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Floristic Composition and Diversity in Response to Varying Degrees of Disturbance in Tropical Dry Deciduous Forests of Southern Haryana, India

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ABSTRACT

The aim of the current investigation was to study the effects of anthropogenic disturbances on the vegetation structure of the three Tropical Dry Deciduous Forests of Southern Haryana i.e., Mandhana, Ghasola, and Mandhiali in the Bhiwani, Charkhi Dadri, and Mahendergarh districts, respectively. The data were collected from March, 2020 to March, 2021. The floristic composition was quantified by randomly placing 15 quadrats per site (45 in total). A disturbance index was developed for each site and high, medium and low disturbance areas were identified based on prevailing disturbances that were found to be maximum for Mandhiali (21), followed by Ghasola (16) and Mandhana (9). Ecological parameters such as frequency, density, abundance, basal area, IVI, and diversity indices were calculated for each siteduring the study. A total of 50 species of plants representing 44 genera and 25 families were observed consisting of 14 trees, 9 shrubs, and 27 herbs during the investigation of floristic composition. The species richness decreased with an increase in the disturbance level on the three sites viz., Mandhana (40), Ghasola (33), and Mandhiali (29) respectively. The value of Shannon Weiner diversity index (H') and Pielou Index of evenness (E) declined with an increasing disturbance while Simpson index of dominance (Cd) increased as the disturbance levels increased across the three sites. The results offer significant evidence that anthropogenic disturbances in arid regions of South Haryana play a vital role in community structure and composition. In a forest ecosystem, anthropogenic disturbances cause habitat fragmentation along with soil erosion, loss of soil fertility and biodiversity, etc. The selected forests are in urgent need of management activities to check the intensity of disturbances by controlling anthropogenic pressure on these ecosystems and save them from further degradation. Thus, the present study intensifies the need for phytosociological studies crucial for proper management and conservation purposes.

Key words: *Anthropogenic disturbances, Biodiversity, Disturbance, Dominance.*

Introduction

Biodiversity delivers a variety of tangible and intangible services like food, fodder, fuelwood, groundwater recharge, eco-tourism, etc., supporting the survival and livelihood of a large number of people along with stakeholders, ecological processes, and functions (Martín-López *et al.*, 2012). Tropical forests are highly diverse land ecosystems covering only 7 % of the earth's terrestrial surface and harbouring nearly half of the global diversity (Hubbell *et al.*, 1983; May and Stumpf, 2000). Of these, nearly 38% of forests with an average annual rainfall of 250-2000 mm and Potential evapotranspiration (PET) of

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more than one, are categorized as tropical dry forests (Holdridge, 1967; Miles *et al.*, 2006), covered over half the tropics once but getting scarce due to anthropic activities. In India, 54 % of tropical forests are categorised as tropical dry deciduous forests (TDDFs) which are getting converted into species-poor grasslands and scrublands due to continuous lopping and forest clearing (Singh and Singh, 1989; Singh and Kushwaha, 2005). The principal cause of biodiversity loss and species extinction is habitat destruction of species residing in these forest ecosystems (Koh *et al.*, 2004; Pimm and raven, 2000). Thus, the present scenario intensifies the need for phytosociological studies crucial for proper management and conservation purposes.

In a forest, the diversity of a species is affected by the equitability of its distribution within the community along with various physiographic factors like elevation, slope aspects, soil, and disturbance-induced inconsistency in the environment (Montagnini and Jordan, 2005; Gairola *et al.*, 2011). In spite of effective management practices, forest disturbances are predominant either natural or human induced, though, the latter may have highly distinct effects (Arya and Ram, 2011). A small degree/level of disturbance may result in the highest diversity in an area by repressing competitive exclusion, but, its frequency and management are a prime concern (Huston, 1979).

Around 60% of the global terrestrial carbon (C) is stored in forests, so the response of forest ecosystems to variation in environment or disturbance regime may have consequences for regional as well as global C cycle (McAlpine *et al.*, 2010; McKinley *et al.*, 2011). The fragmented and sparse populations resulting from human disturbance are budding problems in evolutionary as well asconservation biology (Sork *et al.*, 2002). Thus, the situation demands an in-depth study of deliberating community structure along with regeneration and anthropogenic disturbances that offers a holistic view of forest health along with the management implications necessary for their conservation. Besides its usefulness in forest management, study on species diversity, distribution pattern, and population structure is ecologically significant for the forest ecosystems (Sahu *et al.* 2012). A few floristic studies have been performed in the TDDFs of Haryana (Singh *et al.*, 2014; Dhiman *et al.*, 2020; Saharan *et al.*, 2020). However, available information is limited in arid regions and no such study has been stated in the selected forest areas reporting the effects of anthropogenic disturbances as well.

Hence for the present study, the sites were selected from three districts of Haryana with a certain level of disturbance- Ghasola (Charkhi Dadri), Mandhiali (Mahendergarh), Mandhana (Bhiwani). The disturbance intensity was assessed by developing a disturbance index taking into account the human disturbances on the three sites. For estimating their ecological status various ecological parameters were analyzed like- Frequency (F), Density (D), Basal area (B.A.), Importance value index(IVI), and Diversity indices [Shannon-weiner index (H’), Simpson index (Cd) and Pielou index (E)]. Thus, the study aims to provide significant quantitative information on the current status of the selected TDDFs of Haryana, India that can be helpful during forest management and conservation activities.

Materials and Methods

Study site

Haryana is an agricultural state present in the Northern region of India with 1.3% of the geographical area of the country with poor tree/forest cover of only about 3.62% of the total geographical area of the state (Indian State Forest Report, 2019). The present study was performed in TDDFs of Mandhiali-Mahendergarh, Ghasola-Charkhi Dadri, and Mandhana-Bhiwani of Southern Haryana (Fig. 1), located in arid regions of Haryana where annual rainfall is little during the year. The climate is very hot from June-July and cold from Dec-Jan. The average temperature of Charkhi Dadri is 24.6°C with a wet muggy and warm dry season. There is scanty rainfall with annual precipitation of 483 mm which mainly occurs in the months of July-August. The average temperature of Bhiwani is 25.2°C with annual precipitation of 533 mm. While the average temperature of Mahendergarh is 26.4°C with erratic rainfall patterns and annual precipitation of 500mm (www.worldweatheronline.com).

All the three TDDFs are natural ecosystems which are under anthropogenic pressure causing ecosystem disturbance due to the ever-increasing demands of local people for food, fuelwood, grazing animals, etc. The degree/level of disturbance was deliberated considering various parameters, as shown in Table 1 and the sites were classified according to the varying scores of the perceived dis-

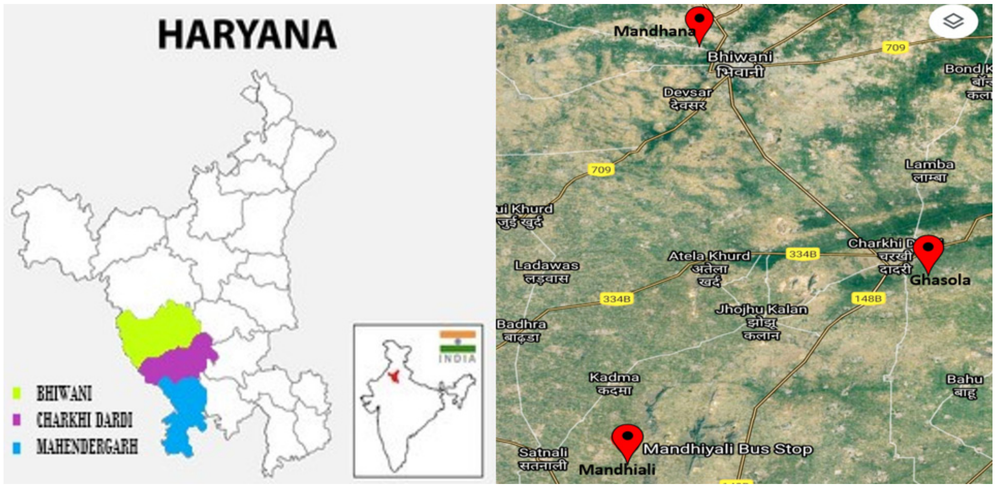

Fig. 1. Location of study sites in Haryana, India (left), google image showing location of selected forests in three districts of southern Haryana with respect to each other (right).

turbance i.e., 1=low, 2=medium, 3=high. Site with a score of <10 is classified as a low disturbance site while the site having a score of 10-20 as a medium disturbance site and with a score of <20 as a high disturbance site (Ramírez-Bravo and Hernández-Santin, 2016).

Vegetation sampling

The fieldwork was carried out from Mar 2020 to Mar 2021 on the selected sites and the data was collected using the quadrat method following the random sampling approach. A total of 45 quadrats were plotted during the study i.e., 15 quadrats on each site with a size of 20×20m. The number of identified tree species was counted in each quadrat and their circumference at breast height or CBH (1.37m above the ground) was measured. Within each quadrat, 2 sub-quadrats of size 5×5m and 5 sub-quadrats of size 1 × 1m were laid down for the enumeration of shrubs and herbs, respectively.

Analysis of vegetation structure and diversity indices

D, F, A, and B.A. of all the plant species was calculated following Phillips (1959) and Mishra (1968). The IVI was analyzed using Curtis and Mcintosh (1951). The frequency class distribution pattern was deliberated as per Raunkiaer(1934)and the abundance to frequency ratio (A/F) was also calculated for each species to analyze their distribution pattern i.e., regular (< 0.025), random (0.025 - 0.05) and contiguous (> 0.05) following Curtis and Cottam (1956). Other than this, the population structure of tree species was determined using CBH values taken for each tree species, by Girth class measurement according to the NRSA manual (2008). To provide the quantitative estimates of plant diversity, Shannon Weiner diversity index-H' (Shannon and Weiner, 1963) and Simpson index of concentration-Cd (Simpson, 1949). Other than this, the evenness of the selected study sites was analyzed using Pielou index (1966) of Equitability-E.

Statistical Analysis

For statistical analysis, Pearson Correlation was calculated for the data and a correlation matrix was prepared using R studio.

Results and Discussion

Any discrete event in a community or ecosystem that disrupts its population structure or the physical environment is considered a disturbance (Pickett and White, 1985). Disturbances are selective thereby causing changes in species composition of natural ecosystems (Kennard *et al.*, 2002), and extreme disturbances may result in loss of forest cover (Plieninger *et al.*, 2004; Dufour-Dror, 2007). The TDDFs are under acute anthropogenic pressure (Miles *et al.*, 2006) and have ranked 3rd highest (after boreal and humid tropical forests) in loss of forest cover (Miles *et al.*, 2006; Hansen *et al.*, 2010).

A variety of anthropogenic disturbances were observed during the study, and the degree of distur-

Table 1. Classification of the study sites with varying degrees of disturbance.

Sl. No.	Disturbance type	Mandhiali HLD	Ghasola MLD	Mandhana LLD
1	Lopping	3	2	1
2	Vegetable cropland	1	1	1
3	Intentional fire	3	1	0
4	Road	1	0	0
5	Soil mining	3	2	1
6	Play ground	1	1	0
7	Local paths	1	2	2
8	Temple	0	1	0
9	Garbage pile	2	3	1
10	Cattle Browsing	3	1	2
11	Dung piles	3	2	1
	Total	21	16	9

Abbreviations: HLD- High level of disturbance, MLD- Medium level of disturbance, LLD- Low level of disturbance.

bance was calculated by developing a disturbance index for each site. For this, the highest value was obtained for Mandhiali (21), followed by Ghasola (16) and Mandhana (9), thus categorizing the three with the high level of disturbance (HLD), medium level of disturbance (MLD), and low level of disturbance (LLD), respectively (Table 1).

Analysis of floristic composition revealed the presence of a total of 50 plant species representing 44 genera and 25 families in the three TDDFs consisting of 14 trees, 9 shrubs, and 27 herbs with the complete absence of any climber species. This can be compared with the results of Sagar *et al.* (2003), as they reported 44 genera and 24 families in the TDDFs in the Vindhyan Hill ranges, Uttar Pradesh. While Saharan *et al.* (2020) reported 70 genera and 37 families during their study in Southwest Haryana, this could be due to the large area under those sites thus inhabiting a higher number of plant species comparatively.

Furthermore, a significant variation was observed in the floristic composition of the three sites due to differences in their disturbance level. The species richness decreased with an increasing level of disturbance across the three sites. The highest number of species were found on Site I (40) followed by Site II (33) and the least number of species were found in Site III (29) within the disturbance regime.

The Habit wise distribution of plant species on the three sites revealed that the site with high disturbance had the minimum proportion of trees i.e., 18% while 21% and 35% were on the sites with MLD and LLD respectively. The reason behind this is high lopping pressure on trees on that site (HLD) to fulfill the needs of fuelwood requirements.

The maximum value of Density was obtained for *Acacia leucophloea* on Site III (D-24.111) and Site II (D-441.67) while for *Prosopis juliflora* (D-32.111) on Site II among tree species. Other than this, among shrubs, the maximum density was observed for *Maytenusemarginata* on Site III (D-10.88) and Site II (D-227.33) while for *Parthenium hysterophorus* on Site I (D-68.444). Amongst herbaceous vegetation, the highest value of density was obtained for *Sisymbrium irio* (D-517.56) in Mandhiali and *Chenopodium murale* in Ghasola (D-11805) and Mandhana (D-384.22), respectively (Table 2). The least amount of density and species richness for trees, shrubs, and herbs was observed in Mandhiali with a High Disturbance Index. This could be attributed to the collection of fuelwood, fodder, and grazing pressure.

The highest value of B.A. for trees was recorded for *Salvadoraoleoides* Site I (15.658) and Site II (28.279) while for *Acacia leucophloea* on Site III (6.8622). This is in accordance with Saharan *et al.* (2020) as the same tree species also showed maximum B.A. on 2 out of 3 sites selected during their study in TDDFs of Haryana.

Among tree species, the Site I was dominated by *Prosopis juliflora* (IVI-64.21) followed by *Acacia leucophloea* (IVI-60.26), *Salvadoraoleoides* (IVI-53.36), and *Ficus religiosa* (IVI-21.49). While the Site II was found to be dominated by *Acacia leucophloea* (IVI-117.96) followed by *Salvadoraoleoides* (IVI-109.85), *Ficus religiosa* (IVI-32.10), and *Prosopis juliflora* (13.22). Other than this, Site III was dominated by *Acacia leucophloea* (IVI-187.64) followed by *Salvadoraoleoides* (IVI- 54.13), *Prosopis juliflora* (IVI-20.83), and *Prosopis cineraria* (IVI-20.22).

For shrubs, the value of IVI varied from 15.4255 to 136.069, 16.008 to 71.506, and 30.4229 to 82.368 on Site III, Site II, and Site I, respectively. The maximum value of IVI was obtained for *Maytenusemarginata* in the TDDFs of both Site III and Site IIi.e., 136.069 and 71.506 respectively followed by *Abutilon indicum* (IVI- 52.28) and *Carissa sapinarum* (IVI-32.08) on Site III while *Capparis decidua* (IVI-70.04), and *Abutilon indicum* (IVI-52.64) on Site II. Whereas, the shrub layer of Site I was dominated by *Parthenium hyterophorus* (IVI-121) followed

Table 2. Consolidated details of phytosociological analysis in the TDDFs of Southern Haryana.

S. No.	Plant Name	Family	Site-I Mandhana			Site-II Ghasola			Site-III Mandhiali		
			D	B.A.	IVI	D	B.A.	IVI	D	B.A.	IVI
A	Trees										
1	*Acacia leucopholea*	Mimosaceae	16.33	4.9594	60.252	441.67	5.3411	117.95	24.11	6.8622	187.63
2	*Acacia nilotica*	Mimosaceae	0.777	1.4444	10.941	18.333	0.299	10.852	0.777	0.2323	17.190
3	*Ailanthus excelsa*	Simaroubaceae	0.555	1.1392	8.2968	_	_	_	_	_	_
4	*Azadirachta indica*	Meliaceae	0.888	4.0111	17.376	3.3333	0.0848	_	_	_	_
5	*Cassia fistula*	Fabaceae	0.222	0.0077	1.9195	_	_	_	_	_	_
6	*Dalbergia sissoo*	Fabaceae	0.333	1.9665	9.9501	_	_	_	_	_	_
7	*Eucalyptus* sp.	Myrtaceae	0.222	0.6175	4.9438	_	_	_	_	_	_
8	*Ficus bengelensis*	Moraceae	0.444	3.0081	12.669	_	_	_	_	_	_
9	*Ficus religiosa*	Moraceae	1.111	5.5472	21.481	3.3333	14.286	32.1	_	_	_
10	*Melia azadirachta*	Meliaceae	0.888	0.6545	12.275	_	_	_	_	_	_
11	*Morus alba*	Moraceae	1.555	0.0476	7.2676	_	_	_	_	_	_
12	*Prosopis cineraria*	Mimosaceae	4.111	0.2732	15.061	11.667	0.6249	10.453	1.444	0.1022	20.217
13	*Prosopis juliflora*	Fabaceae	32.11	1.7082	64.209	20	0.1294	13.211	5.5828	1.555	0.3437
14	*Salvadoraoleoides*	Salvadoraceae	1.777	15.658	53.357	128.33	28.279	109.85	4.666	1.3729	54.127
	Total		**61.33**	**41.043**	**300**	**626.66**	**49.044**	**300**	**36.571**	**10.133**	**300**
B	Shrubs										
1	*Abutilon indicum*	Malvaceae	4.333	0.3833	15.228	131.67	0.6014	52.641	7.555	0.3972	52.275
2	*Calotropis procera*	Asclepiadaceae	2.111	0.3675	20.932	11.667	0.0768	16.008	0.666	0.0477	15.425
3	*Capparis decidua*	Capparaceae	19	2.7085	82.368	128.33	0.546	70.033	1.111	0.5161	21.763
4	*Carrisasapinarum*		_	_	_	_	_	_	5	0.0215	32.077
5	*Capparis saparia*		_	_	_	125	0.1834	47.565	_	_	_
6	*Maytenusemarginata*	Celastraceae	6.888	0.0881	26.942	273.33	0.2292	71.506	10.88	3.2569	136.06
7	*Parthenium hysterophorus*	Asteraceae	68.44	2.2253	121	190	0.1766	42.248	3.111	0.0321	17.029
8	*Solanum viarum*	Solanaceae	0.333	0.0271	3.4229	_	_	_	_	_	_
9	*Ziziphus nummularia*	Rhamnaceae	1.111	1.0647	30.111	_	_	_	2.111	0.0104	25.359
	Total		**102.21**	**5.7998**	**300**	**860**	**1.8134**	**300**	**30.44**	**4.282**	**300**
C	Herbs										
1	*Achyranthes aspera*	Amaranthaceae	38.22	0.3152	13.803	328.33	0.4783	5.8394	_	_	_
2	*Artemisia stelleriana*	Asteraceae	_	_	_	_	_	_	4	0.0094	1.8237
3	*Aera javanica*	Amaranthaceae	_	_	_	40	0.0348	1.9001	4.666	0.1026	4.2885
4	*Argemone mexicana*	Papaveraceae	5.444	0.161	3.6585	_	_	_	_	_	_
5	*Asphodelus tenuifolius*	Asphodelaceae	_	_	_	361.67	0.1253	4.6776	_	_	_
6	*Boerhaviadiffusa*	Nyctaginaceae	_	_	_	61.667	0.0635	4.5743	11.77	0.0751	6.3153
7	*Cannabis sativa*	Cannabaceae	402.5	1.6584	38.471	_	_	_	_	_	_
8	*Cassia occidentalis*	Fabaceae	_	_	_	15	0.0228	1.7971	_	_	_
9	*Chenopodium album*	Amaranthaceae	221.1	0.8948	25.526	11805	1.38	46.034	15.55	0.037	2.8798

Table 2. *Continued ...*

S. No.	Plant Name	Family	Site-I Mandhana			Site-II Ghasola			Site-III Mandhiali		
			D	B.A.	IVI	D	B.A.	IVI	D	B.A.	IVI
10	*Chenopodium murale*	Amaranthaceae	384.2	2.7097	46.566	9756.7	1.295	40.777	288.5	0.77	38.105
11	*Croton bonplandianum*	Euphorbiaceae	24.55	0.8719	12.493	1190	0.2068	6.9692	53.88	0.4515	21.050
12	*Cynodondactylon*	Poaceae	561	1.38	42.418	1286.7	0.1223	6.9059	251.6	0.3005	25.567
13	*Cyperus rotundus*	Cyperaceae	48.44	0.1624	5.475	555	0.1524	4.4008	27.55	0.3429	11.236
14	*Datura innoxia*	Solanaceae	0.444	0.1041	2.2826	–	–	–	–	–	–
15	*Gnaphalium ulignosum*	Asteraceae	6.777	0.0843	1.6413	1470	0.0874	8.0671	161.4	0.161	17.239
16	*Lepidium didymum*	Brassicaceae	31.66	0.2341	6.0389	–	–	–	–	–	–
17	*Malva sylvestris*	Malvaceae	–	–	–	120	0.0351	2.0947	–	–	–
18	*Meliolotus indicus*	Fabaceae	1.222	0.0035	0.845	131.67	0.0183	2.0637	–	–	–
19	*Oxalis corniculata*	Oxalidaceae	4.111	0.0015	0.9522	–	–	–	–	–	–
20	*Phalaris minor*	Poaceae	–	–	–	150	0.0631	3.9466	13.33	0.1258	4.3975
21	*Pupalialappacea*	Amaranthaceae	9.222	0.2582	7.5716	568.33	2.4361	20.874	24.55	0.0102	11.580
22	*Saccharum munja*	Poaceae	20.11	1.1381	9.5461	–	–	–	54.66	0.1633	12.170
23	*Sida cordifolia*	Malvaceae	–	–	–	10	0.0246	0.9512	–	–	–
24	*Sisymbrium irio*	Brassicaceae	299.1	0.8612	25.492	6878.3	20.824	102.54	517.5	0.9603	53.275
25	*Sonchus oleraceus*	Asteraceae	90.66	3.2077	34.627	1501.7	0.6793	11.068	136.8	0.3592	21.147
26	*Spergula arvensis*	Caryophyllaceae	99.11	0.0131	8.8707	4386.7	0.11	17.727	50.11	0.03	6.5973
27	*Verbesinaenceliodes*	Asteraceae	132.2	0.2891	13.724	700	0.2537	6.789	472.8	1.5724	62.324
	Total		**2380.2**	**14.348**	**300**	**41317**	**28.413**	**300**	**2089.1**	**5.4711**	**300**

Abbreviations: D- density, B.A.- basal area, IVI- importance value index.

by *Capparis decidua* (IVI-82.37) and *Ziziphus nummularia* (IVI-30.12).

A total of 20, 19, and 16 herb species were found in TDDFs of Site II (Ghasola), Site I (Mandhana), and Site III (Mandhiali), respectively. Where, the ground floor vegetation was dominated by *Sisymbrium irio* on Site II (IVI-102.55) and Site III (IVI-52.12) while it was dominated by *Chenopodium murale* on Site I with an IVI value of 46.418.

During the investigation of the distribution pattern of vegetation, all the plant species displayeda contiguous/clumped type of distribution and the regular or random distribution was completely absent as the value of A/F ratio was found to be >0.05 for all the plant species. According to Odum (1971), in nature this type of distribution is common whilst the random distribution is observed in uniform environments only. Contiguous distribution of plant species has also been reported by various workers (Rawat *et al.*, 2018; Dhiman *et al.*, 2020; Kumar and Saikia, 2020; Saharan *et al.*, 2020).

To interpret the floristic homogeneity and frequency class distribution of selected TDDFs, frequency diagrams were analysed. During this, most of the species occupied the lower frequency classes revealing the Forest stand as homogenous. In TDDFs of Site II and Site III, the maximum number of the species occurred in frequency class B (21-40%) while Site I displayed the maximum number of species in frequency class A (1-20%) and the minimum number of plant species were reported in class D (61-80%). The J-shaped frequency distribution curve given by Raunkiaer (1934) indicates that the ecosystem is intact without an acute level of disturbance if the curve is J-shaped but if the curve deviates from the J-shape then it shows the presence of ecosystem disturbance. During the present study, Site II and Site III did not exhibit the J-shaped curve as the sites have a sufficient degree of disturbance causing the heterogenous distribution of species. But for Site I, the J-shaped curve was obtained which reflects

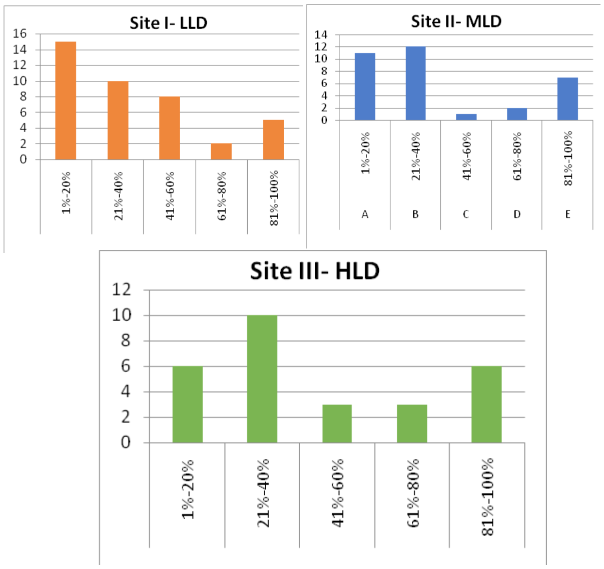

Fig. 2. Frequency class distribution of the plant species encountered during on the selected study sites.

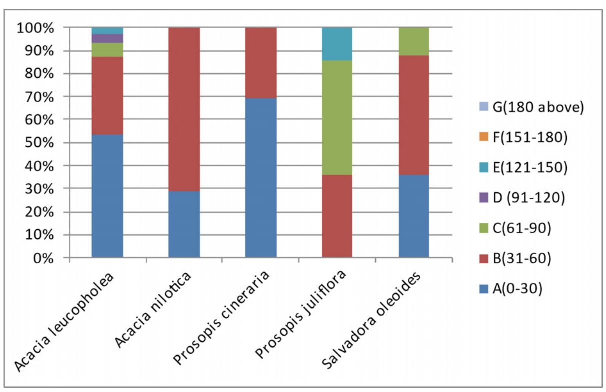

Fig. 3. Population structure of tree species encountered during the study on TDDF of Mandhiali-HLD, Mahendergarh.

that this site is nearly intact with a very low degree of disturbance (Figure 2).

The population structure analysis revealed that the largest fraction of the total tree species belongs to the smallest girth classes with a CBH ranging from 0-30cm (Site I-64.13%, Site II-34.84%, Site III-48.46%) while the minimum percentage of tree species belonged to higher Girth classes ranging from 121-150cm (2.73%) on Site I with LLD, 151-180 cm (6.11%) on Site II with MLD and 151-180 cm (6.11%) on Site III with HLD (Figure 3, 4, 5). The population structure of trees in a forest helps to understand its regeneration behaviour (Saxena and Singh, 1984); the evidenceis utilized by numerous workers to understand the patterns of succession in forest ecosystems (Shugart and West, 1980). The population structure diagrams of the present study sites show that the highest number of individual trees belong to the lowest girth classes i.e., 0 to 30 cm indicating that the stand structure is substantially consisting of young trees, thus having significant regeneration potential. The occurrence of saplings under the adult tree canopies also directs the upcoming community composition. The data can also be utilized in the development of management strategies to attain the desired tree composition and size classes (West *et al.* 1981).

Table 3. Consolidated details of Diversity indices in the forest ecosystem of Mandhana, Bhiwani (Site-I) Ghasola Charkhidadri (Site-II), and Mandhiali, Mahendergarh, Site-III.

Site	Habit	H′	Cd	E
Site-I	Trees	2.25095	0.1363	0.85294
	Shrubs	1.55641	0.26376	0.79984
	Herbs	2.552516	0.09777	0.8576
Site-II	Trees	1.4227	0.30492	0.7311
	Shrubs	1.7112	0.18991	0.955
	Herbs	2.2314	0.17228	0.7449
Site-III	Trees	1.1333	0.43639	0.7042
	Shrubs	1.6167	0.26579	0.8308
	Herbs	2.385	0.1173	0.8602

Abbreviations: H′- Shannon Weiner Index, Cd- Simpson Index, E- Pielou Index.

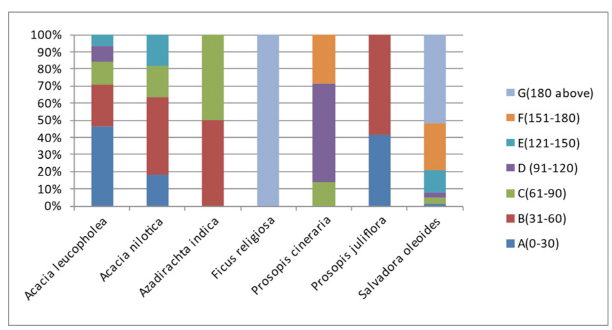

Fig. 4. Population structure of tree species encountered during the study on TDDF of Ghasola-MLD, Charkhi Dadri.

The value of three diversity indices i.e., H′, Cd and E was also measured for the selected TDDFs (Table 3). Species diversity indices depict the rarity or commonness of a species in an ecosystem. The value of H′ was found to be decreasing along with the disturbance regime i.e., LLD (6.3325) >MLD (5.3653) >HLD (5.135) on the three sites, Mandhana

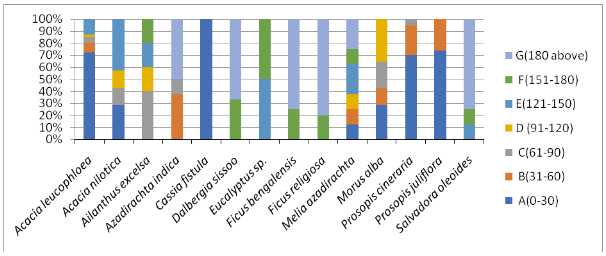

Fig. 5. Population structure of tree species encountered during the study on TDDF of Mandhana-LLD, Bhiwani.

(Site-I), Ghasola (Site-II), and Mandhiali (Site-III) respectively. But the value of Cd was seen to increase along with the increase in disturbance level i.e., Site I- LLD (0.4978) <Site II- MLD (0.66711) <Site III-HLD (0.81948). Other than this, the value of E (Site I- LLD-2.5103> Site II- MLD-2.431> Site III- HLD-2.3952) was found to be steeply decreasing with increasing levels of disturbance on the three sites. The value of H' & E was seen to be decreasing with an increase in disturbance while Cd increased with an increase in the disturbance. The same trend was observed by Mishra *et al.* (2003) during their study in sacred groves of Meghalaya. The diversity, richness, and evenness of species was found to be inversely proportional to the disturbance level by Sagar*et al.* (2003).

After that, Pearson correlation analysis was performed on the data, and a histogram showing the correlation of studied parameters was created using R Studio (Figure 6). Significant results were obtained from statistical analysis. D was found to be positively correlated with A, B.A. & H' while negatively correlated with Cd & E. The value of B.A. correlated positively with D &H' while correlated negatively with A, Cd & E. other than this, H' was found to correlate positively with all the parameters except Cd.

Various studies suggested that in an ecosystem, stability increases with the complexity i.e., with species richness and the sum of their interactions/diversity. Consequently, the present scenario of increasing anthropogenic disturbances in the TDDFs of the Haryana state could potentially result in a reduction in their stability as well as complexity of the species among them.

In South and Southeast Asia, the net forest loss frequency increased by 25% between 2010 and 2015 since the 1990s (Keenan *et al.*, 2015). The tropical forests'disturbancesare mostly attributable to anthropogenic activities that are accountable for the foremost land use-derived atmospheric CO_2 additions around the world (Elmqvist *et al.*, 2007; Grace *et al.*, 2014). The TDDFs of India provision around 81% to 100% needs of household fuel while 80% to 95% of the needs of livestock fodder in the country (Singh and Singh, 1989). Thus, the forests are vital as

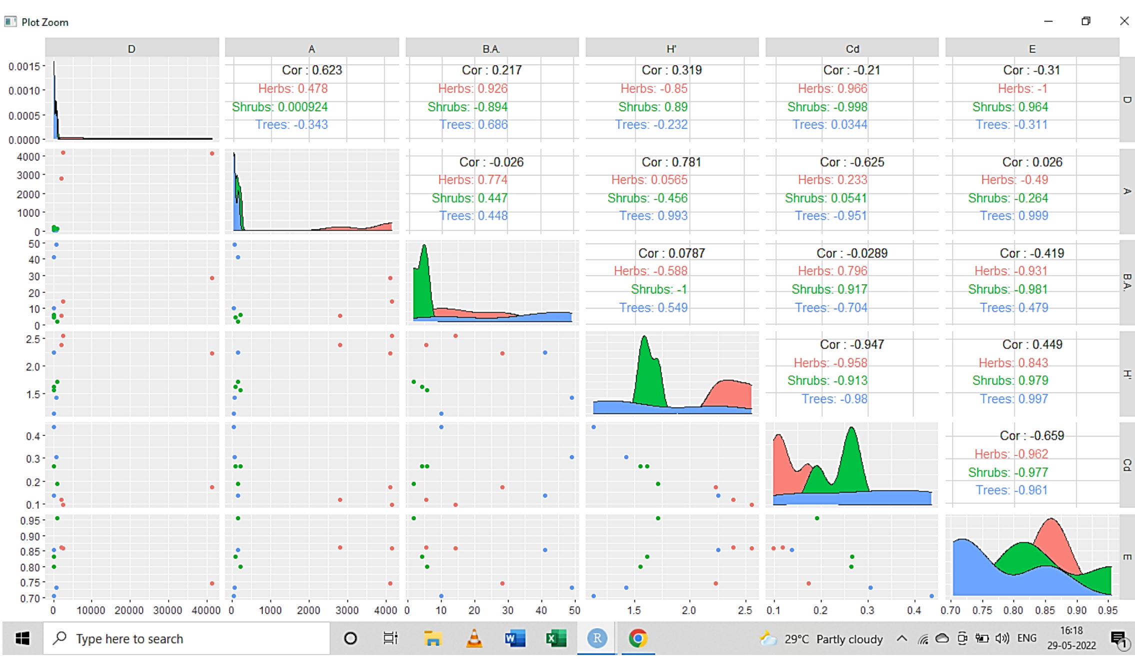

Fig. 6. Correlation matrix prepared using R studio showing the correlation of studied parameters.

they offer substantial and crucial resources to local communities. Thereby, efficient management activities should be performed in these forest ecosystems, focussing primarily on the decline of anthropogenic pressure and their sustainable growth.

The current study advocates that the minor disturbances in the forest ecosystems by fuel-wood collection, and animal grazing does not influence phytodiversity adversely. Though, an increased level of disturbance like uncontrolled tree felling, soil mining, and construction activities resulted in the loss of phytodiversity and lead to change in community structure. Thus, educating the people of local communities deriving benefits from the forest resources via awareness drives for sustainable utilization of resources and their participation in management approaches will help in the conservation of these forest ecosystems.

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Conflict of interest

The authors do not hold any conflict of interest regarding the content of this article.

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