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Floristic diversity assessment and Vegetation analysis of the upper altitudinal ranges of Morni Hills, Panchkula, Haryana, India

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ABSTRACT

A field experiment was conducted in the forests of Morni Hills, Panchkula which form a part of lower Shiwalik range in North-east Haryana. The vegetational data was analysed for two different altitudinal ranges i.e. 800-1000 m AMSL (Range-1) and 1000-1200 m AMSL (Range-2), and parameters observed like floristic composition, phytosociology and diversity indices such as Shannon Wiener index (H'), Simpson index of dominance (Cd) and Pielou index for equitability (E). The data was collected in the months of Feb-Mar, 2019. For sampling of vegetation, 15 large plots were selected in each altitudinal range at random places. A total of 96 plant species (27 trees, 16 shrubs, 46 herbs and 7 climbers) were recorded in Range-1 while a total of 88 plant species (22 trees, 18 shrubs, 42 herbs and 6 climbers) were recorded in Range-2. The explored area was found to be colonized by various invasive plant species, which is an indicator of the area being under acute anthropogenic pressure. It was due to human intercessions; like land clearing for cultivation, construction activities and tourism, etc. Therefore, it is concluded that the site in discussion needs some immediate conservation efforts to prevent ongoing stress and degradation.

Key words: Floristic Composition, Phytosociology, IVI (Important Value Index), Conservation, Anthropogenic Pressure, Species diversity indices.

INTRODUCTION

Around 39-42 % of the world's total tropical forest area is covered by tropical dry forest (TDF) life zone (Brown & Lugo, 1982; Portillo-Quintero & Sanchez-Asofeifa, 2010). TDFs are considered to be the most threatened of all tropical terrestrial ecosystems by many authors (Hoekstra *et al*., 2005: Vieira & Scaroit, 2006). They have also been linked inevitably to the evolutionary as well as social history of humans. The biodiversity of the forests depends on various ecosystem processes and functions such as pedogenesis, nutrient cycling, organic matter decomposition and maintenance of hydrological cycle. However, in the past several decades, TDFs have been significantly affected by the escalation of new consumption practices and effective measures to extract resources. These anthropogenic activities have resulted in forest fragmentation and species loss; ultimately affecting the structure, diversity and distribution of forest flora. Hence, a proper understanding of these forest ecosystems and their components is required for successful management, conservation and restoration activities. So as to retain the ecological equilibrium and to complete the forest product requirements, floristic composition, the species diversity and vegetation structure are important to assess the attainment of conservation efforts performed for the sustainability of natural forests. The aim of present study is to produce quantitative information on species diversity in the two altitudinal ranges so that foresters and villagers have the knowledge of the present condition of the vegetation as it is a key component in determining the structure of an ecosystem. This information can be further used to understand the influence of recent climate change on the forest flora of the area as well as during the management and conservation activities to be performed in case of major degradation of the forest ecosystem of Morni Hills, Panchkula.

MATERIAL AND METHODS

Study site:

The study site was selected between 800m to 1200m above mean sea level at 30′37″ to 30′45″ N and 77°00' to 77°10' E in Morni hills in the North-eastern region of Haryana, India. Morni hills represent tertiary formations of Siwalik Hills. Siwalik Hills form the outermost hills of Himalayas and are composed of alluvial detritus derived from the Sub-aerial waste of mountains (Wadia, 1961). The soil of the region is clay loam and underlying rocks are soft sandstone and conglomerates.

Vegetation analysis and sampling of vegetation:

For the study, 30 plots were selected randomly in the upper two altitudinal ranges (15 plots in each range), 800-1000m (Range-1) and 1000-1200m (Range-2) above mean sea level (AMSL), as shown in Figure 1 and 2. For the phytosociological analysis, the quadrat method was used. Five quadrats of 10 × 10 m in each plot were randomly established in the selected altitudinal ranges for the determination of all the vegetation parameters. Trees were sampled in 10 × 10 m quadrats, shrubs in 5 × 5 m quadrats, and herbs in 1 × 1 m quadrats within each plot (Curtis and McIntosh, 1950; Phillips, 1959). The circumference of trees was also measured at 1.37 m height above from the ground. Using this, population structure or stand structure of the two ranges was calculated by placing the individual trees in different girth classes given in NRSA manual, 2008. Other than this, the frequency class distribution of plant species was calculated following Raunkiaer, 1934.

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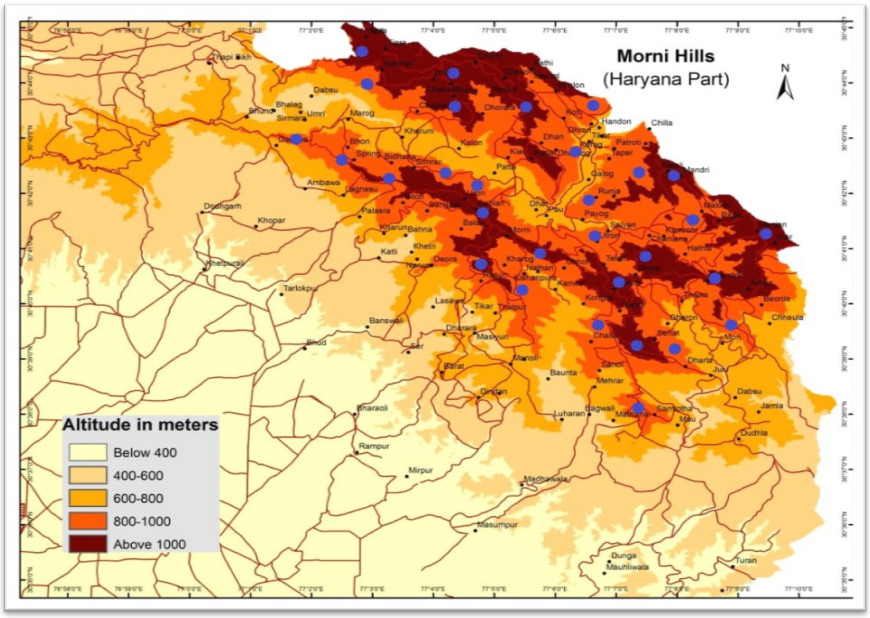

Figure 1. Map showing the location of plots studied on the study site.

The quantitative analysis of the vegetation for Frequency, Density and Dominance was done following Misra, 1968. While various species diversity indices were also calculated, viz. index of species diversity using Shannon and Weaver, 1963; concentration of dominance following Simpson, 1949 and species evenness or equitability by Pielou (1966).

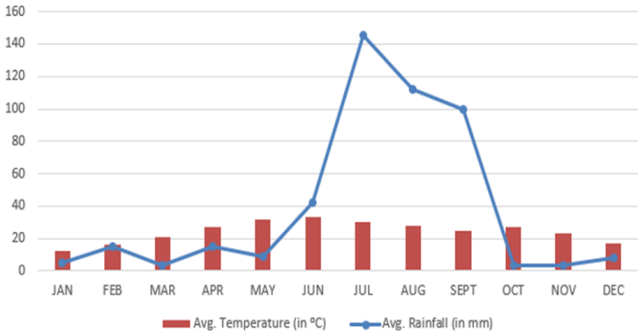

Figure 2. Monthly Average temperature and rainfall of Morni Hills, 2018. (Source: www.worldweatheronline.com)

Other than this, Similarity index was also calculated for the given altitudinal ranges following Muller-Dombois and Ellenberg, 1974.

$$\text{Index of Similarity (IS)} = \frac{2C}{A+B}$$

Where A and B is the number of species in each site and C is the number of common species occurred between the two compared sites.

RESULTS

A total of 121 plant species belonging to 57 families were recorded from the two altitudinal ranges on the study site, Range-1 (i.e. 800-1000m AMSL) and Range-2 (i.e. 1000-1200m AMSL). Many important plant species were documented during the fieldwork with important medicinal value. Some of them are *Aegle marmelos, Terminalia arjuna, Toxicodendron parviflorum, Cassia fistula, Barlaria cristata*, *Justicia adhatoda*, etc. Various species of climbers were also recorded such as; *Bauhinia vahlii*, *Cissampelos pariera*, *Stephania glabra*, *Ichnocarpus frutescens,* etc. Range-1 was found to be more disturbed and easily approachable by people in comparison to Range-2. The most common tree species of this range were *Cassia fistula*, *Flacourtia indica*, *Falconeria insignis*, and *Mallotus philippensis*, etc. while in the other range i.e. Range-2, there was less disturbance and the commonly growing tree species were *Pinus roxburghii*, *Flacourtia indica*, *Grevillea robusta*, *Wendlandia heynei* and *Pyrus pashia*, etc. Bamboos were also found to be present in the form of patches at different places. Extensive thickets of prickly *Lantana camara* and *Chromolaena odorata* were also very common.

Within the tree layer, the maximum frequency was observed for Mallotus philippensis (50%) in Range-1 and *Pinus roxburghii* (83%) in Range-2. It denotes their wide range of niche preferences and capability to establish over a large area. Other than this, among shrubs and herbs, the maximum frequency was recorded for *Lantana camara* and *Oxalis corniculata* in both the ranges. While in climbers, the maximum frequency was obtained for *Stephania glabra* in Range-1 and *Ichnocarpus frutescens* in Range-2.

Other than this, based on the frequency classes given by Raunkiaer (1934), the species distribution curve was also analysed for the given two altitudinal ranges of the study site. According to Raunkiaer's law, a species in a community is either rare or common. The normal frequency distribution curve is J-shaped and the distribution different from the normal one indicates a disturbance in the ecosystem. The analysis shows that Range-2 follows the Raunkiaer's law of frequency and represents a J-shaped curve of species distribution while Range-1 does not. This indicates that Range-1 is more disturbed and easily approachable by the people than Range-2 (Table 2, Figure 3).

In Range-1, the highest value for density was recorded for *Mallotus philippensis* among trees (20 ind./ha), *Lepidagathis cuspidata* among shrubs (124.32 ind./ha), *Oxalis corniculata* among herbs (240.32 ind./ha) and *Galium aparine* among climbers (42.32 ind./ha). While in Range-2, the maximum density was observed for *Pinus roxburghii* (44 ind./ha), *Lantana camara* (86.64 ind./ha), *Oxalis corniculata* (145.6 ind./ha) and *Stephania*

Table 1. Vegetation analysis and diversity indices of plant species in Range-1.

Sl. No.	Name of the plant	Family	D (ind./ ha)	A/F	B.A (m^2/ha)	IVI	H'	Cd	E
A.	**TREES**								
1	*Aegle marmelos*	Rutaceae	1.64	0.156	0.829449	6.9226	0.086971	0.000532	0.026388
2	*Boehmeria rugulosa*	Urticaceae	4	1.445	0.054151	5.8551	0.076829	0.000381	0.023311
3	*Bombax ceiba*	Bombacaceae	1.32	0.125	4.22496	15.368	0.15222	0.002624	0.046186
4	*Callistemon viminalis*	Myrtaceae	1	0.361	0.55926	4.0777	0.058424	0.000185	0.017727
5	*Cassia fistula*	Caesalpiniaceae	5.64	0.128	1.95493	17.228	0.164086	0.003298	0.049786
6	*Cassia siamea*	Caesalpiniaceae	0.64	0.24	0.006925	2.2806	0.037093	0.000057	0.011255
7	*Falconeria insignis*	Euphorbiaceae	5	0.113	1.88647	16.394	0.158852	0.002986	0.048198
8	*Ficus bengalensis*	Moraceae	0.64	0.24	2.19056	7.9232	0.095976	0.000698	0.029121
9	*Flacourtia indica*	Salicaceae	7.64	0.174	0.075322	14.426	0.145936	0.002313	0.044279
10	*Grevillea robusta*	Proteaceae	3.32	0.312	0.32894	7.3556	0.090923	0.000601	0.027587
11	*Grewia optiva*	Tiliaceae	2.32	0.093	1.50032	11.095	0.121948	0.001368	0.037001
12	*Haplophragma adenophyllum*	Bignoniaceae	1	0.04	0.8467	8.0501	0.097087	0.00072	0.029457
13	*Holoptelea integrefolia*	Ulmaceae	0.64	0.062	1.44856	7.4949	0.092177	0.000624	0.027968
14	*Kydia calycina*	Malvaceae	1.32	0.053	1.35104	9.6821	0.110812	0.001042	0.033622
15	*Lannea coromandelica*	Anacardiaceae	1.64	0.156	0.4951	6.0587	0.078809	0.000408	0.023912
16	*Mallotus philippensis*	Euphorbiaceae	20	0.187	2.33218	29.671	0.228826	0.009782	0.069429
17	*Mangifera indica*	Anacardiaceae	0.64	0.24	1.61966	6.4480	0.082535	0.000462	0.025042
18	*Mitragyna parviflora*	Rubiaceae	1	0.093	0.69666	5.9219	0.077481	0.00039	0.023509
19	*Oroxylum indicum*	Bignoniaceae	0.64	0.24	0.3583	3.1885	0.048299	0.000113	0.014654
20	*Pongamia pinnata*	Fabaceae	1.32	0.125	0.58166	5.9535	0.077789	0.000394	0.023602
21	*Pyrus pashia*	Rosaceae	3	0.12	0.544918	9.3253	0.107896	0.000966	0.032737
22	*Senegalia catechu*	Mimosaceae	4	1.445	1.30844	9.0963	0.106	0.000919	0.032162
23	*Syzygium cumini*	Myrtaceae	2.32	0.093	5.96986	22.644	0.195037	0.005698	0.059177
24	*Tectona grandis*	*Verbenaceae*	5	0.498	3.89796	18.304	0.170636	0.003723	0.051773
25	*Terminalia arjuna*	Combretaceae	13.32	0.133	2.3884	29.527	0.228196	0.009688	0.069238
26	*Vitex negundo*	Verbenaceae	4	0.375	0.0029	7.2118	0.08962	0.000578	0.027192
27	*Wendlandia heynei*	Rubiaceae	4.32	0.173	1.24532	12.491	0.132358	0.001734	0.040159
	TOTAL		97.32	7.42	38.69895	300	3.112817	0.052283	0.944469
B.	**SHRUBS**								
1	*Callicarpa macrophylla*	Verbenaceae	12.64	1.187	0.030729	5.6575	0.074883	0.000356	0.027008
2	*Carissa spinarum*	Apocynaceae	26	0.147	0.02642	15.790	0.154976	0.00277	0.055896
3	*Cocculus laurifolius*	Menispermaceae	2	0.187	0.005747	2.9820	0.045836	0.000098	0.016532
4	*Colebrookea oppositifolia*	Lamiaceae	22.64	0.226	0.02994	12.777	0.134426	0.001814	0.048484
5	*Euphorbia royleana*	Euphorbiaceae	13.64	0.136	1.94272	58.855	0.319526	0.038488	0.115245
6	*Ipomoea carnea*	Convolvulaceae	16	1.5	0.04195	6.5857	0.083834	0.000482	0.030237
7	*Lantana camara*	Verbenaceae	73.64	0.266	1.70715	69.592	0.338944	0.053812	0.122248
8	*Lepidagathis cuspidata*	Acanthaceae	124.32	2.825	0.00312	29.101	0.226314	0.00941	0.081625
9	*Murraya koengii*	Rutaceae	72	0.26	0.06147	28.139	0.221986	0.008798	0.080065
10	*Zanthoxylum armatum*	Rutaceae	2.32	0.218	0.000503	2.9126	0.044998	0.000094	0.01623
11	*Parthenium hysterophurus*	Asteraceae	82.32	0.297	0.00806	28.794	0.224941	0.009212	0.08113
12	*Psedocaryopteris bicolor*	Verbenaceae	29.64	2.781	0.00987	8.4131	0.100229	0.000786	0.03615
13	*Reinwardtia indica*	Linaceae	16.32	0.653	0.00069	6.9958	0.087645	0.000544	0.031611
14	*Solanum erianthum*	Solanaceae	2.64	0.963	0.000115	1.7842	0.030479	0.000035	0.010993
15	*Toxicodendron parviflorum*	Anacardiaceae	19.64	0.111	0.12494	17.027	0.162834	0.003221	0.05873
16	*Ziziphus nummularia*	Rhamnaceae	3	0.012	0.00716	4.5898	0.063951	0.000234	0.023065
	TOTAL		518.76	11.769	4.000584	300	2.315802	0.130157	0.835249

Table 1 continued in next page

Table 1. continued

C.	**HERBS**								
1	*Aerva sanguinolenta*	Amaranthaceae	8	0.75	0.00026	2.2525	0.036732	0.000056	0.009828
2	*Agave americana*	Agavaceae	3.32	0.312	0.03817	5.7623	0.075918	0.000368	0.020312
3	*Ageratum conyzoides*	Asteraceae	13	1.218	0.000787	2.6287	0.041502	0.000076	0.011104
4	*Ageratum houstonianum*	Asteraceae	51.64	4.843	0.00145	5.1850	0.070144	0.000298	0.018767
5	*Androsace umbellata*	Primulaceae	32.32	3.031	0.00071	3.8658	0.056076	0.000166	0.015003
6	*Dendrocalamus strictus*	Poaceae	22.32	0.893	0.63642	68.095	0.336589	0.051521	0.090053
7	*Bidens pilosa*	Asteraceae	10.64	1	0.000723	2.4694	0.03951	0.000067	0.010571
8	*Boehmeria macrophylla*	Urticaceae	2.32	0.218	0.21657	23.633	0.200185	0.006206	0.053559
9	*Cannabis sativa*	Cannabinaceae	5.32	1.927	0.00023	1.2536	0.02289	0.000017	0.006124
10	*Cardamine scutata*	Brassicaceae	38.32	0.2	0.000659	5.2099	0.07039	0.000301	0.018833
11	*Centella asiatica*	Apiaceae	13	0.68	0.000006	3.5119	0.052066	0.000137	0.01393
12	*Chromolaena odorata*	Asteraceae	89.32	8.375	0.00678	8.1508	0.097964	0.000738	0.02621
13	*Cirsium arvense*	Asteraceae	15	0.6	0.00093	3.7337	0.054592	0.000154	0.014606
14	*Commelina benghalensis*	Commelinaceae	11.64	0.265	0.00035	4.3142	0.061002	0.000206	0.016321
15	*Cyclospermum leptophyllum*	Apiaceae	13	4.698	0.00008	1.7336	0.029781	0.000033	0.007968
16	*Cynodon dactylon*	Poaceae	106.64	1.56	0.00088	11.347	0.123869	0.001430	0.033141
17	*Cynoglossum zeylanicum*	Boraginaceae	32.32	0.323	0.00174	7.6050	0.093161	0.000642	0.024925
18	*Dichanthium annulatum*	Poaceae	30	2.81	0.000354	3.6805	0.05399	0.000150	0.014445
19	*Dicliptera chinensis*	Acanthaceae	101.64	4.066	0.00156	9.3826	0.108367	0.000978	0.028993
20	*Erigeron canadensis*	Asteraceae	4.32	1.566	0.000299	1.1960	0.022027	0.000015	0.005893
21	*Fragaria nilgerrensis*	Rosaceae	28	10.12	0.00048	2.7408	0.0429	0.000083	0.011478
22	*Fumaria indica*	Fumariaceae	27	2.531	0.000284	3.4800	0.051699	0.000134	0.013832
23	*Geranium ocellatum*	Geraniaceae	12	4.337	0.00011	1.6721	0.028927	0.000031	0.007739
24	*Gnaphalium luteo-album*	Asteraceae	58.32	0.609	0.00155	8.2997	0.099253	0.000765	0.026555
25	*Hemigraphis hirta*	Acanthaceae	11.64	0.466	0.000601	3.4840	0.051745	0.000134	0.013844
26	*Justicia adhatoda*	Acanthaceae	62.64	0.462	0.02675	12.929	0.135513	0.001857	0.036256
27	*Lepidium didymum*	Brassicaceae	22.32	2.093	0.00091	3.2412	0.04892	0.000116	0.013088
28	*Lindenbergia indica*	Scrophulariaceae	28	10.12	0.000248	2.7175	0.042612	0.000082	0.011401
29	*Lysimachia arvensis*	Primulaceae	24	2.25	0.00031	3.2892	0.049483	0.000120	0.013239
30	*Malvastrum coromandelianum*	Malvaceae	20.32	0.462	0.00103	4.9422	0.067642	0.000271	0.018097
31	*Mazus pumilus*	Scrophulariaceae	14	5.06	0.00018	1.8081	0.030808	0.000036	0.008243
32	*Nepeta leucophylla*	Lamiaceae	117.64	2.674	0.019413	13.064	0.136475	0.001896	0.036513
33	*Oplismenus undulatifolius*	Poaceae	69	1.568	0.00068	8.0453	0.097045	0.000719	0.025964
34	*Oxalis corniculata*	Oxalidaceae	240.32	1.068	0.00528	24.043	0.20228	0.006423	0.054119
35	*Rumex dentatus*	Polygonaceae	8.66	3.132	0.000008	1.4466	0.025724	0.000023	0.006882
36	*Rumex hastatus*	Polygonaceae	52.32	4.843	0.00279	5.3643	0.071954	0.000319	0.019251
37	*Saccharum ravennae*	Poaceae	10	3.614	0.012682	2.8071	0.043714	0.000087	0.011695
38	*Salvia plebeia*	Lamiaceae	3.64	1.325	0.000336	1.1559	0.021419	0.000014	0.005731
39	*Sida cordifolia*	Malvaceae	1.32	0.125	0.000018	1.7977	0.030665	0.000035	0.008204
40	*Solanum incanum*	Solanaceae	7.64	0.718	0.008192	3.0269	0.046376	0.000101	0.012408
41	*Solanum virginianum*	Solanaceae	12.64	4.578	0.00113	1.8160	0.030915	0.000036	0.008271
42	*Sonchus oleraceus*	Asteraceae	7	2.53	0.000082	1.3470	0.024273	0.00002	0.006494
43	*Stellaria media*	Caryophyllaceae	14.32	5.18	0.000172	1.8279	0.031079	0.000037	0.008315
44	*Strobilanthus spp*.	Acanthaceae	30	2.812	0.001792	3.8250	0.055619	0.000162	0.014881
45	*Thalictrum foliosum*	Ranunculaceae	63.32	5.937	0.000668	5.8601	0.076878	0.000381	0.020568
46	*Vernonia indica*	Asteraceae	1	0.361	0.000016	0.9535	0.018281	0.00001	0.004891
	TOTAL		1551.14	118.31	0.994671	300	3.208953	0.077473	0.858544
D.	**CLIMBERS**								
1	*Asparagus racemosus*	Asparagaceae	0.64	0.24	0.000034	7.8639	0.095455	0.000687	0.049054
2	*Bauhinia vahlii*	Caesalpiniaceae	2	0.187	0.0094	60.950	0.323793	0.041277	0.166397
3	*Cissampelos pareira*	Menispermaceae	3.32	0.312	0.000046	17.864	0.167986	0.003546	0.086328
4	*Galium aparine*	Ranunculaceae	42.32	3.968	0.00862	111.28	0.367867	0.137609	0.189046
5	*Ichnocarpus frutescens*	Apocynaceae	1.64	0.156	0.00005	15.629	0.153933	0.002714	0.079106
6	*Jasminum dichotomum*	Oleaceae	3	0.281	0.002103	27.298	0.218112	0.00828	0.112088
7	*Stephania glabra*	Verbenaceae	21.64	0.492	0.0006	59.106	0.320049	0.038817	0.164473
	TOTAL		74.56	5.636	0.020853	300	1.647195	0.232931	0.846491

D= Density (individuals/hectare); A/F= Ratio of abundance and frequency; B.A= Basal Area (m^2/hectare); IVI= Important value index; H'= Shannon Wiener Index; Cd= Simpson Index; E= Pielou Index.

Table 2. Frequency class distribution of plant species for Range-1 and Range-2.

Sl. No.	Frequency classes	Range-1		Range-2	
		Number of species	% of the total number of species	Number of species	% of the total number of species
1	1-20%	60	62.5	47	53.4
2	21-40%	23	23.95	19	21.5
3	41-60%	7	7.2	14	15.9
4	61-80%	3	3.1	3	3.4
5	81-100%	3	3.1	5	5.6

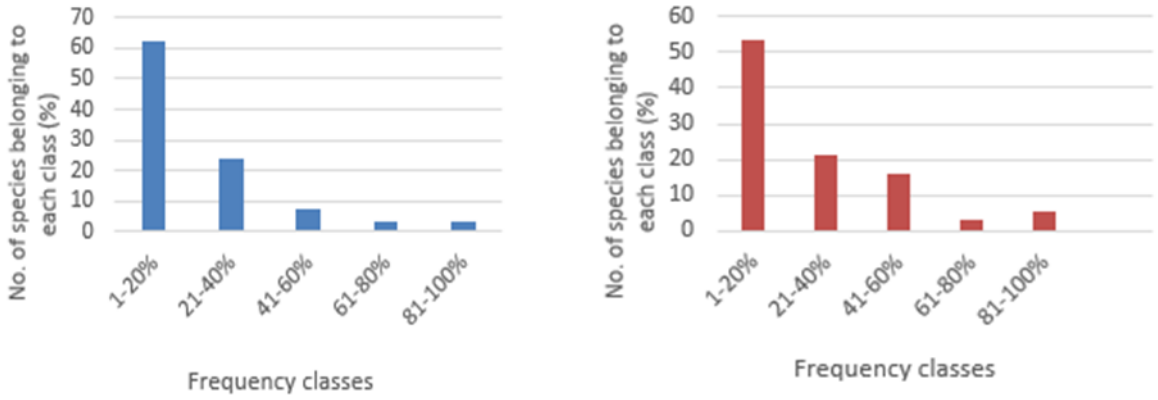

Figure 3. Raunkiaer's percentage frequency class distribution pattern of plant species for Range-1(left) and Range-2(right).

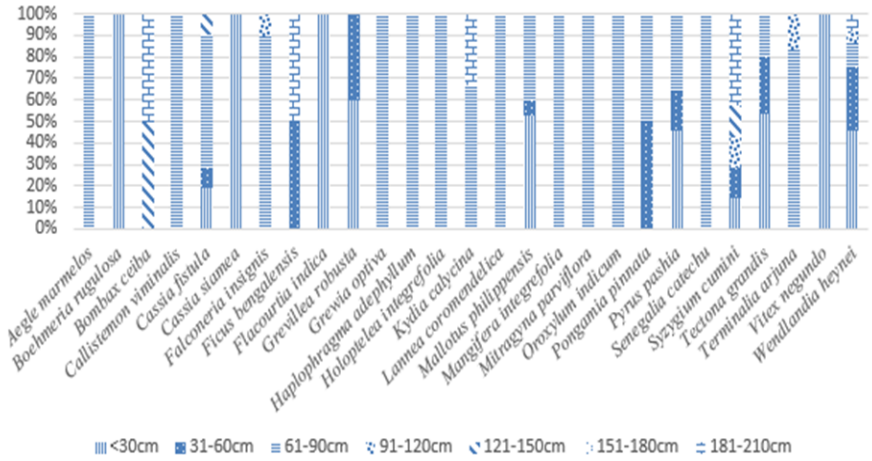

Figure 4. Graph representing the percentage of tree species of Range-1 belonging to different girth classes. A=0-10.4cm, B=10.5-30cm, C=31-60cm, D=61-90cm, E=91-120cm, F=121-150cm, G=151-180cm and H=181-210cm.

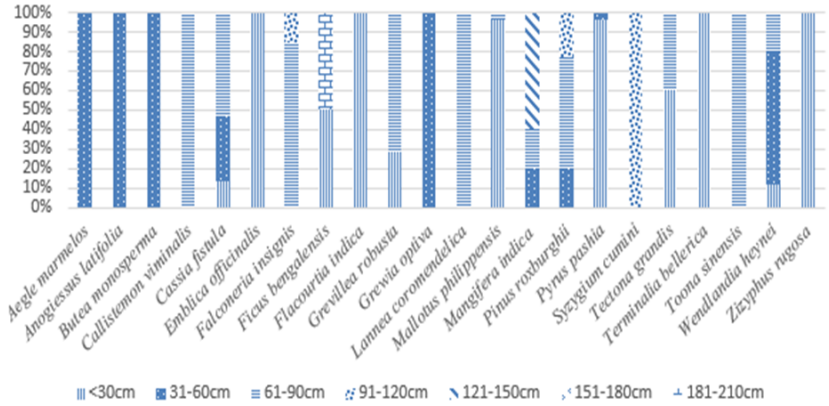

Figure 5. Graph representing the percentage of tree species of Range-2 belonging to different girth classes (in cms). A=0-10.4cm, B=10.5-30cm, C=31-60cm, D=61-90cm, E=91-120cm, F=121-150cm, G=151-180cm and H=181-210cm.

Table 3. Vegetation analysis and diversity indices of plant species in Range-2

Sl. No.	Name of the plant	Family	D(Ind/ ha)	A/F	B.A (m^2/ha)	IVI	H'	Cd	E
A.	**TREES**								
1	*Aegle marmelos*	Rutaceae	0.64	0.24	0.08208	2.25015	0.03669	0.000056	0.011873
2	*Anogeissus latifolia*	Combretaceae	1	0.361	0.285	2.72612	0.04271	0.000082	0.01382
3	*Butea monosperma*	Fabaceae	1	0.361	0.1357	2.59303	0.04106	0.000074	0.013285
4	*Callistemon viminalis*	Myrtaceae	0.64	0.24	0.28812	2.43382	0.03905	0.000065	0.012636
5	*Cassia fistula*	Caesalpiniaceae	4	0.058	1.07524	12.3996	0.13168	0.001708	0.042603
6	*Falconeria insignis*	Euphorbiaceae	1.64	0.602	1.5985	4.42159	0.06215	0.000217	0.020109
7	*Ficus bengalensis*	Moraceae	1.32	0.125	0.00171	4.26883	0.06051	0.000202	0.019576
8	*Flacourtia indica*	Salicaceae	15	0.11	0.12596	23.9542	0.20182	0.006375	0.065294
9	*Grevellia robusta*	Proteaceae	2.32	0.218	0.67366	5.68750	0.07518	0.000359	0.024322
10	*Grewia optiva*	Tiliaceae	0.64	0.24	0.07122	2.24047	0.03657	0.000055	0.011832
11	*Lannea coromandelica*	Anacardiaceae	1.64	0.156	0.73755	5.18707	0.07015	0.000298	0.022697
12	*Mallotus philippensis*	Euphorbiaceae	12	0.088	0.31959	21.6678	0.18980	0.005216	0.061405
13	*Mangifera indica*	Anacardiaceae	1.64	0.156	1.20871	5.60707	0.07438	0.000349	0.024064
14	*Phyllanthus emblica*	Phyllanthaceae	0.64	0.24	0.0402	2.21282	0.03621	0.000054	0.011715
15	*Pinus roxburghii*	Pinaceae	44	0.159	100.4881	142.166	0.35389	0.224570	0.114489
16	*Pyrus pashia*	Rosaceae	18	0.102	0.14872	28.0262	0.22146	0.008727	0.071648
17	*Syzygium cumini*	Myrtaceae	1	0.361	0.80855	3.19282	0.04834	0.000113	0.015642
18	*Tectona grandis*	Verbenaceae	1.64	0.156	0.36451	4.85454	0.06673	0.000261	0.021589
19	*Terminalia bellerica*	Combretaceae	0.64	0.24	0.06282	2.23298	0.03647	0.000055	0.0118
20	*Toona sinensis*	Meliaceae	0.64	0.24	0.4676	2.59381	0.04107	0.000074	0.013288
21	*Wendlandia heynei*	Rubiaceae	11.32	0.453	3.17321	17.0844	0.16319	0.003243	0.052795
22	*Zizyphus rugosa*	Rhamnaceae	0.64	0.24	0.02376	2.19816	0.03602	0.000053	0.011654
	TOTAL		122	5.146	112.1805	300	2.06523	0.252217	0.668135
B.	**SHRUBS**								
1	*Berberis aristata*	Berberidaceae	1	0.361	0.0007	1.36402	0.02452	0.00002	0.008484
2	*Callicarpa macrophylla*	Verbenaceae	2.64	0.25	0.00394	2.82463	0.04392	0.000088	0.015198
3	*Carrissa spinarum*	Apocynaceae	53.32	0.159	0.04096	24.3460	0.20381	0.006585	0.070513
4	*Colebrookea oppositifolia*	Lamiaceae	32.32	0.143	0.04213	17.8092	0.16764	0.003524	0.058002
5	*Euphorbia royleana*	Euphorbiaceae	2.64	0.25	0.02143	3.14560	0.04779	0.000109	0.016534
6	*Lepidagathis cuspidata*	Acanthaceae	62.32	1.416	0.00139	17.4922	0.16571	0.003399	0.057332
7	*Lantana camara*	Verbenaceae	86.64	0.259	4.87483	119.960	0.36652	0.159895	0.12681
8	*Murraya koenigii*	Rutaceae	73.64	0.544	0.09053	24.9200	0.20667	0.006900	0.071506
9	*Naringi crenulata*	Rutaceae	4.32	0.406	0.0055	3.20152	0.04845	0.000113	0.016763
10	*Parthenium hysterophorus*	Asteraceae	49.64	0.282	0.00409	19.4611	0.17744	0.004208	0.061392
11	*Pseudocaryopteris bicolor*	Verbenaceae	13.32	0.533	0.00143	6.23286	0.08048	0.000431	0.027846
12	*Reinwardtia indica*	Linaceae	26	0.38	0.00095	11.0576	0.12165	0.001358	0.042091
13	*Rubus ellipticus*	Rosaceae	13.32	0.303	0.00283	7.36108	0.09097	0.000602	0.031474
14	*Solanum erianthum*	Solanaceae	5	0.468	0.00462	3.32633	0.04991	0.000122	0.01727
15	*Solanum incanum*	Solanaceae	15.32	5.542	0.0157	4.60778	0.06414	0.000235	0.022191
16	*Toxicodendron parviflorum*	Anacardiaceae	25.64	0.076	0.31814	23.6947	0.20049	0.006238	0.069368
17	*Urena lobata*	Malvaceae	3.32	0.312	0.0008	2.90797	0.04494	0.000093	0.015549
18	*Woodfordia fructicosa*	Lythraceae	12	0.48	0.01924	6.28606	0.08099	0.000439	0.028022
	TOTAL		482.4	12.164	5.44921	300	2.18612	0.194369	0.756346
C.	**HERBS**								
1	*Acyranthes aspera*	Amranthaceae	12.32	1.156	0.00122	3.1892	0.048306	0.000113	0.012924
2	*Justicia adhatoda*	Acanthaceae	38.64	0.878	0.04275	17.28941	0.164462	0.00332	0.044001
3	*Aerva sanguinolenta*	Amranthaceae	5.32	0.5	0.00021	2.172277	0.035683	0.000052	0.009547
4	*Ageratum conyzoides*	Asteraceae	11.64	0.17	0.00107	5.46492	0.072965	0.000331	0.019521
5	*Ageratum houstonianum*	Asteraceae	22.32	0.223	0.00066	7.42811	0.091576	0.000613	0.024501
6	*Ajuga parviflora*	Lamiaceae	5.32	0.5	0.00018	2.165397	0.035593	0.000052	0.009523
7	*Andrographis paniculata*	Acanthaceae	6	2.289	0.01751	5.481256	0.073128	0.000333	0.019565
8	*Androsace umbellata*	Primulaceae	8.64	0.812	0.00011	2.521791	0.040171	0.00007	0.010747
9	*Dendrocalamus strictus*	Poaceae	5	0.2	0.00174	3.346387	0.05015	0.000124	0.013417
10	*Barleria cristata*	Acanthaceae	10.64	0.426	0.00059	3.71535	0.054384	0.000153	0.01455
11	*Bidens pilosa*	Asteraceae	34	0.34	0.00335	9.355352	0.108143	0.000972	0.028933
12	*Bryophyllum fedtschenkoi*	Crassulaceae	2.64	0.963	0.00039	1.177896	0.021752	0.000015	0.00582
13	*Cardamine hirsuta*	Brassicaceae	7.64	0.718	0.00018	2.425662	0.038954	0.000065	0.010422
14	*Chromolaena odorata*	Asteraceae	84.32	0.843	0.01354	17.33745	0.164759	0.003339	0.044081
15	*Cirsium arvense*	Asteraceae	5.32	0.213	0.00081	3.168992	0.048067	0.000111	0.01286
16	*Commelina benghalensis*	Commelinaceae	2	0.722	0.00007	1.032708	0.019524	0.000011	0.005223
17	*Cynodon dactylon*	Poaceae	59.64	2.386	0.00046	9.182506	0.106715	0.000936	0.028551
18	*Cynoglossum zeylanicum*	Boraginaceae	32.32	0.323	0.00169	8.786168	0.103402	0.000857	0.027665
19	*Cyperus distans*	Cyperaceae	1.64	0.602	0.00049	1.088648	0.02039	0.000013	0.005455
20	*Dichanthium annulatum*	Poaceae	33.32	3.125	0.00033	5.340925	0.071718	0.000316	0.019188
21	*Dicliptera chinensis*	Acanthaceae	43.64	0.436	0.0015	10.0125	0.113473	0.001113	0.030359
22	*Euphorbia hirta*	Euphorbiaceae	31.64	0.463	0.00137	7.777386	0.094691	0.000672	0.025334
23	*Fragaria nilgerrensis*	Rosaceae	12.64	0.506	0.00058	3.937423	0.056873	0.000172	0.015216
24	*Geranium ocellatum*	Geraniaceae	36	0.818	0.00066	7.340017	0.090782	0.000598	0.024288
25	*Gnaphalium luteo-album*	Asteraceae	8.64	0.812	0.0012	2.771779	0.043279	0.000085	0.011579

Table 3. Continued

26	*Hemigraphis hirta*	Acanthaceae	32	0.727	0.00637	8.200858	0.098398	0.000747	0.026326
27	*Malvastrum coromandelia-num*	Malvaceae	23	0.169	0.00079	8.29786	0.099236	0.000765	0.02655
28	*Mazus pumilus*	Scrophulariaceae	6	2.168	0.00005	1.476853	0.026159	0.000024	0.006999
29	*Micromeria biflora*	Lamiaceae	22	2.062	0.00013	4.025143	0.057844	0.00018	0.015476
30	*Musa paradisiaca*	Musaceae	0.64	0.24	0.3206	74.39282	0.345784	0.061492	0.092513
31	*Nepeta leucophylla*	Lamiaceae	36	0.818	0.00059	7.323963	0.090637	0.000596	0.02425
32	*Oplismenus undulatifolius*	Poaceae	145.6	0.827	0.00102	22.86791	0.19621	0.00581	0.052495
33	*Oxalis corniculata*	Oxalidaceae	22	0.88	0.00262	5.455325	0.072868	0.00033	0.019496
34	*Polygonum plebeium*	Polygonaceae	4	1.445	0.00028	1.305237	0.023657	0.000018	0.006329
35	*Rumex hastatus*	Polygonaceae	1	0.361	0.00003	0.911351	0.017609	0.000009	0.004711
36	*Salvia plebeia*	Lamiaceae	23.32	0.341	0.00062	6.672012	0.084643	0.000494	0.022646
37	*Solanum nigrum*	Solanaceae	5.32	0.5	0.00733	3.80523	0.055397	0.00016	0.014821
38	*Sonchus oleraceus*	Asteraceae	12.64	4.578	0.00009	2.230923	0.036449	0.000055	0.009752
39	*Strobilanthes sp.*	Acanthaceae	5	1.807	0.0004	1.444941	0.025699	0.000023	0.006876
40	*Thalictrum foliosum*	Ranunculaceae	2	0.722	0.00025	1.07399	0.020164	0.000012	0.005395
41	*Vernonia indica*	Asteraceae	2	0.722	0.00005	1.028121	0.019452	0.000011	0.005204
42	*Viola canescens*	Violaceae	27.64	1.106	0.00214	5.977951	0.078026	0.000397	0.020876
	TOTAL		891.4	39.897	0.43602	300	3.117172	0.085579	0.833988
D.	**CLIMBERS**								
1	*Asparagus racemosus*	Asparagaceae	3.32	0.133	0.00111	37.3307	0.25932	0.015484	0.144729
2	*Bauhinia vahlii*	Caesalpiniaceae	2.64	0.25	0.01442	78.3261	0.35061	0.068166	0.195682
3	*Cissampelos pariera*	Menispermaceae	1.32	48.192	0.00006	12.0536	0.12915	0.001614	0.072081
4	*Ichnocarpus frutescens*	Apocynaceae	4	0.09	0.00017	42.8464	0.27795	0.020397	0.155129
5	*Jasminum dichotomum*	Oleaceae	2.32	0.218	0.00428	38.3004	0.26278	0.016299	0.146661
6	*Stephania glabra*	Verbenaceae	12.32	0.493	0.0061	91.1425	0.36194	0.092299	0.202005
	TOTAL		25.92	49.376	0.02614	300	1.64176	0.214261	0.916287

D= Density (individuals/hectare); A/F= Ratio of abundance and frequency; B.A.= Basal Area (m^2/hectare); IVI= Important value index; H'= Shannon Wiener Index; Cd= Simpson Index; E= Pielou Index.

glabra (12.32) among the tree, shrubs, herbs, and climbers respectively (Table 1 & 3). Other than this, A/F values were also calculated for each species in both the altitudinal ranges. This ratio indicates regular (<0.025), random (0.025 to 0.050) and contiguous (>0.050) distribution (Curtis and Cottam,1956). In Range-1, *Haplophragma adenophyllum* (A/F=0.04) was found to show random distribution pattern and *Zizyphus nummularia* (A/F=0.012) was found to follow regular pattern whereas all other plant species followed the contiguous pattern of species distribution (A/F=>050). Analysis of A/F values of Range-2 revealed that all the plant species in that range were found to show a contiguous pattern of distribution.

According to Odum (1971), contiguous or clumped type of distribution is found to be commonly occurring in tropical heterogeneous forests in nature, whereas random and regular distribution occurs only under a uniform environment.

The IVI is very important to understand the ecological importance of a species. The IVI values of all the plant species varied from 0.9535 to 111.28 in Range-1, while it varied from .9113 to 142.166 in Range-2, as shown in Table 1 and Table 3. The dominant species of Range-1 in terms of IVI value were *Mallotus philippensis* (28.671), *Lantana camara* (69.592)*, Dendrocalamus strictus* (68.095) *and Galium aparine* (111.287), whereas in Range-2 dominant species were *Pinus roxburghii* (142.166), *Lantana camara* (119.960), *Musa paradisiaca* (74.858) *and Stephania glabra* (91.142) among trees, shrubs, herbs and climbers respectively.

Plant species diversity is a vital element in the study of forest ecology which envisions the status as well as contribution of the distinct species in the community structure and function of the forest ecosystem. In the present study, it was found that Range-1 had high value species diversity in comparison to Range-2. This can be clearly visualised from the values of different indices calculated during the study (Table 1 & 3). The value of Shannon-Weiner index was found to be higher for Range -1 (Trees-3.112, Shrubs-2.315, Herbs-3.208 and Climbers-1.647) for each category of plant species in comparison to Range-2 (Trees-2.065, Shrubs-2.186, Herbs-3.117 and Climbers-1.641). While in case of Simpson index, expect for climbers the value of concentration of dominance was found to be high for Range-2 (Trees-0.252, Shrubs-0.194, Herbs-0.085 and Climbers-0.214) in comparison to Range-1 (Trees-0.052, Shrubs-0.130, Herbs-0.077 and Climbers-0.232). This revealed that the level of dominance was higher in Range-2 than Range-1. On the other hand, the trend was found to be opposite for Pielou index. As the value of equitability was found to be higher for Range-1 (Trees-0.944, Shrubs-0.835, Herb-0.858 and Climbers-0.846) in comparison to Range -2 (Trees-0.668, Shrubs-0.756, Herbs-0.833 and Climbers-0.0.916 for trees, shrubs and herbs, except for climbers. This indicates that plant species in Range-1 are equal in their distribution as well as abundance, resulting in higher diversity than Range-2.

The value of Similarity index was also computed for the two altitudinal ranges, Range-1 and Range-2 for the better understanding of community relationships between the two. The value was found to be 33.69%, indicating less similarity and variation in spatial distribution of plant species on the forest area under study. So, it can be concluded that the area has a significant value of β diversity.

Other than this, the population structure of the tree species was also derived on the study area as shown in Figure 4 and Figure 5 and it was found that in Range-1, maximum number of tree species occurred in girth class D (CBH=61-90 cm), such as *Aegle marmelos, Callistemon viminalis, Grewia optiva,* and *Senegalia catechu,* etc. So, it can be stated that there are not enough seedlings in the ground to replace large trees. While in Range-2, a maximum number of tree species belonged to the lower and middle girth classes i.e. Class A, B

Table 4. Correlation between different phytosociological parameters.

	F	*D*	*A*	*A/F Ratio*	*BA*	*H'*	*Cd*	*E*
F	1	0.815*	0.708*	0.410	-0.099	0.815*	-0.650	-0.193
D	0.815*	1	0.976*	0.807*	-0.356	0.684	-0.576	0.002
A	0.708*	0.976**	1	0.885**	-0.316	0.061	0.135	0.996
A/F Ratio	0.410	0.807*	0.885**	1	-0.366	0.447	-0.406	0.272
BA	-0.099	-0.356	-0.316	-0.366	1	-0.068	0.324	-0.602
H'	0.815*	0.684	0.669	0.447	-0.068	1	-0.921**	0.248
Cd	-0.650	-0.576	-0.559	-0.406	0.324	-0.921**	1	-0.559
E	-0.193	0.002	0.078	0.272	-0.602	0.248	-0.559	1

**Correlation is significant at the 0.05 level (2-tailed).*
***Correlation is significant at the 0.01 level (2-tailed).*
F=Frequency; D=Density; A/F=Ratio of abundance and frequency; BA=Basal Area; H'= Shannon Wiener Index; Cd= Simpson Index; E= Pielou Index.

(CBH=<30cm) and D (CBH=61-90cm). Whereas only a small number of tree species were found to be in higher girth classes in both the ranges. This could be due to the cutting of mature trees to fulfill fuelwood requirements. The plant species which were found to be in smallest girth class will be occupying the tree canopy in the time ahead.

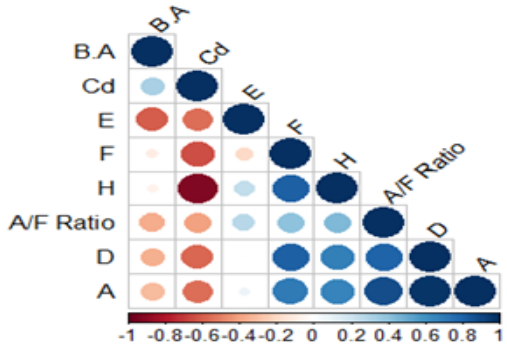

Figure 6. Heatmap representing the correlation between the different phytosociological parameters calculated during the study (R Studio).

Pearson correlation analysis:

The two-tailed Carl-Pearson Coefficient was also calculated between the different phytosociological parameters calculated during the study, as shown in Table 4; as well as a heatmap was also prepared to easily understand the correlation with the help of R Studio (Figure 6). The frequency was found to be positively correlated with density, abundance, A/F ratio, Shannon Weiner index while negatively correlated with Basal area, Simpson index and Pielou index. Other than this, Shannon Wiener index was found to be positively correlated with frequency, density, abundance, A/F ratio, and Pielou index while negatively correlated with basal area and Simpson index.

DISCUSSION

Forests are of immense significance from the environmental conservation and sustainable development viewpoint, as they deliver a gamut of resources to the people; they store carbon to regulate the climate and purify water as well (Baduni & Sharma, 1996). A lot of studies have been reported in the field of ecology as it is very important to know the proper findings of the change exerted by recent climate shift and global warming on the phytosociology and community structure of forest ecosystems in India such as Nath *et al*. (2005) on tropical evergreen forests of northeast India, Sharma *et al*. (2010) on Garhwal Himalaya, Singh *et al.* (2014) on tropical dry deciduous forests of southern Haryana, Sahu *et al*. (2019) on Saptasajya hills of Eastern ghats etc. The floristic composition in hilly regions may vary from place to place because of altitude, climate, slope, aspect and soil characteristics (Lal & Lodhiyal, 2015). The present study revealed that biodiversity found in this part of lower Shiwaliks exhibits varying patterns of floristic composition and diversity along the two altitudinal gradients. The species richness distribution over the large area might be regulated by two or more environmental factors and not by a single factor (Pausas & Austin, 2001). The data analysis of the present study revealed that the total basal area was found to be higher in Range-2 (118.089 m2/ha) than Range-1 (43.714 m2/ha), the reason being Pinus roxburghii dominated in that range. Along with this, maximum IVI value was obtained by Mallotus phippensis (29.671) followed by Terminalia arjuna (29.527), Syzygium cumini (22.644) and *Callistemon viminalis* (17.228), etc. in Range-1, while Pinus roxburghii (142.166) followed by Flacoutia indica (23.954), Wendlandia heynei (17.084) and Cassia fistula (12.399) etc. in Range-2. This may be attributed to their high girth and regenerating ability. An analysis of the distribution pattern of plant species in the two altitudinal ranges indicated that a maximum number of plant species had contiguous distribution. Contiguous distribution has been reported from many parts of India by many workers (Bhat, 2012; Sahu *et al*., 2012; Malik et al., 2014). The phytosociological study also revealed that the area is invaded by a number of invasive plant species such as Ageratum conyzoides, A. houstonianum, Bidens pilosa, Chromolaena ododrata, Lantana camara, Parthenium hysterophorus, etc. And their density on the given study site is so high that they may hinder the growth of native flora as well as they could be able to wipe out the natural herbaceous vegetation of the area in near future. The Morni Hills range in Haryana state is very rich in its floristic diversity and vegetation of hills also maintain the ecological balance of the area in moderating weather conditions by acting a CO2 sink in the environment. Other than this, it also provides habitat to the wild fauna and as well as increases the beauty of nature. However, due to other activities going like pollution and various anthropogenic disturbances immediate attention should be given to conserve this forest ecosystem.

CONCLUSION

Understanding the biodiversity and vegetation structure of forest ecosystems is very important in order to

preserve the inevitable forest resources and to evaluate the complexity within. From the present study, it is easily concluded that Morni Hills which used to be a great aesthetic treasure in the state of Haryana, presently getting degraded due to activities like fire incidents, human interventions, tourism, deforestation, etc. Thus, rigorous actions should be taken for the management and conservation of that area, so as to protect the natural flora of the area which is full of various economically important plant species and is home to wild fauna as well.

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REFERENCES

Baduni, N. P. and Sharma, C. M. 1996. Effect of aspect on the structure of some natural stands of *Quercus semecarpifolia* in Himalayan moist temperate forest. *Indian Journal of Forestry*, 19(4): 335-341.

Batjes, N. H. and Sombroek, W. G. 1997. Possibilities for carbon sequestration in tropical and subtropical soils. Global Change Biology, 3(2): 161–173.

Brown, S. and Lugo, A. 1982. The storage and production of organic matter in tropical forests and their role in the global carbon-cycle. Biotropica, 14930: 161-187.

Brown, S., Sathaye, J., Cannell, M. and Kauppi, P. 1996. Mitigation of carbon emission to atmosphere by forest management. The Commonwealth Forestry Review, 75(1): 80-91.

Curtis, J.T. and Cottam, G. 1956. Plant Ecology Workbook Laboratory Field Reference Manual. Burgess Publishing Co. Minnesota.

Curtis, J.T., and McIntosh, R.P. 1950. The interrelation of certain analytic and synthetic phytosociological characteristics, Ecology, 31: 434-455.

Hoekstra, J. M., Boucher, T. M., Ricketts, T. H. and Roberts, C. 2004. Confronting a biome crisis: global disparities of habitat loss and protection. Ecology Letters, 8(1): 23–29.

Kalembasa SJ and Jenkinson DS. 1973. A comparative study of titrimetric and gravimetric Method for the analysis of organic carbon in soil. Journal of the Science of Food and Agriculture, 1973, 24: 1085-1090.

Kharkwal, G. and Rawat, Y.S. 2010. Structure and composition of vegetation in subtropical forest of Kumaun Himalaya, African J. of Plant Science, 4 (4): 116-121.

Lal, B. and Lodhiyal, L.S. 2015. Vegetation Structure, Biomass and Carbon Content in *Pinus roxburghii* Sarg. Dominant Forests of Kumaun Himalaya. Environ. We Int. J. Sci. Tech., 10: 117-124.

Margalef, D.R. 1958. Information theory in Ecology, Year book of the society for
general systems research, 3: 36-71.

Misra, R. 1968. Ecology work book, Oxford and IBH Publications Co., New Delhi, 244.

Nath, P.C., Arunachalam, A., Khan, M.L., Arunachalam, K. and Barbhuiya, A.R. 2004. Vegetation analysis and tree population structure of tropical evergreen forests in and around Namdapha National Park, northeast India. Biodiversity and Conservation, 14: 2109-2136.

Pausas, J. G., and Austin, M. P. 2001. Patterns of plant species richness in relation to different environments: An appraisal. Journal of Vegetation Science, 12(2): 153–166.

Phillips, B.A. 1959. Methods of vegetation study, Heavy Holt and Co. Inc.

Pielou, E.C. The measurement of diversity in different types of biological collections. Journal of theoretical Biology,1966, 13: 131-144.

Portillo-Quintero, C.A. and Sanchez-Azofiefa, G.A. 2010. Extent and conservation of tropical dry forests in the Americas. Biological Conservation, 143 (1): 144-155.

Raunkiaer, C. 1934. The life forms of plants and statistical plant geography, Clarendon Press, Oxford. 632.

Sahu, S.C., Pani, A.K., Mohanta, M.R. and Kumar, J. 2019. Tree species diversity, distribution and soil nutrient status along altitudinal gradients in Saptasajya hill Range, Eastern Ghats, India. Taiwania 64 (1): 28-38.

Shannon, C.E. and Wienner, W. 1963. The Mathematical Theory of Communication, University of IIIinois, Urana.

Sharma, C.M., Baduni, N.P., Gairola, S., Ghidiyal, S.K. and Suyal, S. 2010. Tree diversity and carbon stocks of some major forest types of Garhwal Himalayas, India. Forest Ecology and Mangement 260: 2170-2179.

Sheikh, M.A., Kumar, M., Bussamn, R.W. and Todaria N.P. 2011. Forest carbon stocks and fluxes in physiographic zones of India. Carbon Balance and Management, 1-10.

Simpson, E.H. 1949. Measurement of Diversity, Nature,163: 688.

Singh, V., Gupta, S.R. and Singh, N. 2014. Vegetation Composition, Species diversity and Soil Carbon Storage in Tropical Dry deciduous forests of Southern Haryana. Indian Journal of Science 7(18): 28-39.

Vieira, D. L. M., & Scariot, A. 2006. Principles of Natural Regeneration of Tropical Dry Forests for Restoration. Restoration Ecology, 14(1): 11–20.

Wadia, D.N. 1961.The Geology of India. Macmillan & Company, London.