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## RESEARCH ARTICLE

# SPECIES RICHNESS AND DIVERSITY ALONG THE DISTURBANCE GRADIENT IN KEDARNATH WILDLIFE SANCTUARY AND ITS ADJOINING AREAS IN GARHWAL HIMALAYA, INDIA

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**ABSTRACT**

Species richness, diversity and distribution pattern of tree species were studied along a disturbance gradient in three mixed broad leaved forests. The forests were selected on the basis of varying disturbance intensities and were categorized into highly disturbed (HD), moderately disturbed (MD) and least disturbed (LD). A total of 34 tree species (belonging to 30 genera and 21 families) were reported along the disturbance gradient. Both tree species richness and diversity markedly declined along the disturbance gradient from LD to HD forests. Maximum species richness (20) was reported from LD while minimum (11) from HD forest. Shannon Wiener index (2.30-3.34), Margalef's index (2.59-4.11), Menheink's index (1.60-1.99) were maximum in LD and minimum in HD forests. Species richness and diversity indices showed significant negative relation with disturbance. Diversity-dominance (d-d) curve showed high equitability in LD forest while high dominance in MD and HD forests. More than 90% of tree species showed contagious distribution that is the most common distribution pattern in nature but it did not show any definite trend along the disturbance gradient. Low maturity value and contagious distribution of species denote the early successional status of the studied forests. The present study reveals that the anthropogenic disturbance causes disruption of forest structure and changes species composition which ultimately leads to reduction of tree species richness and diversity which is a major forest component.



## INTRODUCTION

Biodiversity is essential for human survival, economic well being and for the ecosystem function and stability (Singh, 2002). Biodiversity, as a part of our daily life, constitutes the resource base upon which our fate of future generations depend. Maintenance and periodic assessment of diverse ecosystems and a whole of biological diversity therein and assessment and prevention of the various disturbances affecting it, are therefore, crucial for long term survival of humans (Pushpangadan *et al*., 1997; Malik, 2014). Biological diversity is the richness and evenness (relative abundance) of species amongst and within living organisms and ecological complexes (Polyakov *et al*., 2008). The species is one of the major analytical characteristics of the plant community (Odum, 1959). Species richness is a simple and easily interpretable indicator of biological diversity (Peet, 1974). The plant community of a region is a function of time; however, climate and disturbances play a role in the formation of plant communities and their composition (Malik, 2014).

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The number of species in a particular plant community varies markedly along the altitudinal range of its growth, which depends on the complex suit of factors that characterize the habitat of individual species. Many types of environmental changes influence the processes that can both augment or erode diversity (Sagar *et al*., 2003). Ellu and Obua (2005) have suggested that different altitudes and slopes influence the species richness and dispersion behavior of tree species. Slobodkin and Sanders (1969) opined that species richness of any community is a function of severity, variability and predictability of the environment in which it develops. Therefore, diversity tends to increase as the environment becomes more favourable and more predictable (Putman, 1994).

A diverse ecosystem is more resistant to environmental disturbances, and is likely to contain species that would thrive through natural or imposed perturbations in the ecosystem and compensate for the loss of other members (Stapanian *et al*., 1997). The factors such as soil nutrient content, slope, aspect and altitude have been shown to exert an important control on species richness and diversity on a great variety of ecosystems (Kharakwal, 2005). In an ecosystem, species richness and diversity are determined by a number of factors, disturbance being one of them. Hubbell *et al*. (1999) observed that ecological factors like dispersal limitation control the species distribution pattern, composition and structure of the forests and some focus was also given to local biotic and abiotic ecological interactions to explain the distribution pattern of plant species.

Any relatively discrete event in time that disrupts an ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment is called disturbance. The Himalayan vegetation is subjected to various types of disturbances and most of them are either natural or anthropogenic or both. Natural disturbances like cloud bursting, land sliding and anthropogenic disturbances like grazing, biomass extraction in the form of fuelwood, fodder and litter collection, construction of roads and dams for hydro electric projects affect the ecosystem stability leading to frequent changes in land and resource use, increased frequency of biotic invasions, reduction in species number, creation of stresses and the potential for changes in the climate system and also retard the successional processes (Kumar and Ram, 2005). Human disturbances, particularly from the overexploitation of biological resources, generally have negative impacts on species diversity at a global scale (Goudie, 2005). In the Himalayas, 76% of total natural resource needs are derived from forests and agroforestry systems, mainly because they are free, easy to access and simple to use (Chettri and Sharma, 2006). Kedarnath Wildlife Sanctuary is one of the biodiversity rich sites of India; but unfortunately during the last decade the forests and biodiversity of this area have been degraded largely because of human disturbances. Rapid demographic changes and continuous unplanned collection of the valuable forest species and plant products has led to the over exploitation of natural flora and fauna of this region (Dhar *et al*., 1997). Government projects like construction of dams, tunnels and hydroelectric projects at various places of Kedarnath Valley also cause disturbances. All these disturbances are the cause of concern for the vegetation of this region.

Understanding the species richness and diversity patterns of tree species in relation to disturbances is of key significance to understand the form and structure of a forest community and for planning and implementation of conservation strategy of the community. In forest ecosystems, trees produce and maintain the overall physical structure of habitats (Jones *et al*., 1997). Quantification based on woody species is an important aspect when studying disturbance impact on forest structure. Indeed, woody species is a dominant life form which provides resources and habitat for many animal species and is easy to count (Sagar *et al*., 2003). Under the backdrop of aforesaid facts, the present study was carried out in a part of western Himalaya, India with the aim of assessment of species richness and diversity of tree species along the disturbance gradient or to study the effect of disturbance on tree species richness and diversity.

## MATERIAL AND METHODS

### Study Area

The study area lies in the sub-montane, montane and sub alpine zones of Garhwal Himalaya, India. The study was carried out in a protected area and its adjoining areas. The Kedarnath Wildlife Sanctuary (KWLS) is one of the largest protected areas extending to 975 km$^2$ of districts Chamoli and Rudraprayag of Uttarakhand between the coordinates 30°25'-30°41' N, 78°55'-79°22' E in the Garhwal region of Greater Himalaya and falls under the IUCN management category IV (Managed Nature Reserve). The area covered by the Sanctuary is 97517 ha (25293 ha in Chamoli district and 72224 ha in Rudraprayag district). The sanctuary lies in the upper catchment of the Alaknanda and Mandakini Rivers, two major tributaries of the Ganges. The present study was carried out in the three mixed broad-leaved forests along the disturbance gradient in Rudraprayag district. After reconnaissance survey, these three forests were selected on the basis of varying disturbance index (%) and canopy cover and were categorized into highly disturbed (HD), moderately disturbed (MD) and least disturbed (LD) categories (Table 1 and Fig 1). LD forest in Triyuginarayan area forms the core zone of KWLS; MD forest in Phata marks the fringe area of KWLS while the HD forest in Kund comes under its adjoining areas.

The climate in the study areas is divisible into four distinct seasons, *viz.,* summer (May–July), rainy (mid July–September), winter (October–January) and spring (February-April). The rainfall pattern in the region is largely governed by the monsoon rains (July–September), which account for about 60–80% of the total annual rainfall. However, at higher altitudes, precipitation is almost a daily routine. The soil types found in the region are podozolic soils. Soil texture of the study area is predominantly sandy loam and sandy clay loam whereas soil colour varies from dark brown to black. Soils are generally gravelly and large boulders are common in the area (Malik, 2014).

## METHODOLOGY

**Disturbance Index (%):** This was calculated following Murali *et al.* (1996).

$$\text{DI TBC} = \frac{\text{TBC of cut stumps in the forest per hectare}}{\text{Total TBC of all the standing stems in the forest per hectare}} \times 100$$

Where DI TBC is the disturbance index on the basis of total basal cover of cut stumps.

On the basis of this index the selected forests were categorized into LD, MD and HD forests (Table 1).

### Vegetation analysis

The analysis of tree species was carried out by placing random sampling plots (quadrats) as per Mishra (1968). Trees (≥30 cm dbh) were analyzed by placing twenty 10m × 10m sized quadrats covering an area of 2000 m$^2$ in each forest. The trees were identified with the help of taxonomists, available literature and regional floras (Naithani, 1984-85; Gaur, 1999). Total species richness was taken as a count of number of species present in a particular forest. The tree species diversity was calculated using Shannon-Wiener index (Shannon and Weaver, 1963).

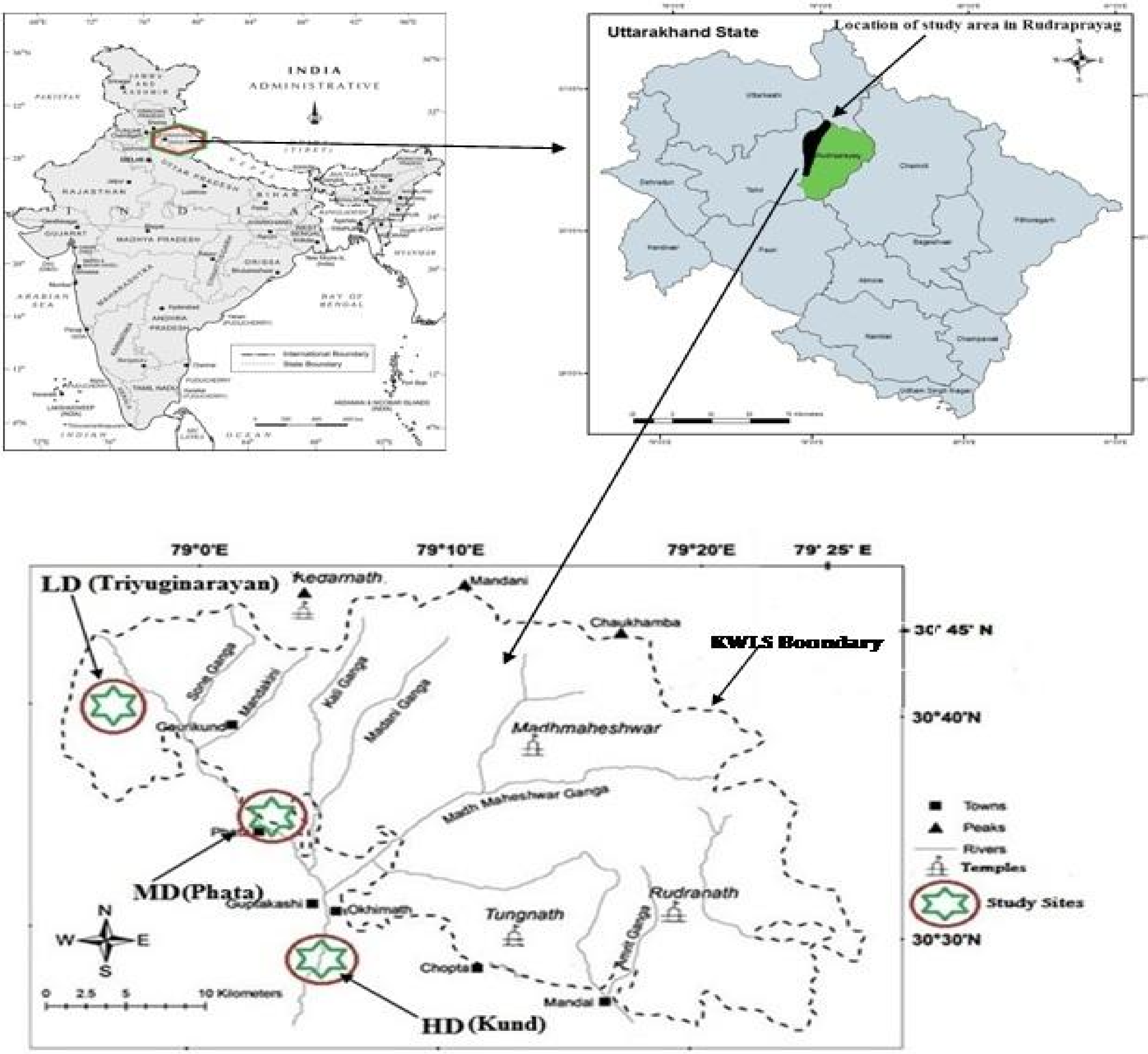


**Fig. 1. Location of the study sites in KWLS and its adjoining areas**

**Table 1. Characteristics of the study area**

| Site | Forest | Altitude (m) | Geo-Coordinates | Aspect | Slope | DI TBC (%) | Canopy Cover (%) |
|---|---|---|---|---|---|---|---|
| Kund | Highly Disturbed (HD) | 1000-1150 | $30^{0}$30'00.30N, $079^{0}$05'25.73E | SE | $23^{0}\pm8^{0}$ | 39.83 | 30 |
| Phata | Moderately Disturbed (MD) | 1650-1750 | $30^{0}$ 35' 07.75N, $079^{0}$12'26.85N | SW | $16^{0}\pm 9^{0}$ | 8.42 | 40 |
| Triyuginarayan | Least Disturbed (LD) | 2250-2400 | $30^{0}$38'47.11N, $078^{0}$58'4.75E | WWS | $30^{0}\pm5^{0}$ | 4.26 | 70 |

Different species richness indices were calculated following standard methods *viz.,* Margalef, 1958 and Menheink, 1964. Concentration of dominance (Cd) was calculated as per Simpson 1949 and Simpson's diversity index (SDI) as per Simpson, 1949. The ratio of abundance to frequency indicated the distribution pattern (Curtis and Cottam, 1956). The Maturity Index was calculated following Pichi-Sermolli (1948).

## RESULTS

A total of 33 tree species were reported along the disturbance gradient. The vegetation of the studied forests along with the resource use pattern is given in the Table 2. Dominant tree species are shown in bold.

**Table 2. Details of vegetation and resource use pattern along the disturbance gradient***

| Forest | Main Vegetation[1] | Anthropogenic disturbances/ Resource use pattern[2] |
|---|---|---|
| HD | *Albizia chinensis, Cinnamomum tamala, Engelhardtia spicata, Ficus auriculata, Lyonia ovalifolia, Mallotus philippensis,* ***Neolitsea cuipala****, Pinus roxburghii, Quercus leucotrichophora, Rhododendron arboreum, Toona hexandra* | HTL, HSC, HG |
| MD | *Aesculus indica, Alnus nepalensis, Betula alnoides,* ***Daphniphyllum himalense****, Fraxinus micrantha, Ilex dipyrena, Juglans regia, Lindera pulcherrima, Litsea elongata, Lyonia ovalifolia, Persea odoratissima, Prunus venosa, Pyrus pashia, Quercus floribunda, Q. leucotrichophora, Rhamnus virgatus,* ***Rhododendron arboreum****, Swida macrophylla* | HG, LSC, HTL, CNTFP |
| LD | *Acer caesium, Acer cappadocicum, Aesculus indica, Buxus wallichiana, Euonymus pendulus, Ilex dipyrena, Juglans regia, Lindera pulcherrima, Litsea elongata, Lyonia ovalifolia, Persea odoratissima, Pyrus pashia, Quercus floribunda, Q. leucotrichophora, Q. semecarpifolia, Rhamnus virgatus, Rhododendron arboreum, Symplocos ramosissima, Taxus baccata* | HG, LSC, HTL, CNTFP |

*Adopted from Malik *et al*. 2014;
[1]Dominant species are written in bold
[2]HTL= heavy tree lopping, HG= Heavy grazing, LSC= low stem cutting, HSC= heavy stem cutting, CNTFP= collection of non-timber/forest products.

**Table 3. Species richness and diversity patterns along a disturbance gradient in the study area**

| Forest | SR | MI | MeI | H' | SDI | Eq | Mat. I |
|---|---|---|---|---|---|---|---|
| Highly Disturbed | 11 | 2.59 | 1.60 | 2.30 | 10.90 | 0.95 | 15.90 |
| Moderately Disturbed | 18 | 3.75 | 1.86 | 3.21 | 17.90 | 0.11 | 16.94 |
| Least Disturbed | 20 | 4.11 | 1.99 | 3.34 | 19.90 | 0.11 | 15.50 |

Abbreviations: SR= Species Richness, MI=Margalef's Index, MeI= Menheink's Index, H'= Shannon Weiner Diversity Index and SDI= Simpson's Diversity Index; Eq= Equitability; Mat. I= Maturity Index

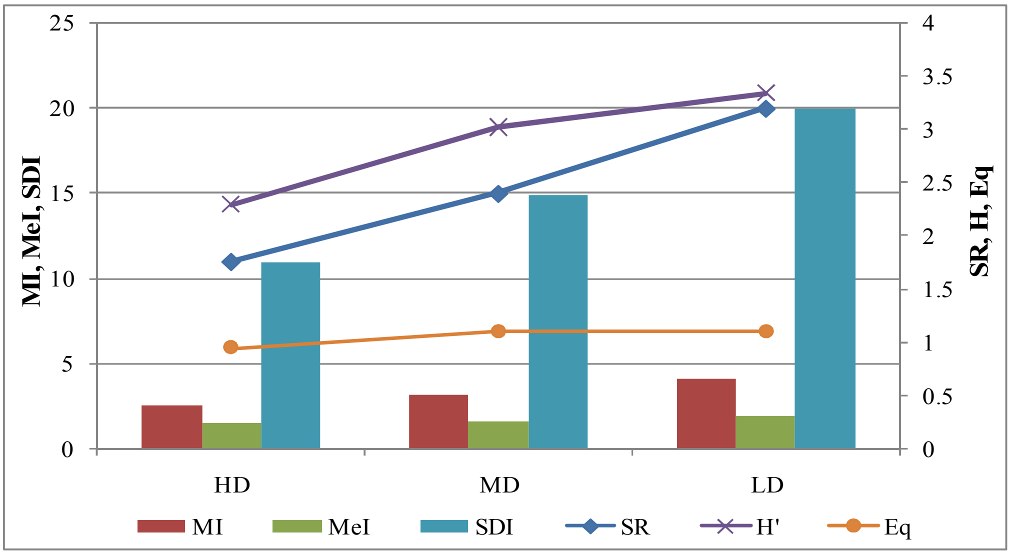


**Fig. 2. Species richness, diversity patterns and equitability along the disturbance gradient**

## Species richness and diversity patterns

In the present study, the species richness and Shannon Wiener diversity index varied from 11 to 20 and 2.3 to 3.34 respectively along the disturbance gradient (Table 3). Lowest number of species (SR=11) was reported from highly disturbed (HD) forest while least disturbed (LD) forest possessed highest number of species (SR=20). MD forest occupied an intermediate position with respect to species richness (SR=18). Equitability or species evenness ranged from 0.95 to 0.11. Fig. 2 shows change in equitability along the disturbance gradient. Both species richness and species evenness markedly declined from least disturbed to highly disturbed forests (Fig. 2). The highest value of Shannon Wiener index (3.34) was reported for LD forest, followed by MD (3.21) and HD (2.3).

In the HD forest maximum and minimum species diversity was recorded for *Neolitsea cuipala* (H=0.37) and *Rhododendron arboreum* (H=0.11) respectively while the maximum and minimum values for Simpson's diversity index (SDI) were recorded for *Rhododendron arboretum* (0.9963) and *Neolitsea cuipala* (0.9633) respectively (Table 4). In the MD forest, maximum and minimum species diversity was recorded for *Daphniphyllum himalense* (0.37) and *Prunus venosa, Swida macrophylla* (0.03 each) respectively while the maximum and minimum value for SDI was recorded for *Prunus venosa, Swida macrophylla* (0.9998 each) and *Daphniphyllum himalense* (0.977) respectively (Table 4). In the LD forest, maximum and minimum species diversity was recorded for *Rhododendron arboreum* (0.43) and *Quercus glauca* (0.05) respectively while the maximum and minimum value for SDI was recorded for *Quercus glauca* (0.999 each) and

*Rhododendron arboreum* (0.960) respectively (Table 4). Margalef's diversity index also decreased (4.11-2.59) along the disturbance gradient *i.e.* from LD to HD. Menheink's value was recorded between 1.60 to 1.99, the minimum value was observed for HD and maximum for LD forest while MD forest occupied an intermediate position. Simpson's diversity ranged from 10.90 (HD) to 19.90 (LD) as presented in Table 3 and Fig. 2. Maturity index varied from 15. 50 (LD) to 16.94 (MD) and did not follow any definite trend along the disturbance gradient (Table 3).

**Table 5. Distribution pattern of tree species in the study area**

| | Distribution Pattern | | |
|---|---|---|---|
| Forest | Regular | Random | Contagious |
| Highly Disturbed | - | 9.09 | 90.9 |
| Moderately Disturbed | - | 22.22 | 77.77 |
| Least Disturbed | - | 10 | 90 |

## Dominance-diversity (d-d) curve

To ascertain the resource apportionment among trees species along the disturbance gradient, d-d curves were drawn.

**Table 4. Species diversity, Simpson's diversity index and distribution pattern of tree species along the disturbance gradient**

| | Disturbance Gradient | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Highly Disturbed | | | Moderately Disturbed | | | Least Disturbed | | |
| Tree Species | H | SDI | Dist | H | SDI | Dist | H | SDI | Dist |
| *Acer caesium* | - | - | - | - | - | - | 0.11 | 0.995 | C |
| *Acer cappadocicum* | - | - | - | - | - | - | 0.08 | 0.993 | C |
| *Aesculus indica* | - | - | - | 0.13 | 0.9989 | C | 0.15 | 0.998 | Ra |
| *Albizia chinensis* | 0.15 | 0.9959 | C | - | - | - | - | - | - |
| *Alnus nepalensis* | - | - | - | 0.2 | 0.9981 | C | - | - | - |
| *Betula alnoides* | - | - | - | 0.24 | 0.9943 | Ra | - | - | - |
| *Buxus wallichiana* | - | - | - | - | - | - | 0.15 | 0.998 | C |
| *Cinnamomum tamala* | 0.25 | 0.9886 | C | - | - | - | - | - | - |
| *Daphniphyllum himalense* | - | - | - | 0.37 | 0.977 | Ra | - | - | - |
| *Engelhardtia spicata* | 0.17 | 0.9959 | C | - | - | - | - | - | - |
| *Euonymous pendulus* | - | - | - | - | - | - | 0.11 | 0.998 | C |
| *Ficus auriculata* | 0.21 | 0.9927 | C | - | - | - | - | - | - |
| *Fraxinus micrantha* | - | - | - | 0.15 | 0.9981 | C | 0.08 | 0.998 | C |
| *Ilex dipyrena* | - | - | - | 0.19 | 0.9971 | C | 0.21 | 0.993 | C |
| *Juglans regia* | - | - | - | 0.15 | 0.9981 | C | 0.14 | 0.997 | C |
| *Lindera pulcherrima* | - | - | - | 0.18 | 0.9971 | C | 0.18 | 0.997 | C |
| *Litsea elongata* | - | - | - | 0.31 | 0.988 | Ra | 0.2 | 0.998 | Ra |
| *Lyonia ovalifolia* | 0.15 | 0.9959 | C | 0.26 | 0.9926 | C | 0.27 | 0.992 | C |
| *Mallotus philippensis* | 0.2 | 0.9927 | C | - | - | - | - | - | - |
| *Neolitsea cuipala* | 0.37 | 0.9633 | Ra | - | - | - | - | - | - |
| *Pinus roxburghii* | 0.2 | 0.9927 | C | - | - | - | - | - | - |
| *Persea odoratissima* | - | - | - | 0.08 | 0.9995 | C | 0.08 | 0.991 | C |
| *Prunus venosa* | - | - | - | 0.03 | 0.9998 | C | - | - | - |
| *Pyrus pashia* | - | - | - | 0.18 | 0.9971 | C | 0.11 | 0.997 | C |
| *Quercus glauca* | - | - | - | - | - | - | 0.05 | 0.999 | C |
| *Quercus floribunda* | - | - | - | 0.12 | 0.9989 | C | 0.23 | 0.995 | C |
| *Quercus leucotrichophora* | 0.2 | 0.9927 | C | 0.26 | 0.9926 | Ra | 0.3 | 0.99 | C |
| *Quercus semecarpifolia* | - | - | - | - | - | - | 0.21 | 0.996 | C |
| *Rhamnus virgatus* | - | - | - | 0.08 | 0.9995 | C | - | - | - |
| *Rhododendron arboreum* | 0.11 | 0.9963 | C | 0.25 | 0.9943 | C | 0.43 | 0.960 | C |
| *Swida macrophylla* | - | - | - | 0.03 | 0.9998 | C | - | - | - |
| *Symplocos ramosissima* | - | - | - | - | - | - | 0.11 | 0.994 | C |
| *Taxus baccata* | - | - | - | - | - | - | 0.11 | 0.994 | C |
| *Toona hexandra* | 0.25 | 0.9886 | C | - | - | - | - | - | - |

Abbreviations: H= Shannon Wiener Index, SDI= Simpson's Diversity Index, Dist= Distribution pattern

## Distribution pattern

Hubbell *et al*. (1999) observed that ecological factors like dispersal limitation control the species distribution pattern, composition and structure of the forests and some focus was also given to local biotic and abiotic ecological interactions to explain the distribution pattern of plant species. The distribution of plants is determined by climatic and related variables including disturbances (Veenandaal *et al*., 1996). In the present study, the tree species did not show any definite trend along the disturbance gradient as far as their distribution pattern is concerned (Table 5). Contagious distribution was shown by most species, followed by random distribution. No tree species had regular distribution in the study area (Table 4 and 5). According to Odum (1971), contagious distribution is common in nature, while random distribution is found only in uniform environments.

The relative importance value is an expressive measure of niche of species, thus treated as an expression of the relative niche size. In the present study, the relative abundance in the least and moderately disturbed (LD and MD) forests was distributed more or less evenly among the different species *i.e.* high equitability or low dominance (Fig 3), while the highly disturbed forest presented a low equitability or high dominance picture.

## Statistical Analysis

Carl-Pearson's correlation coefficient was calculated between disturbance, tree species richness and other diversity indices (Table 6). Disturbance showed a significant negative relation with Margalaf's index (r= -0.999), Menheink's index (r= -0.965), Simpson's diversity index (r= -0.996).

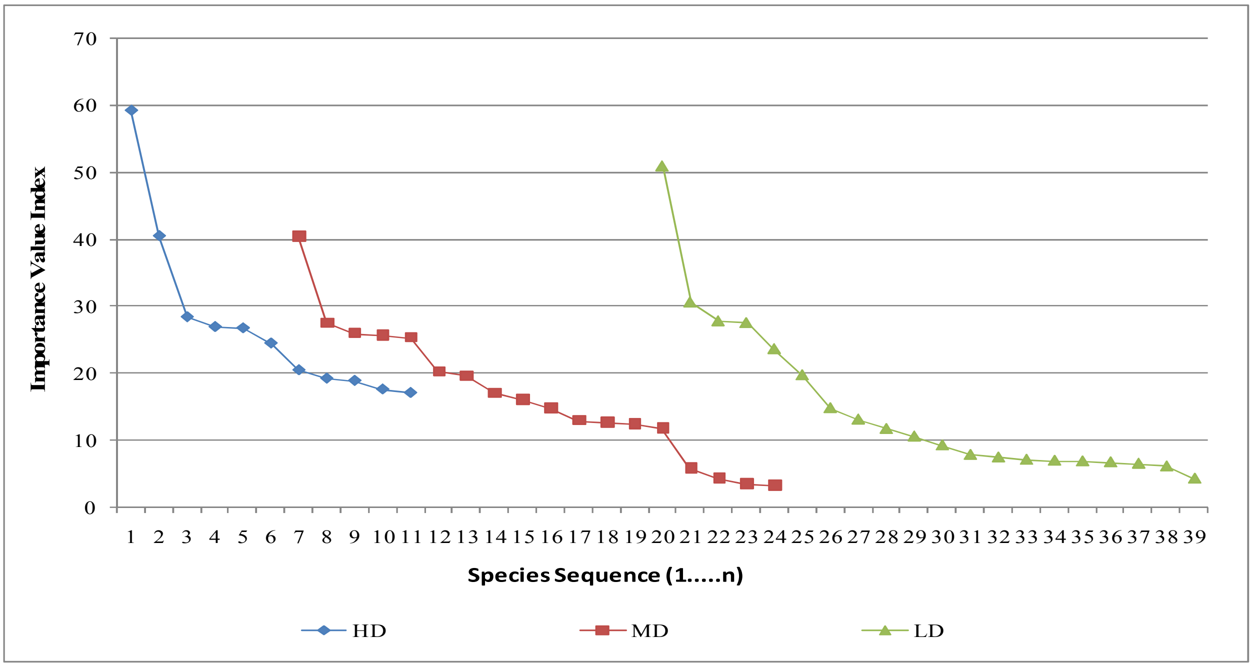


**Fig.3. Dominance-diversity curves for tree strata in different forests**

**Table 6. Carl-Pearson's correlation coefficients between various studied parameters**

| | Disturbance | SR | H | MI | MeI | SDI | Eq |
|---|---|---|---|---|---|---|---|
| Disturbance | 1 | | | | | | |
| SR | -0.899 | 1 | | | | | |
| H | -0.935 | 0.995* | 1 | | | | |
| MI | -0.999* | 0.902 | 0.937 | 1 | | | |
| MeI | -0.965** | 0.754 | 0.811 | 0.963** | 1 | | |
| SDI | -0.996* | 0.930 | 0.960** | 0.942** | 0.942 | 1 | |
| Eq | -0.786 | 0.977** | 0.953** | 0.790** | 0.598 | 0.832 | 1 |

** Correlation is significant at 0.05 level; *Correlation is significant at 0.01

## DISCUSSION

Any relatively discrete event in time that disrupts an ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment is called disturbance. The Himalayan vegetation is subjected to various types of disturbances. In India, although the degree of anthropogenic pressure varies in different parts of the country, manmade disturbance has become a widespread feature in most of the forests throughout the Himalaya and the same is true for the forests of present study area. Disturbance, whether natural or manmade, is an important force capable of moulding plant communities by influencing their composition, structure and functional processes (Shrestha *et al*., 2013). Biodiversity and disturbance are hierarchical concepts. Disturbance can be considered as a basic process responsible for many other processes, such as fragmentation, migration, local and regional extinction, etc. (Behera *et al*., 2005).

In the present study an attempt was made to study the effect of disturbance on tree species richness and diversity in a part of Western Himalaya. These parameters *i.e.* tree species richness and diversity indices declined markedly with increase in the level of disturbances. All these parameters showed a strong negative correlation with disturbance (Table 5).

Species richness and diversity is correlated with disturbance as shown by several authors (Grubb, 1977; Connell, 1978; Huston 1979; Armesto and Pickett, 1985). Sheil (1999) opined that the disturbance of a suitable intensity will increase species richness in consonance with intermediate disturbance hypothesis of Connell (1987). The present study, however, does not conform for the views of Huston (1979), Armesto and Pickett (1985), Connell (1987) and Sheil (1999), who predicted a peak in species diversity at intermediate disturbance intensity or frequency. It may be argued that the characteristics of the system and type of disturbance might be responsible for this trend (Rao *et al*., 1990). Our findings are in contrast to the earlier observations of Bhuyan *et al.,* (2003) and Misra *et al.* (2004), who recorded more number of species in the moderately disturbed stand as compared to undisturbed and highly disturbed stands. The mild disturbance provides greater opportunity for species turnover, colonization and persistence of high species richness (Whittaker, 1972). However, our data on species richness and diversity per unit do not support the intermediate disturbance hypothesis.

In the present study, as far as tree populations are concerned, we found that the least disturbed or comparatively undisturbed stand showed higher species richness and diversity as compared to that of the moderately and highly disturbed stands.

Similar results were obtained by Behera *et al*. (2005) from Eastern Himalaya, Sagar and Singh (2005) from Northern India, Sapkota *et al*. (2010) from Nepal; Prasad and Al-Sagheer (2012) from Western Ghats. These findings are, rather, in conformity with the view held by Clements, 1936 who viewed disturbance as a negative force that destroys climax assemblages and brings instability in the system. The results also conforms the findings of Rao *et al*. (1990) who found that species diversity and abundance markedly declined from undisturbed to the disturbed stands, in their study on the community composition and tree population structure of three forest stands of different degree of disturbance in the sub-tropical broad-leaved forest of Meghalaya, India.

IVI distribution (d-d) curve (Fig 3) showed that the highly disturbed stand had higher dominance or low evenness while the moderately and least disturbed stand had lower dominance or higher evenness among trees. Similar results were obtained by Lalfakawma *et al*., 2009 while studying community composition and tree population structure in undisturbed and disturbed tropical semi-evergreen forest stands of north-east India.

Because of the lack of employment opportunities, the people of the study area are completely dependent on rain fed agricultural land and forests. The average cultivated land per household in the study area was less than 1 ha i.e 0.56 ha (Malik *et al*., 2014). The agricultural land in this area is rainfed and is not much productive. Thus it is clear that the people of this area are completely dependent on the adjacent forests for their basic requirements because the land is less prolific and job opportunities are none (Malik *et al*., 2014). Fuelwood is the most common and primary energy source in this area and is used for cooking and also to heat rooms and water during the winter season. Other forms of commercial energy are beyond the reach of ordinary people because of poor socioeconomic conditions, lack of communication, high prices, and limited supply in this inaccessible hilly area. Malik *et al*. (2014) while studying forest resource use pattern in the study area found that 100% of families used wood as a source of energy for cooking and heating purposes. These forests are the main source of fodder and bedding material for livestock in the area. One of the very severe impacts of repeated fuelwood harvesting on the structure of the forest is the ruthless decline of large old trees resulting in their complete disappearance (Malik, 2014). Once these trees are lost, the size of gaps created either by natural tree falls or logging also increases (Ruger *et al*., 2007), resulting in forest fragmentation and susceptibility to invasion by ephemerals, that inhibit the regeneration of seedlings of tree species (Malik *et al*., 2014; Malik, 2014). Human-induced disturbance (such as mining, timber extraction, etc.) and livestock grazing also cause changes in species number, tree density and basal area (Rao *et al*., 1990). Unrestricted and open accessibility may cause enhanced utilization of the forest resource and this may eventually lead to a species-poor state (Murali *et al*., 1996). Houehanou *et al*. (2012), while studying changes in the woody floristic composition and diversity in the savannahs of West Africa concluded that the disturbances affect on woody diversity at tree layer level and such effect should be mostly linked to the firewood use that selects adult tree individuals of some woody species and consequently decreases woody species richness and diversity. Similar results were reported elsewhere (Bhuyan *et al*., 2003 from Arunachal Pradesh; Sagar *et al*., 2003 from West Central India; Sagar and Singh 2005 from Northern India; Makana and Thomas 2006 from Democratic Republic of Congo; Lalfakawma *et al*., 2009 from North East India, and Houehanou *et al*., 2012 from West Africa) where a significant decrease in woody diversity with the disturbance intensity were reported on various tropical ecosystems.

The maturity index is an important tool for representation of quantitative and qualitative characteristics of a community and in evaluating the biodiversity and conservation of intact habitat and plant life in specific area (Malik, 2014). In the present study, maturity index varied from 15. 50 (LD) to 16.94 (MD) and it did not follow any definite trend along the disturbance gradient. But these values were lower than those reported by Shaheen *et al*. (2012) from Pakistan Himalaya. Various types of disturbances (like landslides, cloud burst, lopping, grazing and fuel wood collection by local people) may be the reason for such lower values of maturity index. Mature communities are composed of few well established and uniformly distributed species occupying maximum space and out-competing the sporadic flora. Species in a mature community manage to establish them to local conditions achieving a balanced state with other members (Nautiyal and Kaechele, 2007). Low maturity index values indicate the heterogeneity within communities due to a lesser adaptation to the ecological conditions of area. The high intensity of anthropogenic disturbances regularly disturbs the natural balance of forest communities, thus preventing them to reach a climax stage of community maturity (Saxena and Singh, 1984). Moreover, most of the tree species showed contagious distribution (Table 5) in the study area and according to Whitford (1949), in pioneer communities plants tend to be aggregated but as the community progresses towards climax, their distribution become more random or even regular. The low maturity value and contiguous distribution of species denote the early successional status of the studied forests (Malik, 2014).

Despite general agreements on the role of disturbances of a suitable intensity in maintaining species diversity (Connell, 1978; Sheil, 1999; Hubbell, 2001; Sheil and Burslem, 2003), the detailed processes that structure the diversity following disturbance remain unclear yet (van Gemerden *et al*., 2003). The present study reveals that the anthropogenic disturbance causes disruption of forest structure and changes species composition which ultimately leads to reduction of tree species richness and diversity which is a major forest component. Leigh (1965) suggested that stability increases with the complexity of the ecosystems, that is with the number of species and with the number of interactions between them. MacArthur (1955) pointed out that diversity is a function of the number of species. The stability has been reported to increase with diversity (Safi and Yarranton, 1973). Therefore, disturbance in the study area (Himalaya) can potentially lead to a decrease in stability and complexity of the ecosystems.

The least disturbed or comparatively undisturbed forest constitutes the core zone of a protected area *i.e.* Kedarnath Wildlife Sanctuary. There is a restriction, to some extent, on human activities like tree felling, grazing, collection of fuelwood and litter etc. in this forest. Hence it is protected, mature and comparatively undisturbed while the moderately and highly disturbed forests come under fringe and adjoining areas of KWLS that are not protected from the above mentioned anthropogenic disturbances. This study also gives the importance of establishment of protected areas for the conservation of biodiversity of Himalaya.

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## REFERENCES

Armesto, J.J., Pickett, S.T.A. 1985. Experiments on disturbance in old-field plant communities: Impact on species richness and abundance. *Ecology,* 66: 230–240.

Behera, MD., Kushwahab, S.P.S, Roy PS. 2005. Rapid assessment of biological richness in a part of Eastern Himalaya: an integrated three-tier approach. *For Eco. Manag.,* 207: 363–384.

Bhuyan P, Khan ML, Tripathi RS. 2003. Tree diversity and population structure in undisturbed and human-impacted stands of tropical wet evergreen forest in Arunachal Pradesh, Eastern Himalayas, *India. Biodiv. Conser.,* 12(8): 1753-1773.

Chettri N, Sharma E. 2006. Assessment of natural resources uses patterns: a case study along a trekking corridor of Sikkim Himalaya, *India. Res. Ener. Dev.,* 3 (1):21–34

Clements FE. 1936. Nature and structure of the climax. *J Eco.,* 24: 252- 284.

Connell JH. 1978. Diversity in tropical rain forests and coral reefs. *Science,* 199: 1302–1310.

Curtis JT, Cottam G. 1956. Plant Ecology Work Book. Laboratory Field References Manual. *Burgus. Publ. Co., Minnesota.* pp. 193

Dhar U, Rawal RS, Samant SS. 1997. Structural diversity and representativeness of forest vegetation in a protected area of Kumaun Himalaya, India: implications for conservation. *Biodiv. Conser.,* 6(8): 1045-1062.

Eilu G, Obua J. 2005. Tree condition and natural regeneration in disturbed sites of Bwindi impenetrable forest National Park, Southwestern Uganda. *Trop. Ecol.,* 46 (1): 99-101.

Gaur, RD. 1999. Flora of the District Garhwal North West Himalaya (with ethanobotanical notes). Transmedia Publication, Srinagar (Garhwal) India

Goudie AS. 2005. The Human Impact on the Natural Environment: Past, Present, and Future. London (UK): Wiley-Blackwell.

Grubb, P.J. 1977. The maintenance of species richness in plant communities. The importance of the regeneration niche. Biol Rev., 52 (1): 107–145.

Houehanou, T.D., Gle`le`, Kakaı, R.L., Assogbadjo, A.E., Kindomihou, V., Houinato, M., Wittig, R. and Sinsin, B.A. 2012. Change in the woody floristic composition, diversity and structure from protected to unprotected savannahs in Pendjari Biosphere Reserve (Benin, West Africa). *Afr. J. Ecol.,* 1-8; doi: 10.1111/aje.12046

Hubbell, S.P. 2001. The Unified Neutral Theory of Biodiversity and Biogeography. Monographs in Population Biology 32. Princeton, New Jersey: Princeton University Press.

Hubbell, S.P., Foster. R.B., O'Brien, S.T., Harms, K.E., Condit, R., Wechsler, B., Wright, S.J. and Loode, L.S. 1999. Light gap disturbance, recruitment limitation and tree diversity in a Neotropical forest. *Science,* 283: 554-557.

Huston, M.A. 1979. A general hypothesis of species diversity. *Am Nat.,* 113: 81-101.

Jones, C.G, Lawton, J.H, Shachak, M. 1997. Positive and negative effects of organisms as physical ecosystem engineers: Positive interactions in communities. *Ecology,* 78 (7): 1946-1957.

Kharakwal, G., Mehrortra, P., Rawat, Y.S. and Pangtey, Y.P.S. 2005. Phytodiversity and growth form in relation to altitudinal gradient in the Central Himalayan (Kumaun) region of India. *Curr. Sci.,* 89(5): 873-878.

Kumar, A. and Ram, J. 2005. Anthropogenic disturbances and plant biodiversity in forests of Uttaranchal, Central Himalaya. *Biodive Conser.,* 14: 309-331.

Lalfakawma, Sahoo U.K., Roy, S., Vanlalhriatpuia, K. and Vanalalhluna, P.C. 2009. Community composition and tree population structure in undisturbed and disturbed tropical semi-evergreen forest stands of north-east india. *Appl. Ecol. Env. Res.,* 7(4): 303-318.

Leigh E. 1965. On a relation between the productivity biomass, stability and diversity of a community. *Proceedings of National Academy of Sciences,* USA 53, 777–783.

MacArthur, RH. 1955. Fluctuations of animal populations, and a measure of community stability. *Ecology,* 36: 533–536.

Makana, J.R. and Thomas, S.C. 2006. Impacts of selective logging and agricultural clearing on forest structure, floristic composition and diversity, and timber tree regeneration in the Ituri Forest, *Democratic Republic of Congo. Biodiv. Conser.,* 15:1375–1397.

Malik, Z.A. 2014. Phytosociological behavoiur, anthropogenic disturbances and regeneration status along an altitudinal gradient in Kedarnath Wildlife Sanctuary (KWLS) and its adjoining areas. Ph. D Thesis HNB Garhwal University, Srinagar Uttarakhand.

Malik, ZA., Bhat, J.A. and Bhatt, A.B. 2014. Forest resource use pattern in Kedarnath Wildlife Sanctuary and its fringe areas (a case study from Western Himalaya, India). *En. Pol.,* 67: 138-145.

Margalef, D.R. 1958. Information theory in ecology. *Gen. Sys.,* 3:36-71.

Menhinick, E.F. 1964. A comparison of some species diversity indices applied to samples of field insects. *Ecology,* 45:859–861.

Mishra, A., Sharma, S.D., Pandey, R. and Mishra, L. 2004. Amelioration of pH in highly alkaline soil by trees in northern India. *Soil Use Manag.,* 20(3): 325-332.

Mishra, R. 1968. Ecology Workbook. Oxford and IBH Publication Co., Culcutta

Murali, K.S., Uma Shankar, Ganeshaih, K.N., Umashaanker, R. and Bawa, K.S. 1996. Extraction of nontimber forest products in the forest of Bilgiri Rangan Hill, India, 2.

Impact of NTFP extraction on regeneration; population structure and species composition. *Eco.Bot.,* 50: 252–269.

Naithani, B. D. 1984-1985. Flora of Chamoli. Vols. I-II: Botanical Survey of India, Calcutta.

Nautiyal, S, Kaechele, H. 2007. Conserving the Himalayan forests: approaches and implications of different conservation regimes. *Biodiv. Conser.,* 16: 3737–3754.

Odum, E.P. 1959. Fundamentals of Ecology 2nd ed. Sounders, Philadelphi

Odum, E.P. 1971. Fundamentals of Ecology. Saunders Company, Philadelphia, USA.

Peet, R.K. 1974. The measurement of species diversity. *Ann Review Ecol. Evo Syst.,* 5: 285-307.

Pichi-Sermolli, 1948. An index for establishing the degree of maturity in plant communities author(s): source. *J. Ecol.,* 36 (1): 85–90.

Polyakov, M., Majumdar, I. and Teeter, L. 2008. Spatial and temporal analysis of the anthropogenic effects on local diversity of forest trees. *For Eco. Manag.,* 255: 1379-1387.

Prasad, A.G.D. and Al-Sagheer, N.A. 2012. Floristic diversity of regenerated tree species in Dipterocarp forests in Western Ghats of Karnataka, *India. J. Environ Biol.,* 33: 791-797.

Pushpangadan, P., Ravi, K. and Santosh, V. 1997. Conservation and Economic Evaluation of Biodiversity. Vols.I-II.oxford abd IBH publishing Co. Pvt. Ltd., New Delhi.

Putman, R.J. 1994. Community Ecology. Chapman and Hall, London.

Rao, P., Barik, S.K., Pandey, H.N. and Tripathi, R.S. 1990. Community composition and tree population structure in a sub-tropical broadleaved forest along a disturbance gradient. *Vegetatio,* 88: 151–162

Ruger, N., Gutierrez, A.G., Kissling, W.D., Armesto, J.J. and Huth, A. 2007. Ecological impacts of different harvesting scenarios for temperate evergreen rain forest in southern Chile-a simulation experiment. *For Ecol.Manag.,* 252: 52-66.

Safi, M.I. and Yarranton, G.A. 1973. Diversity, floristic richness, and species evenness during a secondary (post-fire) succession. *Ecology,* 54: 897–902.

Sagar, R. and Singh, J.S. 2005. Structure, diversity, and regeneration of tropical dry deciduous forest of northern India. *Biodiver.Conser.,*14: 935-959.

Sagar, R., Raghubanshi, A.S. and Singh, J.S. 2003. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. *For Ecol. Manag.,* 186: 61-71.

Sapkota, I.P., Tigabu, M. and Oden, P.C. 2010. Changes in tree species diversity and dominance across a disturbance gradient in Nepalese Sal (Shorea robusta Gaertn. f.) forests. *J. For Res.,* 21(1): 25-32.

Saxena, A.K. and Singh, J.S. 1984. Tree population structure of certain Himalayan forest associations and implications concerning the future composition. *Vegetatio,* 58 (2): 61-69.

Shackleton, C.M., Griffin, N.J., Banks, D.I., Mavrandonis, J.M. and Shackleton, S.E. 1994. Species composition along a disturbance gradient in a communally managed in South African savanna. *Vegetatio,* 115: 157-167.

Shaheen, H., Ullah, Z., Khan, S.M. and Harper, D.M. 2012. Species composition and community structure of western Himalayan moist temperate forests in Kashmir. *For Ecol. Manag.,* 278:138–145.

Shannon, C.E. and Weaver, W. 1963. The mathematical theory of communication. Urbana, USA: University of Illinois Press, p117

Sheil, D. 1999. Tropical forest diversity, environmental change and species augmentation: After the intermediate disturbance hypothesis. *J. Veg. Sci.,* 10: 851-860.

Sheil, D. and Burslem, D.F.R.P. 2003. Disturbing hypotheses in tropical forests. *Trends Ecol. Evol.,* 18: 18–26.

Shrestha, K.B., Maren, I.E., Arneberg, E., Sah, J.P. and Vetaas, O.R. 2013. Effect of anthropogenic disturbance on plant species diversity in oak forests in Nepal, Central Himalaya. *Int. J.Biodiv.Sci, Eco. Ser. Manag.,* 9 (1):21-29.

Simpson, E.H. 1949. Measurement of Diversity. *Nature,* 163: 688-690

Singh, J.S. 2002. The biodiversity crisis: a multifaceted review. *Curr. Sci.,* 82: 638-647.

Slobodkin, L.B. and Sanders, H.L. 1969. On the contribution of environmental predictability to species diversity. *Brookhaven Symposium in Biology*, 22: 82-95.

Stapanian, M.A., Cassell, D.L. and Cline, S.P. 1997. Regional patterns of local diversity of trees: associations with anthropogenic disturbance. *For Eco. Manag.,* 93 (1/2): 33–44.

Van Gemerden, B.S., Olff, H., Parren, M.P.E. and Bongers. F. 2003. The pristine rain forest? Remnants of historical human impacts on current tree species composition and diversity. *J Biogeo.,* 30: 1381–1390

Veenandaal, E.M., Swaine, M.O., Agyeman, V.K., Blay, D., Abebrese, I.K. and Mullins, C.E. 1996. Differences in plant and soil water relations in and around a forest gap in West Africa during the dry season may influence seedling establishment and survival. *J Ecol.,* 83: 83-90.

Whitford, P.B. 1949. Distribution of woodland plants in relation to succession and clonal growth. *Ecology,* 30: 199-208.

Whittaker, R.H. 1972. Evolution and measurement of species diversity. *Taxon.,* 21: 213-215.

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