Indian Journal of Ecology (2024) 51(4): 738-743
DOI: https://doi.org/10.55362/IJE/2024/4302

Manuscript Number: 4302
NAAS Rating: 5.38

Diversity, Spatial Distribution and Biomass Patterns in Oak and Pine Forest Community along Altitudinal Gradient in Paddar Range of Kishtwar Forest Division, Northwestern Himalaya

Anil Thakar, Deeksha Dave and Sagar Singh[1]

School of Interdisciplinary and Transdisciplinary Studies, Indira Gandhi National Open University
New Delhi-110 068, India
[1] Divisional Forest Officer, Kishtwar Forest Division, Kishtwar-182 204, India
E-mail: anilenv0@gmail.com

Abstract: This study explores the phytosociological dynamics of forest vegetation and biomass patterns in selected oak and pine forests of north-western Himalaya spanning an altitudinal range of 1650-2500 meters. The trees density varied between 126 to 214 trees/ha while the density of forest floor vegetation was 214.32 and 126.71/m^2 in oak and pine forests respectively. Herb species richness was slightly higher (23) in the oak forest compared to the pine forest (19). Asteraceae family dominated oak forest whereas Poaceae dominated pine forest stand representing 7 species at each site. The Shannon-Weiner index (H') was maximum for oak forest (3.79) and concentration of dominance (Cd) and evenness (J') were also maximum for oak forest (0.27) and pine forest (0.90) respectively. Simpson diversity was 0.86 in oak and 0.91 in pine forests. Contagious distribution patterns were observed for most species in both study sites. The forest floor biomass was 497.38 g/m^2 in oak and 412.79 g/m^2 in pine stands during the study period (2022-2023) with the rainy season contributing to the maximum biomass whereas winter season attributed to decrease in biomass at both sites.

Keywords: Biomass, Species richness, Simpson diversity index, Shannon-Weiner diversity index, Phytosociological analysis

The Himalaya stands as the World's tallest and most recently formed mountain system, serving as a repository for both biological and cultural diversity (Negi and Dhyani 2012, Chandra et al 2020). This region houses a distinctive ecosystem encompassing a diverse array of plants, animals, and other organisms contributing to its status as the most affluent biodiversity zone (Rawal et al 2018). Apart from constituting a significant portion of the Himalayan global biodiversity hotspot, this area is connected to three additional biodiversity hotspots (Dar and Sundarapandian 2016). The distribution of this region spans from subtropical to alpine zones (Singh 2008, Bhatt and Bankoti 2016). Biodiversity in the Himalayan region comprises the range and diversity of life forms, ecosystems, and ecological processes across all levels of biological organization. It serves as the fundamental basis for human survival and economic prosperity. It is imperative to consistently uphold and evaluate the various ecosystems and the entirety of biological diversity within them to ensure the enduring survival of the human species (Malik 2014, Malik et al 2014a). The altitudinal range (800-6000 meters), especially in the Himalayan region, exerts a significant influence on species distribution. Each altitude harbors distinct species, each contributing uniquely to the sustenance of associated flora and fauna (Pandey et al 2002, Kharakwal et al 2005). Within the mid montane belt (1000-2000 meters) of this geographical area, there is a prevalence of rapidly growing chir-pine (*Pinus roxburghii*) species alongside slowly developing oak species (Shreshtha et al 2007). These forests exhibit distinctions in terms of structure, functionality and the ecosystem services they provide (Joshi and Negi 2011, Bhat et al 2020). Species composition and diversity patterns is a frequently studied thematic area in ecological research as it enhances our comprehension of ecosystem conservation and management strategies (Zhang et al 2013). Abiotic environmental factors exhibit spatial and temporal variations, playing a pivotal role in determining vegetation patterns across landscapes (Kumar et al 2010, Zhang et al 2013, Kumar and Sharma 2016). Numerous studies have focused on the ecological aspects of vegetation on the forest floor. This emphasis underscores the importance of understanding the intricate dynamics and relationships within this specific ecological niche, contributing valuable insights to broader ecological investigations (Sharma et al 2009, Shaheen et al 2011, Singh et al 2016, Rawal et al 2018, Rana et al 2019, Joshi et al 2023). Despite these studies in the Western Himalaya, the database needs a continuous update by undertaking further exploration to decipher various ecosystem properties of forest stands. It is contended that additional research endeavours' are essential for a comprehensive

understanding of varied forest types distributed across subtropical, temperate, and alpine environments encompassing evergreen broad-leaved, deciduous, and coniferous categories. This imperative arises due to the heightened biotic pressures exerted on the majority of Himalayan forests (Bargali et al 2013, Sharma et al 2017). The objective of this study was to characterize the species diversity, density, and distribution patterns, along with herbaceous biomass in oak and pine forest communities in the Paddar Valley to enhance existing knowledge and support sustainable forest management strategies.

MATERIAL AND METHODS

Study area: The study was conducted in the temperate and sub-alpine forest ecosystems of Paddar valley in Great Himalayan region of the Northwest Himalayas, Jammu and Kashmir (Fig. 1). This region was specifically chosen to explore and analyse the ecological dynamics and biodiversity patterns owing to limited research conducted in this specific locale thus emphasizing the need to fill this knowledge gap and enhance our understanding of the ecological complexities within these forest ecosystems. The study area is situated within the geographical coordinates of 33.10° to 33.40° N latitude and 76.10° to 76.50° E longitude, showcasing altitudinal fluctuations ranging from 1600 to 3200 m (Kumar and Sharma 2014). Renowned for its ecological diversity and topographical heterogeneity Paddar valley lies within the Kishtwar Forest Division in Jammu and Kashmir and exhibit a varied range of vegetation. This area is bordered by the Pangi Valley of Himachal Pradesh in the east, Zanskar Valley of Ladakh in north and the Marwah-Warwan valley (Kishtwar High Altitude National Park) in the west. Geologically, the region is characterized by crystalline rocks such as granites and gneiss, alongside sedimentary formations like shale, sandstone, and limestone. Moreover, the soils in the steep slopes have high carbon content whereas lower valley areas tend to be neutral to slightly alkaline, with varying degrees of carbon content ranging from medium to high. The people residing in the area are mainly agropastoral communities thus having remarkable impact on the nearby forests.

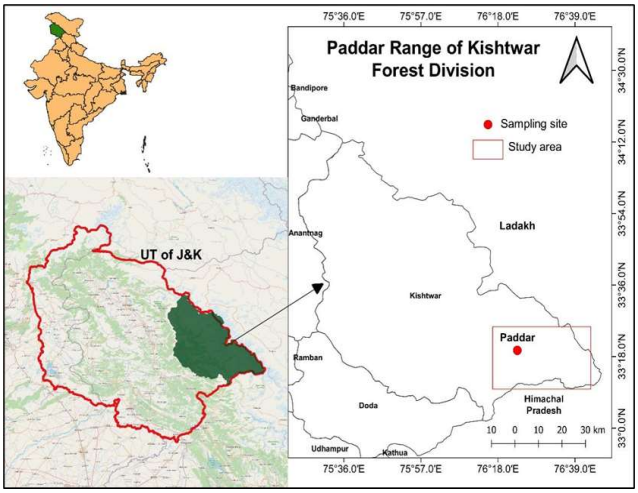

Fig. 1. Map of study area

Methodology: The study was carried out within the altitudinal range of 1650 to 2500 m in oak and pine dominated forest stands of Paddar valley, Kishtwar district, Jammu and Kashmir (Table 1). The oak forest exhibits higher levels of soil moisture, water holding capacity, organic carbon and nitrogen in its sandy clay soil compared to the pine forest with sandy loam soil. The average annual rainfall in the study area is 1200- 1440 mm which is highly variable whereas maximum and minimum temperatures were recorded as 33.15 and 6.7°C, respectively (Kumar and Sharma 2014, Ishtiyak et al 2015). For calculating the tree density, the sampling was conducted in 1 ha plots (100 m × 100 m) by laying quadrats of 5 m x 5 m in each forest stands.

The analysis of herbs and shrubs involved the systematic laying of simple random quadrats within each identified forest stand, specifically during the growing season of 2022-23. A total of 100 quadrats, each measuring 1x1 meter (with 50 in each site), were strategically positioned to examine the forest

Table 1. Attribute description of selected oak and pine forest sites

Parameter	Oak stand	Pine stand
Forest location	Kijayee	Chitoo
Altitude (m)	1750-1900	1650-2350
Latitude N	33.277130	33.221250
Longitude E	76.116738	76.217500
Dominant canopy species (Tree)	*Quercus baloot* Griff.	*Pinus wallichiana* A. B. Jacks
Dominant shrub species	*Berberis lycium* Royle	*Wikstroemia canescens* Wall.ex Meisn
Soil moisture (%)	27.43±3.31	22.13±4.31
Water holding capacity (%)	49.21±3.78	41.35±2.34
Soil Nitrogen (N%)	0.51±0.03	0.28±0.06

floor vegetation in both locations. The evaluation of forest floor vegetation parameters, including density, frequency, distribution and diversity were established using phytosociological methods (Muller-Dombois and Ellenberg 1974). The Importance Value Index (IVI) of the species was calculated by analysing value of relative density, frequency and dominance (Misra 1968). The diversity indices like Shannon and Wiener index (H'), Concentration of dominance (Cd) and Equitability or Evenness (J') were calculated following Shannon-Wiener (1963), Simpson (1949) and Pielou Index (1966) respectively. The assessment of distribution patterns (random, regular, and contagious) involved the computation of the abundance to frequency (A/F) ratio. Specifically, a regular distribution is indicated if the A/F ratio is <0.025, a random distribution is suggested for ratios between 0.025 and 0.05, and a contagious distribution is inferred for ratios >0.05 following the criteria (Curtis and Cottam 1956). For the estimation of forest floor herbaceous biomass encompassing grass and forest ground flora involved the harvesting of 1m x 1m quadrats every two months. Within each quadrat, all herbaceous vegetation was cut at a uniform height of 2 cm above the ground and subsequently sorted into live (green) biomass and standing biomass. The collected samples were then subjected to oven drying for a period of 24 to 48 hours until a constant weight was achieved (Joshi et al 2021).

RESULTS AND DISCUSSION

Species composition and diversity pattern: The oak forest encompasses a total of 27 species across 14 families, with Asteraceae being the most dominant family with 7 species and contributing to 27% of the overall forest species (Table 3). In the pine forest 29 species from 16 families were documented and Poaceae emerged as the dominant family, constituting 17% of the total species (Fig. 2). The species density in the oak forest was 214.32 individuals/m^2, whereas in the pine forest was 126.71 individuals/m^2. The species diversity (H') exhibited variation measuring 3.12 in the oak stand and 3.79 in the pine stand. The higher species diversity and richness were attributed to intensified anthropogenic stress resulting from grazing activities. This heightened competition leads to improved light interference on the forest floor vegetation as documented by Darabant et al (2007) and Harrison et al (2008). Additionally, creates habitat opportunities contributing to increased species diversity and richness. Species evenness was 0.68 for oak and 0.90 for pine forest (Table 2). Similar findings have been reported in numerous studies conducted across different regions of the Himalayas (Gupta and Kumar 2014, Kumar and Sharma 2014, Kumar and Sharma 2015, Lal and Lodhiyal 2016, Malik and Bhatt 2016, Kumar et al 2021, Joshi et al 2021, Joshi et al 2023). The highest species diversity tends to be observed in the herb layer among various forest strata. In the oak forest, Concentration of Dominance (CD) and Shannon Species Diversity (H') were 0.27 and 3.12 respectively, while in the pine forest, were 0.03 and 3.79. The diversity patterns in forest floor vegetation align with observations from previous research (Jhariyal et al 2014, Sinha et al 2015, Joshi and Chandra 2020). The species compositions in the two distinct communities differ due to local environmental conditions, with similarity of 25.13% in their composition, reflecting variations in ecological and environmental conditions.

Forest floor biomass pattern and its correlation with vegetation parameter: The annual average forest floor biomass in oak and pine stands exhibited variation ranging from 412.79 g/m^2 to 497.38 g/m^2 with the highest values during the rainy seasons in all stands. In the temperate banj-oak stand, the total forest phytomass was 411.32 grams in 2021-22, 509.13 grams in 2022-23, and an average of 460.22 grams during the years 2021-2023. The biomass reached at peak in August and reaching a minimum in the month of April. In 2022-23, it ranged from 10.35 to 93.17 grams, with the highest values observed in July and the lowest in April. The total herbaceous biomass was maximum (61%) during the rainy season, followed by 15 and 24% during winter and summer sessions respectively.

Table 2. Comparison of species diversity parameter among oak and pine forest stands

Parameter	Oak forest	Pine forest
Density (ind m^{-2})	214.32	126.71
Species richness	23.00	19.00
Shannon species diversity (H')	3.12	3.79
Concentration of dominance (CD)	0.27	0.03
Species evenness (SE)	0.68	0.90
Simpson Diversity Index (D)	0.86	0.91

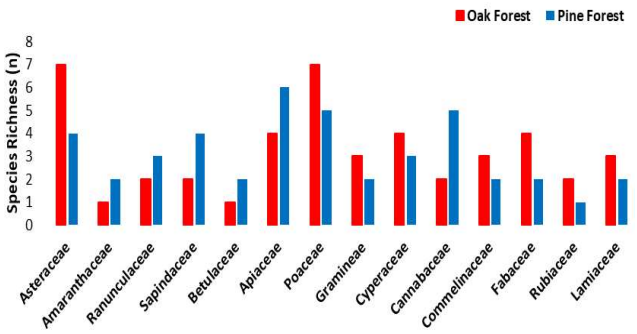

Fig. 2. Family wise distribution of species in the oak and pine forest

Table 3. Vegetation composition, relative density and distribution pattern of species in selected oak and pine forest, North-Western Himalaya

Species	Family	Oak forest		Pine forest	
		RD (%)	DP	RD (%)	DP
Achillea millefolium L.	Asteraceae	4.07	0.32*	7.28	0.97*
Achyranthes bidentata Blume	Amaranthaceae	3.61	0.27*	-	-
Aconitum heterophyllum Wall. ex Royle	Ranunculaceae	-	-	0.45	0.18*
Aesculus indica (Wall. ex Cambess.) Hook.	Sapindaceae	7.98	0.93*	-	-
Alnus nitida (Spach) Endl.	Betulaceae	0.58	0.05**	-	-
Anaphalis margaritacea (L.) Benth. & Hook.f.	Asteraceae	4.92	0.83*	-	
Angelica glauca Edgew.	Apiaceae	-	-	1.21	0.17*
Apluda mutica L.	Poaceae	27.4	1.38*	-	-
Aquilegia fragrans Benth.	Ranunculaceae	11.3	0.99*	-	-
Arisaema serratum (Thunb.) Schott	Araceae	1.0	0.06*	-	-
Artemisia vulgaris L.	Asteraceae	13.16	0.12*	27.36	1.02*
Arundinella nepalensis Trin.	Poaceae	0.86	0.31*	-	-
Arundo donax L.	Poaceae	4.21	0.14*	-	-
Aster thomsonii C.B.Clarke	Asteraceae	-	-	19.0	0.97*
Bidens pilosa L.	Asteraceae	2.11	0.3*	-	
Capillipedium parviflorum (R.Br.) Stapf	Gramineae	0.45	0.12*	1.42	0.12*
Carex nubigena D.Don.	Cyperaceae	3.11	0.58*	-	
Celtis australis L.	Cannabaceae	-	-	1.41	0.11*
Chrysopogon serrulatus Trin.	Poaceae	-	-	1.28	0.23*
Commelina caroliniana Walter	Commelinaceae	2.72	0.17*	-	-
C. paludosa Blume	Commelinaceae	3.19	0.90*	-	-
Cynodon dactylon (L.) Pers.	Poaceae	6.72	0.17*	-	-
Cyperus iria L.	Cyperaceae	4.24	0.12*	-	-
Desmodium triflorum (L.) DC.	Fabaceae	-	-	1.37	0.16*
Dioscorea deltoidea Wall. ex Griseb.	Dioscoreaceae	-	-	0.46	0.12*
Flemingia fruticulosa Wall. ex Benth.	Fabaceae	-	-	0.43	0.07*
Galium aparine Linn.	Rubiaceae	-	-	5.71	0.28*
Geranium wallichianum Oliv.	Geraniaceae	1.40	0.27*	1.36	0.15*
Hedychium spicatum Sm.	Zingiberaceae	0.98	0.11*	-	-
Imperata cylindrical (L.) P. Beauv	Poaceae	1.36	0.33*	-	-
Inula racemose Hook.f.	Asteraceae	-	-	3.22	0.18*
Justicia simplex D.Don	Acanthaceae	0.93	0.12*	-	-
Lonicera purpurascens (Royle ex Hook. fil. & Thoms.) Walp.	Caprifoliaceae	2.49	0.26*	-	-
Micromeria biflora (Buch.-Ham. ex D.Don) Benth.	Lamiaceae	3.25	0.27*	-	-
Morina longifolia Wall. ex DC.	Caprifoliaceae	-	-	2.83	0.13*
Murdannia divergens (C.B. Clarke) G. Brückn.	Commelinaceae	0.98	0.13*	-	-
Neottia listeroides Lindl.	Orchidaceae	3.52	0.04**	-	-
Oplismenus hirtellus (L.) P. Beauv.	Poaceae	-	-	1.32	0.16*
Ophiopogon intermedius D.Don	Asparagaceae	3.42	0.03**	-	-
Phlomoides umbrosa (Turcz.) Kamelin & Makhm	Lamiaceae	-	-	2.76	0.31*
Parrotiopsis jacquemontiana (Decne) Rehder	Hamamelidacea	2.34	0.11*	-	-
Persicaria capitata (Buch.-Ham. ex D. Don)	Polygonaceae	-	-	1.97	0.17*
Pilea microphylla (Linn.)	Urticaceae	-	-	0.95	0.14*
Plectranthus rugosus Wall.	Umbelliferaceae	1.83	0.37*	-	-
Pouzolzia hirta Hassk.	Urticaceae	0.73	0.13*	-	-
Robinia pseudoacacia L.	Fabaceae	0.47	0.12*	-	-
Rosa macrophylla Lindl.	Rosaceae	2.14	0.04**	2.84	0.11*
Roscoea alpina Royle	Zingiberaceae	-	-	12.91	0.93*
Rubia cordifolia L.	Rubiaceae	-	-	3.22	0.18*
Smilax parvifolia Wall	Smilacaceae	-	-	0.57	0.26*
Sorbaria tomentosa (Lindl.) Rehd.	Rosaceae	1.61	0.37*	-	-
Strobilanthes dalhousianus C.B. Clarke	Acanthaceae	0.98	0.11*	-	-
Taraxacum officinale (L.) Weber ex F.H. Wigg.	Asteraceae	-	-	3.22	0.19*
Thymus linearis Benth.	Lamiaceae	-	-	5.79	0.27*
Trifolium pratense L.	Fabaceae	-	-	1.37	0.18*
Urtica dioica L	Urticaceae	1.38	0.33*	-	-
Viburnum grandiflorum Wall. ex DC.	Adoxaceae	-	-	1.31	0.16*

RD- Relative density, DP- Distribution pattern, *Contagious distribution, **Random distribution

Table 4. Correlation among different vegetation parameter and herbaceous biomass

Parameter	Density	SR	H'	CD	SE	Biomass
Density		0.403	0.745	0.339	0.503	0.006
SR	0.805		0.3415	0.064	0.099	0.397
H'	-0.389	-0.859		0.406	0.242	0.738
CD	0.861	0.994	-0.803		0.164	0.332
Biomass	0.999	0.811	-0.398	0.866	-0.710	

SR=Species richness, H'=Species diversity, CD=Concentration of dominance, SE= Species evenness

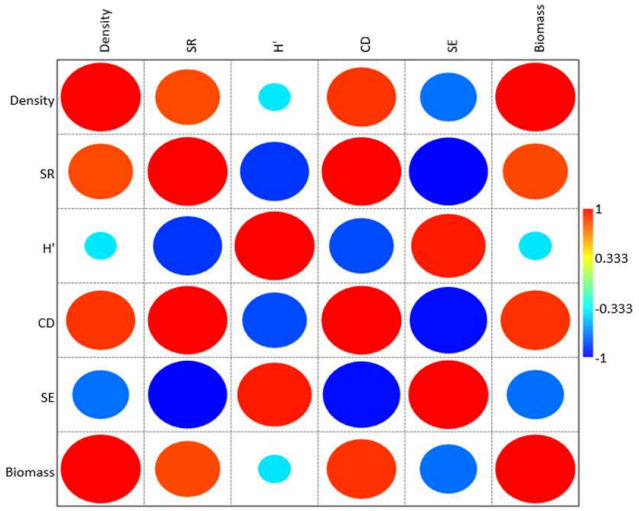

Fig. 3. Correlation matrix for biomass and vegetation factors at both forest stands

The total forest floor biomass increases with increase in density whereas it shows negative correlation with increasing species diversity, richness and evenness. The overall dry biomass of herbaceous species demonstrated a positively significant association with species density, while exhibiting a positive but not significant correlation with species richness (Fig. 3). However, a negatively significant correlation was observed with species diversity, evenness and the concentration of dominance. Species richness displayed a positive and significant correlation with species diversity, evenness and the concentration of dominance among the species (Table 4).

CONCLUSION

The herbaceous vegetation and biomass exhibited variations between the selected oak and pine forests. the pine forest demonstrated a slightly higher richness in terms of species diversity, the oak forest displayed greater potential for storing forest floor biomass. The elevated biomass observed in both forests during the rainy season suggests that the optimal growth of species is influenced by factors such as rainfall, soil properties (including moisture, texture, water holding capacity), and nutrient retention. The oak forest with its higher nutrient retention in both soil and litter, facilitated the storage of increased biomass.

REFERENCES

Bargali K, Bisht P, Khan A and Rawat YS 2013. Diversity and regeneration status of tree species at Nainital Catchment, Uttarakhand, India. *International Journal of Biodiversity and Conservation* **5**(5): 270-280.

Bhat JA, Kumar M, Negi AK, Todaria NP, Malik ZA, Pala NA, Kumar A and Shukla G 2020. Species diversity of woody vegetation along altitudinal gradient of the Western Himalayas. *Global Ecology and Conservation* **24**. https://doi.org/10.1016/j.gecco.2020.e01302.

Bhatt A and Bankoti NS 2016. Analysis of forest vegetation in Pithoragarh Kumaun Himalayas, Uttarakhand, India. *International Journal of Current Microbiology and Applied Sciences* **5**(2): 784-793.

Chandra N, Joshi VC and Mishra AP 2020. Ecological status of fodder and fuel wood species in Banari Devi Sacred grove of Kumaun Himalaya, Uttarakhand. *Indian Journal of Ecology* **47**(4): 1044-1048.

Curtis JT and Cottam G 1956. The use of distance measures in phytosociological sampling. *Ecology* **37**(3): 451-460.

Dar J and Sundarapandian S 2016. Patterns of plant diversity in seven temperate forest types of Western Himalaya, India. *Journal of Asia-Pacific Biodiversity* **9**(3): 280-292.

Darabant A, Rai PB and Tenzin K 2007. Cattle grazing facilitates tree regeneration in a conifer forest with palatable bamboo understory. *Forest Ecology and Management* **252**: 73-83.

Gairola S, Sharma CM, Suyal S and Ghildiya SK 2011. Species composition and diversity in mid-altitudinal moist temperate forests of the Western Himalaya. *Journal of Forest Science* **27**(1): 1-15.

Harrison M, Evans JR and Moore A 2008. Grazing induced changes in light interception and radiation-use efficiency of winter wheat, pp 56-65. Proceedings of *14th Agronomy Conference,* September 21-25, 2008, Adelaide, South Australia.

Ishtiyak P, Ahmad QJ, Wani I and Panse SS 2015. Assessment of floristic diversity and vegetation analysis of Paddar area of Kishtiwar (J and K), India. *Ecology, Environment and Conservation* **(21)**: S91-S95.

Jhariya MK, Bargali SS, Swamy SL, Kittur B, Bargali K and Pawar GV 2014. Impact of forest fire on biomass and Carbon storage pattern of Tropical Deciduous Forests in Bhoramdeo Wildlife Sanctuary, Chhattisgarh. *International Journal of Ecology and Environmental Science* **40**(1): 57-74.

Joshi G and Negi GCS 2011. Quantification and valuation of forest ecosystem services in the western Himalayan region of India. *International Journal of Biodiversity Science, Ecosystem Services & Management* **7**(1): 2-11.

Joshi VC and Chandra N 2020. Pattern of diversity and regeneration potential along altitudinal gradient in selected forest stands of Kumaun Himalaya. *Indian Forester* **146**(4): 301-305.

Joshi VC, Bisht D, Sundriyal RC and Harshit P 2023. Species

richness, diversity, structure, and distribution patterns across dominating forest communities of low and mid-hills in the Central Himalaya. *Geology, Ecology, and Landscapes* **7**(4): 329-339.

Joshi VC, Sundriyal RC and Arya D 2021. Forest floor diversity, distribution and biomass pattern of oak and Chir-pine Forest in the Indian Western Himalaya. *Indian Journal of Ecology* **48**(1): 232-237.

Kharakwal G, Mehrotra P, Rawat YS and Pangtey YPS 2005. Phytodiversity and growth form in relation to altitudinal gradient in the Central Himalayan (Kumaun) region of India. *Current Science* **89**(5): 873-878.

Kumar A and Sharma MP 2015. Estimation of carbon stock of Balganga Reserve Forest, Uttarakhand, India. *Forest, Science and Technology* **11**(4), 1-5.

Kumar A and Sharma MP 2016. Carbon stock estimation in the catchment of Kotli bhel 1A hydroelectric reservoir, Uttarakhand, India. *Ecotoxicology and Environmental Safety* **134**(2): 365-369.

Kumar M, Kumar A, Kumar R, Konsam B, Pala NA and Bhat JA., et al 2021. Carbon stock potential in *Pinus roxburghii* forests of Indian Himalayan regions. *Environment, Development and Sustainability* **23**(4): 12463-12478.

Kumar S and Sharma S 2014. Diversity, disturbance and regeneration status of forests along an altitudinal gradient in Paddar valley, Northwest Himalayas. *Indian Forester* **140**(4): 348-353.

Kumar S, Kumar M and Sheikh MA 2010. Effect of altitudes on soil and vegetation characteristics of *Pinus roxburghii* forest in Garhwal Himalaya. *Journal of Advanced Laboratory Research in Biology* **1**(2): 130-133.

Lal B and Lodhiyal LS 2016. Stand structure, productivity and carbon sequestration potential of oak dominated forests in Kumaun Himalaya. *Current World Environment* **11**(2): 466-476.

Malik ZA 2014. *Phytosociological behaviour, anthropogenic disturbances and regeneration status along an altitudinal gradient in Kedarnath Wildlife Sanctuary (KWLS) and its adjoining areas*. Ph.D. Dissertation, HNB Garhwal University Srinagar Garhwal, Uttarakhand, India.

Malik ZA and Bhatt AB 2016. Regeneration status of tree species and survival of their seedlings in Kedarnath Wildlife Sanctuary and its adjoining areas in Western Himalaya, India. *Tropical Ecology* **57**(4): 677-690.

Malik ZA, Hussain A, Iqbal K and Bhatt AB 2014a. Species richness and diversity along the disturbance gradient in Kedarnath Wildlife Sanctuary and its adjoining areas in Garhwal Himalaya, India. *International Journal of Current Research* **6**(12): 10918-10926.

Misra R 1968. *Ecology workbook*, Oxford and IBH Publishing Company, Calcutta, India, p 224.

Mueller-Dombois D and Ellenburg H 1974. *Aims and Methods of vegetation Ecology*, John Wiley and Sons, New York, p 547.

Negi GCS and Dhyani, PP 2012. *Glimpses of Forestry Research in the Indian Himalayan Region: Special Issue in the International Year of Forest-2011*. ENVIS Centre on Himalayan Ecology, GB Pant Institute of Himalayan Environment and Development, Uttarakhand, India.

Pandey PK, Sharma SC and Banerjee SK 2002. Biodiversity studies in a moist temperate Western Himalayan Forest. *Indian Journal of Tropical Biology* **10**(1/4): 19-27.

Pielou EC 1966. The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology* **13**:131-144.

Rana SK, Gross K and Price TD 2019. Drivers of elevational richness peaks, evaluated for trees in the East Himalaya. *Ecology* **100**(1): e02548. 10.1002/ecy.2548

Rawal RS, Rawal R, Rawal B, Negi VS and Pathak R 2018. Plant species diversity and rarity patterns along altitude range covering treeline ecotone in Uttarakhand: conservation implications. *Tropical Ecology* **59**(2): 225-239.

Shaheen H, Khan SM, Harper DM, Ullah Z and Qureshi RA 2011. Species diversity, community structure and distribution patterns in Western Himalayan alpine pastures of Kashmir, Pakistan. *Mountain Research and Development* **31**(2): 153-159.

Shannon CE and Wiener W 1963. *The Mathematical Theory of Communication,* University of Illinois Press, Urbana, Illinois, USA, p 55.

Sharma CM, Mishra AK, Tiwari OP, Krishan R and Rana YS et al 2017. Effect of altitudinal gradients on forest structure and composition on ridge tops in Garhwal Himalaya. *Energy, Ecology and Environment* **2**(6): 404-417.

Sharma CM, Suyal S, Gairola S and Ghildiyal SK 2009. Species richness and diversity along an altitudinal gradient in moist temperate forest of Garhwal Himalaya. *Journal of American Science* **5**(5): 119-128.

Shrestha BB, Ghimire B, Lekhak HD and Jha PK 2007. Regeneration of treeline birch (*Betula utilis* D.don) forest in a trans-Himalayan dry valley in Central Nepal. *Mountain Research and Development* **27**(3): 259-267.

Simpson EH 1949. Measurement of diversity. *Nature* **163**: 688.

Singh G 2008. *Diversity of Vascular Plants in Some Parts of Kedarnath Wildlife Sanctuary (Western Himalaya)*. Ph.D. Dissertation, Kumaun University, Nainital, Uttarakhand, India.

Singh S, Malik ZA and Sharma CM 2016. Tree species richness, diversity, and regeneration status in different oak (Quercus spp.) dominated forests of Garhwal Himalaya, India. *Journal of Asia-Pacific Biodiversity* **9**(10): 293-300.

Sinha R, Yadav DK and Jhariya MK 2014. Growth performance of Sal in Mahamaya central forest nursery (Ambikapur), Chhattisgarh. *International Journal of Scientific Research* **3**(11): 246-248.

Tynsong H and Tiwari BK 2011. Diversity and population characteristics of woody species in natural forests and arecanut agroforests of south Meghalaya, Northeast India. *Tropical Ecology* **52**(3): 243-252.

Zhang JT, Xu B and Li M 2013. Vegetation patterns and species diversity along elevational and disturbance gradients in the Baihua Mountain Reserve, Beijing, China. *Mountain Research and Development* **33**(2): 170-178.

Received 15 December, 2023; Accepted 10 June, 2024