

# Plant Diversity, Regeneration Status and Standing Biomass Under Varied Degree of Disturbances in Temperate Mixed Oak-Conifer Forest, Kumaun Himalaya

HIMANI KARKI, KIRAN BARGALI, S.S. BARGALI\*, VIBHUTI AND Y.S. RAWAT

*Department of Botany, DSB Campus, Kumaun University, Nainital 263001 Uttarakhand, India*  
E-mails: [karki.glacier@gmail.com](mailto:karki.glacier@gmail.com); [kiranbargali@yahoo.co.in](mailto:kiranbargali@yahoo.co.in); \*[surendrakiran@rediffmail.com](mailto:surendrakiran@rediffmail.com);  
[vibhug20@gmail.com](mailto:vibhug20@gmail.com); [rawatyashwant0@gmail.com](mailto:rawatyashwant0@gmail.com)

\*Corresponding author;

## ABSTRACT

The future composition of forest depends on the potential regeneration status of tree species within a forest stand in space and time, which can be predicted by the age structure of their population. The present study investigated effect of biotic disturbance on plant diversity, regeneration status and standing biomass in a mixed oak-conifer forest in a part of Kumaun Himalaya, India. On the basis of disturbance level, the study area was divided into highly disturbed and least disturbed stands. Each site was further subdivided into three sub sites (hill base, hill slope and hill top). Regeneration status of individual tree species was determined on the basis of the population size of seedlings, saplings and trees. A total of 69 plant species (16 trees, 18 shrubs and 35 herbs) distributed in 66 genera and 47 families were recorded. The total tree density ranged between 610 and 1360 ind ha<sup>-1</sup>. All the sub-sites of highly disturbed site showed J-shaped curve for most of the tree species. At least disturbed site, hill top showed inverted J-shaped curve indicating good regeneration while hill base showed J-shaped curve indicating poor regeneration and hill slope showed no regeneration (absence of seedlings). At highly disturbed site, minimum tree carbon stock was reported in hill base position (82.99 Mg ha<sup>-1</sup>), while at least disturbed site, it was in hill top position (159.91 Mg ha<sup>-1</sup>). Over exploitation of forest resources may lead to site-specific changes in the population structure which decrease the stability and complexity of the species and also alter the future structure and composition of forests/ecosystems. An ecological approach to landscape management is needed which should be based on knowledge of natural vegetation structure and composition.

Key Words: Carbon Stock; Population Structure; Forest Resources; Ecosystems

## INTRODUCTION

Forest plays a dynamic role in protecting the fragile mountain ecosystem and maintaining diverse and complex ecosystems. Forests are important repositories of terrestrial biodiversity and play a key role in influencing socio-ecological and cultural attributes of human societies including livelihood activities of traditional societies living in these areas (Hermann 2006). Biodiversity is essential for human survival and economic well being and for the ecosystem function and stability (Singh 2002). In India, habitat destruction, over exploitation, pollution and species introduction are

identified as major causes of biodiversity loss (UNEP 2001). Floristic inventory and diversity studies help us to understand the species composition and diversity status of forests (Phillips et al. 2003, Bargali et al. 2014, 2015) which also offer vital information for forest conservation (Gordon and Newton 2006 a and b).

The existence of a species in the forest community largely depends on its regeneration under varied environmental conditions. The population dynamics of seedlings and saplings in the forest community indicate the regeneration status/potential of a species. Some workers have predicted regeneration status of tree species based on the age and diameter structure of their

population (Pritts and Hancock 1983). Biomass is one of the very important parameter affecting biosphere-atmosphere interactions. Estimation of woody biomass is a prerequisite for determining the state and flux for biological materials in an ecosystem and for understanding the dynamics of ecosystem (Anderson 1971, Chaturvedi and Singh 1987, Rawat and Singh 1988 and Tewari et al. 2005). Information on biomass is not only important for the standpoint of fundamental ecology, but also relevant to formulate planning for ecologically sustainable development of a region (Singh and Singh 1992, Bargali and Singh 1997, Jhariya et al. 2014, Gosain et al. 2015).

Natural and human disturbances both are considered as major drivers of species diversity in plant communities. In general, frequency and magnitude of disturbance are key factors for changes in species diversity (Shrestha et al. 2013, Baboo et al. 2017). Biotic disturbances, particularly from the over exploitation of biological resources, generally have negative impact on species diversity at a global scale (Abadie et al. 2011). Forest diversity is the main livelihood source for the people of Uttarakhand. The increase in population over the last few decades and consequent dependence on plant products has led to over exploitation of natural flora and fauna of this region (Ram et al. 2004). The vegetation study is important for understanding the functioning of community (Singh and Singh 2010, Behera et al. 2016) and understanding the relationship between disturbance and species diversity is fundamental during the setting of conservation policy.

The Himalayan moist temperate forest extends from 1500 to 3000 m elevation. The Western and Central Himalayas are characterized by extensive pure and mixed Oak-Conifer forest (Champion and Seth 1968). The Present study was carried out in temperate mixed oak-conifer forest dominated by *Cupressus torulosa* D. Don and *Quercus leucotrichophora* A. Camus located at Kumaun Himalaya in Uttarakhand state of India. The main aim of this study was to analyse effect of biotic disturbances on plant diversity, vegetation composition, regeneration status and biomass. This study will help to develop effective management policy in order to prevent overexploitation of forest resources and to maintain sustainable forest.

## STUDY AREA

The study was carried out in the forests located near

Nainital town in Kumaun Himalaya between 29° 36' 56"-29° 36' 79" N latitude and 79° 46' 03"-79° 46' 19" E longitude between 1600 and 1850m above mean sea level. Human activities have been reported from the forests. Lopping for fodder is one of the main practices which causes large-scale disturbance in these forests; however, other practices such as collection of fuel wood, litter and minor forest products, as well as grazing, browsing etc also exist. Two disturbance classes (least disturbed and highly disturbed) were distinguished on the basis of degree of lopping intensity reflected in the variation in canopy cover and proportion of lopped trees. Each site was further subdivided into three sub-sites on the basis of position (hill base, hill slope and hill top).

## Climate

The climate of Nainital is characterized by long-cold often snowy winter and short summer. It is temperate and monsoon type (Singh and Singh 1992) and the year have four distinct seasons viz., monsoon (July to September), post-monsoon or autumn (October to November), winter (December to January) and summer (April to mid-June). The annual average rainfall was 1853 mm, of which 60% occurred in the rainy season and the mean daily temperature ranged from -2.0°C to 30.5°C (Source: ARIES, Nainital) (Figure 1).

## Geology

The present study sites fall within the krol formation and Blaini formations, which are further divided into three subgroups viz; lower, middle and upper krols. Two distinct members such as the lower conglomerate calc-argillaceous-arenaceous unit developed under oxidizing condition and the upper argillaceous horizon indicating prevalence of enxinic condition in the basin of deposition, respectively (Valdiya 1980).

In sloppy regions a very thin soil layer was visible due to their topographic feature (mainly slope) and recurrent landslides. However, in other sites the loose soil was deposited (Adhikari et al. 1998). In the studied site, the texture of soil was loam type in hill base, loam and sandy loam type in hill slope and sandy loam type in hill top position (Joshi 2014).

## METHODS

The study was conducted during November 2013 to

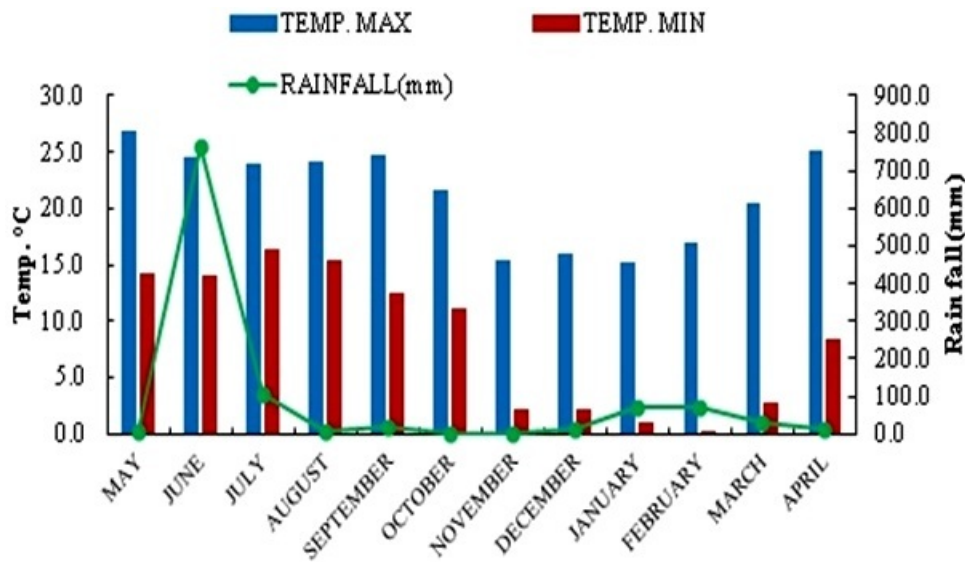


Figure 1. Meteorological data of the study site 2013-2014 (Source: ARIES, Nainital).

February 2014. Ten plots of 10 x 10m at each site were randomly established at hill base, slope and top for vegetational analysis at each site. Trees and saplings were analysed by using 10x10 m size quadrat, shrubs by 5x5 m and herbs by 1x1m quadrats within each plot (Curtis and McIntosh 1950 and Phillips 1959). Circumference at breast height (cbh at 1.37m from the ground) of all the trees and saplings was measured in each quadrat. The Importance Value Index (IVI) of trees was calculated by using the values of the relative frequency, relative density and relative basal area:

$$\text{Importance Value Index (IVI)} = \text{RF} + \text{RD} + \text{RBA}$$

For shrubs and herbs, Provenance value (PV) index was calculated by summing up the values of relative frequency and relative density:

$$\text{Provenance value (PV)} = \text{RF} + \text{RD}$$

Diversity Index was calculated by the following formula (Smith 1974):

$$H' = 3.322 [Ni / N \log_{10} Ni/N]$$

where,  $N_i$  is the total density of species  $i$  and  $N$  is the total density of all the species.

Concentration of dominance was measured by Simpson's index (Simpson 1949):

$$Cd = (Ni / N)^2$$

where,  $N_i$  = total number of individuals of a species  
 $N$  = total number of individuals of all species

Species richness was expressed by the total number of species in a given community or the number of species per unit area (Whittaker 1965).

Equitability or Evenness ( $e$ ) represents the distribution of individuals among the species and calculated following formula (Pielou 1996).

$$e = H' / \ln S$$

where,  $H'$  = Shannon index and  $S$  = the number of species

Similarity between pairs of stands was calculated by the following formula (Mueller and Ellenburg 1974) using species richness values in different forests:

$$\text{Index of similarity (IS)} = \frac{2C}{A + B} \times 100$$

where,  $C$  is the common species in comparison forests;  $A$  the total number of species in forest A and  $B$  the total number of species in forest B.

Regeneration status of individual tree species was determined on the basis of categories following Uma Shankar (2001).

### Biomass Estimation of Vegetation

The biomass for each tree component was estimated by using the linear regression equations (Rawat and Singh 1988 and Adhikari et al. 1998). The linear regression equation used was (Table 1):

$$\ln Y = a + b \ln X$$

where,  $\ln$  = natural log,  $Y$  = dry weight of component (kg per tree),  $X$  = cbh (cm),  $a$  = the intercept and  $b$  = slope of regression.

## RESULTS

### Effects on Plant diversity

A total of 69 plant species were recorded from the study area, out of which 16 were trees, 18 shrubs and 35 herbs belonging to 66 genera and 47 families. Plant diversity was high at least disturbed site as compared to highly disturbed site. *C. torulosa* was the dominant tree species, while *Q. leucotrichophora* was co-dominant tree species at both the sites (Table 2). On the basis of PV value, *M. africana* (187.95) was dominant shrub species in highly disturbed site, where as *B. albiflora* (184.3) was dominant in least disturbed site. *B. asiatica* (119.71) was co-dominant shrub in highly disturbed site, while *R. indica* (113.70) was co-dominant in least disturbed site (Table 3). Within herb stratum, *C. rotundus* (145.15) dominated in highly disturbed site, while *A. lanceolatus* (84.00) dominated least disturbed site. *A. lanceolatus* (128.50) co-dominated in highly disturbed site, while *S. bryopteris* (80.83) in least disturbed site (Table 4).

Only seven tree species were recorded in highly disturbed site, while 15 tree species were recorded in least disturbed site. The total tree density was higher (2960 ind ha<sup>-1</sup>) in least disturbed site as compared to highly disturbed site (2420 ind ha<sup>-1</sup>). The shrub density was also maximum (30810 ind ha<sup>-1</sup>) in least disturbed site as compared to the highly disturbed site (23120 ind ha<sup>-1</sup>). The diversity index was higher in least disturbed site except for the seedling layer. In contrast, dominance index was higher in highly disturbed site as compared to the least disturbed site. The evenness index was higher for tree and sapling layer in highly disturbed site, while for seedlings, shrubs and herbs it was higher in least disturbed site (Table 5).

Table 1. Allometric relationship between the biomass of the tree components (kg tree<sup>-1</sup>) and the cbh (cm)  
Source: Rawat and Singh 1988 and Adhikari et al. 1998.

Species / Components	Intercept (a)	Slope (b)
<b><i>Q. leucotrichophora</i></b>		
Bole	-0.523	1.367
Bole bark	-	-
Branch	-0.718	1.302
Twig	0.065	0.895
Foliage	-0.976	1.254
Stump root	0.982	0.904
Lateral root	-0.312	0.809
Fine root	-1.326	0.504
<b><i>Q. floribunda</i></b>		
Bole	2.0815	0.8858
Bole bark	-0.3287	0.8789
Branch	1.4970	0.8350
Twig	1.6624	0.4244
Foliage	1.3092	0.4997
Stump root	2.4764	0.4804
Lateral root	2.2269	0.3882
Fine root	1.1272	0.3727
<b><i>R. arboretum</i></b>		
Bole	0.2070	0.9638
Bole bark	-3.5917	1.0207
Branch	-0.1113	0.8288
Twig	-0.4734	0.8790
Foliage	-1.5638	0.8044
Stump root	0.9364	0.5874
Lateral root	-0.4078	0.6924
Fine root	-0.9856	0.3754
<b><i>C. deodara</i></b>		
Bole	-5.6628	2.3452
Bole bark	-7.9450	2.2078
Branch	-2.0590	1.2736
Twig	0.0963	0.6103
Foliage	-0.0191	0.5572
Stump root	-2.2520	1.2570
Lateral root	-0.3328	0.6661
Fine root	-1.8519	0.5475
<b><i>C. torulosa</i></b>		
Bole	-5.2568	2.3762
Bole bark	-4.8379	1.5999
Branch	-1.5634	1.3825
Twig	0.7641	0.5677
Foliage	-0.0433	0.7322
Stump root	-2.8713	1.5145
Lateral root	1.6620	0.3638
Fine root	-1.5051	0.7495
<b><i>I. dipyrrena</i></b>		
Bole	0.8036	0.7985
Bole bark	-3.0025	1.0073
Branch	-1.9720	1.2225

diameter) in the forest sites.

--	--	--

Table 3. PV (Provenance Value) of shrubs in the forest sites.

Species	Highly disturbed site			Least disturbed site		
	Hill base	Hill slope	Hill top	Hill base	Hill slope	Hill top
<i>Abelia triflora</i> R. Brown	-	40.44	31.49	-	-	-
<i>Asparagus racemosus</i> Willd.	18.96	47.76	3.92	22.23	31.74	5.43
<i>Berberis asiatica</i> Roxb. ex D. Don	32.79	52.63	34.29	30.80	14.18	58.03
<i>Boenninghausenia albiflora</i> Reich. ex Meisn	-	-	5.67	66.81	69.96	47.53
<i>Caryopteris bicolor</i> (Roxb. ex Hardw.) Mabb.	-	-	-	13.91	-	-
<i>Cotoneaster microphyllus</i> Wall. ex Lindl.	9.28	-	14.91	-	-	-
<i>Debregeasia longifolia</i> (Burm.f.) Wedd.	-	5.97	-	-	-	-
<i>Indigofera heterantha</i> Wall. ex Brandis	-	-	-	-	-	5.43
<i>Inula cuspidata</i> C.B. Clarke	-	-	-	-	13.11	-
<i>Jasminum humile</i> Linn.	5.73	-	5.67	-	-	-
<i>Leptodermis lanceolata</i> Wall.	-	-	3.92	12.38	17.67	15.51
<i>Myrsine africana</i> Linn.	81.90	36.09	69.96	-	-	19.60
<i>Pyracantha crenulata</i> (Don.) Roem	10.27	-	10.29	22.65	-	-
<i>Randia tetrasperma</i> Benth. & Hook.f. ex Brandis	-	5.97	11.34	-	-	-
<i>Reinwardtia indica</i> Dumort.	-	-	-	15.19	50.04	48.47
<i>Rhamnus purpurea</i> Edgew.	20.33	-	-	-	-	-
<i>Rosa moschata</i> Miller ex J. Herrmann.	5.14	11.13	8.54	16.03	3.30	-
<i>Rubus ellipticus</i> Smith	15.60	-	-	-	-	-

### Effects on Present State of Regeneration

The regeneration status of all tree species is given in Figure 2. The population structure indicates that 16.7% and 27.3% species were “not regenerating” at highly disturbed and least disturbed sites, respectively. At hill base tree species showed poor regeneration in the highly disturbed site and good regeneration in least disturbed site. At hill slope position poor regeneration was observed in both the study sites. Hill top showed frequent regeneration in highly disturbed site, while good regeneration was recorded in least disturbed site. At highly disturbed site J-shaped curve was recorded for most of the tree species. However, at least disturbed site, hill top showed inverted J-shaped curve indicating good regeneration, hill base showed J-shaped curve indicating poor regeneration, while hill slope showed no regeneration (absence of seedlings).

### Effects on Standing Biomass

The maximum tree biomass was observed at the hill slope position of both the studied sites. Total tree biomass varied from 174.71 Mg ha<sup>-1</sup> (hill base) to 352.52

Mg ha<sup>-1</sup> (hill slope) in highly disturbed site and from 336.66 (hill base) to 414.51 Mg ha<sup>-1</sup> (hill slope) in least disturbed site. Total tree biomass of least disturbed site was higher as compared to the highly disturbed site. The maximum individual tree biomass was contributed by *C. torulosa* (484.16 Mg ha<sup>-1</sup>) in highly disturbed site. In contrast, at least disturbed site it was contributed by *Q. leucotrichophora* (612.11 Mg ha<sup>-1</sup>). Minimum individual tree biomass was contributed by *L. umbrosa* (5.43 Mg ha<sup>-1</sup>) in highly disturbed site and by *S. chinensis* (0.78 Mg ha<sup>-1</sup>) in least disturbed site.

The biomass of sapling varied from 17.61 (hill top) to 29.64 Mg ha<sup>-1</sup> (hill base) in highly disturbed site, while it varied from 26.32 (hill slope) to 69.26 Mg ha<sup>-1</sup> (hill base) in least disturbed site. At least disturbed site, the biomass of saplings was higher than the highly disturbed site. Highest individual sapling biomass was contributed by *Q. leucotrichophora* in both the studied sites which was 33.54 Mg ha<sup>-1</sup> in highly disturbed site and about three times high (103.83 Mg ha<sup>-1</sup>) at least disturbed site. The minimum individual sapling biomass was contributed by *P. roxburghii* (2.19 Mg ha<sup>-1</sup>) at highly disturbed site and by *S. chinensis* (0.76 Mg ha<sup>-1</sup>) at least disturbed site (Table 6).

Table 4. PV (Provenance Value) of herbs in the forest sites.

Species	Highly disturbed site			Least disturbed site		
	Hill base	Hill slope	Hill top	Hill base	Hill slope	Hill top
<i>Achyranthes bidentata</i> Blume	-	19.91	11.37	19.79	10.84	17.35
<i>Ainsliaea aptera</i> D.C.	-	-	-	19.20	14.09	21.37
<i>Androsace lanuginosa</i> Wall. ex Roxb.	13.02	-	-	-	-	-
<i>Artemisia annua</i> L.	-	3.24	-	6.79	-	-
<i>Arthraxon lanceolatus</i> (Roxb.) Hoch.	30.00	52.13	46.37	26.28	28.61	29.11
<i>Bidens pilosa</i> Hook. f.	-	5.09	-	-	-	-
<i>Clematis buchaniana</i> DC.	-	-	-	2.55	-	1.81
<i>Craniotome versicolor</i> Reichenb.	14.84	31.39	26.50	21.76	25.17	-
<i>Cynodon dactylon</i> (Linn.) pers.	4.60	-	-	3.96	6.00	-
<i>Cyperus rotundus</i> L.	39.21	49.17	56.77	-	39.17	16.66
<i>Dicliptera bupleuroides</i> Nees	-	-	-	-	18.93	9.78
<i>Dioscorea deltoidea</i> Wall. ex Kunth	-	-	-	5.67	-	-
<i>Erigeron billidioides</i> (D.Don) Benth	9.37	-	-	40.27	-	-
<i>Eupatorium adenophorum</i> Spreng.	9.84	-	14.32	11.29	-	-
<i>Fragaria vesca</i> Linn.	-	2.87	-	2.83	-	-
<i>Galium aparina</i> Linn.	13.97	-	-	5.67	-	-
<i>Galium rotundifolium</i> Linn.	-	-	3.62	-	11.30	8.92
<i>Geranium nepalense</i> Sweet	17.14	5.09	4.51	-	-	-
<i>Gerbera gossypina</i> (Royle) Beauv.	7.86	7.69	16.76	-	7.16	8.19
<i>Goldfussia dalhousiana</i> Nees	7.22	-	-	3.40	3.46	19.81
<i>Hedychium spicatum</i> Smith.	-	-	-	-	-	2.29
<i>Justicia simplex</i> D. Don	-	6.43	9.72	3.62	-	--
<i>Lepidagathis cristata</i> Willd.	6.83	10.83	-	-	-	-
<i>Malaxia acuminata</i> D. Don	-	-	-	2.55	-	-
<i>Micromeria biflora</i> (Buch.-Ham.) Benth	7.22	-	-	-	-	-
<i>Onychium cryptogrammoides</i> C.Char.	9.05	-	-	-	6.45	-
<i>Rubia cordifolia</i> Hook. f.	3.41	2.87	-	-	-	-
<i>Selaginella bryopteris</i> (L.) Bak.	-	-	8.93	12.41	21.42	47.00
<i>Stellaria media</i> (Linn.) Vill.	-	-	-	-	3.23	-
<i>Thalictrum foliolosum</i> DC.	-	-	-	-	-	3.61
<i>Tragopogon gracile</i> D. Don.	-	-	-	-	-	6.39
<i>Tridax procumbens</i> L.	-	-	7.24	-	-	-
<i>Viola canescens</i> Wall.	-	-	-	4.24	-	-
<i>Viola serpens</i> Wall.Planch.	-	-	-	-	-	1.81
<i>Vitis himalyana</i>	-	-	-	11.34	4.16	5.90

### Effects on Sequestered Carbon Stock

Total tree carbon stock was maximum at hill slope position of both the studied sites, Minimum carbon stock was reported at hill base position (82.99 Mg ha<sup>-1</sup>) of highly disturbed site and at hill top position (159.91 Mg ha<sup>-1</sup>) of least disturbed site.

Total carbon stock of saplings was highest at hill base position of both the studied sites. Lowest carbon stock was observed at hill top position (8.37 Mg ha<sup>-1</sup>) of highly disturbed site and at hill slope position (12.50 Mg ha<sup>-1</sup>) of least disturbed site (Table 7).

### Effects on CO<sub>2</sub> Mitigation

CO<sub>2</sub> mitigation by trees varied from 5.40 to 479.41 Mg ha<sup>-1</sup> at hill top position of highly disturbed site, while from 1.43 to 394.87 Mg ha<sup>-1</sup> at hill base position of least disturbed site.

On the other hand, CO<sub>2</sub> mitigation by saplings was varied from 0.59 to 38.35 Mg ha<sup>-1</sup> at hill base position of highly disturbed site while, from 1.39 to 106.20 Mg ha<sup>-1</sup> at hill base position of highly disturbed site (Table 8).

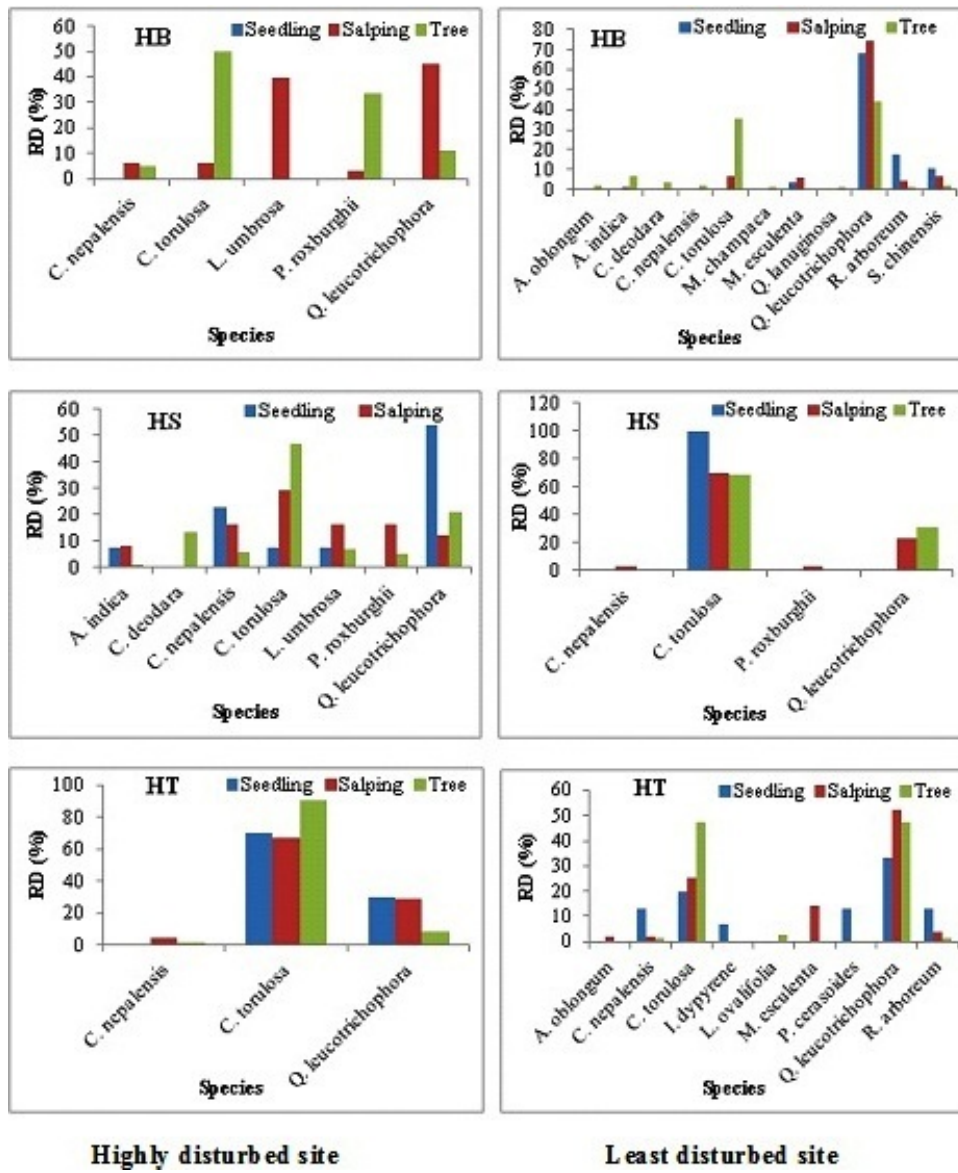


Figure 2. Regeneration status of trees as affected by disturbance level (RD: Relative density).

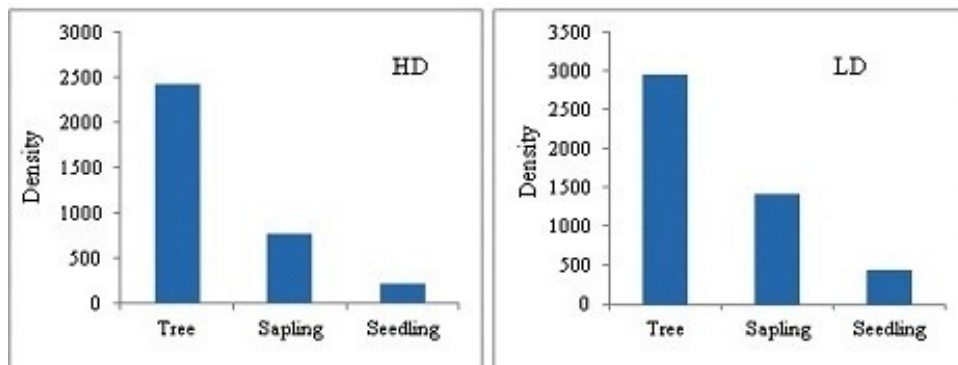


Figure 3. Density of trees, saplings and seedlings in highly (HD) and least disturbed (LD) forest sites.

Table 5. Phytosociological analysis and community indices of highly disturbed and least disturbed sites.

Parameters	Highly disturbed	Least disturbed
No. of species		
Trees	07	15
Shrubs	14	11
Herbs	23	27
No. of families		
Trees	06	12
Shrubs	10	12
Herbs	14	17
Total density (ind ha <sup>-1</sup> )		
Trees <sup>a</sup>	2420	2960
Saplings <sup>b</sup>	780	1420
Seedlings <sup>c</sup>	230	440
Shrubs	23120	30810
Herbs	33440	48120
Diversity index		
Trees <sup>a</sup>	4.27	4.28
Saplings <sup>b</sup>	5.29	4.54
Seedlings <sup>c</sup>	2.71	3.66
Shrubs	6.42	7.66
Herbs	8.86	9.31
Dominance index		
Trees <sup>a</sup>	1.49	1.32
Saplings <sup>b</sup>	1.09	1.42
Seedlings <sup>c</sup>	0.94	0.65
Shrubs	0.93	0.82
Herbs	0.52	0.31
Evenness index		
Trees <sup>a</sup>	2.74	2.48
Saplings <sup>b</sup>	3.46	2.49
Seedlings <sup>c</sup>	2.41	2.34
Shrubs	2.97	3.82
Herbs	3.47	3.42

<sup>a</sup> cbh >30cm; <sup>b</sup> cbh 10-30cm; <sup>c</sup> cbh < 10cm.

## DISCUSSION

The tree species richness in the present study decreased with increase in the intensity of disturbance. In the highly disturbed site, firewood collection and grazing together with the belowground competition of mature trees and other plants increase the mortality rate of seedlings and saplings. A small number of unique species on the more disturbed sites and a decrease in the total number of species along the disturbance gradient may reflect high utilization pressure (Bhatt et al. 2000).

In the complex Himalayan forest ecosystem chronic form of disturbances exists in which people remove only a small fraction of forest biomass in the form of grazing, lopping, surface burning and litter removal at a given time (Singh 2002). These biotic disturbances can alter species' habitats (Sapkota et al. 2009). Therefore, the species richness of a site subject to disturbance depends on the differential responses of species to such disturbances; some species may tolerate the disturbances, while others may become locally extinct (Pande et al. 2014). The stability has been reported to increase with diversity (Safi and Yarranton 1973). Therefore, disturbance in the forest can potentially lead to a decrease in stability and complexity of the ecosystems.

*C. torulosa* was dominant, whereas *Q. leucotrichophora* was co-dominant tree species in both the forest stands. The overall stem density (density of trees, saplings and seedlings) was higher in least disturbed site as compared to highly disturbed site (Table 5). The study of Ramirez-Marcial et al. (2001) showed decreasing density and basal area with disturbance intensity and Smiet (1992) correlated the basal area with the rate of disturbance. Diversity index was highest in least disturbed site at the entire vegetative layer except the seedling layer. Two shrub species viz. *A. racemosus* and *B. asiatica* were present across all the sites while *A. triflora*, *C. microphyllus* and *M. africana* preferred to grow in highly disturbed site.

The distribution of individuals of different species in the study revealed a more contagious distribution pattern (Table 9). Nath et al. (2005) suggested that the contagious distribution is the commonest pattern in nature, whereas random distribution occurs only in a very uniform environment, and regular distribution occurs when severe competition occurs between individuals.

Both the forest stand had a typical J-shaped structure (Figure 3; in terms of density) for girth frequency, which indicated poor regeneration of the constituent species. Barker and Kinkpatrick (1994) reported that the regeneration of species is dependent on internal forest process and exogenic disturbance. In this study, lopping of trees facilitated the growth of herbaceous species that compete with the tree seedlings and saplings for nutrients and space. This may lead to poor tree regeneration of native species in the highly disturbed sites. Nonetheless, a low species similarity between least disturbed and highly disturbed sites indicated the changes in species richness owing to disturbances that alter the microenvironment.

Table 6. Standing Biomass (Mg ha<sup>-1</sup>) in trees and saplings in the highly and least disturbed forest sites.

Species	Highly disturbed site						Least disturbed site					
	Hill base		Hill slope		Hill top		Hill base		Hill slope		Hill top	
	Tree	Sapling	Tree	Sapling	Tree	Sapling	Tree	Sapling	Tree	Sapling	Tree	Sapling
<i>A. oblongum</i>	-	-	-	-	-	-	6.51	-	-	-	-	0.86
<i>A. indica</i>	-	-	13.35	4.40	-	-	32.00	2.53	-	-	-	-
<i>C. deodara</i>	-	-	20.88	-	-	-	2.76	-	-	-	-	-
<i>C. nepalensis</i>	7.46	1.78	21.98	4.16	2.96	1.20	4.2	-	2.26	2.11	4.68	1.50
<i>C. torulosa</i>	74.60	1.93	148.30	5.13	261.26	8.60	73.28	3.49	190.18	13.79	151.74	7.29
<i>I. dypyrene</i>	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. umbrosa</i>	-	4.69	5.43	1.54	-	-	-	-	-	-	-	-
<i>L. ovalifolia</i>	-	-	-	-	-	-	-	-	-	-	2.94	-
<i>M. champaca</i>	-	-	-	-	-	-	1.81	-	-	-	-	-
<i>M. esculenta</i>	-	-	-	-	-	-	-	2.69	-	-	-	5.54
<i>P. roxburghii</i>	74.45	0.33	6.78	1.86	-	-	-	-	-	0.97	-	-
<i>P. cerasoides</i>	-	-	-	-	-	-	-	-	-	-	-	-
<i>Q. lanuginosa</i>	-	-	-	-	-	-	4.13	-	-	-	-	-
<i>Q. leucotrichophora</i>	18.20	20.91	135.80	4.82	30.80	7.81	215.19	57.88	221.97	9.45	174.95	36.50
<i>R. arboreum</i>	-	-	-	-	-	-	2.76	1.91	-	-	2.35	0.71
<i>S. chinensis</i>	-	-	-	-	-	-	0.78	0.76	-	-	-	-
<b>Total</b>	<b>174.71</b>	<b>29.64</b>	<b>352.52</b>	<b>21.91</b>	<b>295.02</b>	<b>17.61</b>	<b>343.42</b>	<b>69.26</b>	<b>414.51</b>	<b>26.32</b>	<b>336.66</b>	<b>53.18</b>

Table 7. Carbon stock (Mg ha<sup>-1</sup>) in trees and saplings in the highly and least disturbed forest sites.

Species	Highly disturbed site						Least disturbed site					
	Hill base		Hill slope		Hill top		Hill base		Hill slope		Hill top	
	Tree	Sapling	Tree	Sapling	Tree	Sapling	Tree	Sapling	Tree	Sapling	Tree	Sapling
<i>A. oblongum</i>	-	-	-	-	-	-	3.09	-	-	-	-	0.41
<i>A. indica</i>	-	-	6.34	2.09	-	-	15.20	1.20	-	-	-	-
<i>C. deodara</i>	-	-	9.92	-	-	-	1.31	-	-	-	-	-
<i>C. nepalensis</i>	3.54	0.84	10.44	1.98	1.40	0.57	2.00	-	1.08	1.00	2.22	0.71
<i>C. torulosa</i>	35.44	0.92	70.44	2.44	124.10	4.09	34.81	1.66	90.33	6.55	72.07	3.46
<i>I. dypyrene</i>	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. umbrosa</i>	-	2.23	2.58	0.73	-	-	-	-	-	-	-	-
<i>L. ovalifolia</i>	-	-	-	-	-	-	-	-	-	-	1.4	-
<i>M. champaca</i>	-	-	-	-	-	-	0.86	-	-	-	-	-
<i>M. esculenta</i>	-	-	-	-	-	-	-	1.28	-	-	-	2.63
<i>P. roxburghii</i>	35.36	0.15	3.22	0.89	-	-	-	-	-	0.46	-	-
<i>P. cerasoides</i>	-	-	-	-	-	-	-	-	-	-	-	-
<i>Q. lanuginosa</i>	-	-	-	-	-	-	1.96	-	-	-	-	-
<i>Q. leucotrichophora</i>	8.65	9.93	64.51	2.29	14.63	3.71	102.22	27.49	105.44	-	83.1	17.34
<i>R. arboreum</i>	-	-	-	-	-	-	1.31	0.91	-	-	1.12	0.71
<i>S. chinensis</i>	-	-	-	-	-	-	0.37	0.36	-	-	-	-
<b>Total</b>	<b>82.99</b>	<b>14.07</b>	<b>167.45</b>	<b>10.42</b>	<b>140.13</b>	<b>8.37</b>	<b>163.13</b>	<b>32.90</b>	<b>196.85</b>	<b>12.5</b>	<b>159.91</b>	<b>25.26</b>

Table 8. CO<sub>2</sub> mitigation (Mg ha<sup>-1</sup>) in trees and saplings in the highly and least disturbed forest sites.

Species	Highly disturbed site						Least disturbed site					
	Hill base		Hill slope		Hill top		Hill base		Hill slope		Hill top	
	Tree	Sapling	Tree	Sapling	Tree	Sapling	Tree	Sapling	Tree	Sapling	Tree	Sapling
<i>A. oblongum</i>	-	-	-	-	-	-	11.94	-	-	-	-	1.57
<i>A. indica</i>	-	-	24.48	8.07	-	-	58.72	4.62	-	-	-	-
<i>C. deodara</i>	-	-	38.31	-	-	-	5.06	-	-	-	-	-
<i>C. nepalensis</i>	13.69	3.26	40.33	10.27	5.40	2.2	7.7	-	4.15	3.87	8.58	2.75
<i>C. torulosa</i>	136.89	3.52	272.13	9.39	479.41	15.78	134.46	6.38	348.98	25.28	278.44	13.35
<i>I. dypyrene</i>	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. umbrosa</i>	-	8.58	9.94	2.82	-	-	-	-	-	-	-	-
<i>L. ovalifolia</i>	-	-	-	-	-	-	-	-	-	-	5.39	-
<i>M. champaca</i>	-	-	-	-	-	-	3.32	-	-	-	-	-
<i>M. esculenta</i>	-	-	-	-	-	-	-	4.92	-	-	-	10.16
<i>P. roxburghii</i>	136.61	0.59	12.44	3.41	-	-	-	-	-	1.76	-	-
<i>P. cerasoides</i>	-	-	-	-	-	-	-	-	-	-	-	-
<i>Q. lanuginosa</i>	-	-	-	-	-	-	7.57	-	-	-	-	-
<i>Q. leucotrichophora</i>	33.39	38.35	249.19	8.84	56.52	14.33	394.87	106.20	407.29	17.32	321.01	66.98
<i>R. arboreum</i>	-	-	-	-	-	-	5.06	3.48	-	-	4.31	2.73
<i>S. chinensis</i>	-	-	-	-	-	-	1.43	1.39	-	-	-	-
<b>Total</b>	<b>320.58</b>	<b>54.3</b>	<b>646.82</b>	<b>42.8</b>	<b>541.33</b>	<b>32.31</b>	<b>630.13</b>	<b>126.99</b>	<b>760.42</b>	<b>48.23</b>	<b>617.73</b>	<b>97.54</b>

Table 9. Distribution pattern of trees, shrubs and herbs at different sites (based on the ratio of abundance to frequency).

Distribution pattern	Highly disturbed site			Least disturbed site		
	Tree	Shrub	Herb	Tree	Shrub	Herb
Regular	0	0	0	0	0	0
Random	21.43	3.70	2.63	16.67	4.55	10.87
Contagious	78.57	96.30	97.37	83.33	95.45	89.13

Table 10. Correlation matrix of different variables in different forest stands.

Variables	Trees	Saplings	Seedlings	Shrubs	Herbs
Trees	<b>1</b>	-0.030	0.370	0.096	-0.214
Saplings		<b>1</b>	<b>0.728</b>	<b>0.837</b>	<b>0.531</b>
Seedlings			<b>1</b>	0.389	0.523
Shrubs				<b>1</b>	0.417
Herbs					<b>1</b>

The dominance-diversity curves (on the basis of IVI and PV) have been drawn to interpret the community organization in terms of resource share and niche space (Figure 4). *Q. leucotrichophora* indicated single species dominance in hill slope position of least disturbed site, while all other sites were dominated by *C. torulosa*. At each site, two or three shrub as well as herb species indicated dominance, while rest of the species showed relatively greater equitable share of resources. Similarity index between two sites indicated 54.54% similarity in tree layer, 56% similarity in shrub layer and 63.83% similarity in herb layer.

PCA was carried out between different variables (trees, saplings, seedlings, shrubs and herbs). Maximum factor loading was observed for saplings (0.89) at F<sub>1</sub> and at F<sub>2</sub>, maximum factor loading was observed for trees (0.93). Total variance of variables was 54.86 in F<sub>1</sub> and cumulative percentage was 79.23 which was total variance of F<sub>1</sub> and F<sub>2</sub> (factor loading). Correlation matrix of different variable is shown in Table 10. All variables were active on the basis of density at different sites, in which DHS (hill slope of disturbed site) showed supplementary due to less density (Figure 5).

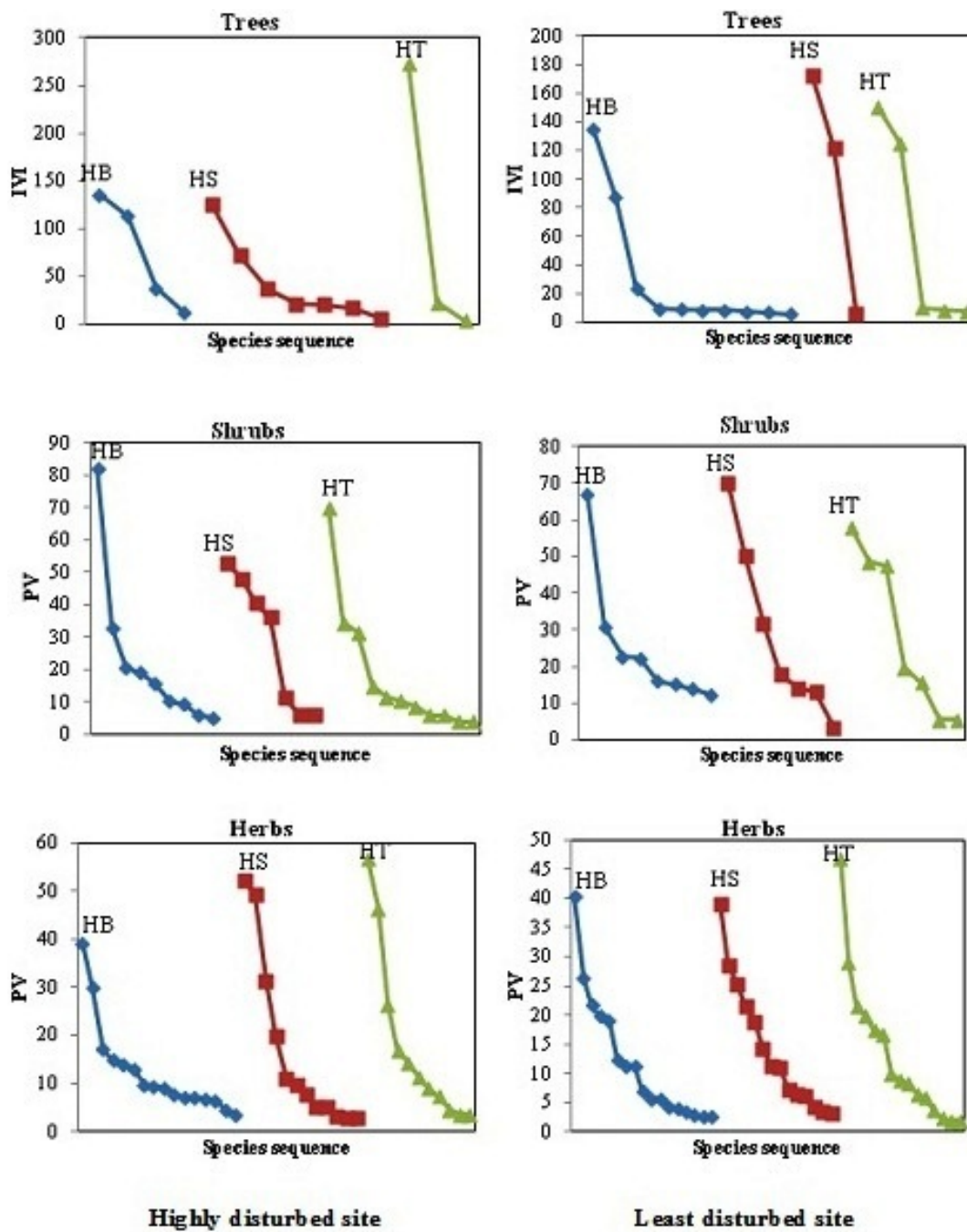


Figure 4. Dominance-diversity curves for highly and least disturbed forest sites.

The forest play a critical role in global carbon cycle and have significant potential to capture and hold carbon, thus, forming an important climate change mitigation option (Gupta 2009). Total tree biomass varied from 174.71 (hill base) to 352.52 Mg ha<sup>-1</sup> (hill slope) in highly disturbed sites. However, at least disturbed site it varied from 343.42 (hill base) to 414.41

Mg ha<sup>-1</sup> (hill slope). CO<sub>2</sub> mitigation was also higher in least disturbed sites as compared to highly disturbed sites. The conservation of biological diversity in forest landscapes requires information on the disturbance regime of landscapes under past-natural and natural conditions to develop management strategies (Spies and Turner 1999).

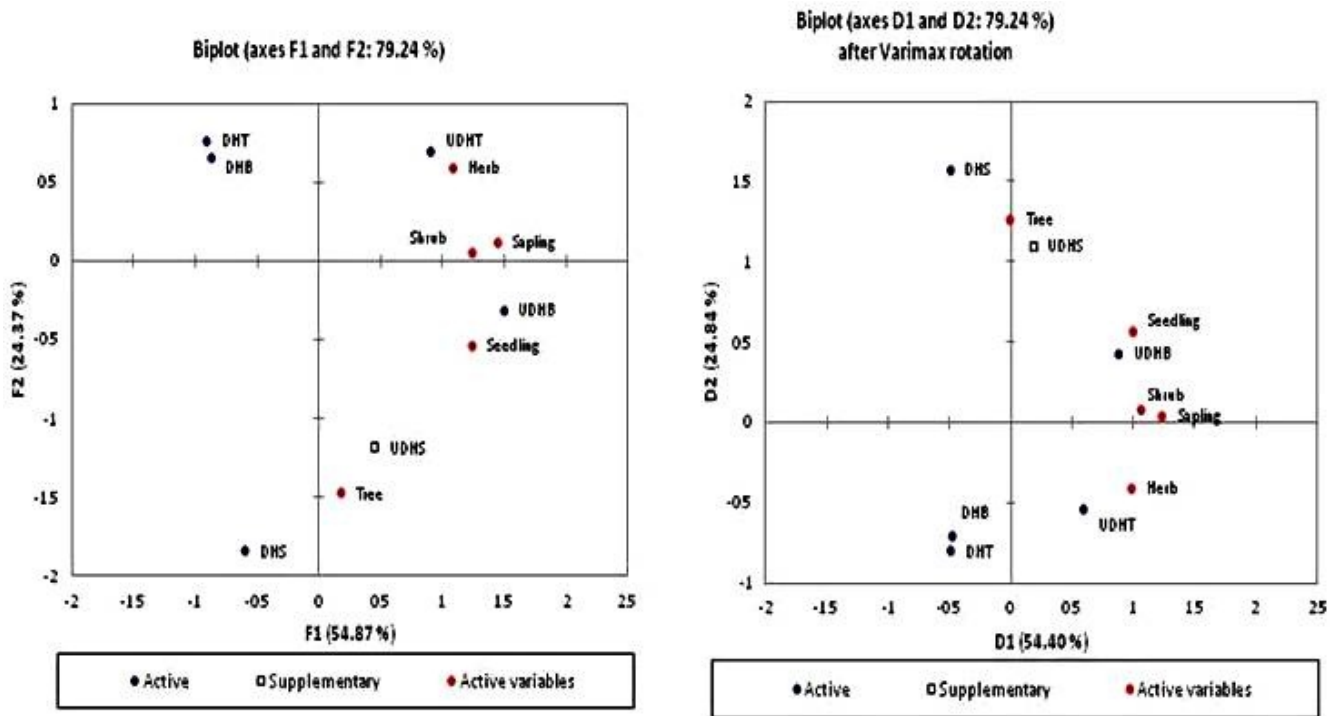


Figure 5. Principal Component Analysis of different variables on the basis of density.

## CONCLUSION

The present study concluded that different levels of biotic disturbances had varying effects on tree species, natural regeneration, diversity and structure. Almost all the observed parameters such as species diversity, density and biomass were high in the least disturbed site as compared to the highly disturbed site. This may be due to the anthropogenic pressures exerted by the human beings on the forests of disturbed site, in order to fulfill their fuel and fodder requirements. Since the rural population in Kumaun Himalaya depends on these forests for their subsistence needs, any management strategy must balance the consumptive needs of the human population with those of species conservation by allowing regulated access. Extraction intensity of forest products should be paid special attention as present study suggested that heavy disturbance change composition and structure of the forest. To maintain the proper stock in such forests, the harvest should be regulated on sustainable basis.

## ACKNOWLEDGEMENTS

We are highly grateful to Head of Department of Botany for providing necessary lab facilities. Financial support from the University Grants Commission, New Delhi is gratefully acknowledged. First author collected the data and prepared the manuscript, second author helped in analysis of data and manuscript preparation, third and fifth author helped in conceptualization and study design and fourth author helped in statistical analysis.

## Conflict of Interest

The authors declare no conflict of interest.

## REFERENCES

- Abadie, J.C.; Machon, N.; Muratet, A. and Porcher, E. 2011. Landscape disturbance causes small-scale functional homogenization, but limited taxonomic homogenization, in plant communities. *Journal of Ecology* 99(5): 1134-1142.
- Adhikari, B.S.; Dhaila, S. and Rawat, Y.S. 1998. Structure of Himalayan moist temperate cypress forest at and around Nainital, Kumaun Himalayas. *Oecologia Montana* 7: 21-31.

- Anderson, M.C. 1971. Methods and preliminary results of estimation of biomass and primary production in a South Swedish mixed deciduous woodland. Pages 281-287, In: Duvigneaud P. (Editor). Productivity of Forest Ecosystems. UNESCO, Paris.
- Baboo, B.; Sagar R.; Bargali S.S. and Verma H. 2017. Tree species composition, regeneration and diversity of an Indian dry tropical forest protected area. *Tropical Ecology* 58(2): 409-423.
- Bargali, K.; Joshi, B.; Bargali, S.S. and Singh, S.P. 2014. Diversity within Oaks. *International Oaks* 25: 57-70.
- Bargali, K.; Joshi, B.; Bargali, S.S. and Singh, S.P. 2015. Oaks and the Biodiversity They Sustain. *International Oaks* 26: 65-76.
- Bargali, S.S. and Singh, R.P. 1997. *Pinus patula* plantations in Kumaun Himalaya. I. Dry matter dynamics. *Journal of Tropical Forest Science* 9(4): 526-535.
- Barker, P.C.J. and Krikpatrick, J.B. 1994. *Phyllocladus asplenifolius*: variability in the population structure and the regeneration niche and a dispersion pattern in Tasmanian Forest. *Australian Journal of Botany* 42:163-190.
- Behera, S.K.; Sahu, N.; Mishra, A.K.; Bargali, S.S.; Behera, M.D. and Tuli, R. 2017. Above ground biomass and Carbon stock assessment in Indian tropical deciduous forest and relationship with stand structural attributes. *Ecological Engineering* 99: 513-524.
- Bhatt, D.M.; Naik, M.B.; Patagar, S.G.; Hegde, G.T.; Kandade, Y.G.; Hegde, G.N.; Shastri, C.M.; Shetti, D.M. and Furtado, R.M. 2000. Forest dynamics in tropical rain forests of Uttara Kannada district in Western Ghats, India. *Current Science* 79: 975-985.
- Champion, H.G. and Seth, S.K. 1968. A Revised Survey of the Forest Types of India. Government of India Publication, New Delhi. 404 pages.
- Chaturvedi, O.P. and Singh, J.S. 1987. The structure and function of pine forest in Central Himalaya. II. Nutrient dynamics. *Annals of Botany* 60: 253-267.
- Curtis, J.T. and McIntosh, R.P. 1950. The interrelations of certain analytic and synthetic phytosociological characters. *Ecology* 31: 434-455.
- Gordon, J.E. and Newton, A.C. 2006a. Efficient floristic inventory for the assessment of tropical tree diversity: A comparative test of four alternative approaches. *Forest Ecology and Management* 237: 564-573.
- Gordon, J.E. and Newton, A.C. 2006b. The potential misapplication of rapid plant diversity assessment in tropical conservation. *Journal for Nature Conservation* 14: 117-126.
- Gosain, B.G.; Negi, G.C.S.; Dhyani, P.P.; Bargali, S.S. and Saxena, R. 2015. Ecosystem services of forests: Carbon Stock in vegetation and soil components in a watershed of Kumaun Himalaya, India. *International Journal of Ecology and Environmental Science* 41 (3-4): 177-188.
- Gupta, H.S. 2009. Forest as carbon sink- Temporal analysis for Ranchi district. *Indian Journal of Forestry* 32(1): 7-11.
- Hermann, T.M. 2006. Indigenous knowledge and management of *Araucaria araucana* forest in the Chilean Andes: Implication for native forest conservation. *Biological Conservation* 15: 647-662.
- Jhariya, M.K.; Bargali, S.S.; Swamy, S.L.; Kittur, B.; Bargali, K.; and Pawar, G.V. 2014. Impact of forest fire on biomass and Carbon storage pattern of Tropical Deciduous Forests in Boramdeo Wildlife Sanctuary, Chhattisgarh. *International Journal of Ecology and Environmental Science* 40(1): 57-74.
- Joshi, J. 2014. Physico-chemical Soil Characteristics of Pine Forest, Oak-pine Mixed Forest and Oak -Cypress Mixed Forest of Nainital Region. M.Sc. Dissertation, Kumaun University, Nainital.
- Mueller-Dombois, D. and Ellenburg, H. 1974. Aims and Methods of Vegetation Ecology, John Wiley, U.K. xxx pages.
- Nath, P.C.; Arunachalam, A.; Khan, M.L.; Arunachalam, K. and Barbhuiya, A.R. 2005. Vegetation analysis and tree population structure of tropical wet evergreen forests in and around Namdapha National Park, northeast India. *Biodiversity and Conservation* 14: 2109-2136.
- Pande, R.; Bargali, K. and Pande, N. 2014. Impacts of disturbance on the population structure and regeneration status of tree species in a Central Himalayan mixed-oak forest, India. *Taiwan Journal Forest Science* 29(3): 179-204.
- Phillips, E.A. 1959. Method of Vegetation Study. Holt Rinehart and Winston, New York, U.S.A. 107 pages.
- Phillips, O.L.; Martinez, R.V.; Vargas, P.N.; Monteagudo, A.L.; Zans, M.C.; Sanchez, W.G.; Cruz, A.P.; Timana, M.; Yli-Halla and Rose. 2003. Efficientplot -based floristic assessment of tropical forests. *Journal of Tropical Ecology* 19: 629-645.
- Pielou, E.C. 1996. The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology* 13:131-134.
- Pritts, M.P. and Hancock, J.E. 1983. The effect of population structure on growth pattern of the weedy goldenrod *Solidago pauciflora*. *Canadian Journal of Botany* 61: 1955-1958.
- Ram, J.; Kumar, A. and Bhatt, J. 2004. Plant diversity in six forest types of Uttaranchal, Central Himalaya, India. *Current Science* 86: 975-978.
- Ramirez-Marcial, N.; Gonzalez-Espinosa, M. and Williams-Linera, G. 2001. Anthropogenic disturbance and tree diversity in montane rain forests in Chiapas, Mexico. *Forest Ecology and Management* 154: 311-326.
- Rawat, Y.S. and Singh, J.S. 1988. Structure and Function of Oak Forests in Central Himalaya. II. Nutrient Dynamics. *Annals of Botany* 62: 397-411.
- Safi, M.I. and Yarranton, G.A. 1973. Diversity, floristic richness and species evenness during a secondary (post-fire) succession. *Ecology* 54:897-902.
- Sapkota, I.P.; Tigabu, M. and Oden, P.C. 2009. Spatial distribution, advanced regeneration and stand structure of Nepalese Sal (*Shorea robusta*) forests subject to disturbances of different intensities. *Forest Ecology and Management* 257: 1966-1975.
- Shankar, U.R. 2001. A case of high tree diversity in a Sal (*Shorea robusta*) dominated lowland forest of Eastern Himalaya: Floristic composition, regeneration and conservation. *Current Science* 81: 776-786.
- Shrestha, K.B.; Maren, I.E.; Sah, J.P. and Vetaas, O.R. 2013. Effect of anthropogenic disturbance on plant species diversity in oak forest in Nepal, Central Himalaya. *International Journal of Biodiversity Science, Ecosystem Services and Management* 1-9.
- Simpson, E.H. 1949. Measurement of diversity. *Nature* 163-688.

- Singh, J.S. and Singh, S.P. 1992. Forests of Himalaya: Structure, Function and Impact of Man. Gynodaya Prakashan, Nainital. 294 pages.
- Singh, J.S. 2002. The biodiversity crisis: a multifaceted review. *Current Science* 82: 638-647.
- Singh, E. and Singh, M.P. 2010. Biodiversity and phytosociological analysis of plants around the municipal drains in Jaunpur. *International Journal of Biological and Life Sciences* 6 (2): 77-82.
- Smiet, A.C. 1992. Forest ecology of Java: Human impact and vegetation of montane forest. *Journal of Tropical Ecology* 8:129-152.
- Smith, R.L. 1999. *Ecology and Field Biology*. Harper and Row, New York. 850 pages.
- Spies, T.A. and Turner, M.G. 1999. Maintaining biodiversity in forest ecosystems. Pages 95-160, In: Hunter, M.L. Jr. (Editor). *Dynamics of Forest Mosaics*. Cambridge University Press, Cambridge, U.K..
- Tewari, A.K.; Agrawal, A.K.S. and Tiwari, S.C. 2005. Analysis of landuse and biomass in Khanda watershed, Garhwal Himalaya using satellite remote sensing data. *Tropical Ecology* 46(2): 253-263.
- UNEP. 2001. Executive Summary. Pages 1-6, In: India: State of the Environment Report 2001. UNEP-TERI-MEOEF, New Delhi.
- Valdiya, K.S. 1980. *Geology of Kumaun Lesser Himalaya*. Wadia Institute of Himalayan Geology, Dehradun, India. 291 pages.
- Whittaker, R.H. 1965. Dominance and diversity in land plant communities. *Science* 147: 250-252.

*Received 31 January 2017*

*Accepted 16 October 2017*

Table 2. Importance value index (IVI) of trees ( $\geq 30$  cm cbh) and saplings (10-30 cm cbh) and Provenance Value of seedlings ( $< 10$  cm basal diameter) in the forest sites.

Species	Highly disturbed site									Least disturbed site									
	Hill base			Hill slope			Hill top			Hill base			Hill slope			Hill top			
	T	S	Se	T	S	Se	T	S	Se	T	S	Se	T	S	Se	T	S	Se	
<i>Acer oblongum</i> Wall.	-	-	-	-	-	-	-	-	-	-	8.3	-	-	-	-	-	-	-	8.9
<i>Aesculus indica</i> (Coledr. ex Comb.) Hook.	-	-	-	6.4	23.2	20.2	-	-	-	23.3	8.84	-	-	-	-	-	-	-	-
<i>Cedrus deodara</i> (Roxb. ex D.Don) G. Don	-	-	-	36.8	-	-	-	-	-	9.6	-	-	-	-	-	-	-	-	-
<i>Coriaria nepalensis</i> Wall.	12.6	19.3	-	21.3	46.9	48.1	3.8	23.0	-	7.4	-	-	5.87	16.2	-	7.3	11.3	22.4	
<i>Cupressus torulosa</i> D.Don	113.7	35.2	-	126.1	95.5	20.2	273.3	185.6	120.0	87.1	38.7	-	172.8	209.3	200	149.9	86.1	47.3	
<i>Ilex dipyrena</i> Wall.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15.8
<i>Litsea umbrosa</i> Nees	-	86.0	-	20.7	50.8	20.2	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Lyonia ovalifolia</i> (Wall.) Drude	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.8	-	-	-
<i>Michelia champaca</i> L.	-	-	-	-	-	-	-	-	-	5.8	-	-	-	-	-	-	-	-	-
<i>Myrica esculenta</i> Buch. Ham. ex D. Don	-	-	-	-	-	-	-	-	-	-	22.8	13.5	-	-	-	-	39.5	-	-
<i>Pinus roxburghii</i> Sarg.	135.8	15.5	-	17.1	42.3	-	-	-	-	-	-	-	-	12.7	-	-	-	-	-
<i>Prunus cerasoides</i> D. Don.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22.4
<i>Quercus lanuginosa</i> Don.	-	-	-	-	-	-	-	-	-	6.7	-	-	-	-	-	-	-	-	-
<i>Quercus leucotrichophora</i> A. Camus	37.9	143.8	-	71.6	41.6	91.4	22.8	91.4	80.0	134.7	188.8	127.9	121.4	61.7	-	124.9	139.8	69.7	
<i>Rhododendron arboreum</i> Smith.	-	-	-	-	-	-	-	-	-	9.1	22.0	37.9	-	-	-	8.1	14.4	22.42	-
<i>Symplocos chinensis</i> (Lour.) Druce	-	-	-	-	-	-	-	-	-	8.1	18.7	20.7	-	-	-	-	-	-	-

T = trees; S = saplings; Se = Seedlings