Pak. J. Bot., 56(4): DOI: http://dx.doi.org/10.30848/PJB2024-4(42)

ANALYZING ANTHROPOGENIC DETERMINANTS OF VEGETATION DISTRIBUTIONS PATTERN IN HIGH-ELEVATION FORESTS OF THE HIMALAYAS

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Abstract

Concise efforts are required to manage forest ecosystems to achieve the global goals envisioned for the UN Decade (2021–2030) of Ecosystem Restoration targets. Among various global drivers of forest degradation, anthropogenic stresses may contribute to the long-persisting impact on vegetation dynamics and are one of the major impediments to the successful restoration of forest ecosystems at the local and regional scales. The research was focused on elucidating how anthropogenic disturbances influenced the forest composition, diversity, and phytosociological attributes of high-elevation forests of the Himalayas. Based on the intensity of anthropogenic stress and location, three differently disturbed sites i.e., Severely Disturbed (SD), Moderately Disturbed (MD), and Low Disturbed (LD) forest sites were selected. A random sampling method was used to record the vegetation parameters of the forest stands. Multivariate PAST software ver. 3.14 was employed to observe the relationship between ecological variables and plant communities. The results showed significant differences in vegetation composition between the forest types. Data collected revealed that composition, diversity, and phytosociological attributes (basal area) were decreased with the increase of anthropogenic stress. SD forest sites exhibited (3.1) times more deforestation rate than MD site (2.08) and declined with decreasing disturbance levels. Anthropogenic stress affected vegetation patterns and associations among plant communities, according to the Principal Component Analysis ordination. The study's findings generated empirical data that could be used to guide the restoration of degraded ecosystems to meet global goals as well as the UN Decade of Ecosystem Restoration targets (2021–2030) for forest management and the sustainable development of mountainous regions.

Key words: Forest structure; Biotic stresses; Venn diagram; Kashmir Himalayas.

Introduction

The United Nations has designated 2021-2030 as the decade of ecological restoration, and in the coming years, the restoration of degraded natural ecosystems will receive more attention (Dubey *et al*., 2021). Therefore, the greatest nature-based solutions to the twin concerns of global climate change and biodiversity loss include restoration of degraded forest landscapes, protection of extant natural forests, and plantation of human-modified landscapes (Keith *et al*., 2021; Waheed *et al.,* 2023). Forest-dominated mountainous landscapes are recognized for being multifunctional, as they supply valuable goods and services to local communities to support their livelihood alternatives. In the recent few decades, human interference in the Himalayan forests has witnessed unprecedented destruction of forest cover (Ishtiyak *et al*., 2016). Furthermore, future habitat and climate change consequences in mountainous areas may be greater than forests' natural capacity to adapt (Thakur *et al*., 2020a; Arshad *et al*., 2023). This vulnerability is exacerbated by residents' heavy reliance on natural forest resources for their livelihoods (Aryal *et al*., 2014). In this setting, several forces such as climate variability, globalization, severe ecological deterioration, and rising reliance on land and forest resources are exerting increased pressure on Himalayan forests (Gerlitz *et al*., 2015; Pandey *et al*., 2018).

Understanding how anthropogenic variables influence species distributions is undergoing a paradigm shift. Until recently, topography was widely assumed to be a composite variable with a significant impact on defining species distribution patterns and diversity on a small scale (Toledo *et al*., 2012; Sinha *et al*., 2018; Thakur *et al*., 2020a; Waheed *et al*., 2023a). However, few studies also reflect that anthropogenic factors would also potentially affect the distribution (Iqbal *et al*., 2021; Lewis *et al*., 2017). Global biodiversity is threatened by several anthropogenic processes (Trakhtenbrot *et al*., 2005), especially in the Himalayan region in particular (Law & Salick, 2005; Haq *et al*., 2019a). Apart from being home to numerous flora and fauna, the Himalayan Forest ecosystems are prone to habitat loss due to the expansion of human-mediated activities (Chabrerie *et al*., 2013). This deforestation, not only destroyed and disturbed the vegetation but also resulted in forest degradation of almost all the natural communities associated with the forest ecosystem (Khan *et al*., 2017).

Anthropogenic stressors such as uncontrolled grazing, logging, timber/fuelwood exploitation, clearing for cultivation, and inoperable road construction have all severely harmed forest structures in the Kashmir Himalayas (Haq *et al*., 2019c,d). Although anthropogenic interactions have had an impact on species distributions at local spatial scales, they have received less attention when it comes to projecting future species assemblages (Wisz *et al*., 2013; Arshad *et al*., 2022a). As a result, quantifying the importance of anthropogenic interactions in generating spatial patterns at multiple scales is critical for understanding and accounting for them in future species assemblage forecasts (Elith & Leatwick, 2009). Despite numerous research studies conducted in Himalayan forests, there is still a lack of knowledge regarding the effects of anthropogenic stress on forest ecosystems and their potential resilience to such impacts (Chakraborty *et al*., 2018). We have specifically addressed the following research problems to answer this ecological query i.e., What are the vegetation composition and phytosociological characteristics of the sampling forest sites in the Langate Forest Division? What kinds of anthropogenic disturbances exist, and how do they impact the diversity, composition, and phytosociological characteristics of forests? (iii) Finally, a multivariate statistics approach to look into how the vegetation and anthropogenic disturbances are related. By providing answers to these queries, it could be better comprehended how anthropogenic stresses influenced patterns of species diversity, composition, and phytosociological attributes at the local scale in the Kashmir Himalayan forest. Such empirical data can help in the development of scientific policy management tools to direct the restoration of degraded ecosystems to achieve both global goals and the UN-Decade of Ecosystem Restoration targets (2021-2030) for effectively mitigating anthropogenic disturbances in the Himalayan forest ecosystems.

Material and Methods

Study area: Kupwara district is one of ten districts in the Kashmir Valley region of Jammu and Kashmir (Fig. 1). Bandipora district borders it on the east, Baramulla district on the south, and Pakistan-controlled Jammu and Kashmir on the north and west. The sampling locations were in the Langate Forest Division, located between 34° 15' and 34° 45' N latitude and 73° 45' and 74° 35' E longitude, with its territory in the Kupwara district. The Division is situated on the northeastern slopes of the Kazinag and Shamsabari hills and covers an area of 36, 061 hectares. The eastern limit of the territory is marked by the Pohru stream, which drains the majority of the region eastward. The region's climate, which is sub-Mediterranean with four distinct seasons and an annual precipitation range of 66–167 cm, is generally comparable to that of the Kashmir Valley. The region experiences mild summers and bitterly cold winters with significant amounts of snowfall from December to February. The region's woody and herbaceous flora is well diversified, with conifers dominating and scattered broad-leaved tree species. For a more in-depth description of the research area (please see Sajad *et al.* (2021).

Sampling design and measurements: The random sampling strategy of vegetation sampling was used for recording the field data (Haq *et al*., 2019b). At each of the selected forest sites, twelve square-shaped 0.1-hectare (hereinafter ha) plots per forest type (i.e., 3 x 12 = 36 plots) were laid. Within each 0.1 ha. Plots, the density of live and dead stems for tree sampling was recorded (Haugaasen *et al*., 2003). In each sampling plot (0.1 ha), two plots of size ($5m^2$) were laid in opposite corners for estimation of the shrub parameter. For the herbaceous layer, 5 plots of size ($1m^2$) (4 in each corner 0.1 ha plot, and one at the center) were laid. Thus, in each forest type, 36 (0.1 ha) plots for trees, 180 (60 plots x 3 forest types = 180) plots ($1m^2$) for herbs, and 72 (24 plots x 3 forest types = 72) plots ($5m^2$) for shrubs were sampled during the present study. For each plant species, the Importance Value Index (hereinafter IVI) was determined using the abundance, cover, and frequency of the species in each quadrant (Curtis & McIntosh, 1951; Naidu & Kumar, 2016). The number of species found in the entire forest was used to calculate the species richness. The Margalef Richness, the Evenness, and the Dominance Indices were calculated as the main diversity indicators (Simpson, 1949; Shannon & Wiener, 1963; Pielou, 1975).

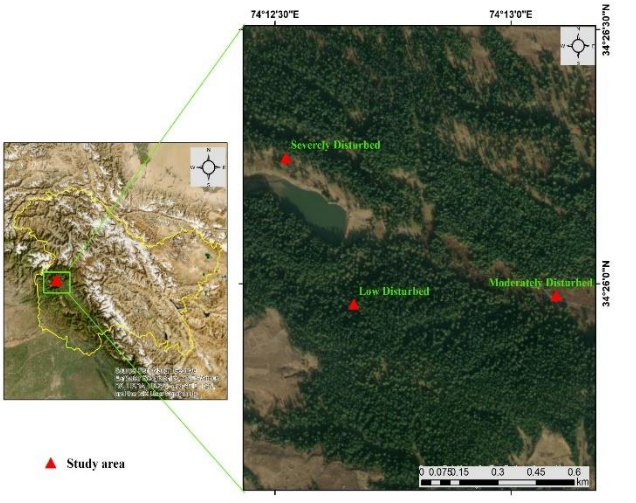

Fig. 1. Map of Kashmir Himalayas and points showing sampling forest sites in the Kupwara District of Kashmir region.

Additionally, according to Haq *et al*., (2019b), a semi-quantitative scale was used to quantify the amount of disturbance in each type of forest. A three-point scale was used to record disturbance levels, with 0 denoting low, 1 moderate, and 2 high levels of disturbance based on visual assessment in the vicinity of each sampling plot. Stem cutting (CT), human habitation (HS), connectivity to roads (RC), tree lopping (LP), livestock grazing (GZ), degradation (DG), and forest fire (FR) were all regarded as disturbance causes (Table 1). Based on the degree of anthropogenic stress and location, three different forest sites such as Severely Disturbed (SD), Moderately Disturbed (MD), and Low Disturbed (LD) were chosen for sampling (Table 1).

Data analysis: The data on species composition and the various ecological variables were statistically analyzed to determine the link. Utilizing PAST software 3.14, the Shannon-Wiener, Equitability, and Dominance diversity indices were calculated (Sajad *et al*., 2021; Waheed *et al.,* 2022a). To compare the rate at which new plant species were observed in various forest types, species accumulation curves were also developed to measure and evaluate species richness. Origin Pro software was used to create hierarchical agglomerative clusters of all plant species to identify similarities and differences at the microclimate level among different forest types. Using Origin software, the species relationships between forest types were visualized using Principal Component Analysis (PCA) (Arshad *et al*., 2022; Haq *et al*., 2022c). To highlight differences in curves for sampling forest locations, the Renyi diversity profile (Tóthmérész, 1995; Dejene *et al*., 2017) was utilized. A Venn diagram was generated using Bioinformatics & Evolutionary Genomics software to emphasize the differences and unique species among forest types (Altaf *et al*., 2021).

Table 1. Physiographic and disturbance variables of the sampling forest site in the Kupwara District of Kashmir region.

Forest types	Geo-coordinates (N, E)	Slope (°)	Crown density (%)	Stem cutting	Tree lopping	Human habitation	Livestock grazing	Road connectivity	Degradation	Fire
Severely disturbed (SD)	34.4374763 74.2087106	28 ±8.42	47 ± 9.06	2	1	2	2	2	2	1
Moderately disturbed (MD)	34.4329531 74.2182566	31 ±7.24	56 ± 8.38	1	1	1	2	1	1	1
Low disturbed (LD)	34.4326756 74.2111041	33 ±6.24	64 ± 7.21	1	1	0	0	1	0	0

Table 2. Species composition, family, growth form, lifespan, and IVI of plant species at different forest sites in the Kupwara District of Kashmir region.

Family	Name of species	Code	LD	MD	SD	Nativity	Growth Form	Lifespan
Araliaceae	*Hedera helix* L.	Hed. hel	8.43	2.41	0	Exotic	Climber	Perennial
Asteraceae	*Achillea millefolium* L.	Ach.mil	1.32	5.99	3.59	Native	Herb	Perennial
	Anaphalis royleana DC.	Ana. Roy	3.06	0	0	Native	Herb	Perennial
	Bellis perennis L.	Bel. roy	0	1.72	0	Native	Herb	Perennial
	Cirsium falconeri (Hook.f.) Petr.	Cir.fal	0	0	1.41	Exotic	Herb	Perennial
	Erigeron acer var. *multicaulis* (Wall. ex DC.) C.B. Clarke	Eri.ace	6.54	12.88	0	Native	Herb	Perennial
	Senecio chrysanthemoides DC.	Leu.vul	14.92	21.22	34.61	Native	Herb	Perennial
	Taraxacum campylodes G.E.Haglund	Tar. cam	3.45	4.78	3.95	Native	Herb	Biennial
	Tussilago farfara L.	Tus.far	0	0	1.76	Native	Herb	Perennial
Acanthaceae	*Strobilanthes glutinosus* Nees	Str.glu	0	3.18	0	Native	Herb	Perennial
Adoxaceae	*Sambucus wightiana* Wall. ex-Wight & Arn.	Sam. wig	2.52	0	2.73	Native	Herb	Perennial
	Viburnum grandiflorum Wall. ex-DC.	Vib.gra	152.96	104.89	116.04	Native	Shrub	Perennial
Boraginaceae	*Myosotis arvensis* (L.) Hill	Myo. arv	0	9.34	0	Native	Herb	Annual
	M. sylvatica Hoffm.	Myo. syl	3.94	9.74	0	Native	Herb	Perennial
Berberidaceae	*Berberis lycium* Royle	Ber. lyc	23.82	36.34	28.29	Native	Shrub	Perennial
Brassicaceae	*Arabidopsis thaliana* (L.) Heynh.	Ara.tha	0	2.17	0	Native	Herb	Annual
Chenopodiaceae	*Chenopodium album* L.	Che. alb	2.22	0	0	Exotic	Herb	Annual
Caryophyllaceae	*Cerastium cerastoides* (L.) Britton	Cer. cer	3.94	8.72	0	Native	Herb	Perennial
Dioscoreaceae	*Dioscorea deltoidea* Wall. ex Griseb.	Dio.del	5.81	0	0	Native	Climber	Perennial
Fabaceae	*Indigofera heterantha* Brandis	Ind. het	26.13	83.58	78.39	Native	Shrub	Perennial
	Medicago polymorpha L.	Med. pol	1.32	0	0	Native	Herb	Annual
	Robinia pseudoacacia L.	Rob.pse	0	0	78.45	Exotic	Tree	Perennial
	Trifolium pratense L.	Tri.pra	15.23	22.22	24.01	Native	Herb	Perennial
	T. repens L.	Tri.rep	10.36	17.81	43.78	Native	Herb	Perennial
Geraniaceae	*Erodium cicutarium* (L.) L'Hér.	Ero.cic	0	1.32	0	Native	Herb	Annual
	Geranium nepalense Sweet	Ger.nep	3.07	3.43	7.51	Native	Herb	Perennial
Lamiaceae	*Clinopodium umbrosum* (M.Bieb.) Kuntze	Cli.umb	0	3.43	0	Exotic	Herb	Perennial
	C. vulgare L.	Cli. vul	1.62	0	0	Exotic	Herb	Perennial
	Mentha longifolia (L.) L.	Men.lon	14.21	8.81	0	Exotic	Herb	Perennial
	Prunella vulgaris L.	Pru.vul	6.58	6.37	4.96	Native	Herb	Perennial
	*Salvia moorcroftiana*Wall.ex. Benth	Sal. moo	1.32	3.95	0	Native	Herb	Perennial
	Thymus linearis Benth.	Thy. lin	1.62	0	0	Native	Herb	Perennial
Orchidaceae	*Dactylorhiza hatagirea* (D.Don) Soó	Dac.hat	1.32	0	0	Native	Herb	Perennial
Oxalidaceae	*Oxalis corniculata* L.	Oxa.cor	3.59	74.54	17.21	Exotic	Herb	Annual
Pinaceae	*Cedrus deodara* G. Don	Ced. deo	142.7	165.5	98.1	Native	Tree	Perennial
	Pinus wallichiana A.B.Jacks.	Pin. wal	156.9	119.8	47.94	Native	Tree	Perennial
Plantaginaceae	*Digitalis purpurea* L.	Dig.pur	0	0	2.51	Exotic	Herb	Biennial
	Plantago lanceolata L.	Pla.lan	3.41	13.82	7.29	Native	Herb	Perennial
	P. major L.	Pla.maj	3.76	2.61	4.46	Native	Herb	Perennial
	Veronica laxa Benth.	Ver. lax	2.55	0	2.13	Native	Herb	Annual
Poaceae	*Poa annua* L.	Poa. ann	16.61	14.15	49.34	Exotic	Herb	Annual
	P. bulbosa L.	Poa.bul	4.63	31.67	23.27	Exotic	Herb	Annual
	Phleum pratense L.	Phl. pra	0	0	3.81	Native	Herb	Perennial
	Stipa sibirica (L.) Lam.	Sti.sib	48.52	17.83	27.32	Native	Herb	Perennial
Polygonaceae	*Persicaria amplexicaulis* (D.Don) RonseDecr.	Per. amp	3.41	2.61	0	Native	Herb	Perennial
	*Rumex nepalensis*Spreng.	Rum.nep	3.58	0	8.65	Native	Herb	Perennial
Phytolaccaceae	*Phytolacca acinosa* Roxb.	Phy.aci	1.92	0	0	Native	Herb	Perennial
Pteridaceae	*Adiantum venustum* D.Don	Adi.ven	6.71	0	0	Native	Herb	Perennial
Ranunculaceae	*Ranunculus laetus* Wall. ex-Hook. f. & J.W. Thomson	Ran.lae	2.73	0	2.49	Exotic	Herb	Perennial
Rutaceae	*Skimmia laureola* Franch.	Ski. lau	16.08	0	0	Native	Shrub	Perennial
Rosaceae	*Fragaria nubicola* (Lindl. ex-Hook.f.) Lacaita	Fra.nub	85.16	50.57	21.67	Native	Herb	Perennial
	Geum elatum Wall. ex-Hook. f.	Geu.ela	4.51	2.17	4.46	Native	Herb	Perennial
	Rubus ellipticus Sm.	Rub. ell	0	28.86	0	Native	Shrub	Perennial
	Rosa webbiana Wall. ex-Royle	Ros.web	80.98	46.31	77.27	Native	Shrub	Perennial
Rubiaceae	*Galium aparine* L.	Gal.apa	1.62	0	0	Native	Herb	Annual
Salicaceae	*Populus alba* L.	Pop.alb	0	15.43	55.86	Exotic	Tree	Perennial
	Salix alba L.	Sal. alb	0	0	27.74	Exotic	Tree	Perennial
Urticaceae	*Urtica dioica* L.	Urt.dio	0	0	3.38	Exotic	Herb	Biennial
Verbenaceae	*Verbena officinalis* L.	Ver.off	0	3.18	3.22	Exotic	Herb	Perennial
Violaceae	*Viola odorata* L.	Vio.odo	12.47	8.03	3.81	Native	Herb	Perennial

Results and Discussion

Impact of anthropogenic stress on vegetation composition parameters: During the current study, 60 plant species from all forest types were recorded, representing 56 genera and 29 families (Table 2). The majority (78%) of species were found in herbaceous life forms, followed by trees (9%), shrubs (10%), and climbers (3%) (Table 2). Perennials dominated the life span category with 47 species (78%), followed by annuals with 10 species (17%), and biennials with 3 species (5%) (Table 2). At the Low Disturbed, Moderately Disturbed, and Severely Disturbed Forest sites, 43, 40, and 34 species were documented, respectively. At local and regional scales, anthropogenic influences on forest vegetation, particularly developmental processes, and other anthropogenic stresses, have a range of impacts on species richness, and forest structure diversity (Ramírez-Marcial *et al*., 2001; Bhatt & Bhatt, 2016; Dar *et al*., 2018). However, frequent and intensive disturbances may result in the accumulation of various stress and have a significant impact on forest community structure (Barlow *et al*., 2016; Malhi, 2017; Haq *et al*., 2019b; Waheed *et al*., 2022). The role of anthropogenic stress at the community level in this work was evaluated, as well as the spatial distributions of all species at local scales. The total number of species found in the study area ranged from 34 at SD forest sites to 43 at LD forest sites. The number of species studied was in line with earlier phytosociological research studies carried out in the Himalayas (Shaheen *et al*., 2012; Shaheen *et al*., 2018; Dar *et al*., 2019). The diversity of a region's species can also be impacted by variations in anthropogenic impacts (Rawal *et al*., 2012; Haq *et al*., 2022c). In the current study area, a total of 60 species have been found. The figure was reported to be within the range of many Himalayan Forest studies (Shaheen *et al*., 2011; Bhat *et al*., 2015; Shaheen *et al*., 2018). In contrast to the number of species Observed from other research, more species were found during the current studied area. For example, Nazir *et al*., (2012), reported 40 species from Pakistani Himalayas. 35 species have been reported from Himalayan Shivalik hills (Shahid & Joshi, 2016). Singh *et al*., (2015), categorized 52 species in the Garhwal Himalaya, and Ijaz *et al*., (2018) analyzed 26 species from the Sarban Hills of Pakistan.

The distribution of species comprised 29 families, containing 17 families possessing just one species and 6 families making up half of the species. The dominant family, Asteraceae, had 8 species (13%) and was followed by Fabaceae with 5 species (8%) and Lamiaceae with 6 species (10%) (Table 2). These families are cosmopolitan and have a high level of ecological adaptability and resistance to adversity (Haq *et al*., 2022b). The Asteraceae and Lamiaceae families were observed to predominate in temperate forests throughout India and the rest of the world (Khan *et al*., 2012; Koul *et al*., 2015; Dar *et al*.,2016; Sharma *et al*., 2017). The current study demonstrated an unbalanced distribution of species across families possessing a significant number (17) of monotypic families. These findings were consistent with earlier Western Himalayan studies (Gogoi & Sahoo, 2018; Haq *et al*., 2019a,d; Haq *et al*., 2022a). The results demonstrated that on a landscape scale or in regional areas, degradation changes the microclimate, causing more disturbance, and as a result, opening up new areas for exotic plants.

Impact of anthropogenic stress on diversity parameters: The diversity indices and phytosociological parameters were decreased as the level of anthropogenic stress increased. From LD to SD Forest sites, the species richness per unit area was decreased. The richest forest site was LD, followed by MD and SD forest sites (Table 3). The six diversity indices (Table 3) decreased as anthropogenic stresses increased. While the LD Forest type had the greatest Shannon and Simpson diversity indices, SD Forest sites had the highest dominance value (Table 3). According to the Rényi diversity profiles, the LD Forest types had significantly higher values of diversity than the SD Forest types (Fig. 2a). SD>MD>LD was the total number of species based on increasing order in the community richness and diversity. The species accumulation curves for each sampling showed how plant species steadily accumulated in each forest stand (Fig. 2b). Pandey *et al*. (2020) observed 30 comparable results in Himalayan forests. Shannon diversity ranged from a high of (3.16) at LD forest sites to a low of (2.96) at SD forest sites. There was less anthropogenic pressure because the LD forest sites were located away from the road and human settlements. Present findings were comparable to Shameem and Kangroo (2011) who reported a diversity value of 3.25 from forests in the Kashmir Himalaya. Anthropogenic causes were determined to be the cause of the reduced diversity values at the MD and SD forest sites (Dar *et al*., 2019). Similar approaches were carried out by Shaheen *et al*. (2011) in Pakistan's Western Himalayas, and Malik *et al*., (2016) in India's Western Himalayas. In areas of India's Kashmir Himalaya, similar observations have been recorded (Haq *et al*., 2019b). The results of the investigation were found to be consistent with values reported by other researchers in various Himalayan forests (Shaheen *et al*., 2018; Dar *et al*., 2019; Haq *et al*., 2019c, d).

Table 3. Comparative diversity and phytosociological attributes of the sampled forest sites in the Kupwara District of Kashmir region.

Forest sites	SR	SP	DO	$\bar{H}$	EN	MRI	FA	BA	DN	CDN	CBA
Low disturbed	43	0.94	0.05	3.16	0.59	6.88	12.61	84.41 ± 7.94	226 ±13.4	16.5 ±2.4	1.4 ±1.01
Moderately disturbed	40	0.93	0.06	3.07	0.63	5.91	10.36	43.84 ±8.32	261.34±7.72	33.34 ±5.05	5.8 ±1.57
Severely disturbed	34	0.91	0.08	2.96	0.45	6.93	11.92	22.75 ±13.76	305.34 ±6.4	50.34 ±10.4	6.93 0.72

SR=Species richness; SP=Simpson; DO=Dominance; $\bar{H}$=Shannon-Weiner diversity index; EN= Evenness; MRI= Margalef richness index; FA= Fisher alpha; BA= Basal area (m2 ha-1); DN= Density (Nha-1); CDN= Cut stem density; CBA= Cut stem basal area

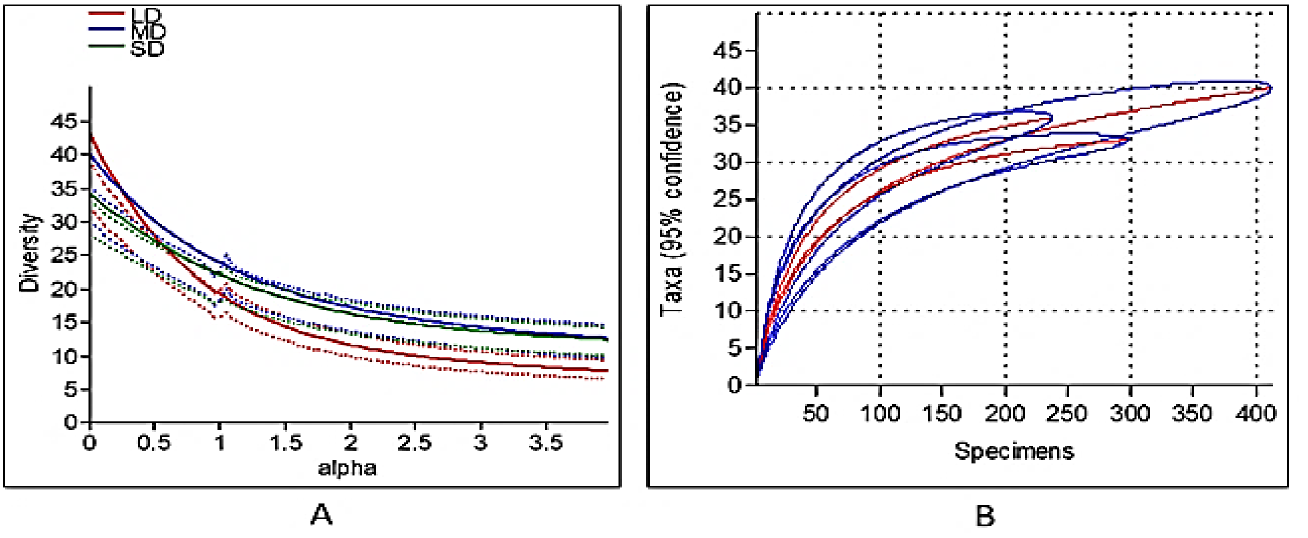

Fig. 2. (a) Comparative Rényi diversity profiles (b) species accumulation curves in the sampled forest sites in the Kupwara District of Kashmir region.

Impact of anthropogenic stress on phytosociological attributes: The results exhibited significant (p<0.073) differences between the forest sites in terms of species diversity, basal area, and phytosociological parameters (Table 3). The average density of cut stem was 34.45 ±15.05 Nha^{-1} recorded in all forest sites, with a maximum of 50.34 ± 10.4Nha^{-1}, at SD forest sites and a minimum of 16.5 ± 2.4Nha^{-1}, at LD forest sites. The mean basal area of cut stems per hectare was greater than 6.93 ± 0.72 m^2ha^{-1} in the SD forest sites than 5.8 ±1.57 m^2ha^{-1}in the MD forest sites. The reason for the high number of stem cuttings at SD sites was due to easy road connectivity and the proximity of the forest to human settlements. In the Kashmir Himalayas, Haq *et al.* (2019a) reported similar findings from the Keran Forest Division. The results revealed that on average per hectare basis density of 264.23 ± 39.74 Nha^{-1} was recorded in all forest sites, with a maximum at 305.34 ± 6.4Nha^{-1}, at SD forest sites and a minimum of 226 ± 13.4Nha^{-1}, at LD forest sites. An average basal area of 52.56 ± 30.87m^2 ha^{-1} was recorded from all forest stands. The SD forest sites had the least 22.75 ± 13.76 m^2 ha^{-1} but the highest 84.41 ± 7.94 m2 ha-1 was found at LD forest sites. Basal area decreased with the increase in the level of anthropogenic stress. Several employees from different sections of the Himalayas noticed a comparable tendency (Haq *et al*., 2019b; Sahoo *et al*., 2020; Pant & Tewari, 2020). The results revealed that on average 264.23 ± 39.74 Nha^{-1} were recorded in all forest sites, with a maximum of 305.34 ± 6.4 Nha^{-1} at SD forest sites and a minimum of 226 ± 13.4 Nha^{-1} at LD forest sites. Plantation of tree species such as *Populus alba* and *Robinia pseudoacacia* had resulted in high stem density at SD forest sites. The cut stem tree density possessed varied differences between the analyzed sites. SD forest sites exhibited a 3.1 times higher deforestation rate than MD sites (2.08) and declined with decreasing disturbance levels. The main cause of low tree density in SD forest types, caused by a variety of anthropogenic stresses on forest types, was the ruthless and unchecked removal of indicator species from forest stands, especially *Cedrus deodara* and *Pinus wallichiana* were the preferred and most ideal sources of timber for nearby communities (Shaheen *et al*., 2018). The tree structure parameters (basal area) are critical for understanding the structure and function of forest stands (Yam & Tripathi, 2016; Shaheen *et al*., 2018). The average basal area of 52.56 ± 30.87m^2ha^{-1} was recorded in all forest stands. SD forest sites had the least 22.75 ± 13.76 m^2ha^{-1} but the highest 84.41 ± 7.94 m^2ha^{-1} was found at LD forest sites. Similar significantly higher values than those reported for disturbed sites by various workers in other regions of the Himalayas were found at less disturbed sites, demonstrating the detrimental effects of anthropogenic stressors on the forest, for example, Dar *et al*., (2019) reported basal area values ranged from 19.4 to 51.9 m^2 ha^{-1} from Kashmir Himalayas and Pandey *et al*., (2020) reported basal area values ranged from 107.10 to 157 m^2 ha^{-1}).

Impact of anthropogenic stress on species distribution patterns: The results from the Venn diagram depicted that 12 species (*Anaphalis royleana, Adiantum venustum, Clinopodium vulgare, Dactylorhiza hatagirea, Dryopteris stewartia, Phytolacca acinosa, Salvia moorcroftiana, Chenopodium album, Skimmia laureola, Medicago polymorpha, Galium aparine,* and *Geranium nepalense*) were unique to LD forest sites followed by 11 species (*Arabidopsis thaliana, Rubus ellipticus, Clinopodium umbrosum, Prenulla vulgare, Strobilanthes glutinosus, Viola odorata, Myosotis arvensis, Bellis perenis, Salvia moorcroftiana, Myosotis sylvatica,* and *Erodium cicutarium*) at MD forest sites and 7 species (*Phleum pratense, Robinia pseudoacacia, Cirsium falconeri, Digitalis purpurea, Tussilago farfara,* and *Salix alba*) at SD forest sites. However, 18 species (*Achillea millefolium, Berberis lyceum, Fragaria nubicola, Geum elatum*, *Senecio chrysanthemoides, Oxalis corniculata, Taraxacum officinale, Pinus wallichiana, Poa annua, P. bulbosa, Plantago lanceolata, P. major, Rosa webbiana, Stipa sibirica, Indigofera heterantha, Trifolium repens, T. pretense* and *Viburnum grandiflorum*) were common in all forest sites. Seven species (*Thymus linearis, Persicaria amplexicaulis, Cerastium cerastoides, Mentha longifolia, Erigeron acer, Hedera helix,* and *Cedrus deodara*) were common between

LD and MD forest sites and four species (*Veronica laxa, Geranium nepalense* and *Urtica dioica*) were common between *MD* and SD forest sites (Fig. 3). The high constraint of anthropogenic pressure has been reported in the forests of the Himalayas (Shrestha *et al*., 2013; Thakur *et al*., 2020b). These anthropogenic stresses disrupted the natural balance of forest vegetation communities regularly, preventing them from reaching the climax stage of community maturity (Shaheen *et al*., 2012; Seidl *et al*., 2017). People residing in forests relied heavily on coniferous tree species for timber, fuelwood, and leaf litter because there weren't many other options. The issue with the type of disruption was exacerbated by human never ceasing activity, resulting in no chance of the forest to recover (Cohen *et al*., 2010). All forest sites had a substantially higher number of (18 species), common species, and a decrease in the overall number of species uniqueness along the disturbance gradient could influence high usage pressure. Many species' habitat fitness might be altered by anthropogenic pressures such as grazing and trampling (Richardson & Bond, 1991).

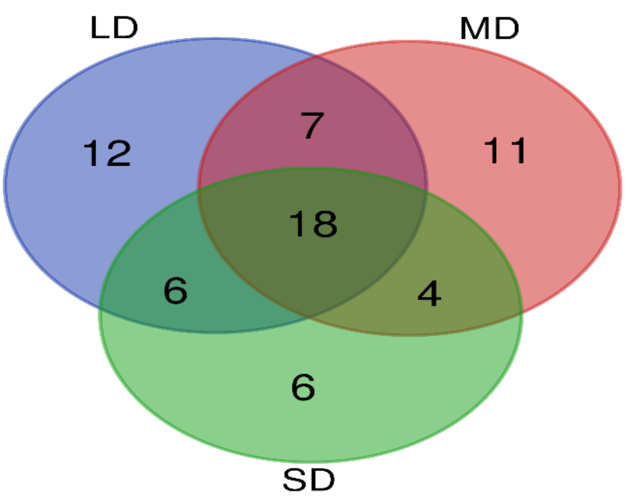

Fig. 3. Venn diagram illustrating the distribution of plant species across various forest sites in the Kupwara District of Kashmir region.

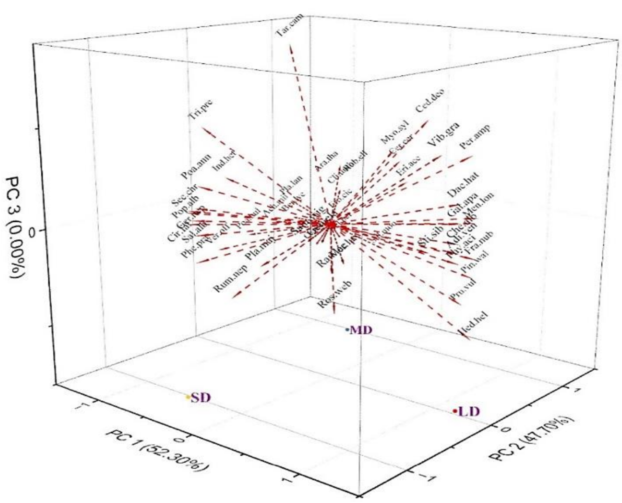

Fig. 4. Biplot of Principal Component Analyses (PCA) of different plant communities studied in the Kupwara District of Kashmir region. Table 2 displays the full name of each species.

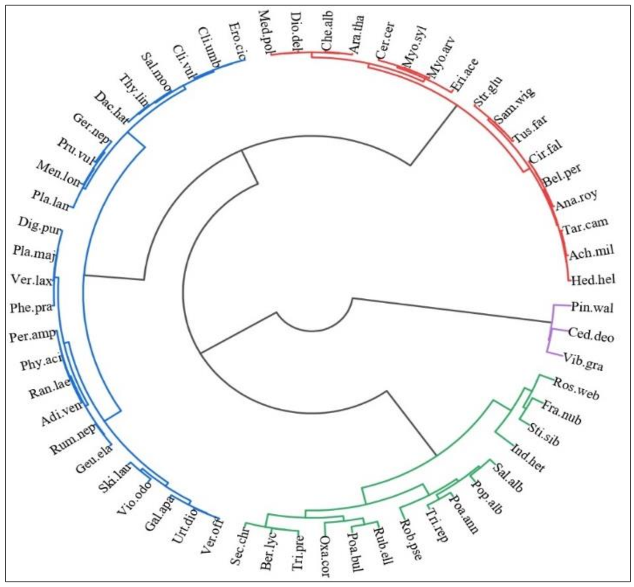

Fig. 5. The agglomerative hierarchical clustering dendrogram of plant species based on the Sorenson measure depicts three types of plant communities in the Kupwara District of the Kashmir region. Table 2 displays the full name of each species.

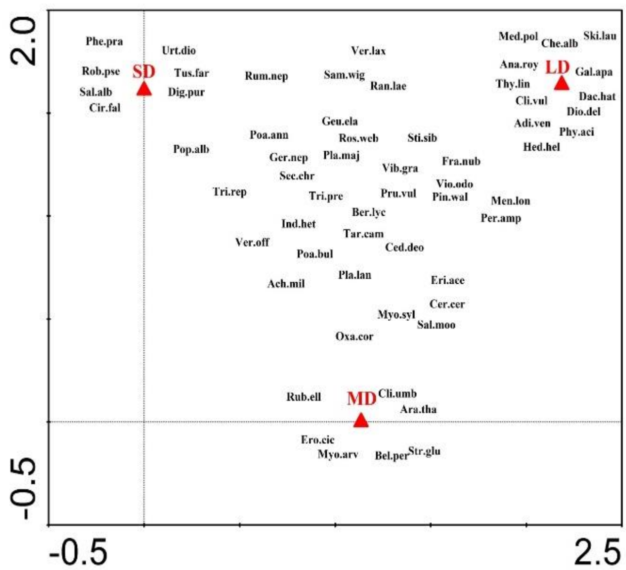

Fig. 6. DCA ordination of distribution of plant species in different forest sites in the Kupwara District of Kashmir region.

The PCA ordination (Fig. 4) revealed that the majority of species were positively correlated with both axes 1 and 2. The species including (*Achillea millefolium, Senecio chrysanthemoides, Poa annua,* and *Oxalis corniculata*) were linked to SD forest sites. Species (*Geum elatum*, *Galium aparine*, *Trifolium pretense,* and *T. repens*) were specific to MD forest sites, and plants (*Adiantum venustum, Clinopodium vulgare, Fragaria nubicola* and *Stipa sibirica*) were associated with LD forest sites. The IVI values and comparative species mix of the various forest types are shown in Table 2. Using cluster analysis, which showed that existing plant communities could be divided into three groups (clusters) based on differences in disturbance intensity, three different plant community groups were found

(Fig. 5). The plant species separating into clusters 1 and 2 were significantly more alike than any of them were to the species in cluster 3, which displayed the greatest dissimilarity from the other plant species. Previous Himalayan forest researchers (Haq *et al*., 2021 a,b,d; Altaf *et al*., 2021; Haq *et al*., 2022 c,d) utilized a similar vegetation classification. The majority of the species (73%) were indigenous, while 27% were exotic. The exotic weedy herbaceous plant species were *Poa annua, Mentha longifolia, Erigeron acer, Digitalis purpurea,* and *Urtica dioica,* growing in the forest ecosystems of the study area. Such alien weedy plants have also been observed in the woods of other Himalayan locations (Koul *et al*., 2015; Haq *et al*., 2019a;b). Initial forest invasions may promote species invasions by creating conditions that favor newcomer invasive species over native species, allowing biological invasions to develop (Haq *et al*., 2021a,b). When communities shift from native desirable plants to monospecific invader species stands, a variety of mechanisms can cause changes in vegetation composition, potentially leading to the extinction of plant species (Haq *et al*., 2020; Haq *et al*., 2022a,b). As a result, the potential importance of anthropogenic pressures in changing different forest communities on a large scale has been highlighted.

DCA Ordination: The distribution of various species along the two axes and their relationship to the gradients were shown in a DCA scattered diagram (Fig. 6). On the DCA diagram's far upper left side, the species *Digitalis purpurea*, *Tussilago farfara*, *Salix alba*, *Phleum pratense*, *Urtica dioica*, *Cirsium falconeri, Populus alba*, *Rumex nepalensis, Trifolium repens, Poa annua, Senecio chrysanthemoides,* and *Geranium nepalense* suggested a low score on axis 1 and a high score on axis 2. These species are recorded mostly from severely disturbed areas of forest. The diagram's top right-side position suggests that *Phytolacca acinosa, Dactylorhiza hatagirea*, *Adiantum venustum*, *Anaphalis royleana, Thymus linearis, Chenopodium album, Galium aparine, Skimmia laureola, Dioscorea deltoidea, Medicago polymorpha, Clinopodium vulgare* and *Hedera helix* had high scores on axes 1 and 2. These species are found in low-disturbed regions of forest. On the bottom center, the species *Clinopodium umbrosum, Rubus ellipticus*, *Strobilanthes glutinosus*, *Myosotis arvensis*, *Arabidopsis thaliana*, *Bellis perennis*, and *Erodium cicutarium* indicated moderate disturbance in the forest. The species depicted in the center of the diagram i.e., *Achillea millefolium*, *Taraxacum campylodes, Sambucus wightiana*, *Populus alba*, *Viburnum grandiflorum*, *Indigofera heterantha*, *Trifolium pratense*, *Oxalis corniculata*, *Plantago lanceolata, P. major, Persicaria amplexicaulis, Fragaria nubicola, Rosa webbiana, Verbena officinalis, Viola odorata, Salvia moorcroftiana* and *Ranunculus laetus* exhibited the widespread occurrence of such species throughout all communities and did not favour any particular habitats (Fig. 6). Previous researchers used similar multivariate methods to categorize and order plant associations in various forest types such as Haq *et al*. (2021d, 2022b,c) from Kashmir Himalaya and Rahman *et al.* (2022) from moist temperate forests of Pakistan.

Conclusions

The study concludes that all forms of anthropogenic stress had significant effects on species diversity, distributions, and forest structure consequently playing an important role in shaping different forest communities. As the level of anthropogenic stress increased, the diversity indices and phytosociological indicators declined. The species richness per unit area dropped from LD to SD Forest types. At the Low Disturbed, Moderately Disturbed, and Severely Disturbed Forest types, 43, 40, and 34 species, respectively, were documented. As the level of anthropogenic stress increased, the basal area decreased. By comparing the relative significance of Low Disturbed Forest sites and within-forest disturbance on forest composition, structure, and species distributions, the study also shed light on the need for more measures to lessen forest disturbance.

Future recommendations: We found that as the level of anthropogenic stress increased, the diversity indices and phytosociological indicators decreased, implying that legal conservation measures should be used to reduce threats to forest ecosystem recovery. The management plan for dealing with various forest threats/disturbances may include controlling before the disturbance. These include enacting restrictions to prohibit the import of exotic tree species such as *Robinia pseudoacacia* and improving habitat recovery through regeneration and the planting of native tree species such as *Pinus wallichiana* and *Cedrus deodara*. All forest sites had a significantly higher number of (18 species), common species, and a decrease in overall species uniqueness along the disturbance gradient could have an impact on high usage pressure. Methods for reducing the number or frequency of disturbances, such as stem cutting, linear construction, wildfires, human habitation, tree lopping, and livestock grazing. The majority of species recovery initiatives concentrated on managing forest habitat right away following disturbance (such as road construction) or on managing to hasten recovery (such as planting and reseeding species like (*Berberis lycium, Indigofera heterantha, Pinus wallichiana, Cedrus deodara*), reducing susceptibility to future disturbances. This information is essential for creating successful conservation strategies as well as for directing the recovery of disturbed or invaded forest ecosystems. To accomplish ambitious ecosystem restoration goals for forest management and sustainable mountain development, the study's findings could be used to create scientific policy management tools to direct the restoration of degraded ecosystems.

Author contributions: SMH and FL collected the data. SMH and MW analyzed and interpreted the data and results. SMH wrote the initial draft of the manuscript. SMH, MW, FA, MHS; FL; and RWB, revised the manuscript. Finding- MHS; All authors read and approved the final manuscript.

Acknowledgments

The authors extend their appreciation to the Researchers Supporting Project number (RSP2024R347), King Saud University, Riyadh, Saudi Arabia.

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(Received for publication 11 November 2022)