# Plant diversity in two forest types along the disturbance gradient in Dewalgarh Watershed, Garhwal Himalaya

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**This study deals with the plant diversity and effects of disturbance on two types of forest namely, *Anogeissus latifolius* mixed forest (700–1200 m asl) and *Quercus leucotrichophora* forest (1500–2200 m asl) in Dewalgarh Watershed in Pauri District of Uttarakhand. Undisturbed, moderately disturbed and highly disturbed stands were identified within both types of forest of the watershed on the basis of canopy cover percentage, tree density ha$^{-1}$ and cut stumps analysis. For *Q. leucotrichophora* forest, the undisturbed forest stand had canopy cover > 60%, cut stump index < 2 and 2144 trees ha$^{-1}$, whereas the highly disturbed stand had canopy cover <49%, cut stump index > 7 and 804 trees ha$^{-1}$. For *A. latifolius* mixed forest, the undisturbed forest stand had canopy cover > 45%, cut stump index < 2 and 1275 trees ha$^{-1}$, whereas the highly disturbed stand had canopy cover < 38%, cut stump index > 7 and 845 trees ha$^{-1}$. The moderately disturbed stand occupied the intermediate position with respect to these parameters for both types of the forest. The study showed that the moderately disturbed stand favoured density and species richness in both the forest types. The Margalef index, Shannon diversity index and evenness index exhibited a similar trend, the highest value in moderately disturbed stand and lowest in highly disturbed stand. A sharp decline was recorded in tree density and basal area with increasing disturbance magnitude in both types of forests.**

**Keywords:** Biodiversity, Dewalgarh Watershed, disturbance gradient, plant diversity.

HIMALAYAN vegetation is subjected to various types of disturbances and most of them are either geological or anthropogenic or both. The geological disturbances are natural and include landslides, soil erosion and earthquakes whereas the anthropogenic disturbances include deforestation, grazing, lopping of tree branches for fodder and fuel wood, removal of leaf and wood litter from the forest floor and frequent fires. Both types of disturbances affect ecosystem stability and retard the successional process[1]. Anthropogenic disturbance can occur in a chronic form. Removal of just a small amount of biomass at any given time can continuously affect the ecosystem without any respite or recovery[2]. The problem with this chronic form of forest disturbance is that plants and ecosystems often do not get time to recover adequately because the human onslaught never stops[2].

Himalayan biodiversity is severely threatened by natural and anthropogenic disturbances. Forest diversity is the main source of livelihood of the people living in Uttarakhand, Central Himalaya. The increasing population trend over the last few decades and consequent over dependence on plant products has led to the vast exploitation of natural flora and fauna of this region. These anthropogenic disturbances not only influence the soil, nutrient and water conditions but also influence climatic conditions. Thus, the biodiversity of these forests is under great anthropogenic pressure. The growing pressure of populations on Central Himalayan region and its forests has depleted the good forest cover, resulting in frequent landslides and floods respectively in the hills and plains. Besides, all the species have become threatened and are on the verge of extinction[3]. Most of the human population is concentrated between 1000 and 2000 m elevation in the mountainous zone of Uttarakhand, Central Himalaya where the forests are severely impacted by human activities[1]. Large-scale tree felling for timber and other industrial raw materials during the colonial period until the 1960s and 70s (ref. 4) and conversion of forest into agricultural land[5] are the major causes of deforestation in the Uttarakhand Himalaya. Broadleaf evergreen species like *Quercus* is lopped for fodder, fuel wood and is used to make agricultural implements by the local inhabitants. The day-to-day needs of the people are animal fodder; leaf litter for animal bedding and composting, grazing and fuel wood, and the periodical needs are timber, raw materials for local cottage industries and nontimber forest products. Recurrent fire is another major disturbance which is used for the growth and establishment of grass for grazing as well as off season animal stall feeding[1].

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Human-induced disturbance and livestock grazing cause changes in species number, tree density and basal area[6]. Unrestricted and open accessibility may cause enhanced utilization of the forest resources and this may eventually lead to a species poor state[7,8].

Several authors have studied disturbance in the Himalayan region. The effect of disturbance in the forest of Meghalaya was studied by various workers[6,9]. They all identified three categories (undisturbed (UD), moderately disturbed (MD) and highly disturbed (HD)) in different forest types and observed that increased degree of disturbance caused loss in plant diversity and brought about change in community characteristics. Tree diversity, population structure and distribution pattern in the UD (0% disturbance index), MD (40% disturbance index) and HD (70% disturbed index) stands of tropical wet evergreen forests of Arunachal Pradesh was studied by Bhuyan[10]. Sagar[11] studied tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. Disturbance in the six forest types of Uttarakhand was studied by Jeet Ram[3].

The present paper aims to focus the effects of disturbance on species richness and plant diversity at watershed level, which is a new approach.

## Study area

The study site is Dewalgarh Watershed, Pauri District, Garhwal Himalaya which is located between 30°40′–30°45′N lat. and 78°50′–78°55′E long., having an area of 2600 ha approximately, with elevational range between 700 and 2200 m asl (Figure 1). A total of 30 villages are present in the watershed. The average rainfall is 1500–2500 mm/yr. Higher elevations of the watershed receive good snowfall during winter. Types of forest in the watershed vary from sub-tropical (*Anogeissus latifolius* mixed forest) to temperate (*Quercus leucotrichophora* forest)[12].

## Methodology

Vegetation study was conducted during 2006–07. Two types of forests, *Q. leucotrichophora* (1500–2200 m asl) and *A. latifolius* mixed (700–1200 m asl) have been taken up for vegetation analysis. Sampling was done in stratified random manner in both types of forests along the altitudinal transects. In *A. latifolius* mixed forest, four transects and in *Q. leucotrichophora* forest, seven transects were laid down along the altitudinal gradient. The number of transects was decided according to the availability of the forest area. Transects were laid down along pathways and streams in forest and spatially distributed so as to minimize the autocorrelation in the vegetation. Quadrats were laid down in stratified random manner in both types of forests. For tree species, a total of 68 quadrats (28 for MD, 20 for UD and 20 for HD) and 140 quadrats (76 for MD, 36 for UD and 28 for HD) were laid down in *A. latifolius* mixed forest and *Q. leucotrichophora* forest respectively. Species area curve was used to determine minimal sample area which is based on quantitative variation of the vegetation terms of species number[13]. The adequacy of sample size was estimated by stopping sampling at the point at which additional quadrats did not significantly affect the mean of

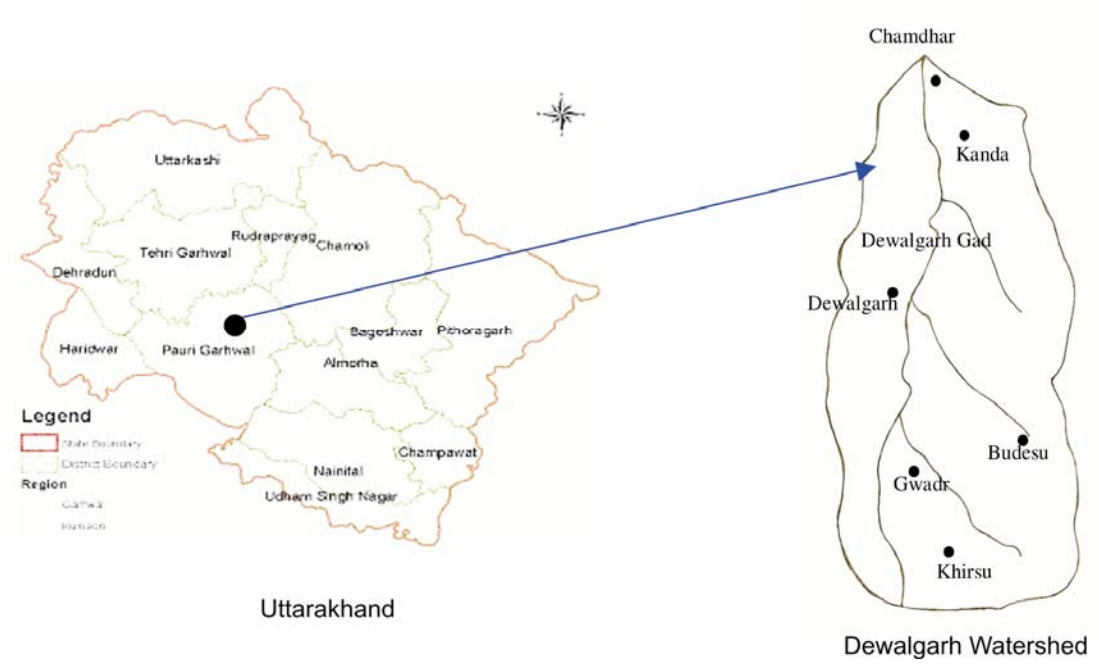


**Figure 1.** Map of the study area.

species. A minimal sample area was determined for sampling purpose by laying the random quadrat, on which the species composition of the community was adequately represented. Unequal sample size was related in proportion with the available area for each category. Quadrats of $10\ m \times 10\ m$ were used for tree layer, $5\ m \times 5\ m$ for shrubs and $1\ m \times 1\ m$ for herbs species. About 5% of total forest area was sampled, of which 0.1% area was enumerated. Disturbance was estimated in terms of tree density ($ha^{-1}$), canopy cover (%)[10] and cut stumps analysis[6]. Both types of forests have been classified into different disturbance categories, i.e. UD, MD and HD stand with the help of disturbance index which was based on the minimum and maximum values of observed disturbance parameters. All ranges were classified according to field observations. Canopy cover was measured by a densiometer. Canopy cover is one of the important parameters in the measurement of the disturbance[1]. The characters of the canopies of both the dominant tree species were different from each other and thus the ranges of the canopy cover values were different for both types of forests. Separate index has been prepared for each of the forest types. Basal area is the area occupied by the base of a tree. It is considered as good indicator of the size, volume or weight of a tree. The GBH (girth at breast height, 1.37 m) was used to calculate the basal area. Girth of cut stump was measured at ground level and basal area for cut stump was calculated. Cut stump index was calculated on the basis of the ratio of basal area of cut stumps to the total stand basal area including felled ones[6] (Table 1).

Plant species present in the three stands were listed and vegetation was quantitatively analysed for density, frequency, abundance and basal area using appropriate methods[14,15]. Species richness[16], Shannon diversity index[17], important value index (IVI)[18], Simpson dominance index[19] (*D*), Berger–Parker diversity index[20] and evenness[21] were also computed.

## Results

### *Anogeissus latifolius mixed forest*

*Species richness and diversity:* A total of 166 species belonging to 129 genera were recorded in UD, MD and HD stands of *A. latifolius* mixed forests of Dewalgarh Watershed, among which 47 were trees, 46 were shrubs and 73 were herbs. Among the tree species, *A. latifolius* was dominant with highest value of IVI (76.10 in UD, 60.01 in MD and 81.76 in HD) in all the three stands followed by *Mallotus phillippensis*, *Lannea coromandelica*, *Terminalia alata*, *Haldiana cordifolia* and *Pinus roxburghii*. *A. latifolius* was the most frequent (75% in UD, 64% in MD and 70% in HD) tree species in all the three disturbed strata. The highest tree density (1257 trees $ha^{-1}$) was found in UD stand which decreased with increased disturbance level; 1089 trees $ha^{-1}$ in MD and 845 trees $ha^{-1}$ in HD stand. In case of shrub species, *Carrisa opaca* was dominant in UD and MD stands whereas *Flacourtia indica* was dominating in HD stand. Shrub density was found highest (58.64 plants/25 $m^2$) in MD stand whereas the lowest (55/25 $m^2$) density was recorded in HD stand. Among herbs, *Micromeria biflora* was dominant species in UD stand, *Apluda mutica* was dominating in MD and *Oxalis corniculata* in HD stand. UD stand was most dense with 16 plants/$m^2$ and a slight reduction with increasing disturbance was recorded, i.e. 15 plants/1 $m^2$ in MD as well as HD stands. The highest tree species richness (41 species) was found in MD stand while UD and HD stands recorded 38 and 29 tree species respectively. Shrub and herb strata also achieved the highest species richness with 39 species and 53 species in MD stand and in both cases, the lowest species richness was observed in HD stands.

Shannon index for tree species varied between 2.43 and 3.08 and the minimum and maximum values were observed for HD and MD stand respectively. Similar trend was repeated in case of shrub species while for herbs UD stand as well as MD stand recorded highest Shannon index value (3.7); just the opposite trend was found for Simpson dominance index. It was recorded highest (0.17) for tree species in HD stand followed by UD (0.14) and MD (0.086) stands. Whereas in the case of shrub species, it was highest (0.10) in UD stand and decreased with increasing disturbance level. In herb strata, Simpson index repeated the trend of tree species, as its higher value was found in HD (0.050) stand followed by UD (0.035) and MD (0.028) stand. Berger–Parker values were highest (0.34) in UD stand for trees and it was recorded 0.33 and 0.24 for HD and MD stands respectively. Berger–Parker values were recorded in decreasing manner (0.18 in UD, 0.17 in MD and 0.12 in HD) for shrub strata while it was recorded highest in HD (0.15) stand followed by UD (0.12) and MD (0.06) stands for herbs. Margelef index value for tree species favoured the intermediate position of disturbance with highest value (7.0) which decreased towards either side, in UD (6.68) and in HD (5.46) stand. More or less similar trend was found for herbs and shrubs stratum as its higher values were recorded in MD stand. Evenness was found highest in MD (0.83) stand which means MD stand has more even distribution of plants (Table 2). Total basal area for *A. latifolius* mixed forest was recorded in decreasing order with increasing disturbance level and drastic downfall was observed in total basal cover from UD to MD disturbed stand, but after that a slight reduction was recorded from MD to HD stand (Figure 2).

### *Quercus leucotrichophora forest*

*Species richness and diversity:* A total of 182 species belonging to 144 genera were recorded in oak forest of

**Table 1.** Disturbance index categorization of *Quercus leucotrichophora* and *Anogeissus latifolius* mixed forests of Dewalgarh Watershed

| Parameters | Undisturbed | Moderately disturbed | Highly disturbed |
|---|---|---|---|
| *Quercus leucotrichophora* forest | | | |
| Tree density ($ha^{-1}$) | 2144 | 1576 | 804 |
| Canopy cover (%) | >60 | 49–60 | <49 |
| Cut stump index | <2 | 2–7 | >7 |
| *Anogeissus latifolius* mixed forest | | | |
| Tree density ($ha^{-1}$) | 1275 | 1089 | 845 |
| Canopy cover (%) | >45 | 38–45 | <38 |
| Cut stump index | <2 | 2–7 | >7 |

**Table 2.** Different diversity indices under different degree of disturbances for *Quercus leucotrichiphora* and *Anogeissus latifolius* mixed forests of Dewalgarh Watershed

| | *Quercus leucotrichophora* forest | | | *Anogeissus latifolius* mixed forest | | |
|---|---|---|---|---|---|---|
| | UD | MD | HD | UD | MD | HD |
| Tree | | | | | | |
| Density (trees/ha) | 2144 | 1576 | 804 | 1275 | 1089 | 845 |
| Species richness | 16 | 17 | 14 | 38.00 | 41.00 | 29.00 |
| Shannon index | 1.4 | 1.3 | 0.7 | 2.78 | 3.08 | 2.43 |
| Simpson index | 0.35 | 0.43 | 0.24 | 0.14 | 0.08 | 0.17 |
| Berger–Parker values | 0.52 | 0.63 | 0.34 | 0.34 | 0.24 | 0.33 |
| Margelef values | 2.27 | 2.25 | 2.21 | 6.68 | 7.00 | 5.46 |
| Evenness | 0.50 | 0.47 | 0.67 | 0.76 | 0.83 | 0.72 |
| Shrub | | | | | | |
| Density (plants/25 $m^2$) | 44.8 | 42 | 36 | 57.68 | 58.64 | 55.30 |
| Species richness | 42 | 53 | 34 | 30.00 | 39.00 | 30.00 |
| Shannon index | 2.72 | 2.75 | 2.49 | 2.74 | 3.00 | 2.97 |
| Simpson index | 0.140 | 0.143 | 0.18 | 0.10 | 0.08 | 0.06 |
| Berger–Parker values | 0.336 | 0.341 | 0.393 | 0.18 | 0.17 | 0.12 |
| Margelef values | 5.07 | 5.93 | 4.33 | 3.74 | 4.69 | 3.77 |
| Evenness | 0.707 | 0.693 | 0.690 | 0.80 | 0.82 | 0.87 |
| Herb | | | | | | |
| Density (plants/$m^2$) | 16.34 | 14.03 | 14.98 | 16 | 15 | 15 |
| Species richness | 78 | 83 | 58 | 49 | 53 | 39 |
| Shannon index | 3.86 | 3.84 | 3.69 | 3.7 | 3.7 | 3.3 |
| Simpson index | 0.029 | 0.033 | 0.032 | 0.035 | 0.028 | 0.050 |
| Berger–Parker values | 0.062 | 0.083 | 0.073 | 0.12 | 0.06 | 0.15 |
| Margelef values | 9.9 | 9.8 | 7.6 | 6.87 | 7.01 | 5.34 |
| Evenness | 0.890 | 0.869 | 0.911 | 0.94 | 0.94 | 0.91 |

HD, Highly disturbed; MD, Moderately disturbed; UD, Undisturbed.

Dewalgarh Watershed, among which 24 were trees, 55 were shrubs and 103 were herbs. Among the tree species, *Q. leucotrichophora* was dominant with highest value of IVI in UD (132.55), MD (149.33) and HD (114.09) stands followed by *Rhododendron arboreum*, *Myrica esculenta* and *Lyonia ovalifolia* in UD and MD and *P. roxburghii* in HD stand. *Q. leucotrichophora* was most frequent (100% in UD, 97% in MD and 75% in HD) tree species in all the three disturbance strata. Tree density ranged from 804 trees $ha^{-1}$ in HD stand to 2144 trees $ha^{-1}$ in UD stand. In case of shrub species, *Eupatorium adenophorum* was dominant at all three levels of disturbances followed by *Pteracanthus angustifrons*, *Rubus ellipticus* and *Berberis aristata*. Shrub density showed trend similar to trees (density ranged from 36 plants/25 $m^2$ in HD to 44.8 plants/25 $m^2$ in UD stand) whereas no trend was found in herb density. Among herbs, *Oxalis corniculata* was dominating in UD and MD stands while *Reinwardtia indica* was dominant in HD stand. The dominant species were identified on the basis of individual numbers. Maximum tree species (17) were recorded at intermediate level of disturbance followed by UD (16) and HD (14) stands. Similar results have been shown by shrub species as they were highest in MD (53) stand

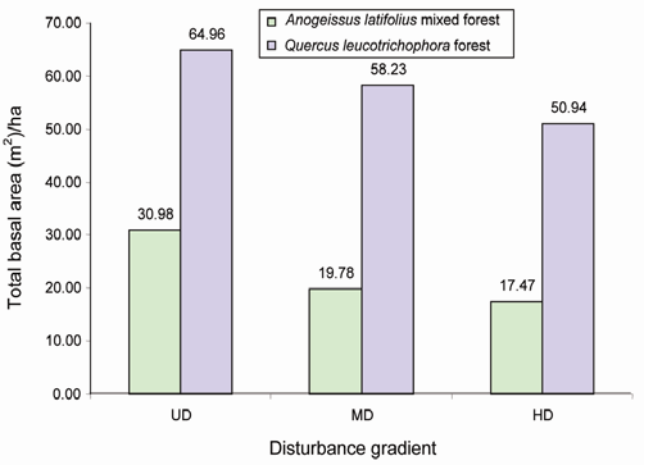


**Figure 2.** Total basal area ($m^2$/ha) under different categories of disturbance in *Quercus leucotrichophora* and *Anogeissus latifolius* mixed forests of Dewalgarh Watershed.

followed by UD (42) and lowest in HD (34) stand. Herbaceous species were also highest in MD (83) stand followed by UD (78) and lowest in HD (58) stand.

As far as the Shannon diversity index value of tree species was concerned, it decreased (1.4–0.7) with increasing disturbance. But in case of shrub species, the highest value (2.75) of Shannon index was observed in MD stand. For herb species, this index was also found in decreasing order (3.86 for UD, 3.84 for MD and 3.69 for HD). Berger–Parker index for tree species was also highest in MD (0.63) and minimum in HD (0.34) stand. Whereas in the case of shrub species, Berger–Parker index values slightly increased with increasing disturbance level. In herb species, it was recorded maximum for MD (0.083) stand. Simpson index for tree species also showed its maximum value in MD (0.43) stand. Whereas in shrubs, Simpson index favoured disturbance and its values were observed as 0.140, 0.143 and 0.179 from UD to HD stands. In herbaceous biota, the highest (0.033) Simpson index was recorded in UD stand. Evenness index for tree species was found highest in HD stand (0.67) and it was recorded lowest (0.47) at intermediate level of disturbance. The higher the values of evenness index, the more even the species are in their distribution. Thus HD stand has more even distribution than UD and MD stands, even though they have more species richness than disturbed stand (Table 2). The total basal area for tree species (>31.5 cm circumference at breast height (cbh)) decreased with increasing magnitude of disturbance (Figure 2).

## Discussion

IVI is the most important parameter to understand the community organization in relation to the competitive ability. In *A. latifolius* mixed forest, maximum IVI was recorded for *A. latifolia* in UD, MD and HD stands. Similarly, in *Q. leucotrichophora* forest, the maximum IVI was recorded for *Q. leucotrichophora* in UD, MD and HD stands. The observations indicate absolute dominance of these two tree species over other species in the study area. Hence each forest type has been named after the dominant tree species.

In both types of forests of Dewalgarh Watershed, tree species richness declined with increasing level of disturbance. The stability increases with the complexity of ecosystem, i.e. with the number of species and with the number of interactions between them[22]. In these forests, the stem density declined with increasing disturbance level and it may be due to a gradual and consistent increase in extraction of fuel wood and fodder as *Q. leucotrichophora* and *A. latifolius* are the dominating species in these forests which are extensively used as fuel wood and fodder. Here, basal area also declined with disturbance which agreed with earlier findings[10,23], which showed decreasing density and basal area with increasing disturbance intensity. Basal area has also been correlated with the rate of disturbance[23]. A decrease in the total number of species along the disturbance gradient may reflect high utilization pressure[24]. Our findings are more or less similar to earlier observations[10,25], which recorded more number of species in the MD stand. It also indicates that MD forest is a stable community for more species. According to intermediate disturbance hypothesis[26,27] with no or little disturbance, only the competitive dominants can survive, while at sufficient high level of disturbance only fugitive species can survive, therefore, the diversity is maximum at intermediate level of disturbance[28]. The mild disturbance provides greater opportunity for species turnover, colonization and persistence of high species richness[29].

This study reveals that the two types of forests behave differently in terms of impact of disturbance on level of species richness, density and diversity. While density of shrubs and herbs was recorded highest in UD stand, the herb and shrubs species richness was maximum in MD stand, similar results were also reported previously by other workers[1,10,25]. Higher density and species richness for herbs and shrubs in MD stand indicate that opening of canopies favours herb and shrub growth which gives overall stability to the forest ecosystem. Minimum density and species richness for shrubs and herbs in HD stand is possibly due to collection of fuel wood and fodder and grazing pressure. The disturbance led to thinning of the woody layer and change in the forest microclimate which in turn, might have impaired regeneration processes of the tree species.

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