the Parties (CoP7) of the Convention on Biological Diversity (CBD) as an indicator for immediate testing in relation to the adopted target of significantly reducing the rate of biodiversity loss (Chape *et al.*, 2005). Protected area acts as an important indicator of global targets and environmental assessment. It is also used as an indicator of the success of Millennium Development Goal 7 which deals with the ensuring environmental sustainability. Millennium Development Goal target 9 integrates the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources. Land area protections are also necessary to

maintain biological diversity (MDG Indicator 26). Svoboda *et al.*, (2010) demonstrate the importance of dead wood for forest regeneration and recovery from disturbance and the protection of an area is necessary.

Floristic inventories are considered necessary to understand the present and past biodiversity status, consequences of habitat degradation or destruction, etc. and provide an important information regarding changes in community composition. The outcome of these can be used for developing effective conservation policies, which may have dramatic consequences for ecosystem stability (Worm and Duffy, 2003). This information is necessary to identify the mechanisms (e.g. environmental variables, human-induced disturbances, etc.) controlling the variation in species richness through space and time, as well as to identify sites of conservation concern and appropriate policies to improve the current biodiversity pattern. In the Himalayan region, considerable work of Floristic investigation has been done by Royle (1839-1840), Hooker (1872-1897), Strachey and Winterbottom (1982), Duthiei (1960). Some studies on Floristic aspects in Kumaun Himalaya includes; Duthiei (1960), Gupta (1968), Samant (1987), and Samant and Pangtey (1995).

Several ecological studies related to the general vegetation description have been made by various workers in the region. A highly diverse compositional pattern of forests characteristic of the Indian west Himalayan region has been explored by Singh and Singh (1992). A considerable amount of data exists on compositional, structural and functional aspects of the forest of Kumaun Himalaya (Singh *et al.*, 1987; Singh and Singh, 1992). Studies show that the distribution and occurrence of species had been affected by human interventions (Singh *et al.*, 1987). Climate change and global warming influence the plant diversity and shift in the diversity pattern (Telwala *et al.*, 2013). Among human influence, commercial exploitation, agricultural requirements, forest fire, and grazing pressure are the important sources of disturbance. So far very few studies have been conducted to understand the ecological restoration, in areas that were under high anthropogenic disturbance. The interaction between abiotic and biotic factors in a mountain geo-ecosystem impacts on the forest management (Dorren *et al.*, 2004). Understanding disturbance and subsequent recovery of vegetation after disturbance is crucial for overall ecosystem dynamics. There have been several efforts of intensive plantation under various forestry operations and at many places these plantations have now matured. These mature stands of plantations have also started influencing the composition and processes of neighboring natural system. However, no systematic investigations have been undertaken to understand the intensity of influence, if any. In the present study, an attempt has been made to assess the floristic diversity of GBPNIHED, which is protected from human disturbance since last one decade of so.

MATERIALS AND METHODS

The Study Area

G. B. Pant National Institute of Himalayan Environment & Sustainable Development (GBPNIHED) formerly G.B. Pant Institute of Himalayan Environment & Development (GBPIHED), established in 1988, is an autonomous Research and Development Institute of the Ministry of Environment & Forests, Government of India. The study area, GBPNIHED, is located at Kosi- Katarmal, 14 km away from district headquarter Almora (Uttarakhand), India along sides the National Highway 87 (E). The Study area is located on a hillock and spread over an area of approx. 92 acres that comprise of institutional building, Surya-Kunj, residential complex, natural forest, etc. Geographically the GBPNIHED has located in Kumaon Himalaya around 29˚38’23” N latitude and 79˚37’21” E longitude, with 1250 m elevation above mean sea level. Almost all regions of Kumaon Himalaya are facing a loss of biodiversity due to tourism and use of forest and nearby area as a grazing field by villagers. The entire area of the G.B. Pant Institute of Himalayan Environment & Development (GBPIHD) also faced the degradation due to grazing and other activities by nearby villagers. No any anthropogenic activity is allowed in a GBPNIHED area since its establishment in 1988. The protection allows this area to grow naturally.

The area falls under temperate Himalayan zone and has a subtropical climate. The forest types are mainly chir–pine and oaks. Monsoon patterns of rainfall influence the climate of the study area. The

characteristics of selected study sites are presented in Table 1. Over the years, through various interventions, this site is now being strengthened as Nature Interpretation and Learning Center (NILC) of the Institute which on one hand attempts to ensure *ex-situ* conservation of representative species (especially rare, endangered threatened and endemic ones) and on the other acts a site for nature exposure and learning for different stakeholders.

Extensive floristic surveys were conducted during August - September 2009 covering different habitats. Identification of plants (woody species) in the field was made with the help of the Forest Flora of Kumaun (Osmaston, 1927). The herbarium of GBPNIHED was consulted to cross-check the identity of various species. Based on this, a checklist of plant species was prepared for the study area.

Vegetation Sampling and Data Analysis

After systematic reconnaissance of the area, three representative sites were identified in the present study. The study area is divided into three stands on the basis of trees presented. i.e. Chir-Pine Mixed, Pure Chir-Pine and Mixed conifer- broad leaves. At each site, three (50x50m) size plots were marked for data collection. Information on site characteristics and different vegetation parameters were collected through field investigations and using handheld GPS (Garmin make). The details of site characteristics of the study area are given in Table 1. The phytosociological surveys of the identified plots were conducted by using five (10x10 m) quadrates for tree and sapling. In each 10x10 m quadrate, two (5x5 m) quadrates were used randomly for recording shrub species and five (1x1 m) for seedling and herbs. Individuals of each species were enumerated in all quadrates. In the case of trees, for each species, number and circumference at breast height (CBH above 1.37 m) were measured. Plants with > 30 cm cbh and >3m straight bowl were considered as trees following Muller-Dombois and Ellenberg (1974). Saplings (10-30 cm CBH and >1.5 m height) and seedlings (one or two leaf stage to 10 cm cbh) were recorded to investigate the regeneration pattern. The wood species having branching from the base of the stem were considered as shrubs (Muller-Dombois and Ellenberg, 1974).

Table 1: Characteristics of Selected Study Sites

Forest stands	Latitude	Longitude	Altitude (m asl)	Aspect	Slope (º)
Chir-Pine Mixed	$29^0$38’23” N to $29^0$38’27” N	$79^0$37’11” E to $79^0$37’15” E	1190-1250	East	20-30˚
Pure Chir - Pine	29^u38’29” N to $29^0$38’35” N	79^u37’19” E to $79^0$37’22” E	1180-1230	East	20-50˚
Mixed Conifer-broad leaves	29^u38’15” N to $29^0$38’18” N	79^u37’20” E to $79^0$37’25” E	1210-1250	East	10-30˚

The compositional features of vegetation that include density, frequency, total basal area (TBA) and their relative values were determined following Misra (1968) and Muller-Dombois and Ellenberg (1974). Species diversity was computed by using Shannon-Wiener index (Shannon and Wiener, 1963). The Importance Value Index (IVI) for the tree layer was determined as the sum of Relative Frequency (RF), Relative Density (RD) and Relative Total Basal Area (RTBA). Species richness was calculated by counting a total number of species observed in sapling plots.

RESULTS AND DISCUSSION

The present study reveals the presence of 154 plant species were recorded from the study area, in which 36 are tree, 16 are shrubs 102 are herbs. Table 2, 3 and 4 enumerates the list of the tree, shrub and herbaceous species and their families respectively found in the studied region. Based on existing information, it was apparent that before the establishment of the Institute (study area); the area was represented by highly degraded slopes, interspersed with some pine trees and shrubs. The area was also subjected to heavy grazing and collection of firewood, etc. With the establishment of GBPNIHED campus, the site was completely protected and consequently the anthropogenic pressure diverted to

adjacent areas. The results reveal that due to the protection of the area from anthropogenic pressure, the process of ecological restoration started and facilitated the normal growth of plant species.

Table 2: List of Tree Species Enumerated in GBPNIHED and its Surrounding Area

S. No.	Botanical Name	Local Name	Family
1	*Aesculus indica*	Pangar	Hippocastanaceae
2	*Albizia lebbeck*	Sirish	Mimosaceae
3	*Alnus nepalensis*	Uttish	Betulaceae
4	*Bauhinia variegate*	Kachnar	Leguminosae
5	*Cedrus deodara*	Deodar	Pinaceae
6	*Celtis australis*	Kharik	Ulmaceae
7	*Cinnamomum tamala*	Tajpat	Lauraceae
8	*Cupressus torulosa*	Shurai	Cupressaceae
9	*Dalbergia sissoo*	Shisham	Fabaceae
10	*Dendrocalamus strictus*	Bansh	Poaceae
11	*Falconeria insignis*	Khin	Euphorbiaceae
12	*Ficus palmate*	Beru	Moraceae
13	*Grevillea robusta*	Silver oak	Proteaceae
14	*Grewia optiva*	Bhimal	Tiliaceae
15	*Jacaranda mimosaefolia*	Jacranda	Bignoniaceae
16	*Leucenia sp.*	Subabul	Leguminosae
17	*Ligustrum lucidum*	Sadabahar	Oleaceae
18	*Lyonia ovalifolia*	Ayar	Ericaceae
19	*Melia azedarach*	Bitan	Meliaceae
20	*Morus alba*	Sahatut	Moraceae
21	*Murraya koenigii*	Kari patta	Rutaceae
22	*Myrica esculenta*	Kafal	Myricaceae
23	*Pinus roxburghii*	Chir	Pinaceae
24	*Pittosporum nepalense*	Ruditiya/Tumari	Pittosporaceae
25	*Populus nigra*	Populas	Salicaceae
26	*Prunus cerasoides*	Padam	Rosaceae
27	*Punica granatum*	Anar	Punicaceae
28	*Pyrus pashia*	Mehal	Rosaceae
29	*Quercus glauca*	Flayat	Fagaceae
30	*Quercus leucotrichophora*	Banj	Fagaceae
31	*Robinia pseudo-acacia*	Rubiniya	Fabaceae
32	*Salix tetrasperma*	Jalmalya	Salicaceae
33	*Sapindus mukorossi*	Ritha	Sapindaceae
34	*Toona ciliate*	Toon	Meliaceae
35	*Toona serrata*	Sooni	Meliaceae
36	*Triadica sebifera*	Charbi	Euphorbiaceae

Species richness and diversity pattern of trees, sapling, seedling, shrubs and herbs are tabulated in Table 5, whereas; Table 6 describes the phytosociological parameters of the studied sites that include total basal area (TBA), tree, sapling, seedling, shrubs and seedling density. In Table 7, 8 and 9 phytosociological parameters of tree species of chir-pine mixed stands, pure chir-pine and mixed conifer broad leaves stands respectively. In these tables, we computed frequency, density, basal area, relative frequency, relative density, relative total basal area and importance value index (IVI) of each tree species in the studied stands.

Table 3: List of Shrub Species Enumerated in GBPNIHED and its Surrounding Area

S. No.	Botanical Name	Local Name	Family
1	*Asparagus racemosus*	Satawari	Liliaceae
2	*Barleria cristata*	-	Acanthaceae
3	*Berberis asiatica*	Kilmora	Berberidaceae
4	*Bischofia javanica*	Kunj	Euphorbiaceae
5	*Cornus oblonga*	Kanaki	Cornaceae
6	*Desmodium elegans*	-	Fabaceae
7	*Elaeagnus parvifolia*	Gewai	Elaeagnaceae
8	*Lantana camara*	Lantana	Verbenaceae
9	*Myrsine Africana*	-	Myrsinaceae
10	*Osyris quadripartite*	-	Santalaceae
11	*Premna barbata*	Padhyru	Verbenaceae
12	*Prinsepia utilis*	Jataylu	Rosaceae
13	*Pyracantha crenulata*	Ghingaru	Rosaceae
14	*Rosa moschata*	-	Rosaceae
15	*Rubus ellipticus*	Hisalu	Rosaceae
16	*Sinarundinaria falcate*	Ringal	Poaceae

Table 4: List of Herb Species Enumerated in GBPNIHED and its Surrounding Area

S. No.	Botanical Name	Local Name	Family
1	*Achyranthes aspera*	Chatcuri	Amaranthaceae
2	*Adiantum lunulatum*	Fern	Pteridaceae
3	*Ageratum conyzoides*	Bhubuniya	Asteraceae
4	*Alysicarpus bupleurifolius*		Fabaceae
5	*Amaranthus viridis*		Amaranthaceae
6	*Anaphalis busua*	Bakol	Asteraceae
7	*Androsace rotundifolia*		Primulaceae
8	*Artemisia annua*	Jhaoo	Asteraceae
9	*Artemisia capillaries*		Asteraceae
10	*Artemisia japonica*		Asteraceae
11	*Artemisia sp.*		Asteraceae
12	*Arthraxon hispidus*		Poaceae
13	*Arthraxon lanceolatus*		Poaceae
14	*Arundinella bengalensis*		Poaceae
15	*Asplnium dalhousiaae*	Fern	Aspleniaceae
16	*Aster molliusculus*		Asteraceae
17	*Astragalus graveolens*		Fabaceae
18	*Bupleurum hamiltonii*		Apiaceae
19	*Calendula officinalis*		Asteraceae
20	*Cannabis sativa*	Bhang	Cannabaceae
21	*Capsella bursa-pastoris*		Brassicaceae
22	*Cassia dimidiate*		Caesalpiniaceae

23	*Centella asiatica*	Bhrami	Umbeliliferae
24	*Cheilanthes alabamensis*	Fern	Pteridaceae
25	*Cissampelos pareira*	Bail	Menispermaceae
26	*Cissampelos* sp.		Menispermaceae
27	*Commelina benghalensis*		Commelinaceae
28	*Craniotome furcata*		Lamiaceae
29	*Cyanodon dactylon*	Dub	Poaceae
31	*Cymbopogon jwarancusa*	Muzir grass	Poaceae
30	*Cymbopogon* sp.		Poaceae
32	*Cynoglossum glochidiatum*	Kumar	Boraginaceae
33	*Cyperus distans*		Cyperaceae
34	*Cyperus rotundus*	Motha	Cyperaceae
35	*Desmodium floribundum*		Fabaceae
36	*Desmodium heterocarpon*		Fabaceae
37	*Desmodium microphyllum*		Fabaceae
38	*Dioscorea belophylla*	Gijaru	Dioscoreaceae
39	*Drosera peltata*		Droseraceae
40	*Dryopteris* sp.	Fern	Dryopteridaceae
41	*Equisetum* sp.		Equisetaceae
42	*Erigeron Canadensis*		Asteraceae
43	*Erigeron multiradiatus*		Asteraceae
44	*Erigeron* sp.		Asteraceae
45	*Eriophorum comosum*	Babil	Cyperaceae
46	*Eriophorum* sp.		Cyperaceae
47	*Euphorbia helioscopia*		Euphorbiaceae
48	*Euphorbia hirta*		Euphorbiaceae
49	*Euphorbia prolifera*	Dudil	Euphorbiaceae
50	*Fragaria rubiginosa*	Bhikaphal	Rosaceae
51	*Galinsoga parviflora*		Asteraceae
52	*Galium asperifolium*		Rubiaceae
53	*Habenaria marginata*		Orchidaceae
54	*Hedyra nepalensis*		Araliaceae
55	*Hibiscus sp.*		Malvaceae
56	*Impatiens balsamina*		Balsaminaceae
57	*Lespedeza gerardiana*		Fabaceae
58	*Leucas hyssopifolia*		Lamiaceae
59	*Leucas lanata*		Lamianceae
60	*Micromeria biflora*	Barpan	Lamiaceae

61	*Micromeria* sp.		Lamiaceae
62	*Nepeta ciliaris*		Lamiaceae
63	*Nerium oleander*		Apocynaceae
64	*Notholirion thomosonianum*		Liliaceae
65	*Origanum vulgare*	Vantulshi	Lamiaceae
66	*Oxalis corniculata*	Chalmora	Oxalidaceae
68	*Parthenium hysterophorus*	Gajar ghash	Asteraceae
67	*Parthenium* sp.		Asteraceae
69	*Paspalum paspalodes*		Poaceae
70	*Persicaria barbata*		Polygonaceae
71	*persicaria capitata*		Polygonaceae
72	*Phyllanthus amarus*		Euphorbiaceae
73	*Pogostemon benghalense*		Lamiaceae
74	*Polygala arvensis*	Miradu	Polygalaceae
75	*Potentilla nepalensis*		Rosaceae
76	*Pteris cretica*	Fern	Pteridaceae
77	*Ranunculus laetus*		Ranunculaceae
78	*Salvia mukerjeea*	Paniya	Lamianceae
79	*Scutellaria scandens*		Lamiaceae
80	*Selaginella* sp.	moss	Selaginellaceae
81	*Senecio nudicaulis*		Asteraceae
82	*Setaria barbata*		Poaceae
83	*Setaria intermedia*		Poaceae
84	*Setaria* sp.		Poaceae
85	*Setaria* sp.		Poaceae
86	*Setaria* sp.		Poaceae
87	*Sida cordata*		Malvaceae
88	*Solanum nigrum*	Makoi	Solanaceae
89	*Striga angustifolia*		Scrophulariaceae
90	*Striga asiatica*		Scrophlariaceae
91	*Striga* sp.		Scrophulariaceae
92	*Strobilanthes atropurpureus*		Acanthaceae
93	*Swertia angustifolia*	Chirata	Gentianaceae
94	*Tagetes minuta*	Vanhajari	Asteraceae
95	*Tanacetum dolichophyllum*		Asteraceae
96	*Thalictrum foliolosum*	Mamira	Ranunculaceae
97	*Trifolium alexandrium*		Fabaceae
98	*Trigonella emodi*		Fabaceae

99	*Urtica dioica*	Canta bash	Urticaceae
100	*Valeriana jatamansii*	Samyo	Valerianaceae
101	*Verbascum Thapsus*	Ekalvir	Scrophulariaceae
102	*Vigna vexillata*		Fabaceae

Results for the each Stand are Presented below:

Chir-pine Mixed Stand

In chir – pine mixed stand, a total of 16 tree species were encountered (Table 5). We found tree density 820 ind/ha, which is highest among all three studied stands (Table 6). The sapling density was recorded to be 467 ind/ha and a total of 6 species were recorded in sapling stage. A total of 4 species were recorded in seedling layer and density was recorded 2000 ind/ha.

We found 7 shrub species and shrubs density is 4240 ind/ha in this stand. We found 40 herbs species in this stands, and their density is 564267 ind/ha.

Species diversity index in different layers reveals maximum diversity in herb layer (3.89) and the minimum in sapling layer (1.74). On the basis of importance value index (IVI), the dominant tree species on this site are *Pinus roxburghii* (IVI-69.2); *Populus nigra* (IVI- 36.12) and *Salix tetrasperma* (IVI-33.69) (Table 7). *Pinus roxburghii* frequency was maximum followed by *Celtis australis* and *Quercus leucotrichorphora.* Tree cover 22.57 m2 /ha basal area in this stand that is maximum in all studied stands. Almost fifty percent of total basal areas were covered by the *Pinus roxburghii, Populas nigra* and *Alnus nepalensis.*

Table 5: Species Richness and Diversity Pattern in Different Forest Stands

Forest Stands	Parameters	Tree	Sapling	Seedling	Shrub	Herb
Chir-Pine Mixed						
	Species richness	16	6	4	7	40
	Diversity index	2.57	1.74	1.92	2.14	3.89
Pure Chir -Pine						
	Species richness	12	4	5	5	35
	Diversity index	1.04	1.5	1.87	1.78	2.69
Mixed Conifer broad leaves						
	Species richness	17	7	3	5	38
	Diversity index	1.96	2.43	1.19	1.84	3.79

Table 6: Phytosociological Parameters in Study Sites

Forest Stands	Tree Density (Ind/ha)	Sapling Density (Ind/ha)	Seedling Density (Ind/ha)	Shrub Density (Ind/ha)	Herb Density (Ind/ha)
Chir-Pine mixed	820	467	2000	4240	564267
Pure Chir -Pine	727	413	3867	2120	2809333
Mixed Conifer broad leaves	687	307	3200	1387	608933

Table 7: Phytosociological Parameters for Tree Species in Chir-Pine Mixed Stands

Name of Species	Frequency (%)	Basal Area (m^2/ha)	R. frequency (%)	R. Density (%)	R.TBA (%)	IVI
Pinus roxburghii	66.66	5.80	18.87	26.74	23.60	69.2
Quercus leucotrichophora	33.33	1.16	9.13	3.83	5.02	17.97
Alnus nepalensis	40	2.34	12.16	6.21	10.03	28.4
Populus nigra	26.67	3.60	9.57	12.94	13.63	36.12
Salix tetrasperma	26.67	2.01	8.29	17.92	7.47	33.69
Triadica sebifera	13.33	0.46	6.06	2.38	2.03	10.47
Myrica esculenta	6.66	0.23	3.03	1.19	1.03	5.26
Melia azedarachta	20	0.22	4.65	3.23	8.00	15.89
Grevillea robusta	13.33	1.66	3.51	3.42	5.09	12.02
Jacranda mimosifolia	13.33	1.08	3.51	2.56	3.32	9.39
Celtis australis	46.67	1.15	11.09	11.83	6.39	29.27
Toona cilita	6.67	1.29	1.45	0.59	5.11	8.48
Robinia pseudo-acacia	13.33	0.42	2.9	4.16	2.09	9.15
Bauhinia variegata	6.67	0.23	1.45	0.60	1.19	5.86
Quercus glauca	6.67	0.64	1.45	1.19	3.22	5.52
Pyrus pashia	13.33	0.28	2.9	1.19	1.44	3.22
Total		**22.57**	**100**	**100**	**100**	**300**

Where, R. frequency: Relative frequency; R. density: Relative density; RTBA: Relative total basal area; IVI: Important value Index

Table 8: Phytosociological Parameters for Tree Species in Chir - Pine Stands

Name of Species	Frequency (%)	Basal Area (m^2/ha)	R. Frequency (%)	R. Density (%)	RTBA (%)	IVI
Pinus roxburghii	80	5.67	71.6	70.17	73.88	215.6
Quercus leucotrichophora	20	0.44	3.70	4.09	2.61	10.41
Melia azedarachta	26.67	0.45	4.94	4.09	2.65	11.68
Toona serrata	6.67	0.28	1.23	1.17	1.64	4.04
Prunus cercaidus	13.33	0.26	2.47	1.17	1.54	5.18
Dalbergia sissoo	6.67	0.40	1.23	1.17	2.36	4.77
Cedrus deodara	20	0.50	3.70	9.94	2.97	16.61
Cupressus torulosa	20	0.43	3.70	2.34	2.55	8.59
Toona ciliate	20	0.35	3.70	1.75	2.08	7.54
Quercus glauca	6.67	0.32	1.23	0.58	1.90	3.72
Populus nigra	6.67	0.73	1.23	2.92	4.33	8.49
Celtis australis	6.67	0.25	1.23	0.58	1.49	3.31
Total		**10.08**	**100**	**100**	**100**	**300**

Where R. frequency: Relative frequency; R. density: Relative density; RTBA: Relative total basal area; IVI: Important value Index

Pure Chir - Pine Stand

Twelve tree species were encountered in pure chir – pine stand. Tree density in pure chir-pine was 727 ind/ha. Sapling density was found to be 413 ind/ha with a total of 4 species. In Seedling layer, 5 species were enumerated, and total seedling density was recorded 3867 ind/ha, which is highest among all studied

forest stands. As far as shrub density is a concern, it was 2120 ind/ha and 5 shrubs species are found in this stand. We found 35 herbs species in this stands with density 2809333 ind/ha that was maximum as compared to other studied forest stands. Herb diversity index was maximum i.e. 2.69 followed by shrub and seedling, trees diversity index is minimum i.e. 1.04 in this stand. The total basal area in this stand was reported 10.08 m^2/ha that was lowest in all studied forest stands. More than 70% area was covered by the *Pinus roxburghii* only, which is most dominant species in this stand. On the basis of IVI, the dominant tree species were *P. roxburghii* (IVI-215.67), *Cedrus deodara* (IVI-16.61) and *Melia azedarachta* (IVI-11.68) (Table 8).

Mixed – Conifer Broad Leaved Stand

In mixed – conifer broad leaved stand 17 tree species were recorded which is highest in all studied stands. However, the tree density was reported minimum (687 ind/ha) among all studied forest stand. In sapling layer, a total of 7 species were reported, and total sapling density was 307 ind/ha (Table 5, 6). Seedling density was 3200 ind/ha and 3 species were found in a seedling layer that are growing naturally. Five shrub species were found in this stand, and their density is 1387 ind/ha. We found 38 herbs species in this stands, and their density is 608933 ind/ha. Total basal area (TBA) in this forest stand was 20.48 m^2/ha. On the basis of IVI, *Pinus roxburghii* (IVI-102.27), *Salix tetrasperma* (IVI-33.66) and *Alnus nepalensis* (IVI-30.47) were recorded as dominant species (Table 9).

Table 9: Phytosociological Parameters for Tree Species in Mixed Conifer Broad-Leaved Stands

Name of Species	Frequency (%)	Basal Area (m^2/ha)	R. Frequency (%)	R. Density (%)	RTBA (%)	IVI
Pinus roxburghii	53.33	2.79	34.92	37.88	29.48	102.3
Grevillea robusta	13.33	2.03	7.22	3.53	13.7	24.45
Alnus nepalensis	33.33	1.38	11.19	13.3	5.99	30.47
Dalbergia sissoo	13.33	1.13	4.76	2.47	5.79	13.02
Quercus glauca	13.33	0.81	4.76	2.47	4.17	11.39
Salix tetrasperma	26.67	3.89	7.38	12.17	14.13	33.66
Triadica sebifera	20	1.02	5.71	3.13	4.39	13.37
Albizia lebbeck	6.67	0.42	2.38	1.23	2.17	5.77
Quercus leucotrichophora	26.67	0.77	6.67	4.76	2.2	13.63
Melia azedarach	6.67	0.86	1.67	0.96	2.45	5.07
Toona serrata	6.67	0.57	1.67	3.81	1.63	7.1
Celtis australis	6.67	1.69	1.67	0.95	3.86	7.45
Pyrus pashia	6.67	1.30	1.67	0.95	3.70	6.32
Ficus palmate	6.67	0.39	1.67	1.90	1.12	4.69
Aesculus indica	6.67	0.44	1.67	0.95	1.27	3.89
Morus alba	13.33	0.61	3.33	8.57	1.74	13.64
Falconeria insignis	6.67	0.38	1.67	0.95	1.09	3.71
Total		**20.48**	**100**	**100**	**100**	**300**

Where, R. frequency: Relative frequency; R. density: Relative density; RTBA: Relative total basal area; IVI: Important value Index

Species Diversity and Effects

The study area has been protected since its establishment. After the establishment of GBPNIHED, a lot of efforts have been done to enhance tree cover and floral diversity of the site. A total of 36 tree species were reported in the studied three stands. Of these, sixteen, twelve and seventeen tree species were reported in chir-pine mixed, pure chir-pine and mixed conifer broad leaved stand respectively. In this area, deodar does not occur naturally but has been planted at some places. This diversity is more as compared to the natural forest stands of Chir-pine or its associations in the region. As such, in natural condition, it has been reported that Chir-pine (*Pinus roxburghii*) allows only a few trees to establish

(Singh and Singh, 1992). The study reveals the regeneration capacity, and it is seen in the seedling density. At this point, there is a need to assess carefully the dynamics of seedling recruitment and sapling establishment. In the present study, it was observed that some species, such as *Alnus nepalensis* with fast growing properties have been planted as early succession species to make the soil fertile and moist. Ohsawa (1991) considered *Alnus nepalensis* a 'habitat pioneer' species, to occupy the newly formed habitats. However, the species have now started regeneration in certain silts that would require attention for future expansion. Similarly, the expanding species *Pinus roxburghii* can pose a serious threat to native species plantations. The ecological nature of *P. roxburghii* does not allow other broad-leaf species to replace. In this situation, *P. roxburghii* may continue to hold a site indefinitely upon its establishment. However, the chir-pine mixed and mixed conifer broad leave stands exhibited high seeding density than pure chir - pine stand. This indicates certain changes in species composition and densities are likely to take place in due course of time. Among three studied forest stands Total Basal Area (TBA) was reported highest in Chir-pine mixed stands and minimum in pure chir - pine. Sapling and shrub density were maximum for pure Chir-Pine and minimum for mixed conifer broad leaved stands. Pure Chir-Pine strand exhibited maximum seedling and herbs density as compared to another studied stand (Table - 6). The value of species diversity of tree species was higher in Chir-pine mixed stands (2.57) as compared to pure chir - pine (1.04) and mixed conifer broad leaved stand (1.96). However, in sapling layer, the diversity was higher in mixed conifer broad leaved stand (2.43) and for seedling layer it was maximum (1.92) in Chir-pine mixed stands.

Shrub diversity was maximum in chir pine mixed stand and lower in pure chir - pine stand. However, herb diversity was reported maximum (3.89) for the chir-pine mixed stand (Table 5). Among studied vegetation parameters, the density and total basal area values of the stands have approached nearly the value reported for such stand in natural forest sites. This indicates the plantation in the studied area have attained the maturity and can be considered as a representative sample for explaining structural and functional features of similar forest stands in natural condition.

Conclusion

The vegetation of the study area was largely of conifer (mainly Chir - pine) and mixed conifer broad leaves. It was observed that some species, such as *Alnus nepalensis* with fast growing properties have been planted as early successional species to make the soil fertile and moist. Observed, herb diversity (on the basis of species richness and diversity index) in almost all studied stands is high which indicates that the herb diversity increases in the stands under protection. The diversity of species in sapling and seedling stage is indicative that the planted stands have started regeneration naturally. The study indicates that small efforts of protection at the site can enhance the regeneration capacity of the site. Continuous protection of an area needs to be continued for vegetation recovery and biodiversity restoration. Protection of forest helps in the preservation of ecosystem integrity with satisfying human needs, the ultimate goal of Millennium Development Goal.

ACKNOWLEDGEMENTS

Authors are thankful to Dr. K. Chandra Sekar, Scientist, G. B. Pant Institute of Himalayan Environment and Development (GBPNIHED), Kosi - Katarmal, Almora to help in the identification of the different plant species.

REFERENCES

Chape S, Harrison J, Spalding M and Lysenko I (2005). Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. *Philosophical Transactions of the Royal Society of London Series B, Biological Sciences* **360** 443–55.

Dorren LK, Berger F, Imeson AC, Maier B and Rey F (2004). Integrity, stability and management of protection forests in the European Alps. *Forest Ecology and Management* **195** 165–176.

Duthiei JE (1960). Vegetation of Western Himalaya and Western Tibet in relation to their climates. *Journal of Indian Botanical Society* **4** 327-334.

Gupta RK (1968). *Flora Nainitalensis*: *A Handbook of the Flowering Plants of Nainital*, (Navayng Traders, New Delhi, India).
Hooker JD (1872-1897). *Flora of British India*, **1-7**, (Reeve and Co., London, UK).
Mishra R (1968). *Ecology Workbook*, (India, Calcutta: Oxford & IBH Publ. Co.) 244.
Muller – Dombols D and Ellenber H (1974). *Aims and Methods of Vegetation Ecology*, (USA, New York: John Wiley & Sons) 547.
Ohsawa M (1991). Montane Evergreen Broad-Leaved Forests of the Bhutan, 89 - 156. In: M. Ohsawa (edition) *Life Zone Ecology of Bhutan Himalaya II*, (Japan, Chiba: Chiba University Press).
Osmaston AE (1927). *A Forest Flora of Kumaun*, (International Book Distributors, Dehradun, India) (Reprint, 1978).
Royle JF (1839-1840). *Illustration of the Botany and Other Branches of the Natural History of the Himalayan Mountains and the Flora of Cashmere*, (Today's and Tomorrow's Printers and Publishers, New Delhi, India) (Reprinted 1970).
Samant SS (1987). Flora of central and South Eastern parts of pithoragarh district, **I and II**. Ph.D Thesis, Kumaun University, Nainital.
Samant SS and Pangtey YPS (1995). Additions to a forest flora of Kumaun University plants of Indian Subcontinent. *Indian Journal of Forestry* **5** 258-315.
Shannon CZ and Wiener W (1963). *The Mathematical Theory of Communication*, (USA, Urbana: University of Illinols Press).
Singh JS and Singh SP (1992). *Forest of Himalaya*, (Gyanodaya Prakashan, Nainital, India).
Singh RS, Rahlan PK and Singh SP (1987). Phytosociological and population structure of mixed Oak conifer forest in a part of Kumaun Himalaya. *Environmental Ecology* **5** 475-487.
Strachey R and Winterbottom JE (1982). Scientific botany in: E.T. Atkinson (edition), *The Himalayan District of the New Provinces of India*, (COSMO Publication, New Delhi, India).
Svoboda M, Fraver S, Janda P, Bače R and Zenáhlíková J (2010). Natural development and regeneration of a Central European montane spruce forest. *Forest Ecology and Management* **260** 707–714.
Telwala Y, Brook BW, Manish K and Pandit MK (2013). Climate-induced elevational range shifts and increase in plant species richness in a Himalayan biodiversity epicentre. *PloS One* **8** e57103.
Worm B and Duffy JE (2003). Biodiversity, productivity and stability in real food webs. *Trends in Ecology and Evolution* **18** 628-632.
Young TP (2000). Restoration ecology and conservation biology. *Biological Conservation* **92** 73–83.