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Human-driven disturbances change the vegetation characteristics of temperate forest stands: A case study from Pir Panchal mountain range in Kashmir Himalaya

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ABSTRACT

Globally, biodiversity-rich forest ecosystems are facing higher risk of climate and land-use changes. Therefore, understanding the role of anthropogenic factors in affecting forest community composition and vegetation patterns assume urgent research priority and are prerequisites for conservation and sustainable management of forest ecosystems. We used a systematic random sampling method to obtain data on floristic diversity within four forest compartments of Pir Panchal Range in Kashmir Himalaya. We characterized the comparative disturbance levels based on a visual assessment within and around each of the forest compartment. The importance value indices along with environmental data of the sampled compartments were obtained and analyzed using hierarchical cluster analysis and ordination techniques. Floristically, in all the compartments, we found 74 species distributed among 33 families and 4 life forms. The species number per hectare showed a declining trend with an increase in disturbance level. Plant community diversity indices were positively correlated with decreasing levels of anthropogenic disturbances. The phytosociological features such as tree basal area and density were negatively correlated with increasing levels of anthropogenic disturbance. Our study, using standard statistical methods, has empirically characterized the intensity of anthropogenic impacts in each forest compartment, and analyzed the relationship between these impacts and the forest vegetation patterns. Our results will help in a better understanding of the role of anthropogenic factors in affecting forest community composition, which in turn will foster the sustainable forest management and biodiversity conservation in this Himalayan region.

1. Introduction

Biodiversity is distributed non-uniformly across the globe, and therefore the impacts of its loss will be relatively more catastrophic in biologically rich regions such as global biodiversity hotspots (Myers et al., 2000; Dar and Khuroo, 2020), harboring the most threatened endemic flora and fauna (Deak et al., 2016). To address these global challenges at a regional level, it is important to investigate the magnitude of floristic diversity and factors influencing the vegetation pattern in a region, which is a prerequisite for the conservation and sustainable utilization of biodiversity (Devictor et al., 2010; Haq et al., 2019). The biodiversity hotspots located within the developing world (e.g., the Himalaya) are currently experiencing intense anthropogenic pressure on natural ecosystems, with dire consequences for the long-term sustenance of life-supporting ecosystem goods and services (Pandit, 2017; Wester et al., 2019; Haq et al., 2020).

Although the relationship between disturbance and plant biodiversity has been investigated for decades (Miller et al., 2011), the patterns of diversity and disturbance relationships remain a source of debate (Bongers et al., 2009). The intermediate disturbance hypothesis (IDH), a popular theory explaining the link between disturbance and diversity, predicts that low disturbance frequency, intensity, or extent (i.e., area disturbed) would favour late successional species, while high disturbance frequency, intensity, or extent would favour early-successional

Abbreviations: Canonical correspondence analysis, (CCA); Compartment 44, (C44); Compartment 47, (C47); Compartment 48, (C48); Compartment 49A, (C49A); Degradation, (DG); Detrended correspondence analysis, (DCA); Distance from settlements, (DFS); Grazing intensity, (GZ); Importance Value Index, (IVI); Nestedness-resultant components, (βsne); Soil erosion, (SE); Spatial turnover of species, (βsim); Stem cutting, (CT); Tangmarg Forest Division, (TFD).

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species (de Avila et al., 2018). Intermediate disturbance frequency, on the other hand, would allow both early and late successional species to coexist, thus promoting overall high diversity. Multiple disturbance components (such as disturbance frequency, intensity, or expanse) interact and may explain variances in diversity reaction to disturbance in terrestrial landscapes (Johst and Huth, 2005). For example, depending on the frequency of disturbance, it has been hypothesized that the coexistence of two species peaks at low, intermediate, or high degree of disturbance. Nonetheless, various additional factors, such as understory plant species richness are expected to influence the geometry of diversity-disturbance relationships, and knowing these effects would help us better understand the impact of disturbance on diversity (Sheil and Bongers, 2020).

The Kashmir Himalaya, one of the biodiversity-rich and ecologically significant mountainous regions in the Himalayan biodiversity hotspot, harbor large tracts of Himalayan temperate forest types (Haq et al., 2020), with a forest cover of 51% (Forest Survey of India, 2017). In recent times, the application of statistical techniques in phytosociological studies such as classification and ordination of vegetation data has significantly improved our understanding of community composition and structure, and vegetation patterns which determine the magnitude of biodiversity more objectively (Shaheen et al., 2011; Khan et al., 2012; Khan et al., 2017; Haq et al., 2017). In comparison to other Himalayan regions, such type of studies is still insufficient in the Kashmir Himalaya.

It is in this backdrop that the present study was undertaken to characterize the comparative vegetation pattern in the Tangmarg Forest Division of the Pir Panjal Range in Kashmir Himalaya. We investigated how the different levels of anthropogenic impacts determine the phytosociological associations in the forest community in the study area. Specifically, we addressed the following research questions: (i) What is the vegetation composition of the selected forest sites within the Pir Panjal Range of the Kashmir Himalaya? (ii) What are the various anthropogenic disturbances and how they influence the forest vegetation patterns? By answering these questions, we show how anthropogenic factors alter the forest composition and phytosociological attributes and how their interactions play role in determining the vegetation patterns. Such empirical data can help in developing policy and management tools for effectively mitigating anthropogenic disturbances in the forest ecosystems of this Himalayan region.

2. Materials and methods

2.1. Study area

The present study was conducted in the Tangmarg Forest Division (TFD), located in the Pir Panchal Range of Kashmir Himalaya at an altitude ranging from 2400–4300 m above sea level (masl) (34^{o} 26′99′to 34^{o} 10′ 95N Latitude and 74^{o} 75′ 75′ to 74^{o} 51′ 07E Longitude; Fig. 1); however, the forests in the area occur up to *ca.* 3450 masl (Hamid et al., 2020). The area is mountainous, showing a continental temperate type of climate with annual precipitation of 66-167 cm and dominated by the coniferous forest vegetation (Romshoo et al., 2020). The region has moderate summers and cold winters, receiving snowfall from December to February. The forest vegetation mainly comprises broad-leaved tree species, such as *Acer caesium, Prunus cornuta* and *Robinia pseudoacacia,* whereas conifer species include *Abies pindrow, Picea simithiana, Cedrus deodara,* and *Pinus wallichiana*, and shrubs include *Rosa webbiana, Berberis lycium, Indigofera heterantha.* The coniferous tree species are native in the region whereas *Robinia pseudoacacia* is an alien invasive tree species in the region.

2.2. Sampling design and measurements

Field sampling was conducted during 2018 and 2019. We selected four forest compartments of TFD, namely: Compartment 48 (C48), Compartment 49A (C49A), Compartment 47(C47) and Compartment 44 (C44) (Fig. 1). The four compartments are located along an elevation gradient between Tangmarg (2100 masl) and Gulmarg (2500 masl) (Table 1). A compartment is a permanent unit of forest for the purpose of administration and record; and the smallest Working Plan unit of forest management.

We used a systematic random sampling method (Shaheen et al., 2012) to obtain data on floristic diversity at eight square shaped 31.6 m x 31.6 m (≅ 0.1 hectare) (hereafter ha) plots per compartment (i.e., 4 × 8 = 32 plots). For tree sampling, we recorded the density of live stems in each plot. The tree species composition and DBH (diameter at breast

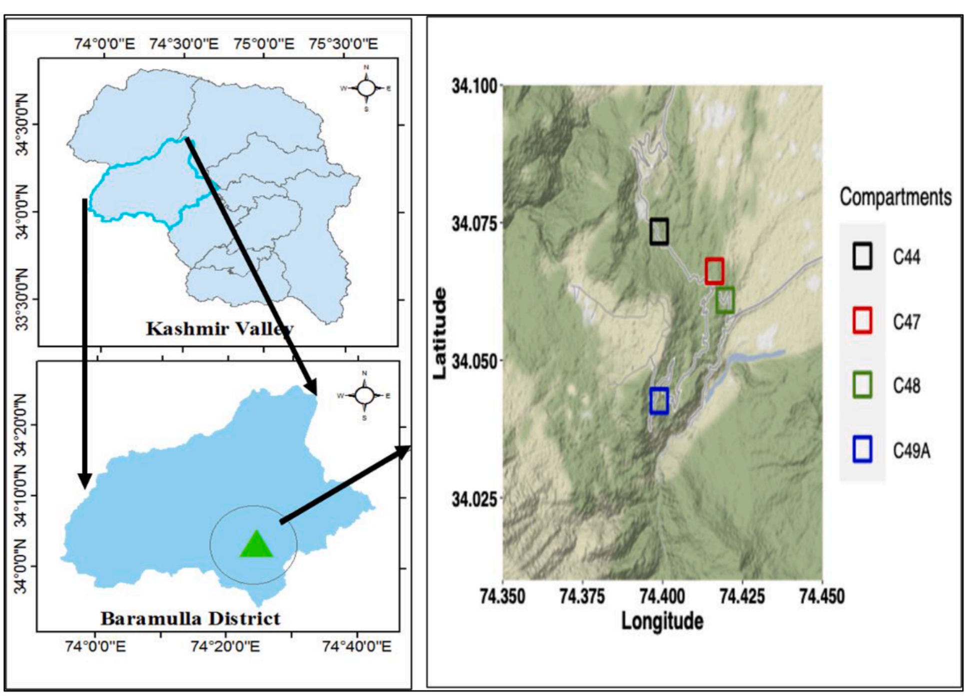

Fig. 1. Map of the study area and points showing the sampled forest compartments in the Pir Panjal Range of Kashmir Himalaya.

Table 1
Details of the sampled forest compartments in the Pir Panjal Range of Kashmir Himalaya.

Forest compartments	C48	C47	C44	C49A
Geo-coordinates (N, E)	34.060898 74.419570	34.066181 4.416267	34.073380 74.398941	34.042599 74.398941
Altitude (masl)	2100	2200	2300	2500
Slope (°)	27.4 ±6.24	25.1 ±8.42	34.76 ±5.42	32.03 ±7.24
Distance from settlements	2	2	1	0
Stem cutting	2	2	1	1
Livestock grazing	1	1	1	2
Degradation	2	2	1	1
Soil erosion	2	2	1	1

height, i.e., 1.37 m) of each tree was recorded. Shrubs were sampled in four square shaped subplots($5m^2$) delimited within each plot. Finally, herbaceous diversity was sampled in five square shaped subplots ($1m^2$); one in each corner and one in the center of each plot. In total, one hundred twenty-eight (4 subplots x 8 plot x 4 compartments =128) ($5m^2$) sub plots for shrubs and one hundred sixty (5 subplots x 8plots x 4 compartments=160) ($1m^2$) subplots for herbs were sampled in the present study.

Plant specimens were collected from the field to serve as herbarium voucher specimens, and identified using relevant taxonomic tools and literature (Stewart, 1972; EFLORAS (http://www.efloras.org/) and further authenticated by matching the plant specimens with material in KASH herbarium(https://species.wikimedia.org/wiki/KASH). The online taxonomic database of the POWO, (http://www.plantsoftheworldonline.org/) was used for updating nomenclature. After collecting specimens in each compartment, we classified plants according to growth form (trees, shrubs, climbers and herbs). We calculated the importance value index (henceforth IVI) for each plant species per compartment. The IVI was determined as the sum of relative values of density, frequency and dominance using the formula given by Curtis and McIntosh (1950). We used the IVI because it is a standard ecological tool to measure the dominance of plant species of an ecosystem. The total number of species was simply taken as a count of the number of species in that particular selected forest compartment. Fisher's alpha was calculated by the formula $S=a*\ln(1+n/a)$, where S is number of taxa, n is number of individuals and a is the Fisher's alpha. Simpson index as: $D = 1-(N-1)/\Sigma(n-1)$ Where D = Diversity index, n = Number of individual of a species and N = Number of individual of all the species. Concentration of dominance (Cd), known as Simpson index, was measured according to Simpson (1949): Index of dominance (Cd) = $\Sigma (ni/N)^2$. where ni = proportion of individual belonging to ith species and N = total number of individuals.

Additionally, in each compartment, the degree of disturbance was characterized using a semi-quantitative scale according to Haq et al. (2019). A three-point scale (0 = none-low, 1 = moderate, 2 = high) was used to record disturbance levels based upon visual assessment in the vicinity of each sampling plot in the selected forest compartments (Seipel et al., 2012). The disturbance factors such as stem cutting (CT), distance from settlements (DFS), degradation (DG), soil erosion (SE), and grazing intensity (GZ) were taken into consideration (Table 1). A global positioning system (GPS Garmin map76cs) was used to record altitude as well as geo-coordinates of the forest sites. The data of the slope angle of each compartment were measured using a clinometer (Haq et al. 2019b).

2.3. Data analysis

We compared the relationship among the four forest vegetation compartments through a detrended correspondence analysis (DCA), which is an ordination technique supported by reciprocal averaging. We analyzed the relationship between plant species and environmental variables by extracting major gradients among combinations of explanatory variables using canonical correspondence analysis (CCA). After CCA, the Monte Carlo test was used to evaluate the effect of explanatory variables obtained on the vegetation composition. DCA, CCA, and Monte Carlo were performed in CANOCO software (Ter Braak and Smilauer, 2002). The Venn diagram was prepared by using Bioinformatics and Evolutionary Genomics software (available at http://bioinformatics.psb.ugent.be/webtools/Venn/). The commonly used diversity indices: Shannon and Wiener, (1963), Simpson (1949), Fisher's Alpha, Dominance index, and Evenness Index (Pielou, 1975) were calculated using PAST software ver.3.14. (https://www.techworld.com/download/office-business/past-314-3330821/linkid=163338).

Finally, we used β-diversity analysis to compare vegetation composition dissimilarities among the sampled forest compartments. We used two distance matrices based on the "Sorensen" family as dissimilarity index: (1) spatial turnover (replacement), and (2) nestedness-resultant components of beta diversity. The first distance matrix (spatial turnover) is based on Simpson pairwise dissimilarity, and the second one is measured as the nestedness-fraction of Sorensen pairwise dissimilarity (Baselga et al., 2018). Cluster and dissimilarity analyses were carried out in the package "*dendextend*" (Galili, 2015) and "*betapart*" (Baselga et al., 2018) respectively, using the R software 3.6.1.

3. Results

3.1. Forest vegetation composition

In all the forest compartments, we found 74 plant species taxonomically distributed among 65 genera and 33 families. The list of plant species in each compartment is presented in table 2. The number of species contributed by 33 families was disproportionate, with seven (7) families contributing half of the species, while as the remaining half belonged to 25 families and of which 18 families were monotypic. The dominant plant families included Asteraceae with 10 species (13 %), followed by Lamiaceae and Plantaginaceae with six species each (8 %), and Fabaceae with five (7%) species (Table 2). The reported plant species represent different life forms: herbs (81%), shrubs (8 %), trees (8 %), and climbers (3 %).

In each compartment, we studied the species composition to observe the effect of disturbance on each compartment. Out of total recorded species, it was observed that 10 plant species were unique to C44 followed by eight species in C48, seven species each in C49A and C47 (Fig. 2). However, 21 species were common in all the four compartments that included *Viburnum grandiflorum, Leucanthemum vulgare, Berberis lycium, Plantago lanceolata, Achnatherum sibiricum, Cerastium cerastoides, Geum elatum, Fragaria nubicola, Prunella vulgaris, Rosa webbiana, Indigofera heterantha, Abies pindrow, Urtica dioica, Poa annua, Geranium nepalense, Plantago major, Poa bulbosa, Viola odorata, Trifolium pratense, Oxalis corniculata, Pinus wallichiana.* Similarly, four species were common between C47, C48, and C49A. Three species were common between C44 and C48. One species was common between C44, C47, and C48 (Fig. 2).

Plant community composition and diversity varied as a function of location and disturbance levels. The relative intensity of disturbances exhibited significant differences between the variables in the sampled compartments ($F_{[1,4]} = 0.01$; $p = 0.009$). The number of species per hectare exhibited a declining trend with an increase in disturbance level. The C49A was the richest forest compartment, followed by C44, C47 and C48 respectively (Table 1). C48 presented the highest dominance value, while C49A presented the highest values of Shannon and Simpson diversity indices, Pielou's Evenness, and Fisher's alpha (Table 3). Also, C44 had the highest basal area, while C49A presented the highest density. The less disturbed forest C49A was 1.7 times denser than C44 and tree density declined with an increase in disturbances level (Table 3).

In DCA ordination, we observed that the 74 plant species found in the

Table 2

. Importance value index of the species recorded in the sampled forest compartments of Pir Panjal Range in Kashmir Himalaya. “X” sign denotes absence of species.

Name of plant species	Family	C47	C48	C49A	C44
Tree layer					
Abies pindrow (Royle ex D. Don) Royle	Pinaceae	56	128	71	263
Picea smithiana (Wall.) Boiss.	Pinaceae	72	75	74	X
Pinus wallichiana A.B. Jacks.	Pinaceae	156	47	119	36
Robinia pseudoacacia L.	Fabaceae	X	X	15	X
Taxus wallichiana Zucc.	Taxaceae	X	47	X	X
Cedrus deodara G. Don	Pinaceae	14	X	18	X
Shrub layer					
Berberis lycium Royle	Berberidaceae	26	36	28	23
Indigofera heterantha Brandis	Fabaceae	91	83	78	26
Rosa webbiana Wall. ex Royle	Rosaceae	57	46	77	80
Rubus ellipticus Sm.	Rosaceae	X	28	X	X
Skimmia laureola (DC.) Decne.	Rutaceae	X	X	X	16
Viburnum grandiflorum Wall. ex DC.	Adoxaceae	125	104	116	152
Herb layer					
Achillea millefolium L.	Asteraceae	5	3	1	X
Adiantum venustum D.Don	Pteridaceae	X	3	6	X
Anaphalis royleana DC.	Asteraceae	3	X	X	X
Arabidopsis thaliana (L.) Heynh.	Brassicaceae	2	X	X	X
Asplenium ofeliae Salgado.	Aspleniaceae	X	3	X	X
Barbarea vulgaris W.T.Aiton	Brassicaceae	X	X	X	13
Bellis perennis L.	Asteraceae	1	X	X	X
Caltha alba Cambess.	Ranunculaceae	X	X	X	4
Dichodon cerastoides (L.) Rchb.	Caryophyllaceae	8	5	3	7
Chenopodium album L.	Chenopodiaceae	X	X	2	X
Cirsium falconeri (Hook.f.) Petr.	Asteraceae	X	X	1	X
Clinopodium umbrosum (M. Bieb.) Kuntze	Lamiaceae	X	X	1	3
Clinopodium vulgare L.	Lamiaceae	3	X	X	X
Dactylorhiza hatagirea (D.Don) Soó	Orchidaceae	X	X	1	X
Digitalis lanata Ehrh.	Plantaginaceae	X	2	X	1
Digitalis purpurea L.	Plantaginaceae	X	2	X	X
Dioscorea deltoidea Wall. ex Griseb.	Dioscoreaceae	X	2	X	X
Dryopteris stewartii Fraser-Jenk.	Dryopteridaceae	X	X	5	X
Erigeron acer var. *multicaulis* (Wall. ex DC.) C.B.Clarke	Asteraceae	12	X	6	X
Erodium cicutarium (L.) L'Hér.	Geraniaceae	X	X	1	X
Fragaria nubicola (Lindl. ex Hook.f.) Lacaita	Rosaceae	50	21	81	16
Galium aparine L.	Rubiaceae	1	X	1	6
Geranium nepalense Sweet	Geraniacea	3	7	3	1
Geum elatum Wall. ex Hook.f.	Rosaceae	2	4	4	6
Hedera helix L.	Araliaceae	2	X	8	X
Impatiens sodenii Engl. and Warb.	Balsaminaceae	X	X	X	1
Leucanthemum vulgare Lam.	Asteraceae	24	21	14	20
Medicago polymorpha L.	Fabaceae	X	X	1	X
Myosotis sylvatica Ehrh. ex Hoffm.	Boraginaceae	3	X	3	3
Myosotis arvensis (L.) Hill	Boraginaceae	2	X	X	X
Myriactis nepalensis Less.	Asteraceae	2	X	X	X
Nepeta erecta (Royle ex Benth.) Benth.	Lamiaceae	X	X	X	5
Nepeta connata Royle ex Benth.	Lamiaceae	X	X	X	2
Oxalis corniculata L.	Oxalidaceae	8	17	3	1
Pedicularis siphonantha D.Don	Orobanchaceae	X	X	X	3
Koenigia alpina (All.) T.M. Schust. and Reveal	Polygonaceae	X	X	X	2
Phleum pratense L.	Poaceae	X	3	X	X
Phytolacca acinosa Roxb.	Phytolaccoideae	X	1	X	1
Plantago lanceolata L.	Plantaginaceae	2	4	3	3
Plantago major L.	Plantaginaceae	13	7	3	3
Poa annua L.	Poaceae	14	49	16	19
Poa bulbosa L.	Poaceae	31	23	4	31
Podophyllum hexandrum Royle	Berberidaceae	X	X	X	2
Bistorta amplexicaulis (D.Don) Greene	Polygonaceae	2	X	3	6
Persicaria hydropiper (L.) Delarbre	Polygonaceae	X	X	X	24
Prunella vulgaris L.	Lamiaceae	6	4	6	6
Pteris cretica L.	Pteridaceae	X	1	X	X
Ranunculus bulbosus L.	Ranunculaceae	X	2	2	7
Rumex nepalensis Spreng.	Polygonaceae	X	8	3	X
Salvia moorcroftiana Wall.ex. Benth	Lamiaceae	3	X	1	X
Sambucus wightiana Wall. ex Wight and Arn.	Adoxaceae	X	2	2	3
Achnatherum sibiricum (L.) Keng ex Tzvelev	Poaceae	17	27	48	39
Strobilanthes glutinosus Nees	Acanthaceae	3	X	X	X
Taraxacum campylodes G.E. Haglund	Asteraceae	4	3	3	X
Trifolium pratense L.	Fabaceae	28	14	15	31
Trifolium repens L.	Fabaceae	17	30	10	X
Tussilago farfara L.	Asteraceae	X	1	X	X
Urtica dioica L.	Urticaceae	2	3	3	6
Verbena officinalis L.	Verbenaceae	X	X	2	2
Veronica persica Poir.	Plantaginaceae	3	3	X	7
Veronica laxa Benth.	Plantaginaceae	X	2	X	2
Viola odorata L.	Violaceae	8	3	12	2

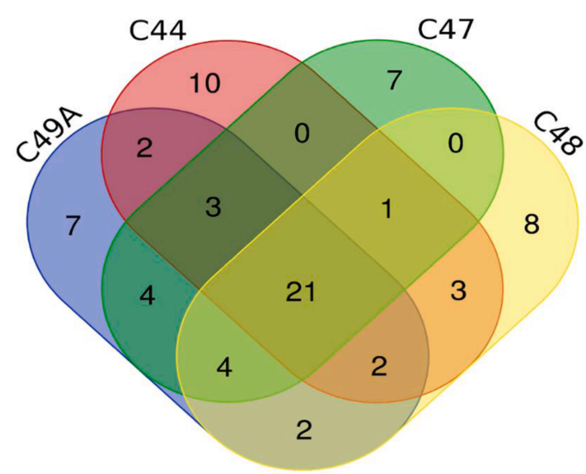

Fig. 2. Venn diagram showing unique and common number of plant species occurring in the sampled forest compartments of Pir Panjal Range in Kashmir Himalaya.

Table 3

Diversity and phytosociological attributes of forest vegetation in Pir Panjal Range of Kashmir Himalaya. SD – Standard Deviation.

Forest compartments	C47	C48	C49A	C44
Total number of species	40	41	45	42
Concentration of dominance	0.07	0.07	0.05	0.06
Shannon	3.05	2.99	3.25	3.12
Simpson	0.92	0.93	0.94	0.93
Evenness	0.47	0.48	0.64	0.53
Fisher's Alpha	11.47	11.39	12.32	12.04
Basal Area (mean±SD; m^2ha^{-1})	18 ±4	22 ±13	43 ±13	104 ±6
Density (mean±SD; trees/ha^{-1})	226 ±32	230 ±14	533 ±99	300 ±15

sampled forest compartments were clustered differently on positive and negative sides of the DCA axis (Fig. 3). Maximum plant species were positively correlated with both axes 1 and 2. The plants include *Anaphalis royleana, Arabidopsis thaliana, Barbarea vulgaris, Clinopodium umbrosum, Leucanthemum vulgare* and *Viburnum grandiflorum*. The

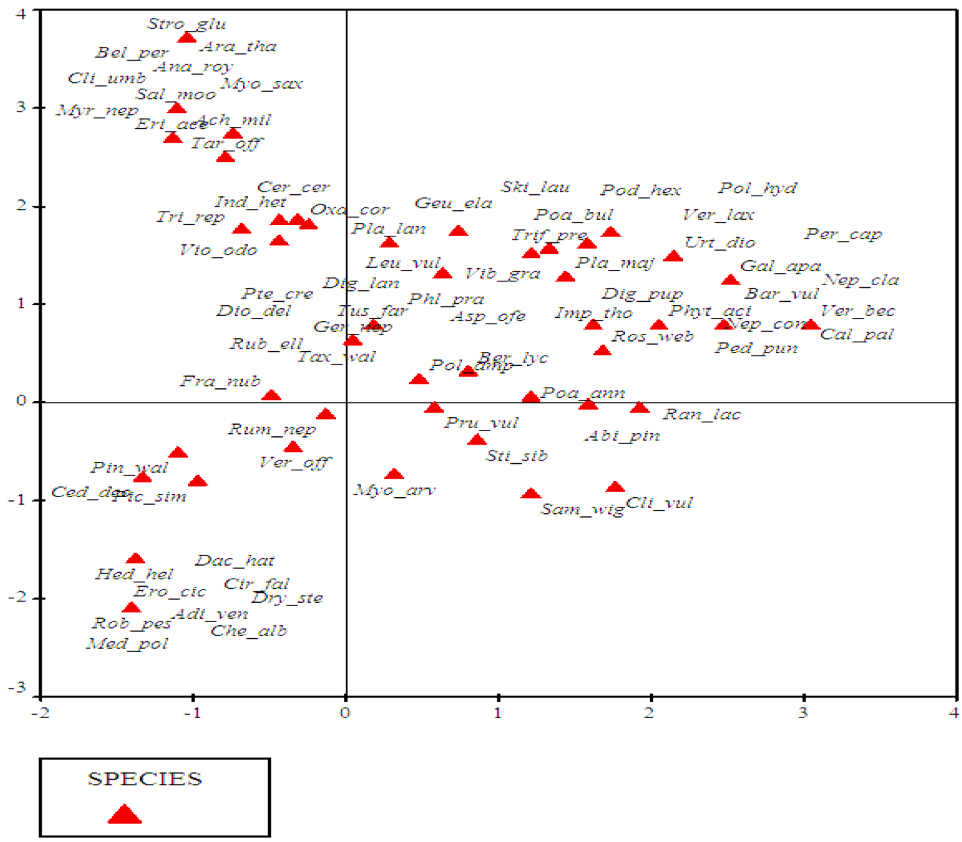

Fig. 3. DCA ordination of the forest vegetation in the Pir Panjal Range of Kashmir Himalaya.

species clusters on the negative side of both axes in ordination space showed differences in habitat types and included: *Abies pindrow, Cedrus deodara, Cirsium falconeri, Clinopodium vulgare* and *Verbena officinalis* (Fig. 3). DCA results also showed that the gradient length of axis 1 was 6.84 with 0.81 of Eigenvalue, while axis 2 showed a gradient length of 3.04 with 0.42 Eigenvalue (Table 4). The total inertia (sum of all Eigenvalues) was 4.61, and the first two axes explained 26.8 % of the variation of species data.

The CCA ordination indicated that vegetation is unevenly distributed along with various anthropogenic and environmental variables. The species that are influenced by stem cuttings, soil erosion, and degradation included *Achillea millefolium, Asplenium ofeliae, Bellis perennis, Clinopodium umbrosum, Dioscorea deltoidea, Myosotis sylvatica, Taraxacum campylodes, Taxus wallichiana, Verbena officinalis, Viola odorata*, and *Vibrurnum grandiflorum*. The species influenced by slope and human settlements included *Adiantum venustum, Cedrus deodara, Dryopteris stewartii, Dactylorhiza hatagirea, Fragaria nubicola, Pinus wallichiana, Robinia pesudoacacia, Myosotis arvensis*, and *Medicago polymorpha*. Finally, the species that were influenced by altitude and grazing include *Abies pindrow, Clinopodium vulgare, Caltha alba, Nepeta connata, Skimmia laureola, Sambucus wightiana, Galium aparine*, and *Rosa webbiana* (Fig.4).

In the CCA ordination, the maximum Eigenvalue was recorded for axis 1 (0.75) followed by axis 2 (0.50) and axis 3 (0.48) (Table 5). The percentage accumulative variance explained for axis 1, 2, and 3 were 16.4, 27.3, and 37.8, respectively. The total variance (inertia) in the species data was 4.60, and explanatory variables accounted for 100 %. Pseudo-canonical correlations for all axes were 0.98. The Monte Carlo test showed significant results after permutations (Eigenvalue: 0.75; F-ratio: 0.977; P-value: 0.028).

Table 4
Summary of the four axes of the DCA for the vegetation data (using importance value index) in the sampled forest compartments of Pir Panjal Range in Kashmir Himalaya.

Statistic	Axis 1	Axis 2	Axis 3	Axis 4
Eigen values	0.81	0.42	0.28	0.04
Accumulative Explained Variation	17.6	26.8	32.9	33.9
Gradient length	6.84	3.04	2.44	2.07
Total inertia	4.103			

3.2. Beta diversity

The spatial turnover of species (βsim) and nestedness-resultant components (βsne) revealed two distinct clusters between the forest compartments (Fig. 5). In βsim cluster, C49A was clustered with C44, and dissimilar from C47 and C48. On the other hand, βsne cluster presented C44 and C48 as the first cluster and C49A and C47 as a second cluster. C48 and C49A represent the most dissimilar forest compartments. Finally, since βsne had values close to zero (no patterns of dissimilarity), we can state that beta-diversity patterns in the sampled forest plots are almost a result of species replacement.

4. Discussion

The findings of the present study showed that the plant associations were clearly influenced by different environmental factors, forming different clusters of plant species. Each group had particular physiognomy, which was determined by specific environmental variables. The diverse assemblages of individuals of the similar and dissimilar plant species in a specific association result from abiotic and spatial factors, along with time and biotic relationships (Khan et al., 2017) yet their relative impacts differ across habitat types and study scales (Liu et al., 2015; Wang et al., 2019). In this sense, the classification of vegetation provides a useful way of summarizing the knowledge of vegetation

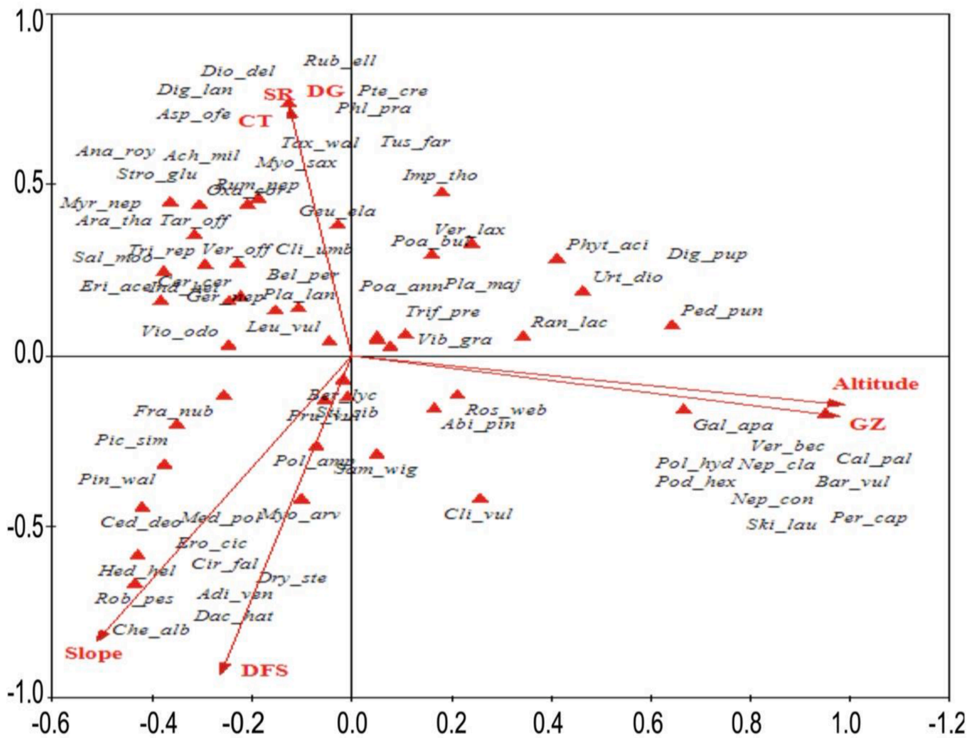

Fig. 4. CCA diagram showing distribution of plant species along the anthropogenic and environmental variables. Triangles represent species, and arrows represent explanatory variables (Altitude, Slope, DFS – Distance from settlements, DEG – Degradation, GZ – Grazing, CT – Cutting, SR – Soil Erosion).

Table 5
Forest vegetation data according to the seven environmental variables included in CCA analysis in Pir Panjal Range of Kashmir Himalaya.

Statistic	Axis 1	Axis 2	Axis 3	Axis 4
Eigen values	0.753	0.506	0.480	0.381
Explained Variation	16.4	27.3	37.8	46.0
Pseudo-canonical correlation	0.984	0.958	0.980	0.962
Explained fitted variation	28.7	47.9	66.2	80.7
Total inertia	4.603			

patterns of forest ecosystems. Here we presented the results of an assessment of the anthropogenic disturbances on the forest vegetation pattern in the Pir-Panjal Range of Kashmir Himalaya, providing insights into how forest parameters (composition, diversity and phytosociological attributes) are spatially influenced by anthropogenic disturbances in the study area. We showed that (i) plant community composition and diversity varied as a function of location and disturbance levels, (ii) the composition and distribution pattern of plant species reflected the differences in the anthropogenic and environmental factors, mainly slope, altitude, access, grazing and cutting, (iii) and anthropogenic drivers have significant effects on beta diversity, particularly the spatial turnover. Overall, our results fill some existing gaps of knowledge about impact of anthropogenic disturbances on the variation in the species composition between the forest compartments.

In comparing the vegetation composition of the forests in the Pir-Panjal Range, relatively few species were recorded in other forests of the Himalaya. Sharma and Kant (2014) reported 112 plant species in the Jammu hills, India; 114 species by Bhutia et al. (2019) from Sikkim, Eastern Himalayas; 93 species by Nafeesa et al. (2021) from Bhimber

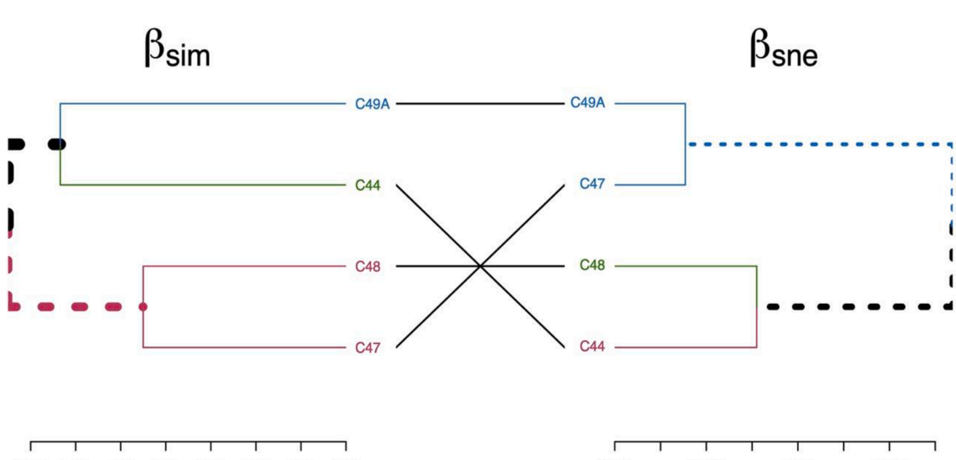

Fig. 5. Spatial turnover (replacement) (βsim) and nestedness-resultant components (βsne) of beta diversity of species dissimilarity between the sampled forest compartments in the Pir Panjal range of Kashmir Himalaya.

hills of Kashmir Himalaya and 122 species by Shaheen et al. (2012) from western Himalayan moist temperate forests, Pakistan, implying thereby that forests in the Pir-Panjal Range are relatively less diverse than these forests. Thus, we observe that even though floristic composition studies are done in the same region, plant species richness can vary greatly, suggesting that different environmental and anthropogenic factors are affecting these communities. The species richness per unit area exhibited a declining trend with an increase in disturbance level. These results are in conformity with Sahoo et al. (2020) where a similar trend in the forest from Odisha, India was reported.

In the present study, Asteraceae, Lamiaceae, Plantaginaceae and Fabaceae were the most diverse families. Similar results were reported by Hussain et al. (2015) and Saima et al. (2018) in a forest of Pakistan, Himalaya. Lamiaceae was recorded as the dominant family by Suyal et al. (2010) in Garhwal Himalaya and Khan et al. (2015) in Pakistan. Fabaceae was the dominant family reported by Singh et al. (2018) from Western Himalaya. Many researchers have reported Asteraceae and Lamiaceae as the most representative families in the Himalayan forests of India and other places (Shaheen et al., 2011; Khan et al., 2012; Sharma et al., 2013; Dar and Sundarapandian, 2016; Khan et al., 2016; Nafeesa et al., 2021), which shows the high adaptive capacity of this family in different regions and climates. It is evident that across the western Himalaya forests a high percentage of resemblance is found at the family level. Furthermore, the present study highlighted that families show unequal distribution patterns, with 25 families being monotypic, which is in accordance with the findings by several studies from different areas of Western Himalaya (Gairola et al., 2010).

Most values of diversity indices found for the four forest compartments of TFD were higher in C49A and lower in C47. The reason for this result was the fact that C49A was located away from road (less anthropogenic pressure) and at a higher altitude as compared to C47 and C48, which was inversely proportional, that is C47 was located at lower altitudes and near to human settlements, conducive to anthropogenic pressures. These results are further corroborated with the findings of Pandey et al. (2020) from forests of Central Himalaya. Shaheen et al. (2011) also found similar results from Pakistan, and others like Malik and Bhatt (2015), Malik et al. (2016), Sreejith et al. (2016), and Haq et al., 2019) from forests in different regions of India. The dominance reported in the different sites of the present study ranged from 0.05 to 0.07. The concentration of dominance (CD) is lower than reported by other workers in some parts of western Himalayas (Malik and Bhatt, 2015; Pilania et al., 2014; Shahid and Joshi, 2016; Supriya-Devi and Yadava, 2006). According to Whittaker and Niering (1965), the value of CD for temperate forests lies within the range of 0.10 to 0.99.

The phytosociological features (basal area and density) were negatively correlated with increasing levels of anthropogenic disturbance. The reported basal area in the present study ranges from 18.53 in C47 104 m^2 ha^{-1} in C44. The possible reason for this variation might be due to the presence of high-pressure of anthropogenic disturbance as it has been reported by Haq et al. (2019, 2020) in which large and medium-size trees have been continuously cut for timber and other human uses, and small-sized trees and shrubs have taken their place. The low basal area reflected the higher levels of deforestation intensity and unchecked anthropogenic pressure in these local forest reserve. The current findings are in agreement with Shaheen et al. (2011) for Himalayas in Pakistan; and also with Malik and Bhat (2016a) from Western Himalaya, India. Moreover, the comparison of the present result of the total basal area of Tangmarg Forest Division with other related forests shows that it has a lower basal area than Dar and Sundarapandian (2016) (19.4–51.9 m^2ha^{-1}) and Singh and Gupta (2009) (18.49–52.54 m^2ha^{-1}) both from India; and similar to Shaheen et al. (2012) (42.3–105.2 m^2ha^{-1}) from Pakistan Himalayas, and Singh et al. (1994) (5–114m^2ha^{-1}) from the central Himalayas.

In the case of tree density, the high-altitude forest C49A is (1.7) times denser than C44 and declined with an increase in disturbances level. The possible reason may be that the local people use the forest as the livelihood source and possible factors forthe decreased tree density in the forest compartment is proximity to human settlements and easy road accessibility. We reported the tree density within a range of 226–533 N ha^{-1}. The present results are in conformity to those reported from the Garhwal Himalaya (Sharma et al. 2009; 440–550 N ha^{-1}), Northern Kerala (Sreejith et al. 2016; 625–850 N ha^{-1}), Manipur, Northeast India (-Supriya-Devi and Yadava, 2006; 534–620 N ha^{-1}), Pakistan Himalayas (Ahmed et al., 2006 Ahmed et al. 2006; 530–940 N ha^{-1}), North-Western Himalaya in India (Singh and Samant 2010; 457 N ha^{-1}), Pakistan Himalayas (Shaheen et al. 2011; 344 N ha^{-1}); Kashmir Himalaya, India (Dar and Sahu 2018; 578 N ha^{-1}), Himalayas in Pakistan (Shaheen et al. 2016; 492 N ha^{-1}); Saptasajya hill, India (Sahu et al. 2019; 390–433 N ha^{-1}). The basic reason for low tree density in the study area is due to cutting of keystone species like *Cedrus deodara, Abies pindrow* and *Pinus wallichiana.* These plant species are preferred and ideal timber sources of the local communities, owing to varying anthropogenic pressures of forest degradation (Ijaz et al., 2018; Haq et al., 2019c).

The CCA diagram (bi-plot) revealed that the composition and distribution pattern of plant species reflected the differences in the anthropogenic and environmental factors, mainly slope, altitude, access, grazing and cutting. Furthermore, any change in these variables, especially, altitude and slope can pose a substantial upshot in the formation of plant communities (Khan et al., 2013; Shaheen et al., 2012). Shaheen et al. (2011), Khan et al. (2012), and Khan et al. (2017) also described the plant communities, using a phytosociological approach which support our results. The DCA ordination shows that more species having a positively correlation with both axis 1 and 2. Haq et al. (2017) also reported similar results from Nandiar valley, Western Himalayas. Davies et al. (2008) correlated slope as an important factor in determining the plant composition and assemblage, and Zare et al. (2007) found that both altitude and slope are important environmental variables in shaping the plant species composition. Topographical features and biological interactions are often seen to correlate with distributions of different plant species (Harms et al., 2001; Shaheen et al., 2011).

We found that anthropogenic drivers have significant effects on beta diversity, particularly the spatial turnover. These results indicate that there is not a significant loss of the number of species between the compartments, but a variation in the species composition. This variation may be closely linked to the anthropogenic effects in the study area, which induces the appearance of species adapted to disturbance-mediated habitats. The local species replacement along spatial gradients implied the simultaneous loss and gain of species due to anthropogenic events, competition, and environmental filtering (Guo et al., 2018; Haq et al., 2020a). This indicates the relationship among forest types and among species on the basis of multiple factors. Although we did not find a large variation in βsne (loss of species between compartments), it is important to note that temporal analysis might be important to consider a notable variation in this component of beta diversity and βsne variations will be better observed in long-term analysis in future studies.

5. Conclusions

The present study contributes in understanding impacts of anthropogenic factors on forest plant communities within the Kashmir Himalaya, which are facing many threats: land use and climate change. Understanding relationship between forest types and species' assemblages based on multiple-factor classification and multivariate analyses can assist in vegetation assessment and monitoring. Our study sheds light on how environmental variables and anthropogenic factors can affect the diversity and association of forest plant communities. We demonstrate that human-driven changes are affecting plant communities through deforestation and road construction, which may get further aggravated with impending impacts of changing climate. Our study can be useful in assessing environmental impacts and developing mitigation measures for the conservation of the forest ecosystems in this

Himalayan region.

Author Contribution

AAK and IR conceived the research idea; SMH collected field data; SMH and ESC analyzed the data; SMH and AAK interpreted the data; SMH andAAK wrote the manuscript with inputs from IR and ESC; SMH and AAK revised the manuscript with approval from all the authors.

Declaration of Competing Interest

The authors of the manuscript entitled “Human-driven disturbances change the vegetation characteristics of temperate forest stands: A case study from Pir Panchal Mountain Range in Kashmir Himalaya” hereby declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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