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COMPOSITIONAL PATTERNS OF CONIFEROUS FORESTS IN THE GARHWAL HIMALAYA

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ABSTRACT

Forests in the Garhwal Himalaya, Uttarakhand, India, are vital for biodiversity and ecosystem services, including climate regulation and soil erosion prevention. This study investigated eight distinct coniferous forest types across an altitudinal gradient from 700 m to 3350 m asl, within latitudes 29°192 –31°002 N and longitudes 78°002 –80°302 E. Using the nested quadrat method, a reconnaissance survey was conducted from March 2022 to April 2023, resulting in 80 sample plots analyzed for tree density, basal cover, and diversity. The findings revealed that 44.3% of tree species exhibit a random distribution, with significant clustering. FT1, a conifer mixed broad-leaf forest at 2400-2650 m elevation, dominated by *Abies pindrow*, exhibited the highest species richness (19), highest frequency (580%) and Shannon diversity index (2.537). Conversely, FT3, a pure *Pinus roxburghii* forest at 700-1000 m elevation, displayed low species richness (2) and high dominance concentration (0.860). FT2, mainly *Abies pindrow* forest at 2550-2700 m, showed moderate species richness (10) and the highest basal cover (113.262 $m^2 h^{-1}$). FT5, mainly *Pinus wallichiana* forest showed lowest frequency (160%), abundance (6.6 individual ha^{-1}) and total basal cover area (39.46 $m^2 ha^{-1}$). FT6, FT7, and FT8, all pure *Cedrus deodara* forests at similar elevations, displayed varying densities and basal covers but maintained relatively high diversity indices. Results highlighted the ecological importance of these forests, emphasizing species richness and diversity's role in maintaining ecosystem functions. This study underscores the need for targeted conservation efforts to enhance species richness and ecosystem health, providing vital insights for managing and conserving Himalayan forests amidst anthropogenic disturbances and climatic changes.

(Key words: Altitudinal gradient, coniferous forests, diversity parameters, Garhwal Himalaya)

INTRODUCTION

The Himalayan forests are of immense ecological importance due to their rich variety of conifer species that play crucial roles in maintaining biodiversity and ecological balance in the region (Singh *et al.,* 2024). The region serve habitat to various conifers such as *Cedrus deodara*, *Abies pindrow* and *Pinus wallichiana*, particularly in the sub-alpine forests (Bhardwaj *et al.,* 2020). These conifers are essential for the biodiversity and functioning of the forests in the Northwestern Himalayas (Ahmed *et al.,* 2010). Coniferous forests show importance in the vegetational composition of the Garhwal Himalayas through their diversity and unique regeneration dynamics (Gairola *et al.,* 2012). The rich biodiversity of the Garhwal region, including these conifers, contributes significantly to the overall forest structure and composition (Gairola *et al.,* 2011). The composition and diversity of major forest types, including conifer-dominated forests, have been studied to understand the unique characteristics and species richness of these ecosystems (Kumar and Ram, 2005). Furthermore, the ecological status and traditional knowledge of medicinal plants underscore the importance of conifers in the local ecosystem (Bhat *et al.,* 2013).

Coniferous forests are of major importance to human society as they contribute several crucial ecosystem services (Gamfeldt *et al.,* 2013). They are expected to play an essential role in climate change mitigation as they can sequester more carbon than non-forested ecosystems (Schwaab *et al.,* 2020). The soil fertility status which reflects the ability of various soils to provide essential nutrients for growth (Sadanshiv *et al.,* 2017) directly affects forest productivity and consequently the regeneration patterns of conifers. These patterns, observed along altitudinal gradients in the moist temperate valley slopes which demonstrate their adaptability to varying environmental conditions (Gairola *et al.,* 2011). Additionally, the impact of anthropogenic disturbances on plant biodiversity, including conifers, highlights the challenges these species face due to human activities (Adhikari and Rawat, 2009). This underscores the urgent need for systematic policies addressing climate change

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(Hussain, 2023). Investigations into the vegetation dynamics and community patterns in different forest types of the Garhwal Himalayas provide further insights into the species richness and distribution of conifers in these diverse habitats to ensure effective conservation and sustainable forest management, it is essential to understand the composition, diversity, and dynamics of these coniferous communities. Our aim was to comprehensively analyze the tree community composition of various coniferous forest types across different altitudes. By doing so, we aim to gain valuable insights that will inform conservation strategies and promote the sustainable management of these vital ecosystems.

MATERIALS AND METHODS

Study Area

The present study was conducted eight different coniferous forests located in the Garhwal Himalayan region, within the Uttarakhand state of India. This area spans latitudes 29°192 –31°002 N and longitudes 78°002 –80°302 E. The studies forest type encompasses a wide elevation range from 750 m to 3300 m above sea level. Following a comprehensive reconnaissance survey, eight distinct forest types were selected along an altitudinal gradient from the subtropical to subalpine zone of the Garhwal Himalaya (Table 1).

Methodology

A reconnaissance survey was undertaken from March 2022 to April 2023 to evaluate different conifer-dominated forests across varying altitudes. Forest types were named according to their dominant tree species, following Ram Prakash (1986). Physiographic factors were measured using a Garmin, Rino-130 device. The compositional pattern of tree species was analyzed using the nested quadrat method (Kent and Coker, 1992). Ten 0.1-hectare plots stand^{-1}, were randomly laid, totaling 80 sample plots adhering to the methodologies outlined by Curtis and Mc Intosh (1950) and Phillips (1959). Key quantitative parameters such as frequency, abundance, density, and total basal cover were calculated following Cottam and Curtis (1956).Shannon-Wiener diversity Index (H) (Shannon and Weaver,1963) and Simpson Dominance Index (Cd) (Simpson, 1949) were computed. Pielou's evenness (1966), were computed for each forest type. Trees were categorized into different diameter at breast height (dbh) classes to facilitate a detailed understanding of forest structure. Plant identification was based on (Gaur, 1999) and the Herbarium of H.N.B. Garhwal University Srinagar (GUH), along with existing taxonomic literature.

RESULTS AND DISCUSSION

The study analyzed eight conifer forest types in the Garhwal Himalaya, Uttarakhand, India, examining their density, basal cover, and diversity metrics (Table 1). According to Luna (2005), common species in the western Himalaya include *Pinusroxburghii*, various *Quercus species*, *Rhododendron arboreum*, *Lyonia ovalifolia*, *Cedrus deodara*, and *Pinus wallichiana*. Forest type (FT1) is a mixed coniferous forest dominated by *Abies pindrow*, with *Quercus semecarpifolia*, *Lyonia ovalifolia*, and *Acer caesium* as major species. It exhibited the highest density (820 trees ha^{-1}), species richness (SR) of 19, frequency (580), abundance (25.8) and Shannon diversity index (SDI) of 2.537, indicating a diverse and evenly distributed species composition. Sharma and Baduni (2000) noted that *A. pindrow* forms the upper canopy due to its higher diameter at breast height (dbh). The occurrence of *A. pindrow*, various oak species, and *R. arboreum* across different forest types and altitudinal gradients suggests their resilience to biotic pressures and broad ecological adaptability (Gairola *et al.,* 2009).

FT3, characterized by a pure *P. wallichiana* forest at a very high altitude (3350 m asl), exhibits a lower SR of 2 species and a density of 450 trees ha^{-1}, with a low total basal cover (TBC) of 55.606 m² ha^{-1}. At this altitude forest vegetation was found spare and less dense. This forest stand has the lowest SDI among all forest types at 0.14, reflecting a species composition dominated by very few species, particularly noted by its high MeI value of 0.30. FT3's low evenness (Ep) of 0.39 suggests uneven species distribution and high dominance concentration (0.860), with a single species dominating the forest composition. *P. wallichiana*, noted as a light-demanding species by Negi (1985), thrives in dryer habitats at these elevations and can reach up to 150 cm in girth. FT3 specifically showed a high importance value index (IVI) of 277.21 for *P. wallichiana* among the studied forest types. FT2, represented by *A. pindrow*, and FT8, represented by *C. deodara*, had high basal covers (113.262 m² ha^{-1}and 95.957 m² ha^{-1}, respectively) but lower diversity indices, suggesting less species evenness. This implies that the species present are primarily in higher dbh classes, reinforcing that *A. pindrow* forests are considered the climax successional stage for the region (Champion and Seth, 1968). Although, the density for *A. pindrow* forests was slightly higher than previous studies in the Garhwal Himalaya (Rawat *et al.,* 2020; Gairola *et al.,* 2011). FT7 showed a high density of *C. deodara* with 710 individuals ha^{-1} and an IVI of 214.90. Sheikh *et al.* (2021) found maximum tree density of *C. deodara* at mid altitudes, reaching up to 444.5 ind. ha^{-1}.

FT4, represented by *P. wallichiana,* associated with *C. deodara*, and FT5, a pure *P. roxburghii* forest presented moderate values across all parameters, balancing density, basal cover, and diversity. These results are supported by studies identifying *P. roxburghii* as a pioneer or invasive species in the western Himalayas (Ohsawa *et al.* 1986). FT4, situated at an elevation range of 2900 to 3000 m, was also found to harbor *C. deodara*, a shade-loving species, suggesting that unlike chir-pine, blue-pine can share the same habitat (Bhandari, 2023). FT6, *pure Cedrus deodara* forest and FT7, *pure Cedrus deodara* showed higher SDI values (0.55 to 0.68) compared to FT4,Pure *Pinus wallichiana* forest and FT5,Mainly *Pinus wallichiana* forest, suggesting more balanced species distribution despite variations in density and TBC, although FT5 showed the lowest frequency (160) and abundance (6.6), indicating it is a less widespread forest type. Additionally,

varying diameter class distributions across forest types (Table 2) showed FT1, FT3, and FT5 with more trees in lower dbh classes, indicating dominance of younger tree species, whereas FT6 and FT7 have higher numbers in larger DBH classes, suggesting more mature tree species. Among the eight studied forest types, we identified a total of 35 species belonging to 22 families and 30 genera. The most diverse families were Rosaceae and Pinaceae, each with four species. The spatial distribution pattern across these forest types varied, with 44.3% of tree species exhibiting a random distribution, 40.98% showing a contagious distribution, and 14.75% demonstrating a regular distribution. Nearly half of the species were randomly arranged, with significant portions forming clusters or being evenly spaced.Given the continuous decrease in the land-to-people ratio and the constant population growth in emerging nations like India, the only way to meet the demand for agricultural goods is to enhance productivity without compromising forest conservation or environmental sustainability (Pandey *et al.,* 2024). Targeted strategies should focus on intact forests and sustainable practices. These results reveal the important sites showing rich diversity and density of coniferous forests in the Garhwal Himalaya, underscoring the necessity of conservation efforts. The data on species richness, ecosystem health, and habitat quality are essential for maintaining critical ecosystem services such as climate regulation, water cycle stability, and soil erosion prevention. By offering a comprehensive understanding of forest composition and structure, the findings highlight the significant ecological roles and distributions of various species across different disturbance regimes and altitudinal gradients. This research is crucial for informed biodiversity management in this ecologically significant region, emphasizing the vital role conifers play in maintaining biodiversity and ecological balance

Table 1. General details of the studies forest types and diversity parameters of tree community

Sl. No.	Acronym	Forest Type	Elevation (asl)	Locality	SR	Densit (T h^{-1})	Fq	Ab	TBC (m^2h^{-1})	H	SDI	Ep	MeI
1.	FT1	Conifer mixed broad-leaf forest	2400-2650m	Kanchula-dhotidhar	19	820	580	25.8	89.429	2.54	0.89	0.86	2.10
2.	FT2	Mainly *Abies pindrow* forest	2550-2700m	Pangair-Chopta	10	550	360	12.4	113.262	1.67	0.74	0.72	1.35
3.	FT3	Pure *Pinus roxburghii* forest	700-1000m	Village khola	2	450	200	12.5	55.606	0.27	0.14	0.39	0.30
4.	FT4	Pure *Pinus wallichiana* forest	3250-3350m	Gamshali (Bampa valley)	3	490	200	6.73	64.789	0.95	0.57	0.86	0.43
5.	FT5	Mainly *Pinus wallichiana* forest	3000-2900m	Ferkya (Malari)	7	570	160	6.6	39.464	1.01	0.43	0.52	0.93
6.	FT6	Pure *Cedrus deodara* forest	2050-2150m	Palakurali	8	640	280	11.7	81.243	1.23	0.55	0.59	1.00
7.	FT7	Pure *Cedrus deodara* forest	2060-2180m	Naini forest	6	710	260	11	84.994	1.22	0.58	0.68	0.74
8.	FT8	Pure *Cedrus deodara* forest	2050-2150m	Dandachali	6	650	230	10.4	90.957	1.01	0.47	0.56	0.71

Abbreviations:FT= Forest type ;**asl=** above sea level ; **SR=** Species richness ; **Den**= Density ; **T h^{-1}** = Trees ha^{-1}; **Fq =** Frequency ; **Ab =** Abundance ; **TBA**= Total basal area ; **SDI**= Simpson's index ; **H =** Shannon-Wiener index ;**E_r =** Pielou evenness ;**MeI =** Menhinick index

Table 2. Diameter class (dbh class) based distribution of density (Trees/hectare) in each forest type

Sl.No.	FT/ dbh class	FT1	FT2	FT3	FT4	FT5	FT6	FT7	FT8
1.	**10-20**	200	50	30	60	180	90	140	100
2.	**21-40**	410	210	230	220	360	280	230	270
3.	**41-60**	150	120	190	170	20	220	210	220
4.	**61-80**	50	140	-	40	-	50	-	50
5.	**>81**	10	30	-	-	10	-	10	10

Abbreviations: FT= Forest type ,**dbh class=** Diameter at breast height class

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