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Research paper

Floristic status of the Himalayan foothills in Haryana – vegetation composition, diversity and population structure

Himanshi Dhiman, Harikesh Saharan, Harish Punia and Somveer Jakhar*

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Abstract. The current research was performed in the Morni Hills, a part of the outer Himalayas. Floristic assessment is critical for a plant community, reflecting both the gene pool and adaptability of the community. For this, different parameters like density, frequency, basal area, IVI, and various diversity indices were calculated by dividing the area into two altitudinal ranges, i.e. 400–600 m AMSL (AR_1) and 600–800 m AMSL (AR_2). The vegetation sampling was done by randomly selecting 30 plots in the selected area. The study showed that AR_2 (118 plant species: 31 trees, 17 shrubs, 58 herbs, and 12 climbers) had a higher number of plant species in comparison to AR_1 (106 plant species: 26 trees,14 shrubs, 54 herbs, and 12 climbers) with Poaceae being the family with the greatest number of species. The area was seen to be dominated by *Acacia nilotica* (L.) willd. Ex Delile, *Cassia fistula* L., and *Leucaena leucocephala* (Lam.) de Wit in AR_1 while by *Pongamia pinnata* (L.) Pierre, *Cassia fistula*, and *Oroxylum indicum* (L.) Kurz in AR_2. The upper range, i.e. AR_2 was also more diverse than AR_1 because of a high Shannon Wiener Diversity Index value and a lower Simpson Index value. Whereas the population structure study demonstrated that girth class D (CBH=61–90 cm) had the highest number of tree species in both altitudinal ranges, followed by girth class C (CBH=31–60 cm). Moreover, the forest was also observed to be occupied by various invasive plant species as well as under anthropogenic pressure, hence in immediate need of proper management and conservation.

Key words: biodiversity, floristic composition, IVI, tropical dry deciduous forests, phytosociology.

Authors' address: Department of Botany, Kurukshetra University, Kurukshetra, 136119 – Haryana, India; *e-mail: somveer.botany@kuk.ac.in

Introduction

Forests constitute one of the indispensable resources for the survival of mankind for the services they provide such as maintaining environmental stability, providing food and raw materials, livelihood, and employment for millions of people in rural areas (FAO, 2010; Arce, 2019). Additionally, forest ecosystems eliminate CO_2 from the atmosphere and store more C than any other land type per unit area. (Lorenz & Lal, 2010). Tropical forests have been identified as the richest biological communities of the

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earth (Baraloto *et al.*, 2013). They contribute around 1/3rd of the global terrestrial primary productivity and display a broad spectrum of vegetative and reproductive phenology (Beer *et al.*, 2010). Of these, the dry deciduous forests are seen to be the least protected and highly disturbed ecosystems (Murphy & Lugo, 1986), which are disappearing at alarming rates worldwide attributable to overexploitation of forest resources, agricultural land expansion, and livestock overgrazing (Anitha *et al.*, 2010).

To prevent this ongoing forest deterioration, it is essential for foresters and ecologists to examine the current status of these forests by studying their species diversity and making forest inventories to carry out proper management activities. This will help to deliver a valued source for forest assessment and will also expand our knowledge of valuable plant species ecologically as well as economically. In this direction, the phytosociological analysis underpins the understanding of the forest ecology of any vegetated land (Mandal & Joshi, 2014; Dar & Sundarapandian, 2016). It includes the quantification of plant species, their distribution as well as abundance and structural analysis that is critical for acquiring sufficient knowledge on the species diversity and richness of forest ecosystems for management purposes and, also for a deeper knowledge of forest ecology and ecosystem functioning. (Siraj *et al.*, 2017).

Diversity and structure are crucial in forest communities (Gadow *et al.*, 2016). Plant species diversity controls a forest's stability, trophic structure, and productivity (Lillo *et al.*, 2019). It also varies by biogeography, environment, and perturbation (Majumdar *et al.*, 2012). Vegetation structure and species variety are essential for forest ecosystem protection and sustainability. Thus, quantitative data on a forest's floristic composition and vegetation structure is essential for strategizing and implementing conservation programs, which are presently scarce in the Morni forest, Panchkula, Haryana.

Physio-graphically, Haryana comes under the Indo-Gangetic plains while some of the areas also fall in Shiwalik Hills i.e. the foothills of the Himalayas. Morni forest belongs to the tertiary formations of the Shiwalik Hills that contain tropical dry deciduous forests filled with ample floristic as well as functional diversity (Dhiman *et al.*, 2020; Himanshi *et al.*, 2021). But due to increasing anthropic activities, it might be under ecological disturbance widening the forest gaps and the risk of shifts in community composition in the near future. Only a few studies including vegetation composition (Rout & Gupta, 1989), diversity of invasive plants (Dhiman *et al.*, 2021) and floristic richness (Kumar *et al.*, 2023) have been reported in the study area.

Thus, the present study was designed to quantify the floristic composition, diversity and population structure of Morni Hills forest lying in the foothills of Himalayas, with a small elevation change, thereby helping to comprehend the present conditions of these forests in a better way. Given that the distribution of mountain biota is shifting upward because of climate change (Steinbauer *et al.*, 2018; Rumpf *et al.*, 2018), this study would be helpful for understanding how plant species adapt to such altitudinal shifts on a warming planet.

Material and Methods

Study site

Haryana is a North Indian agricultural state with a forest cover of 1602.44 km^2, or 3.62 percent of its total geographical area (FSI, 2019). Morni Hills of the Panchkula district lie in the north-eastern region of Haryana. They consist of tertiary formations of Shiwalik Hills and form a part of the active Sub-Himalayan belt that is mainly composed of sandy facies and an interbedded sequence of medium to coarse-grained sandstone as well as fine-grained shales. The current study was performed

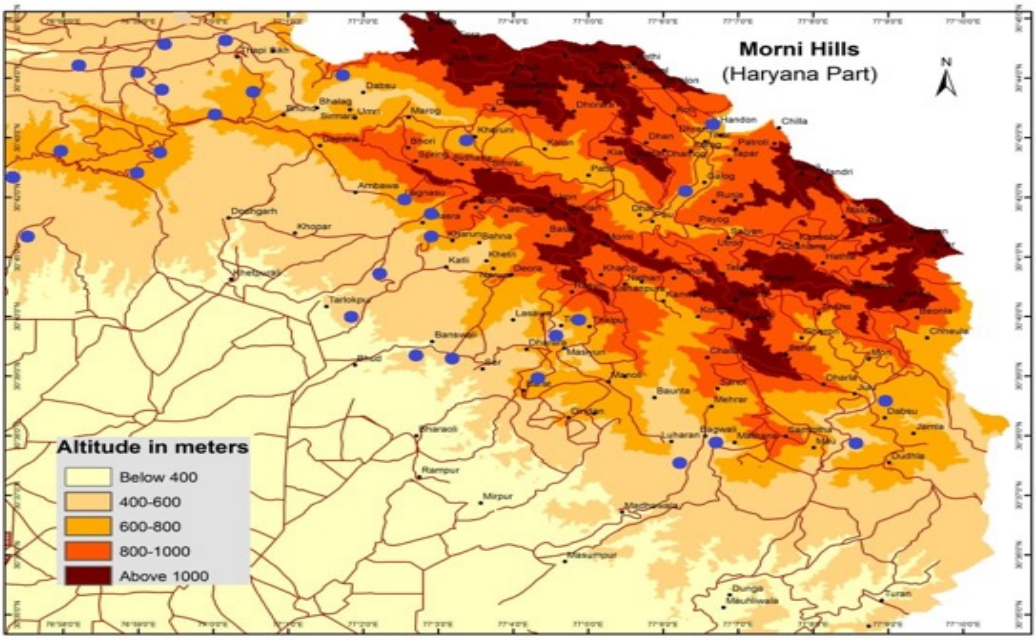


Figure 1. Map of the study site showing the location of plots (blue dots) studied in the selected altitudinal ranges of Morni Hills forest.

in lower altitudinal ranges of Morni Hills at an altitude of 400–800 m AMSL from 30′39′′N to 30′45′′ N and 77′2″E to 77′10″ E (Figure 1).

Sampling of vegetation and data analysis

The data was collected from the year 2018 to 2021, by selecting a total of 30 plots of size 0.1ha (15 plots/range) randomly in the lower two altitudinal/elevational ranges of the selected area, i.e. 400–600 m (AR_1) and 600–800 m (AR_2) AMSL (above mean sea level), as shown in Figure 1. The current ecological analysis was performed using the quadrat method. In each plot, 5 quadrats (10 × 10 m) were randomly established for the calculation of different ecological parameters. Trees and climbers were sampled in these quadrats whilst for shrubs and herbs quadrats of 5 × 5 m and 1 × 1 m were placed within, respectively (Curtis & McIntosh, 1950; Phillips, 1959). For plant species whose scientific names were not immediately known in the field, local names were employed. The parts of unidentifiable plants, such as twigs, leaves, flowers, and fruits, were gathered, brought to the lab and referred to the flora.

The quantitative analysis of plant species including Frequency (F), Density (D), Abundance (A), and Basal Area (B.A.) was performed following Cottam & Curtis (1956). As per Phillips (1959), the important value index (IVI) was computed by adding the relative density, relative frequency, and relative dominance. Moreover, a frequency class distribution pattern was obtained for the plant species in two ranges following Raunkiaer (1934). To understand the distribution pattern of plants, the A/F ratio was also calculated following Cottam & Curtis (1956) *viz.* regular (less than 0.025), random (0.025–0.050), and contiguous (more than 0.050). Various diversity indices were also estimated, *viz.* Shannon-Wiener Index (Shannon & Weaver, 1963) for species diversity (H′), Simpson Index (Simpson, 1949) for the concentration of dominance (CD), Pielou Index (Pielou, 1966) for species evenness or equitability (E), and Margalef (1958) for species richness (d). Subsequently, the Similarity index was also deliberated following the Sørensen Index (Sørensen, 1948) for the two altitudinal ranges. By taking the girth of trees at 1.37 m from the ground, the population/stand structure was analysed using the NRSA (2008) manual by putting the individual trees in different girth classes. To understand the correlation between different parameters studied, the Pearson correlation was analyzed using R studio. The following formulae were used during the study for the calculation of analytical characters of the vegetation:

$$Frequency\ (F\%) = \frac{No.of\ quadrats\ of\ occurence}{Total\ no.of\ quadrats} \times 100 \tag{1}$$

$$Density\ (D) = \frac{Total\ no.of\ individuals}{Total\ no.of\ quadrats} \tag{2}$$

$$Abundance\ (A) = \frac{Total\ no.of\ individuals}{No.of\ quadrats\ of\ occurence} \tag{3}$$

$$Basal\ area\ (B.A.) = \frac{CBH^2}{4\pi} \tag{4}$$

$$CBH = 2\pi r^2 \tag{5}$$

Where ‘r’ is the radius of the tree at breast height (1.37 m).

$$Relative\ Frequency\ (RF\%) = \frac{Frequency\ of\ one\ species}{Total\ frequency\ of\ all\ species} \times 100 \tag{6}$$

$$Relative\ Density\ (RD\%) = \frac{Density\ of\ one\ species}{Total\ density\ of\ all\ species} \times 100 \tag{7}$$

$$Relative\ Dominance\ (RDo\%) = \frac{Basal\ area\ of\ one\ species}{Total\ Basal\ area\ of\ all\ species} \times 100 \tag{8}$$

$$Important\ Value\ Index\ (IVI) = RF\% + RD\% + RDo\% \tag{9}$$

$$Shannon\ Weiner\ Index\ (H') = \sum_{i=1}^{s} pi \times lnpi \tag{10}$$

Where, pi is the proportion of individuals belonging to ith species, calculated as pi = ni/N.

$$Ni = IVI\ of\ one\ species\ and\ N = Total\ IVI\ of\ all\ the\ species \tag{11}$$

$$Simpson\ Index\ (CD) = \sum_{i=1}^{s} (pi)^2 \tag{12}$$

$$Pielou\ Index\ \ (E) = \frac{H'}{lnS} \tag{13}$$

Where, H’ = Value of Shannon Wiener Index and S = Total number of species.

$$Margalef\ Index\ (d) = \frac{S-1}{lnN} \tag{14}$$

Where, S = Total no. of species and N = Total density obtained for all the species encountered on an area.

Results

Floristic composition and diversity analysis

During the present investigation, a total of 143 species of plants (39 trees, 19 shrubs, 68 herbs & 17 climbers) representing 56 families were found in the selected altitudinal ranges of Morni Hills, Panchkula. Poaceae exhibited the maximum number of species i.e. 12 subsequently Asteraceae and Fabaceae (10 species each); Euphorbiaceae (8 species); Lamiaceae (7 species); Amaranthaceae and Mimosaceae (6 species each), followed by others.

In AR_1 (400–600 m AMSL), 106 plant species (26 trees, 14 shrubs, 54 herbs, and 12 climbers) while in AR_2 (600–800 m AMSL), 118 plant species (31 trees, 17 shrubs, 58 herbs, and 12 climbers) were found as shown in Table 1 to 4. The area was found to be covered with a large number of trees like *Bauhinia purpurea, Cassia fistula, Falconeria insignis, Grewia optiva, Lannea coromandelica, Leucaena leucocephala, Mangifera indica, Prosopis cineraria,* etc. Several of the plant species observed were invasive, like *Ageratum conyzoides, A. haustonianum, Chromolaena odorata, Lantana camara, Parthenium hysterophorus,* etc.

In AR_1, the maximum frequency was observed for *Acacia nilotica* (50%) among trees, *Parthenium hysterophorus* (91.6%) among shrubs, *Malvastrum coromandelianum* (66.6%) among herbs, and *Ichnocarpus frutescens* (41.6%) among climbers. While, in AR_2, the maximum frequency was obtained for *Cassia fistula* (66.6%), *Lantana camara* (100%), *Ageratum houstonianum* (75%), and *Ichnocarpus frutescens* (66.6%) among trees, shrubs, herbs, and climbers, respectively.

During vegetation analysis, the highest density was observed for *Acacia nilotica* (15 ind./ha) in AR_1 and *Cassia fistula* (13.64 ind./ha) in AR_2 within the tree layer (Table 1). Conversely though, within the understory *Lantana camara* (AR_1- 102.64 ind./ha, AR_2- 189.64 ind./ha) and *Cynodon dactylon* ((AR_1- 285 ind./ha, AR_2- 251 ind./ha) were found to have the maximum density in both the ranges among shrubs and herbs, respectively (Table 3). Whilst among climbers, the highest density was observed for *Ichnocarpus frutescens* (14 ind./ha) in AR_1 and *Bauhinia vahlii* (26.4 ind./ha) in AR_2 (Table 4).

Table 1. Phytosociological analysis of tree species in the two altitudinal ranges of Morni Hills, Panchkula.

S.N.	Name of the plant	Family	AR_1 (400–600 m AMSL)				AR_2 (600–800 m AMSL)			
			D	A/F	B.A.	IVI	D	A/F	B.A.	IVI
1	*Acacia nilotica* (L.) willd. Ex Delile	Mimosaceae	15	0.15	6.954	56.92	1.32	0.12	1.006	6.189
2	*Albizia lebbeck* (L.) Benth.	Mimosaceae	1.64	0.15	0.286	6.799	3.32	1.2	1.027	7.197
3	*Alstonia scholaris* (L.) R. Br.	Apocynaceae	1.32	0.12	0.225	6.06	3	0.06	2.072	12.93
4	*Azadirachta indica* A. Juss.	Meliaceae	0.64	0.06	0.671	6.322	1	0.09	1.053	5.94
5	*Bauhinia purpurea* L.	Verbenaceae	0.64	0.06	0.702	6.422	0.64	0.37	0.941	3.585
6	*Boehmeria rugulosa* Wedd.	Urticaceae	-	-	-	-	7.32	1.23	0.042	17.7

Table 1 continues

S.N.	Name of the plant	Family	AR_1 (400–600 m AMSL)				AR_2 (600–800 m AMSL)			
			D	A/F	B.A.	IVI	D	A/F	B.A.	IVI
7	*Bombax ceiba* L.	Bombacaceae	0.64	0.24	3.519	13.82	-	-	-	-
8	*Butea monosperma* (Lam.) Taub.	Fabaceae	2.64	0.1	1.32	13.35	2	0.008	0.172	6.37
9	*Cassia fistula* L.	Caesalpiniaceae	6.64	0.15	3.122	27.42	13.64	0.07	4.32	25.19
10	*Cassia siamea* Kurz	Caesalpiniaceae	-	-	-	-	2.32	0.21	0.039	5.162
11	*Dalbergia sisso* Roxb. Ex DC.	Fabaceae	1.32	0.53	0.269	3.565	-	-	-	-
12	*Eucalyptus citriodora* Hook.	Myrtaceae	1	0.04	0.401	7.647	-	-	-	-
13	*Falconeria insignis* Royle	Euphorbiaceae	-	-	-	-	1	0.09	0.153	3.952
14	*Ficus bengalensis* L.	Moraceae	-	-	-	-	1	0.09	1.892	7.791
15	*Ficus racemosa* L.	Moraceae	-	-	-	-	1	0.09	0.887	5.572
16	*Ficus religiosa* L.	Moraceae	0.64	0.06	0.663	6.297	-	-	-	-
17	*Flacourtia indica* (Burm.f.) Merr.	Salicaceae	1.32	0.48	0.011	3.83	5	0.11	0.029	10.63
18	*Grevillea robusta* A. Cunn. Ex R. Br.	Proteaceae	-	-	-	-	1	0.09	0.586	4.909
19	*Grewia optiva* J. R. Drumm. Ex Burret	Tiliaceae	0.64	0.06	0.177	4.755	2.64	0.1	1.108	9.146
20	*Jacaranda mimosifolia* D. Don.	Mimosaceae	-	-	-	-	1	0.09	0.988	5.795
21	*Kydia calycina* Roxb.	Malvaceae	0.64	0.06	0.269	5.047	0.64	0.24	1.537	5.356
22	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	2	0.04	2.798	18.52	-	-	-	-
23	*Leucaena leucocephala* (Lam.) de Wit	Mimosaceae	4.33	0.04	0.977	19.81	3.32	0.13	1.65	11.1
24	*Mallotus philippensis* (Lam.) Müll.Arg.	Euphorbiaceae	1.32	0.48	0.181	4.369	4.64	0.18	2.746	14.98
25	*Mangifera indica* L.	Anacardiaceae	1.32	0.12	4.6	19.96	1.32	0.053	4.673	15.55
26	*Moringa oleifera* Lam.	Moringaceae	-	-	-	-	1	0.09	0.537	4.801
27	*Morus alba* L.	Moraceae	1	0.09	0.468	6.29	-	-	-	-
28	*Oroxylum indicum* (L.) Kurz	Bignoniaceae	-	-	-	-	6.32	0.03	2.798	23.23
29	*Phoenix dactylifera* L.	Arecaceae	-	-	-	-	0.64	0.24	0.388	2.818
30	*Pongamia pinnata* (L.) Pierre	Fabaceae	2	0.18	1.153	10.16	10.64	0.96	6.203	27.98
31	*Prosopis cineraria* (L.) Druce	Mimosaceae	3.32	0.3	0.353	9.864	1	0.09	0.404	4.506

Table 1 continues

S.N.	Name of the plant	Family	AR_1 (400–600 m AMSL)				AR_2 (600–800 m AMSL)			
			D	A/F	B.A.	IVI	D	A/F	B.A.	IVI
32	*Prosopis juliflora* (Swartz) de Candolle	Mimosaceae	3.64	0.33	0.54	11	-	-	-	-
33	*Pterospermum acerifolium* (L.) Willd.	Sterculaceae	-	-	-	-	2	0.08	1.81	9.987
34	*Pyrus pashia* Buch.-Ham. Ex D. Don	Rosaceae	-	-	-	-	1	0.09	0.117	3.873
35	*Tectona grandis* L.f.	Verbenaceae	1.32	0.03	1.078	11.89	1.32	0.12	0.258	4.539
36	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	1.64	0.15	0.236	6.64	1.64	0.15	2.097	8.953
37	*Thevetia peruviana* (Pers.) K.Schum.	Apocynaceae	0.64	0.24	0.303	3.603	-	-	-	-
38	*Wendlandia heynei* (Schult.) Santapau & Merchant	Rubiaceae	-	-	-	-	6.32	0.14	3.689	20.13
39	*Zizyphus jujuba* Mill.	Rhamnaceae	1.64	0.03	0.195	9.632	1.32	0.12	0.08	4.145
	Total		58.89		31.47	300	90.32		45.3	300

Abbreviations: D = Density (individuals/hectare); A/F = Ratio of abundance and frequency; B.A. = Basal Area (m^2/hectare); IVI = Important value index.

Table 2. Phytosociological analysis of shrub species in the two altitudinal ranges of Morni Hills, Panchkula.

S.N.	Name of the plant	Family	AR_1 (400–600 m AMSL)				AR_2 (600–800 m AMSL)			
			D	A/F	B.A.	IVI	D	A/F	B.A.	IVI
	Trees									
1	*Abutilon indicum* (L.) Sweet	Malvaceae	37.64	0.84	0.002	12.91	-	-	-	-
2	*Barleria cristata* L.	Acanthaceae	14.64	0.33	0.002	9.487	6.32	0.57	6E-04	3.404
3	*Calotropis procera* (Aiton) Dryand.	Apocynaceae	12.32	1.11	0.047	6.34	-	-	-	-
4	*Carissa spinarum* L.	Apocynaceae	8.64	0.78	0.014	5.179	19	0.27	0.035	9.367
5	*Colebrookea oppositifolia* Sm.	Lamiaceae	7.32	0.66	0.011	4.916	61.64	0.27	0.088	20.56
6	*Dodonea viscosa* L.	Sapindaceae	-	-	-	-	3.64	1.32	0.059	2.542
7	*Eranthemum pulchellum* Hort.	Acanthaceae	-	-	-	-	7	0.63	6E-04	3.487
8	*Ipomoea carnea* Jacq.	Convolvula-ceae	13	0.57	0.016	5.86	9.32	0.84	0.011	3.916
9	*Lantana camara* L.	Verbenaceae	102.64	0.36	2.517	80.43	189.64	0.47	4.834	103.7
10	*Murraya koenigii* (L) Spreng.	Rutaceae	89.64	0.32	0.447	39.89	133.64	0.39	0.615	39.04

Table 2 continues

S.N.	Name of the plant	Family	AR_1 (400–600 m AMSL)				AR_2 (600–800 m AMSL)			
			D	A/F	B.A.	IVI	D	A/F	B.A.	IVI
11	*Naringi crenulata* (Roxb.) Nicolson	Rutaceae	-	-	-	-	2.64	0.24	0.008	3.058
12	*Parthenium hysterophorus* L.	Asteraceae	366.32	1.09	0.699	87.59	312	0.92	0.06	53.37
13	*Ricinus communis* L.	Euphorbia-ceae	-	-	-	-	1.64	0.15	2E-04	2.827
14	*Solanum incanum* L.	Solanaceae	-	-	-	-	11.64	0.46	0.002	5.399
15	*Spermadictyon suaveolens* Roxb.	Rubiaceae	4	1.44	0.091	4.098	20.32	7.34	0.196	6.422
16	*Toxicodendron parviflorum* (Roxb.) Kuntze	Anacardia-ceae	7.32	0.66	0.166	7.812	15.32	1.38	0.357	9.278
17	*Urena lobata* L.	Malvaceae	2.32	0.84	4E-04	2.167	7.64	0.75	4E-04	3.562
18	*Woodfordia fructicosa* (L.) Kurz	Lythraceae	3.64	0.33	1.347	29.29	12	0.17	1.19	23.99
19	*Ziziphus nummularia* Aubrev.	Rhamnaceae	2.32	0.21	0.004	4.042	5.64	0.12	0.007	6.046
	Total		671.76		5.361	300	819.04		7.464	300

Abbreviations: D = Density (individuals/hectare); A/F = Ratio of abundance and frequency; B.A. = Basal Area (m^2/hectare); IVI = Important value index.

Table 3. Phytosociological analysis of herb species in the two altitudinal ranges of Morni Hills, Panchkula.

S.N.	Name of the plant	Family	AR_1 (400–600 m AMSL)				AR_2 (600–800 m AMSL)			
			D	A/F	B.A.	IVI	D	A/F	B.A.	IVI
1	*Acanthospermum hispidum* DC.	Asteraceae	14.64	0.33	0.002	3.087	-	-	-	-
2	*Achyranthes aspera* L.	Amarantha-ceae	99	0.55	0.016	10.67	23	0.52	0.005	3.841
3	*Aerva sanguinolenta* (L.) Blume	Amarantha-ceae	66.32	0.37	0.004	7.837	69	0.3	0.004	8.75
4	*Ageratum conyzoides* L.	Asteraceae	32.32	0.72	0.004	4.116	84.32	0.47	0.01	9.791
5	*Ageratum houstonianum* Mill.	Asteraceae	18.32	1.65	0.015	3.547	76.32	0.56	0.007	8.432
6	*Ajuga parviflora* Benth.	Lamiaceae	4	1.44	3E-04	0.775	4	1.44	4E-05	0.741
7	*Alternanthera pungens* Kunth	Amarantha-ceae	-	-	-	-	5.32	0.48	6E-05	1.345
8	*Alycicarpus vaginalis* (L.) DC.	Fabaceae	15.32	1.38	0.001	1.963	-	-	-	-
9	*Amaranthus virdis* L.	Amarantha-ceae	-	-	-	-	16	1.44	3E-04	1.903
10	*Anisomeles indica* (L.) Kuntze	Lamiaceae	50.64	2.02	0.005	4.452	25.64	2.31	0.005	3.018

Table 3 continues

S.N.	Name of the plant	Family	AR_1 (400–600 m AMSL)				AR_2 (600–800 m AMSL)			
			D	A/F	B.A.	IVI	D	A/F	B.A.	IVI
11	*Argemone mexicana* L.	Papaveraceae	4	1.44	5E-04	0.792	-	-	-	-
12	*Bidens pilosa* L.	Asteraceae	-	-	-	-	49	0.71	0.005	5.795
13	*Boerhavia diffusa* L.	Nyctaginaceae	11.32	0.45	2E-04	2.228	-	-	-	-
14	*Cannabis sativa* L.	Cannabinaceae	-	-	-	-	10.64	0.96	0.001	1.752
15	*Celosia argentea* L.	Amaranthaceae	2.64	0.96	2E-04	0.706	5.32	1.92	3E-04	0.836
16	*Commelina bengalensis* L.	Commelinaceae	22.64	0.51	9E-04	3.365	13.64	0.54	6E-04	2.364
17	*Coronopus didymus* (L.) Sm.	Brassicaceae	7.64	0.3	1E-04	2.053	17	1.53	2E-04	1.945
18	*Croton bonplandianus* Baill.	Euphorbiaceae	68.32	6.17	4E-04	4.158	10.64	0.96	3E-04	1.639
19	*Cymbopogon martini* (Roxb.) Stapf.	Poaceae	35.64	3.22	6E-04	2.753	146.32	3.29	0.002	9.653
20	*Cynodon dactylon* (L.) Pers.	Poaceae	285	2.85	0.002	16.1	251	2.51	0.002	15.97
21	*Cyperus cyperoides* (L.) Kuntze	Cyperaceae	5	0.45	6E-04	1.418	14	1.26	8E-04	1.869
22	*Dactyclotenium aegyptium* (L.) Willd.	Poaceae	31	1.24	2E-04	3.082	49.32	1.11	3E-04	4.639
23	*Dendrocalamus strictus* (Roxb.) Nees	Poaceae	1.32	0.48	0.053	6.405	3.32	0.3	0.161	21.34
24	*Dichanthium annulatum* (Forssk.) Stapf.	Poaceae	101.64	4.06	0.001	6.299	36.64	3.31	5E-04	2.963
25	*Digitaria ciliaris* (Retz.) Koeler	Poaceae	38.32	0.55	6E-04	4.582	34.32	3.1	3E-04	2.813
26	*Echinochloa colona* (L.) Link	Poaceae	12.32	0.49	2E-04	2.267	-	-	-	-
27	*Emilia sonchifolia* (L.) DC. ex DC.	Asteraceae	7	0.63	1E-04	1.451	4.32	0.39	5E-05	1.294
28	*Eragrostis cilianensis* (All.) Janch.	Poaceae	139.32	1.02	8E-04	10.16	121.32	1.75	5E-04	8.788
29	*Eschenbachia leucantha* (D.Don) Brouillet	Asteraceae	-	-	-	-	0.64	0.24	4E-05	0.573
30	*Euphorbia maculata* L.	Euphorbiaceae	-	-	-	-	2.08	3.01	3E-04	0.671
31	*Euphorbia heterophylla* L.	Euphorbiaceae	8.32	0.75	0.001	1.62	12	1.08	1E-03	1.794
32	*Euphorbia hirta* L.	Euphorbiaceae	68.32	0.38	5E-04	7.587	79.32	0.58	6E-04	7.788
33	*Geranium occelatum* L.	Geraniaceae	9	0.81	6E-05	1.534	21	0.47	2E-04	3.219
34	*Hexasepalum teres* (Walter) J.H.Kirkbr.	Rubiaceae	-	-	-	-	53.64	2.14	3E-04	4.319

Table 3 continues

S.N.	Name of the plant	Family	AR_1 (400–600 m AMSL)				AR_2 (600–800 m AMSL)			
			D	A/F	B.A.	IVI	D	A/F	B.A.	IVI
35	*Indigofera linifolia* (Lf) Retz.	Fabaceae	39.32	3.55	5E-04	2.91	5.64	0.22	6E-05	1.904
36	*Justicia adhatoda* L.	Acanthaceae	63	0.46	0.048	11.97	43.64	0.43	0.012	6.961
37	*Justicia procumbens* L.	Acanthaceae	7.32	2.65	0.002	1.069	12	1.08	1E-04	1.688
38	*Launaea nudicaulis* (L.) Hook. fil.	Asteraceae	-	-	-	-	17.32	0.69	3E-04	2.509
39	*Leucas cephalotes* (Roth) Spreng.	Lamiaceae	13.32	1.2	0.001	1.855	-	-	-	-
40	*Leonotis nepetifolia* (L.) R. Br.	Lamiaceae	-	-	-	-	23	0.23	0.364	49.97
41	*Lindenbergia indica* (L.) Vatke	Scrophulariaceae	-	-	-	-	14.32	1.29	5E-04	1.846
42	*Lindernia crustacea* (L.) F. Muell	Linderniaceae	12.64	1.14	2E-04	1.705	-	-	-	-
43	*Malvastrum coromandelianum* (L.) Garcke	Fabaceae	128	0.72	0.003	10.47	60	0.86	0.003	6.002
44	*Martynia annua* L.	Martyniaceae	23.64	2.13	0.005	2.726	-	-	-	-
45	*Mazus pumilus* (Burm. F.) Steenis	Scrophulariaceae	59.32	2.37	6E-04	4.363	15	1.35	2E-04	1.841
46	*Mesosphaerum suaveolens* (L.) Kuntze	Lamiaceae	17	0.68	0.001	2.607	-	-	-	-
47	*Nepeta leucophylla* Benth.	Lamiaceae	-	-	-	-	40	3.61	0.002	3.283
48	*Oplismenus undulatifolius* (Ard.) Roem. & Schult.	Poaceae	15	1.35	1E-04	1.801	93	0.68	0.002	8.612
49	*Oxalis corniculata* L.	Oxalidaceae	31.32	1.25	2E-04	3.1	112.64	1.62	8E-04	8.401
50	*Paspalidium flavidum* (Retz.) A.Camus	Poaceae	12.64	0.5	2E-04	2.278	13.32	1.2	2E-04	1.759
51	*Pentanema indicum* (L.) Ling	Asteraceae	-	-	-	-	6.32	0.25	3E-04	1.962
52	*Peristrophe bicalyculata* (Retz.) Nees	Acanthaceae	34	1.36	0.004	3.62	6.64	0.6	1E-04	1.417
53	*Phyllanthus niruri* L.	Phyllanthaceae	16.32	1.47	1E-04	1.86	19.64	1.77	4E-04	2.102
54	*Physalis minima* L.	Solanaceae	6.64	0.6	0.002	1.638	0.64	0.24	2E-04	0.592
55	*Polygonum plebeium* R.Br.	Polygonaceae	22.4	2.04	4E-04	2.152	1.32	0.48	1E-05	0.603
56	*Pupalia lappacea* (L.) Juss.	Amaranthaceae	28.32	1.13	0.003	3.224	11	0.99	0.001	1.777
57	*Saccharum benghalense* Retz.	Poaceae	47.64	0.47	0.46	55.58	33.32	0.75	0.119	18.76

Table 3 continues

S.N.	Name of the plant	Family	AR_1 (400–600 m AMSL)				AR_2 (600–800 m AMSL)			
			D	A/F	B.A.	IVI	D	A/F	B.A.	IVI
58	*Senna occidentalis* (L.) Link	Caesalpinia-ceae	9	0.36	0.004	2.553	5.32	0.48	8E-04	1.433
59	*Senna tora* (L.) Roxb.	Caesalpinia-ceae	151.32	1.11	0.256	38.48	48	0.48	0.079	15.48
60	*Setaria viridis* (L.) P.Beauv.	Poaceae	18.32	1.65	3E-04	1.97	7	0.63	4E-05	1.426
61	*Sida acuta* Burm.f.	Malvaceae	105	9.48	0.002	5.898	53	2.12	8E-04	4.348
62	*Sida cordifolia* L.	Malvaceae	49.32	1.11	0.001	4.547	23.64	0.94	1E-04	2.809
63	*Solanum nigrum* L.	Solanaceae	-	-	-	-	10	0.9	8E-04	1.666
64	*Torenia violacea* (Azaola ex Blanco) Pennell	Lindernia-ceae	-	-	-	-	24	2.16	0.001	2.453
65	*Trianthema portulacastrum* L.	Aizoaceae	7.32	0.66	9E-04	1.55	-	-	-	-
66	*Tridax procumbens* L.	Asteraceae	82	7.4	0.002	4.906	65.64	0.65	0.001	6.673
67	*Trifolium indicum* L.	Fabaceae	83.32	3.33	8E-04	5.43	-	-	-	-
68	*Xanthium strumarium* L.	Asteraceae	45.64	1.82	0.01	4.736	2.32	0.21	4E-04	1.233
	Total		2288.4		0.918	300	2008.76		0.799	300

Abbreviations: D = Density (individuals/hectare); A/F = Ratio of abundance and frequency; B.A. = Basal Area (m^2/hectare); IVI = Important value index.

Table 4. Phytosociological analysis of climber species in the two altitudinal ranges of Morni Hills, Panchkula.

S.N.	Name of the plant	Family	AR_1 (400–600 m AMSL)				AR_2 (600–800 m AMSL)			
			D	A/F	B.A.	IVI	D	A/F	B.A.	IVI
	Trees									
1	*Abrus precatorius* L.	Fabaceae	2	0.18	0.03325	79.31	1	0.09	0.00041	14.84
2	*Aspidopterys wallichii* Hook.f.	Malpighia-ceae	-	-	-	-	1	0.36	0.00021	7.995
3	*Asparagus racemosus* Willd.	Asparagaceae	1.64	0.15	0.00105	12.39	-	-	-	-
4	*Bauhinia vahlii* Wight & Arn.	Caesalpinia-ceae	0.64	0.24	0.01108	27.56	26.4	0.24	0.00197	59.89
5	*Cissampelos pareira* L.	Menisperma-ceae	-	-	-	-	8.32	0.33	0.00013	20.39
6	*Coccinia grandis* (L.) Voigt	Cucurbitaceae	7.64	0.30	0.00045	26.13	-	-	-	-
7	*Convolvulus arvensis* L.	Convolvula-ceae	4.64	0.42	0.00013	16.18	-	-	-	-
8	*Cryptolepis buchananii* Roem. & Schult.	Euphorbia-ceae	-	-	-	-	3.64	0.33	0.00035	16.35
9	*Dioscorea bulbifera* L.	Dioscorea-ceae	0.64	0.24	0.00005	4.88	16.32	0.052	0.00056	21.16

Table 4 continues

S.N.	Name of the plant	Family	AR_1 (400–600 m AMSL)				AR_2 (600–800 m AMSL)			
			D	A/F	B.A.	IVI	D	A/F	B.A.	IVI
10	*Ichnocarpus frutescens* (L.) R. Br.	Apocynaceae	14	0.20	0.00058	45.57	9.32	0.053	0.00034	54.33
11	*Ipomoea cairica* (L.) Sweet	Convolvulaceae	6.64	0.26	0.00049	24.32	-	-	-	-
12	*Ipomoea muricata* (L.) Jacq.	Convolvulaceae	9.64	0.38	0.00076	30.57	2	0.18	0.00003	9.124
13	*Ipomoea quamoclit* L.	Convolvulaceae	-	-	-	-	6.32	0.12	0.00008	9.344
14	*Pueraria tuberosa* (Willd.) DC.	Fabaceae	3	0.27	0.00065	14.15	5.32	0.21	0.00136	39.13
15	*Pueraria montana* (Lour.) Merr.	Fabaceae	-	-	-	-	2	0.18	0.00009	10.18
16	*Stephania glabra* (Roxb.) Miers	Menispermaceae	1.32	0.12	0.00006	9.766	21.32	0.48	0.00015	37.25
17	*Trichosanthes dioica* L.	Cucurbitaceae	1	0.09	0.00005	9.127	-	-	-	-
	Total		52.8		0.04861	300	102.96		0.00568	300

Abbreviations: D = Density (individuals/hectare); A/F = Ratio of abundance and frequency; B.A. = Basal Area (m^2/hectare); IVI = Important value index.

Among trees, the maximum value of the basal area was obtained for *Acacia nilotica* (6.95423 m^2/ha) in AR_1 while for *Pongamia pinnata* (6.20303 m^2/ha) in AR_2. Whereas among shrubs, the maximum was observed for *L. camara* in both ranges, i.e. AR_1 (2.51676 m^2/ha) and AR_2 (4.8336 m^2/ha). In herbs, the basal area was found to be the highest for *Saccharum benghalense* (0.46003 m^2/ha) in AR_1 and *Dendrocalamus strictus* (0.1606 m^2/ha) in AR_2. On the other hand, among climber species the maximum basal area was occupied by *Abrus precatorius* in AR_1 and by *Bauhinia vahlii* in AR_2. Other than this, the maximum IVI value of trees was found for *Acacia nilotica* (56.9184) followed by *Cassia fistula* (27.4220), *Mangifera indica* (19.9606), and *Leucaena leucocephala* (19.8086) in AR_1 while *Pongamia pinnata* (27.9808) followed *Cassia fistula* (25.1929), *Oroxylum indicum* (23.2338) and *Wendlandia heynei* (20.1264) in AR_2. Thus, the same species are represented as the dominant tree species of their respective altitudinal ranges.

Except for *Eucalyptus citriodora, Leucanea leucocephala, Lannea coromandelica,* and *Zizyphus jujuba* in AR_1 and *Butea monosperma* in AR_2 which showed the random distribution, all the other plant species were contiguously distributed. No plant species were found to display the regular type of distribution. The analysis of frequency class distribution from the present study site revealed that the two ranges do not follow Raunkiaer's frequency distribution law and represent a graph different from the normal frequency distribution curve reflecting the heterogenous nature of the forest community (Figure 2).

The analysis of diversity indices revealed that AR_2 is more diverse than AR_1 because the H′ value was obtained higher for AR_2 than AR_1 except for climbers, i.e. for trees, shrubs, and herbs, as shown in Table 5. While the value of CD

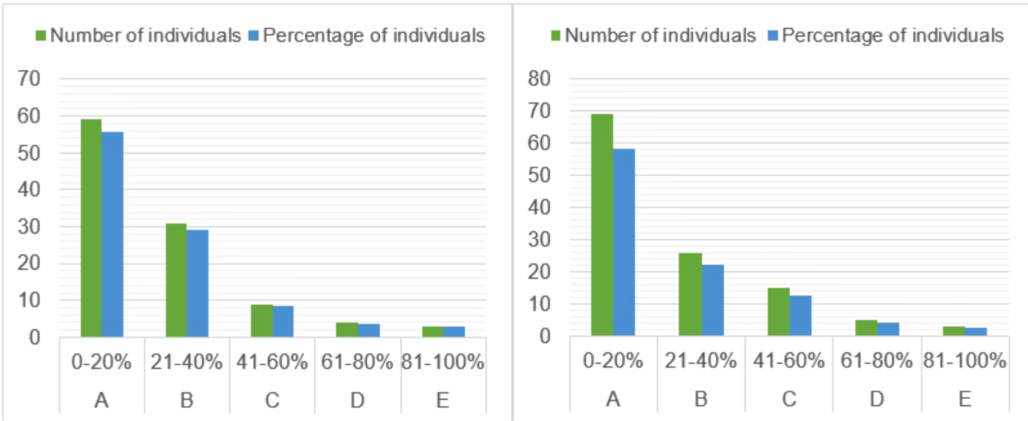


Figure 2. Frequency class distribution (Raunkiaer, 1934) of the plant species encountered during the study in two altitudinal ranges, AR_1 (left) and AR_2 (right).

was found to be just opposite of it, i.e. higher for AR_1 for trees, shrubs, and herbs but lower for climbers and vice versa for AR_2. On the other hand, the value of E was higher for trees and herbs for AR_2 while for shrubs and climbers for AR_1 (Table 5). Other than this, to understand the similarity in flora among the selected altitudinal ranges, Sørensen's Index of similarity was deliberated. A total of 81 species of plants remained common in both altitudinal ranges and the similarity index value was found to be 0.36, i.e. less than 0.5, indicating low similarity between them.

Table 5. Diversity indices of the selected altitudinal ranges in the foothills of the Himalayas.

S.N.	Habit	400–600 m AMSL				600–800 m AMSL			
		H′	CD	E	d	H′	CD	E	d
1	Trees	2.958	0.0723	0.908	6.134	3.224	0.0479	0.9388	6.662
2	Shrubs	1.996	0.1897	0.7561	1.997	2.117	0.1832	0.7474	2.385
3	Herbs	3.370	0.0655	0.8449	7.371	3.467	0.0532	0.8538	7.383
4	Climbers	1.798	0.1959	0.9427	2.219	2.136	0.1556	0.8597	1.625

Abbreviations: H′ = Shannon Wiener Index (Diversity); CD = Simpson Index (Concentration of dominance); E = Pielou Index (Evenness), d = Margalef Index (Richness).

Population structure

On the selected study area, the population structure was also deliberated for tree species (Figure 3 and Figure 4), and it was found that in both the altitudinal ranges, girth class D had the maximum number of tree species (CBH=61–90 cm) followed by girth class C (CBH=31–60 cm), such as *Acacia nilotica, Butea monosperma, Cassia fistula, Grewia optiva, Kydia calycina, Pongamia pinnata, Prosopis cinereria*, etc. While only a few tree species were found to belong to A and B girth classes (CBH- <30 cm).

Pearson correlation analysis

Pearson correlation revealed that D was strongly and positively correlated to A ($r = 0.98$) along with d ($r = 0.53$) and H′ ($r = 0.57$) but negatively correlated with B.A. ($r = -0.46$), CD ($r = -0.43$), and E ($r = -0.36$). Other than this, H′ showed a strong positive correlation with d ($r = 0.98$) as well as D ($r = 0.57$), A ($r = 0.65$), B.A. ($r = 0.37$), and E ($r = 0.28$) while correlated negatively to CD ($r = -0.98$) (Figure 5).

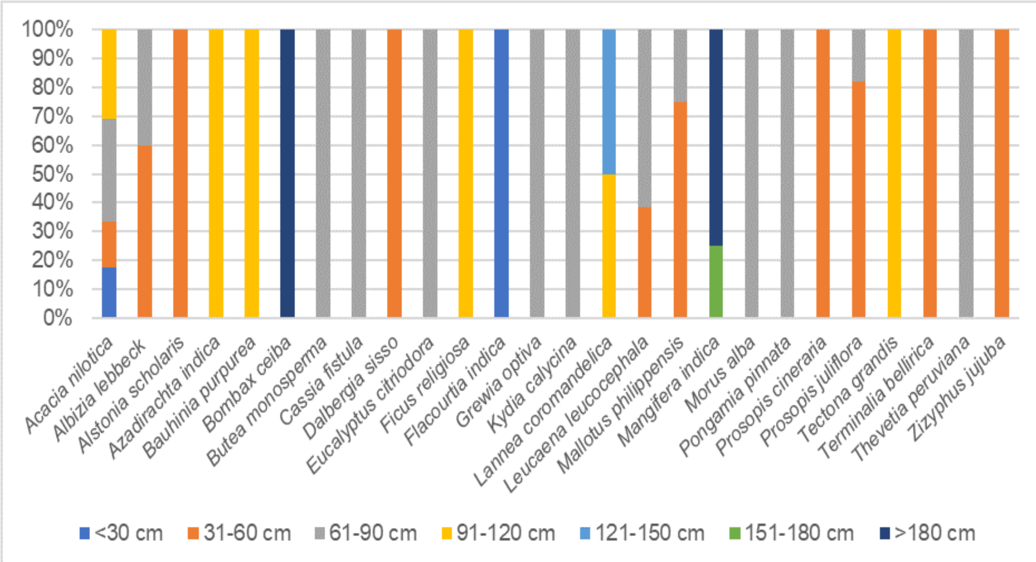


Figure 3. Graph showing the tree species percentage of AR_1 belonging to girth classes; A=0–10.4 cm, B=10.5–30 cm, C=31–60 cm, D=61–90 cm, E=91–120 cm, F=121–150 cm, G=151–180 cm and H=181–210 cm.

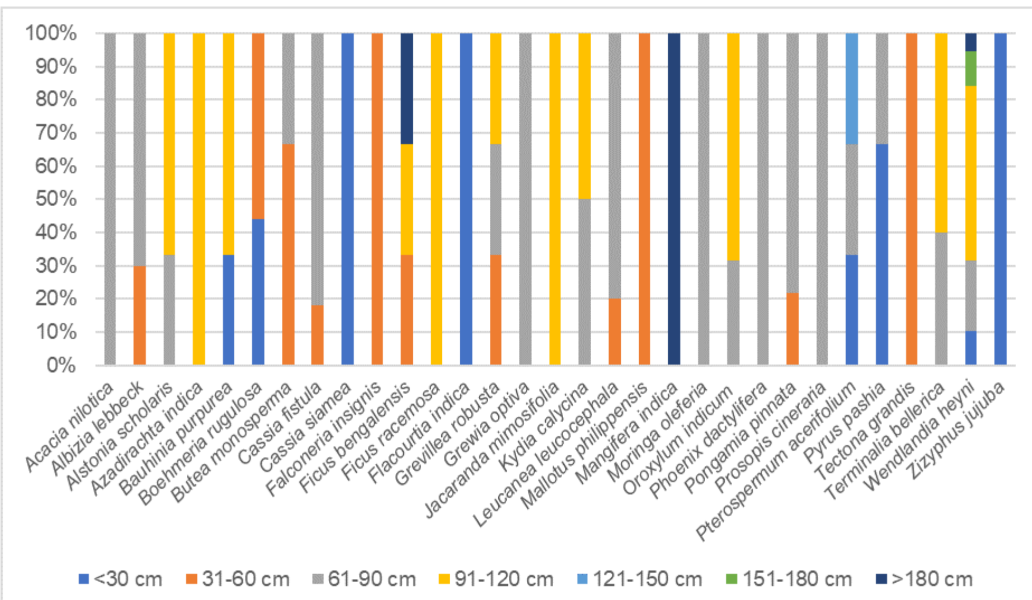
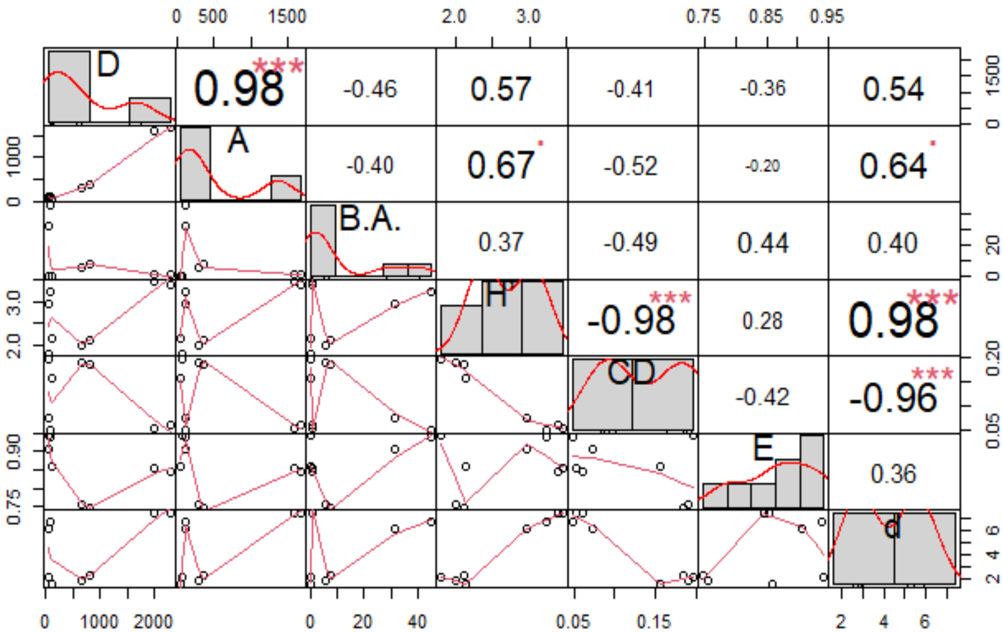


Figure 4. Graph showing the tree species percentage of AR_2 belonging to girth classes; A=0–10.4 cm, B=10.5–30 cm, C=31–60 cm, D=61–90 cm, E=91–120 cm, F=121–150 cm, G=151–180 cm and H=181–210 cm.



**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed).

Figure 5. Pearson correlation between different phytosociological parameters under study.

Discussion

Different forest ecosystems have their distinct floristic composition as the species occurring in them differ in their richness and abundance. In an ecosystem, the spatial and temporal patterns of vegetation are governed by different environmental variables such as climate, resource availability, herbivory, and level of human intervention (Poorter *et al.*, 2024). The present investigation showed that the plant community in the selected area of lower Shiwaliks exhibited differences in floristic composition and diversity with even a small change in elevation. This spatial variation in floristic composition in hilly areas may arise due to factors like climate, altitude, aspect, slope, and edaphic factors (Lal & Lodhiyal, 2015).

A total of 39 trees, 19 shrubs, 68 herbs, and 17 climbers out of 143 species of plants representing 56 families in the lower altitudinal ranges of Morni Hills forests were identified with Poaceae being the dominating family. This can be compared to the results obtained by Devi & Yadava (2006) of 123 plant species (17 trees, 36 shrubs, and 70 herbs) representing 48 families, with Poaceae being the most species-rich. Similarly, Ao *et al.* (2021) found a total of 118 species with 43 families of plants in the sub-tropical forest of Mokokchung, Nagaland with Fabaceae as the most species-rich family. Kumar & Saikia (2020) found 137 plant species belonging to 51 families in the tropical moist-deciduous forests of Ranchi, Jharkhand. Dagne & Birhanu (2023) also found a total of 137 plant species (47 trees, 36 shrubs, 48 herbs and 11 climbers) with Fabaceae as the dominant species followed by Asteraceae.

The density of trees was calculated as 58.89 ind./ha and 90.32 ind./ha for AR_1 and AR_2, respectively. While Kumar *et al.* (2010) found tree densities ranging from 458 to 728 ind./ha, Singh *et al.* (2014) reported that the tree density varied from 7.5 to 175 ind./ha during their investigation. Additionally, Maiguru (2024) found the density of tree species varying from 56 to

136 ind./ha in the Kwesati Forest Reserve, Nigeria. Thus, the present study site has a significant stand density of trees which can be improved by taking care of tree felling as well as improving the growth of saplings. On the other hand, the B.A. of tree species was observed to be 31.47 m^2/ha and 45.301 m^2/ha for AR_1 and AR_2, respectively. This can be compared with the results of Sahoo *et al.* (2017), who found the B.A. of trees to be varying from 7.77 to 31.62 m^2/ha. Whereas it is lower than the value observed by Kalita & Yumnam (2024), i.e. 71.74 m^2/ha but higher than the value of Sherafu *et al.* (2024), i.e. 29.88 m^2/ha.

The dominant plant species among trees, shrubs, herbs, and climbers of the area are *Acacia nilotica, Parthenium hysterophorus*, *Saccharum benghalense,* and *Abrus precatorius* in AR_1 while *Cassia fistula, Lantana camara*, *Leonotis nepetifolia,* and *Bauhinia vahlii* in AR_2, respectively as they possess the maximum value of IVI (Tables 1– 4). Because the high value of IVI of a species contributes to its ecological success in a community reflecting adaptation to high disturbance pressure, different factors may be natural and environmental as well as the impact of local communities (Misra, 1968).

Raunkiaer's law states that a species might be rare or numerous in a group, generating two peaks of the distribution with intermediate occupancies for the rest. This is the J-shaped normal frequency distribution curve, and any departure demonstrates forest community heterogeneity. Figure 2 shows a frequency class distribution pattern that differs from the conventional J-shaped curve and may have been caused by biotic and abiotic disruptions, mostly by anthropic activities. Stephenne & Lambin (2004) noted that anthropic activities (e.g. disturbance regimes, such as tree felling) may affect species regeneration directly or indirectly, resulting in frequency decline. All plant species except a few have contiguous distribution. Kumar & Saikia (2020) and Punia *et al.* (2022) found the same in the forest stands studied.

In addition to this, the presence of widely held species of trees in intermediate girth classes indicates that Morni Hills forests are entering the transition phase since the tree species belonging to lower girth classes are growing to form the forest composition. This sort of stand structure also shows that the replacement of tree size classes by the saplings is disproportionate, thus advocates that if the ongoing seedling recruitment does not recover, the population might decline in the near future.

According to Odum (1983), the diversity of species is a function of the species number in a region, including the equitability with which the individuals are present amongst them. Kent & Coker (1992) stated that the value of H′ generally varies from 1.5 to 3.5 while hardly exceeds 4.5 indicating very high diversity. Thakur & Khare (2006) observed the value of H′ ranging from 2.22 to 3.66 during their study conducted in the forests around Sagar, Madhya Pradesh. Sherafu *et al.* (2024) reported the H′ value of 3.56 during their study. Thus, the value of H′ calculated during our study was found to follow the trend as it varied from 1.99 to 3.58 for trees, shrubs, herbs, and climbers in the two altitudinal ranges during the present study. It is also very high compared to the range observed by Kumar *et al.* (2010), i.e. 0.67–0.79. Hence, based on the high H′ value, it can be stated that Morni forest has a high species diversity.

During the present investigation, the CD value varied from 0.047 to 0.205 for trees, shrubs, herbs, and climbers in the two altitudinal ranges. This was found to be way lower than the value observed by Tiamiyu *et al.* (2023) i.e. 0.955, thus showing low dominance and high diversity. While the evenness or equitability index (E) for trees, shrubs, herbs and climbers ranged from 0.74 to 0.94 during the current study, which is more than the 0.02–0.05 range noted by Kumar *et al.* (2010) but is more or less comparable to the results of Iqbal *et al.* (2012), i.e. 0.95–1.11, Sarkar (2016), i.e. 0.73–0.85, Fnd *et al.* (2024), i.e. 0.71 and Sherafu *et al.*

(2024), i.e. 0.87. Evenness is a chief element of diversity as it indicates the consistency of abundance among the species of a community. Thereby, high evenness ensues if the distribution and abundance of species are equivalent. Other than this, the value of the Margalef Index (d) varied from 1.625 to 7.383 for trees, shrubs, herbs, and climbers in the 4 altitudinal ranges. This is very high in comparison to Sharma *et al.* (2009) who reported the value of d to vary from 1.19 to 1.18 during their study but to be comparable to Tiamiyu *et al.* (2023), i.e. 7.862 and Fnd *et al.* (2024), i.e. 8.7.

Evaluating the difference or dissimilarities between communities has become essential in the field of community ecology. It is among the most readily identifiable attributes of natural forests (Jost *et al.*, 2011) and may reflect distinct mechanisms that generate and preserve biodiversity, as well as habitat effects that outline the forest's structure and composition (Socolar *et al.*, 2016). During the current investigation, the value of Sørensen's Index of similarity was obtained as 0.36 which is less than 0.5, thus indicating low similarity between the two altitudinal ranges. This indicates that the two ranges do not have a high similarity in floristic composition and are significant in terms of their floristic diversity.

The present study found a positive correlation between D, A, H′ and d, but a negative correlation between D, B.A., CD and E. Negi *et al.* (2022) also reported a positive correlation of D with H′, d and E whereas a negative correlation between CD, H′, B.A. and D. Other than this, H′ showed a strong negative correlation with CD, which is also supported by the results of Negi *et al.* (2022) and Nandy *et al.* (2024). If we compare the two altitudinal ranges, we see that AR_2 is more diverse and floristically rich than AR_2. According to Rahbek (1997) and Kessler (2000), productivity may peak at intermediate elevations sometimes. Consequently, activities like grazing, agriculture, development, and tourism were also observed on the current study site which leads to indiscriminate exploitation of vegetation. This could promote invasive species spread as well as the formation of vegetation patches in the forest land degrading the integrity of the forest and reduction in its diversity. And in the present scenario of turning these hills into a tourism hub of the state, they require even more protection and conservation to preserve the wonderful biodiversity they hold.

Conclusions

The biodiversity of the Himalayan ranges is distinct due to the high level of topographic and climatic heterogeneity. The vegetation analysis of the foothills of the Himalayas in Haryana state revealed a substantial value in terms of diversity, basal area, and density. The two altitudinal ranges showed a significant difference in terms of floristic composition and vegetation structure. However, there may be a risk of biodiversity loss in the near future as a result of a variety of abiotic and biotic disturbances, including deforestation for developmental activities, tourism, and medicinal plant collection, as well as forest fires, landslides, and the invasion of alien plant species. Consequently, to maintain the biodiversity and maintain the natural state of these forests, it is imperative that appropriate management activities be implemented. Additionally, the rural residents of that region should be educated on the significance of biodiversity and encouraged to collaborate with the government and forest department in utilizing the benefits of forests in a sustainable manner.

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