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Research Article

CONSEQUENCES OF DISTURBANCE IN BANJ OAK (*QUERCUS LEUCOTRICHOPHORA* A. CAMUS) FORESTS OF GARHWAL HIMALAYA

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Abstract: Present study measures the impact of forest disturbance on banj-oak (*Quercus leucotrichophora* A. Camus) forests of Garhwal Himalaya. The study was carried out by placing 1250 sample plots in 125 altitude ranges of banj-oak forests between 1500 and 2500m masl. The study revealed that out of 125 altitude ranges, 70 were present under moderately disturbed category, 30 were under highly disturbed and 25 were under undisturbed categories. It was also evident that tree species diversity and species richness were recorded highest in moderately disturbed category but a continuous downfall was recorded in tree basal area from undisturbed to highly disturbed category. Disturbance was found most sensitive to herb species in terms of diversity and species richness as both diversity and richness were decreasing with increasing disturbance. Shrub species richness was found highest in highly disturbed category and lowest in undisturbed category that indicates shrub species colonize well under disturbance regime. The study advocates a minimum canopy opening for improving species richness in banj-oak forests.

Keywords: *Disturbance, Banj-oak, Diversity, Altitude range, Garhwal Himalaya*

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Introduction

High biodiversity favors ecological stability, whereas accelerating species loss could lead to collapse of the ecosystem. The world over destruction of vegetation has been continuing at an alarming pace due to variety of causes [1] such as human settlement, urbanization, industrial establishment *etc*. Therefore, in many areas reconstruction of disturbed ecosystems is being taken up on a priority basis, both for biodiversity conservation and maintaining landscape productivity [2]. Human play a vital role in disturbing natural ecosystem and such kind of disturbance is termed as anthropogenic disturbance. The anthropogenic disturbance greatly affects the biodiversity and structural characteristics of the community and it resulted into the elimination of many valuable species from areas dominated by human influences. One of the major drawbacks with the anthropogenic disturbance in Himalaya is that it occurs in chronic form involving removal of a small amount of biomass at any given time, but persisting all the time, without any respite of recovery [3]. Himalaya has a long altitudinal spreading gradient from sub-montane to alpine with much diversified vegetation, which ranges from forest through Savanna to open grazing land. The Garhwal Himalaya embodies a number of forest types, which are found distributed at various altitudes, geological formation and soil types [4]. The forest species also varies with altitude ranging from *Shorea robusta* in sub-montane zone to *Quercus semicarpifolia* near to timberline and *Quercus leucotrichophora* and Pinus roxburghii in the montane zone. Montane zone is the most populated area in Garhwal Himalaya where banj-oak forest represents climax vegetation between 1000 - 2500 m asl. This banj-oak forest plays a vital role in conservation of soil, water, native flora and fauna, thereby, providing numerous ecosystem services to mankind. As local populace is receiving several ecological services from the forest therefore, the forest community is in threat of anthropogenic disturbances. It is evident that anthropogenic disturbance hits plant community hardly and create changes in quality and quantity of species present in plant community and it greatly affect the biodiversity and structural characteristics of the community.

Unrestricted and open accessibility under disturbance regime may cause enhanced utilization of the forest resource and this may eventually lead to a species poor state [5]. A higher disturbance level may be intense enough to change the habitat fitness especially for the herbaceous species [6]. In view of growing threat to biodiversity, it is important to see how plant communities and their structural attributes are affected by progressive erosion of biodiversity caused by anthropogenic disturbances [7]. The evergreen Oak (*Quercus leucotrichophora*) species play a major role as it dominates in the mid-hills of Garhwal Himalaya, and is often under strong anthropogenic pressures due to multifarious use of species, such as lopping for fodder, cutting for fuel-wood and minor timber. Currently the mid-elevation Oak forest recognized as most critical communities due to its superior characteristics and its wide acceptance as fuel, fodder and other ecosystem services throughout montane stretch. Many researchers acknowledged a gradual pressure on oak forest throughout the Himalaya and they often considered disturbance as a devastating factor for plant community. Present study aimed to assess how plant community response under various categories of disturbance.

Materials and methods

Study area

The study was conducted between altitudinal ranges of 1500m to 2500m masl in the Garhwal region of state of Uttarakhand, India that forms part of western Himalaya. Garhwal Himalaya lies between latitude 29°31' to 31°26' N and longitude 70°35' to 80°06' E exhibiting sub-montane to alpine climates with different characteristics of the specific vegetation types. The study was conducted in the nineteen banj-oak forest sites [plate-1] in five hill districts (Tehri, Pauri, Chamoli, Rudraprayag and Dehradun) of Uttarakhand in 2007-2008. Both north and south aspects have been taken for study and two vertical transects of 100m width has been laid down in each aspect at each site.

Table-1 *Geographical distribution of oak forest stands in study sites*

SN	District	Site	Elevation range (m masl)	Latitude	Longitude
1	Tehri	Bhawan	2100-2200	30° 14' 35.5" N	78° 14' 50.4" E
2	Tehri	Chandrabadani	1700-2100	30° 18' 58.1' N	78° 36' 18.4" E
3	Tehri	Dagar	1800-2100	30° 23' 02.8" N	78° 41' 28.8" E
4	Tehri	Ghuttu	1800-2300	30° 32' 02.6' N	78° 49' 15.2" E
5	Tehri	Koti	1700-1800	30° 21' 15.6' N	78° 38' 52.4" E
6	Dehradun	Mussoorie	1700-2200	30° 25' 24.4' N	78° 05' 23.4" E
7	Chamoli	Pipalkoti	1500-2000	30° 23' 57.5' N	79° 25' 41.9" E
8	Chamoli	Joshimath	2300-2400	30° 32' 45.7' N	79° 32' 44.1" E
9	Chamoli	Nauti	1800-1900	30° 11' 34.9' N	79° 11' 07.9" E
10	Chamoli	Diwalikhal	1500-2200	30° 05' 29.9' N	79° 14' 30.4" E
11	Uttarkashi	Radi	2100-2400	30° 46' 17.3' N	78° 15' 17.9" E
12	Uttarakashi	Chaurangikhal	2100-2500	30° 38' 30.7' N	78° 28' 59.2" E
13	Pauri	Chakisain	1700-1900	30° 06' 03.7' N	79° 00' 39.4" E
14	Pauri	Khirsoo	1600-2100	30° 08' 17.4' N	78° 50' 47.4" E
15	Pauri	Lansdown	1600-1800	29° 50' 54.8' N	78° 41' 08.3" E
16	Pauri	Naugonkhal	1500-1800	29° 57' 47.3' N	78° 51' 58.1" E
17	Pauri	Tripalisain	1800-2000	30° 04' 42.5' N	79° 04' 32.5" E
18	Rudraprayag	Guptakashi	1600-1800	30° 30' 54.8' N	79° 04' 35.4" E
19	Rudraprayag	Makku	1800-2300	30° 29' 11.4' N	79° 07' 32.0" E

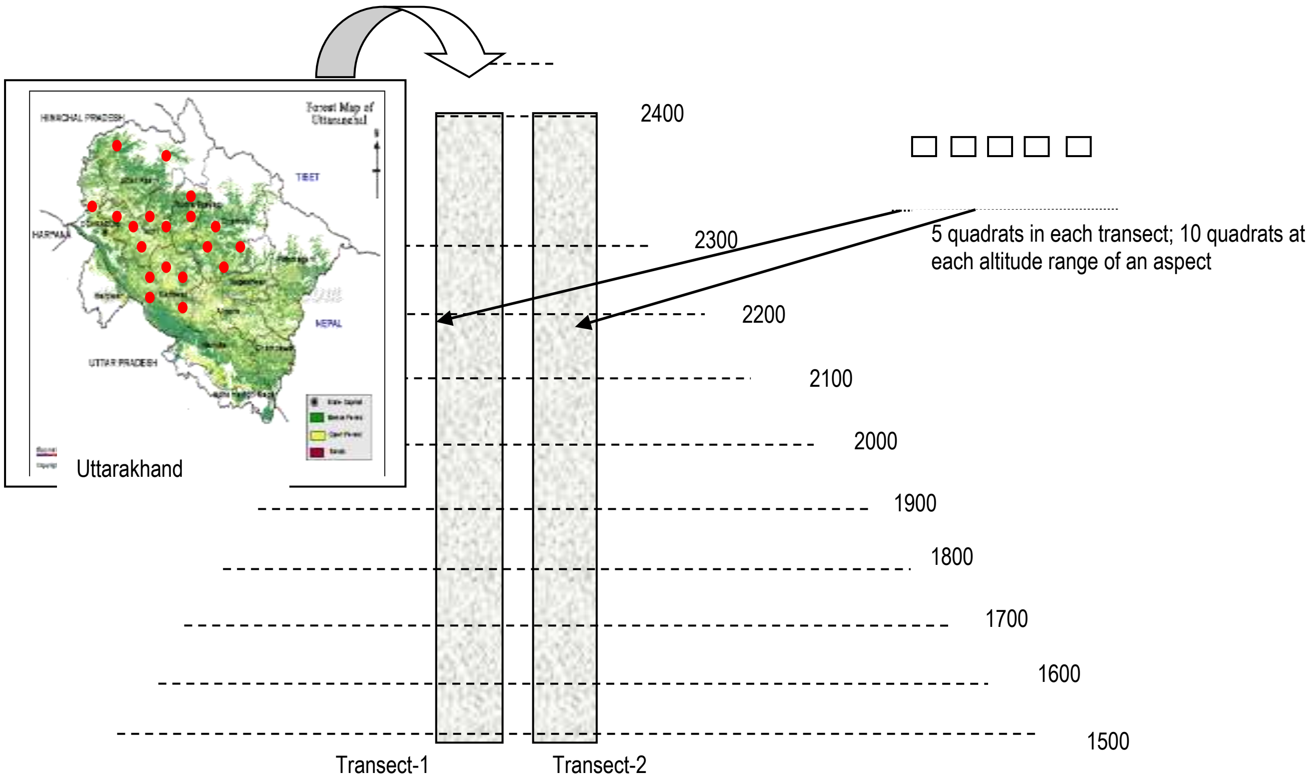

Plate-1 Study area (19 oak sites) & study design along altitudes (m masl) for North aspect; same was followed for South aspect

Quadrat based assessment of vegetation was carried out by placing quadrats at every 100m altitude interval within transect. A total of 125 altitude ranges has been studied under this study. Geographical distribution of oak forest stands in study sites presented in [Table-1].

Assessing disturbance categories

There are several kinds of anthropogenic disturbances are evident in banj-oak forest communities in the study area *e.g.* leaf fodder extraction, grazing, pole cutting, fuel-wood collection, leaf litter removal *etc.* The quantitative assessment of anthropogenic disturbances has been carried out in terms of canopy cover (%), tree density (h^{-1}), lopping intensity (%), and number of cut stumps (ha^{-1}). On the basis of observed minimum and maximum values of above mentioned disturbance indicators, we developed a disturbance index; an undisturbed stand (>1200 trees/ha, >50%canopy cover, <10%lopping, and <20 cut stumps/ha), the highly disturbed stand (<500 trees/ha, <30%canopy cover, >30%lopping, and >60cut stumps/ha). The moderately disturbed stands occupied the intermediate position with respect to these parameters [Table-2]. Canopy cover was recorded directly from the forest floor by spherical densitometer and expressed in term of percent (%) canopy cover. Lopping % = total number of lopped trees/density X 100 (A lopped tree was one whose >40% branches were lopped). Cut stumps were directly counted from forest floor.

Study was carried out within a total of 125 elevation ranges and all the studied ranges has been classified into three disturbance categories by using the values of various disturbance indicators; tree density, canopy cover, lopping %, and cut stump density. All the phytosociological characteristics have been recorded from each elevation ranges. Study confirmed the domination of moderately disturbed forest patches (70 elevation ranges, 56%) in the study area followed by highly disturbed (30 elevation ranges, 24 %) and undisturbed (25 undisturbed ranges, 20 %) patches.

Plant community characteristics

Vegetation analysis was carried out during the year 2007-2008 using the methods given by Mishra [8]; Density= total no. of individuals of a species/total no. of quadrats studied, Frequency= total no. of quadrats in which species occurred/total no. of quadrats studiesx100, Abundance= total no. of individuals of a species/total no. of quadrats in which species occuredx100, IVI= a sum of relative values of frequency, density and abundance. Ten quadrats or sampling plots were systematically established at each altitudinal range. Thus, a total of 1250 plots (n= 125 altitudinal ranges X 10 quadrats = 1250) were studied in this study. The nested quadrat sampling technique was used in the sampling of vegetation which entails the use of square quadrats of 10m x 10m. All the individuals of all tree species along with their circumferences at breast height were recorded. Shrub species were recorded by placing two 5m x 2m quadrats nested within 10m x 10m mother quadrat whereas the herb species were estimated through studying five quadrats of 1m x 1m size nested within the 10m x 10m mother quadrat. Trees (>31.5cm cbh) were individually measured for cbh. Further, each altitude range has been classified into different disturbance categories as undisturbed, moderately disturbed and highly disturbed, and data has been analyzed for each disturbance category separately.

Table-2 *Disturbance indicators of Himalayan oak forests*

Parameter	Undisturbed	Moderately disturbed	Highly disturbed
Tree density (ha^{-1})	>1200	501-1200	<500
Canopy cover (ha^{-1})	>50	31-50	<30
Lopping (%)	<10	Nov-30	>30
No. of cut stumps (ha^{-1})	<20	21-60	>60

Data Analysis

Field data were analyzed for various phytosociological characters and plant diversity values. Abundance, frequency and density were calculated following Mishra [8]. Importance Value Index was determined as sum of the relative values of frequency, density and abundance. Richness was determined by computing the Margalef index of species richness [9] as d = (S - 1) / ln N, where S is the number of species, and N is the total number of individuals in the sample. Shannon diversity index [10] was calculated as H'=-Σ pi ln pi. Concentration of Dominance (Cd) was calculated as Σ pi^2 by using Simpson Index [11]. Dominance diversity covers for trees were plotted by a co-ordinate point method by placing IVI on y-axis and its position in the sequence of species from highest to lowest IVIs on x-axis [12]. Basal area was calculated following Curtis and McIntosh [13].

Results

Disturbance vs forest area

As mentioned earlier, a total of 125 elevation ranges were surveyed in present attempt both in north and south aspects. There was a dominance of moderately disturbed altitude ranges (70 ranges, 56%) followed by highly disturbed altitude ranges (30 ranges, 24%) and undisturbed altitude ranges (25 ranges, 20%) [Fig-1].

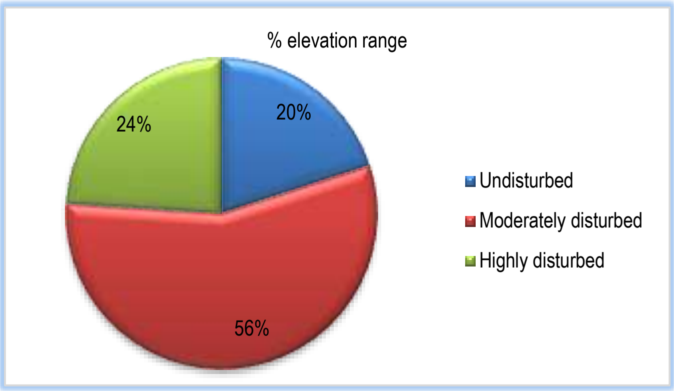

Fig-1 Altitude ranges under different disturbance categories

Disturbance vs number of plant species

Highest number of plant species (127) encountered in moderately disturbed altitude ranges while the lowest plant species (102) were recorded in highly disturbed altitude ranges. Tree species were recorded highest (31) in moderately disturbed ranges, shrub species were encountered highest (51) in highly disturbed ranges whereas undisturbed altitude ranges were the leading (55 species) ranges in terms of herb species. A noteworthy difference in the number of species was found between highly disturbed altitude ranges (51 species) and undisturbed altitude ranges (30 species) in case of shrub flora. Herb species has also showed a significant gap in number of species between undisturbed altitude ranges (55) and highly disturbed altitude ranges (35) [Table-3].

Table-3 *Number of species recorded under different level of disturbance*

Disturbance Class	Tree	Shrub	Herb	Total
Undisturbed	25	30	55	110
Moderately disturbed	31	45	51	127
Highly disturbed	17	51	35	102

Disturbance vs tree basal area

The total basal area of tree species ranges between 20.12m^2/ha in highly disturbed altitude ranges to 39.56 m^2/ha in undisturbed altitude ranges. An important connection has been seen between disturbance and tree basal area as basal area was recorded decreasing with escalating disturbance [Fig-2].

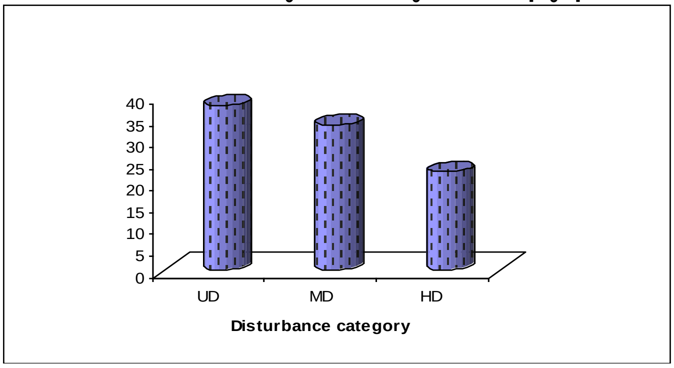

Fig-2 Tree basal area recorded under different level of disturbance

Disturbance vs diversity

Tree Shannon diversity (H') was recorded highest (1.64) in moderately disturbed altitude ranges and lowest (1.04) in highly disturbed altitude ranges. In shrub species, highly disturbed elevation ranges envisaged highest Shannon diversity (1.82) whereas moderate disturbed altitude ranges conceived lowest (1.66) Shannon diversity. A continuous downfall was recorded in herb diversity from undisturbed (2.03) altitude ranges to highly disturbed altitude ranges (1.69) [Fig-3].

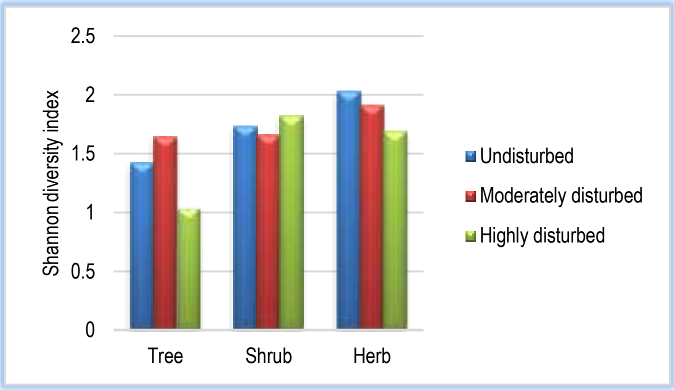

Fig-3 Species diversity (H) under different level of disturbance

Disturbance vs Margalef species richness

Margalef species richness for tree species was recorded highest (1.41) in moderately altitude ranges, 2.09 for shrub species in highly disturbed ranges and 2.66 for herb species in undisturbed altitude ranges [Fig-5].

Discussion

The present study was focused on banj-oak dominated forests which are usually exploited by the local villagers for their daily needs. The temperate forests of western and central Himalayas are usually distributed from 1200 m to 3000m asl and characterized by extensive oak and coniferous species [14 &15] and banj-oak

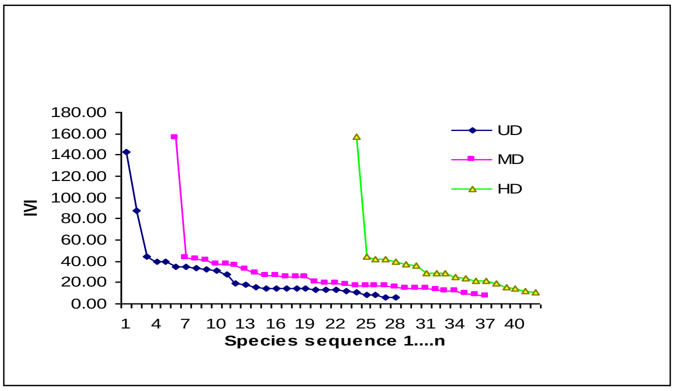

Fig-4 Dominance-diversity curve of tree species in different level of disturbance

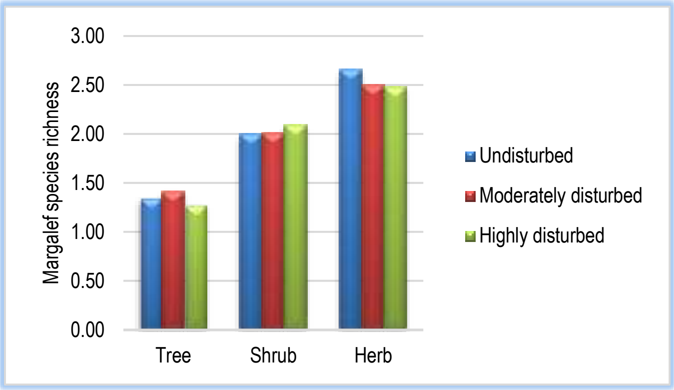

Fig-5 Margalef species richness under different level of disturbance

is most preferred tree species for fodder, fuel and small timber in the temperate region [15] of Himalaya where most of the Himalayan population breathe. Highest numbers of altitude ranges were found under moderately disturbed categories which reflect a progressive extraction of biomass from the forest floor. Lower percentage of undisturbed altitude ranges indicates that most of the banj-oak zone is under human interference all along the study area. Tree species were recorded highest in mid disturbed altitude ranges itself point out that a control and minimum extraction of biomass from forest creates better niche for tree species to flourish. Actually, moderate disturbance creates boosted environment due to lesser inter-species competition as well as minimum canopy opening. Findings of present attempt is consistent with Sheil and Burslem [16] who believed that the Intermediate Disturbance Hypothesis (IDH) is still relevant in explaining higher species richness as too much disturbance leads to the loss of late-succession species and too little disturbance leads to exclusion of species adapted to colonizing younger sites. Boring *et al*. [17] have also emphasized the positive role of moderately disturbance in improving the tree regeneration of various tree species. Shrub flora revealed an encouraging relation with disturbance as shrub species were found increasing with increasing magnitude of disturbance. This colonization of shrub species in disturbed zones showed that ecological success of shrub flora is more prominent within the areas where human interference is high. The lack of IDH affect on shrubs and herbs as they represent early and late succession groups respectively. Moreover, shrub species showed their tolerance with disturbance in present study; they might be encountered rapidly in the blanks created by the disturbances-indicates that open canopy provides opportunity for their recruitment. A high vulnerability of herb species for disturbance was evidenced in this study as least disturbance facilitates their species diversity and richness more vigorously. It might be so because least disturbed forest patches often experience a low level of species exploitation and also ensure high resource availability [18] as well as undisturbed and pristine forests maintain soil moisture regimes on the forest floor. A clear trend in the basal area has seen along disturbance in our study as basal area reduces with increasing disturbance. Kumar *et al*. [15] also carried out similar kind of study in an oak dominant forest and has reported similar trend in tree basal area along disturbance. Their study revealed basal area values ranged from 11.38 m^2/ha (highly disturbed forest) to 31.70 m^2/ha (undisturbed forest) and these values are more or less similar to our findings. Bhuyan *et al*.[19]also reported a decrease in basal area with increasing disturbance in tropical wet-evergreen forest of north-east, India. Aravena *et al*. [20] indicated that basal area increased significantly in undisturbed plots in comparison to plots that showed the combined presence of fire and logging which is in confirmation of our results. Similarly, Baboo *et al*. [21], reported that anthropogenic disturbances reduced the basal area of tree species at all the stages of life; adults, poles and stem. Tree diversity has recorded highest in mid level of disturbance indicates increase in number of pioneer light-demander species. Mild disturbance activities create a sufficient opportunity to exist for species to establish and perform vigorously. Whereas, next level of disturbance (highly disturbance) offers diversity and richness decline due to loss of shade-demanding species both in tree and herb species. Results of the present study are in conformity with the study of Thonicke *et al*.[22] who pointed out that area opened up by disturbance allows the regeneration of vegetation, thereby often maintaining the composition and succession cycle of species. In shrub species, the highest value of Shannon diversity was observed in highly disturbed ranges and it might be the result of colonization dynamics. It is an example of colonization ability and success in shrub flora in human impacted forest areas. For herb species, a negative relationship has been observed with disturbance and many workers like Collins *et al*. [23] also found a significant monotonic decline in species diversity with increasing frequencies of experimental disturbances. Actually, undisturbed elevation ranges have natural micro-habitat conditions that favour co-existence of a variety of plant species and this might be a principal cause of maximum species diversity in undisturbed areas especially for herb species. Raghubanshi [24] also pointed out that habitat destruction is the chief cause of biodiversity loss and ecosystem degradation. Actually, these existing elevation ranges at various levels of disturbances can be regarded as a dynamism that determines the pattern of recovery.

Conclusion

Present study spawns the scope for intensity-based disturbance studies and advocates disturbance intensity-based management practices in oak zones. Since anthropogenic disturbance is occurred in a chronic form all along the Garhwal Himalayas that could be converted into a prescribed forest biomass utilization system. This system will not only contribute in sustainable forest resource use of local populace but also could play a vital role in the maintenance of forest plant diversity.

Application of research: The findings of this study will be useful during silviculture and management practices to be carried out in banj-oak forests.

Research Category: Biodiversity at Garhwal Himalaya

Abbreviations: MoEF&CC- Ministry of Environment, Forest & Climate Change, cbh- Circumference at breast height, m masl- mean meter above sea level, IVI-Importance value Index, no.- Numbers

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Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Garhwal Himalaya

Cultivar / Variety / Breed name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
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