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Vegetational Diversity in Submerged Hydro-Electric Project in the Eastern Himalaya

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Abstract: The study was conducted to assess the vegetation diversity and forest structure in and around the Dumbur Hydroelectric Project in the Lower Eastern Himalayan Region of Tripura, India. A nested quadrat design was used with slight modifications to assess plant diversity. A total of 221 plant species were recorded, of which, 112 were herb species (53 families), followed by 45 shrub species (20 families), and 64 tree species (26 families). The Simpson index (1–D = 0.83) and Shannon diversity (H = 2.15) reflect moderate taxonomic diversity, while the evenness (E^H = 0.64) suggests that some shrub species are far more abundant than others. The diversity analysis showed a clear stratified pattern of species distribution and revealed gradient of decreasing diversity from herbs to shrubs to trees. This structure reflects ecological conditions that favour herbaceous species richness and suggests varying levels of disturbance, succession, or competitive interactions across vegetation strata in the study area. The vegetation of the study area is vital for sustaining the livelihoods of the local people, as most of the surrounding communities are forest-dwelling communities. This study calls for an urgent conservation initiative to conserve biological diversity, while ensuring food security, livelihood, and sustainable development.

Keywords: Bioresource, Indian Himalayan Region, Plant diversity, Socio-ecological landscape, Sustainable resource use

Globally, more than 1.6 billion people depend on forests for subsistence, livelihood, employment, and income generation (UNDESA-UNFFS 2021). It plays an essential role in soil conservation, mitigation of the impact of climate change, and control of water runoff, food security, and job opportunities in tropical areas (FAO 2006). The National Forest Policy (NFP) of 1988 foresees a target of achieving 33 per cent forest cover with respect to forest and tree cover. The total forest cover of India, as per the current assessment, is 7,15,342.61 $km^{2,}$ that is, 21.76 per cent of the total geographical area of the country, of which Tripura constitutes 7,584.77 km^2 of forest land, that is, 72.33 per cent of the total geographical area of the state (FSI 2023). However, the global biodiversity crisis has given rise to growing concerns for which conservation and sustainable use of biodiversity and natural resources is the only key to sustainable development (Johnson et al., 2024). The assessment of species diversity is crucial for checking ecosystem health, as it influences key ecological processes (Naidu and Kumar 2016). The Himalayan region is a rich biodiversity area that boasts about 8000 angiosperms, 44 gymnosperms, and 60 pteridophytes (Singh and Hajra 1996, Thakur et al., 2005) and the state of Tripura is endowed with rich biodiversity with 1463 species of angiosperms and 13 species of gymnosperms (Naithani 2020).

The Dumbur Reservoir is an artificial lake created in 1976 by the creation of the 15 MW hydroelectric project at Dumbur, which falls on the river Gomati in the Indian Lower Eastern Himalayan Region, Tripura. The HEP had a submerged area of approximately 40 sq. km. The land lies within the Gumti wildlife sanctuary. This has led to about 27000 indigenous farmers being displaced and relocated towards the biodiversity-rich natural forest hill slopes, leading them to over-dependency on forest resources due to the absence of sustainable livelihood options. Hence, they ultimately become a threat to local biodiversity, however, no assessment of the available biodiversity, especially regarding vegetation diversity. The ethnic communities residing in these landscapes were mostly Reang, Tripura, Chakma, Jamatia, Molsom, and Bengalis. They collect resources from forests for food, fodder, and livelihoods, in addition to practising jhum/shifting cultivation. Limited livelihood options, sometimes, drive them to adopt monoculture-based commercial plantations by converting natural forests into areca nut or rubber plantations. This type of land use conversion may soon create serious issues. Owing to their dependence on forests and deforestation, some minor fruits, tuberous crops, and important bamboo species are threatened by conservation. It is widely accepted that indigenous peoples and local communities are custodians of a vast share of the world's genetic resources. Their traditional knowledge and practices have proven to be impertinent to biodiversity conservation and sustainable use (UNDP 2011). Thus, engaging the community in identifying important plant diversities enhances awareness and conservation efforts. The impact of HEPs on terrestrial biodiversity can be understood by studying the richness of local species and bioclimatic conditions. This study was conducted to obtain a detailed understanding of the vegetation structure and its importance for HEP-affected people. This will also provide baseline information on the availability of different plant species and help natural resource managers to generate management plans for the area.

MATERIAL AND METHODS

Standard methods were adopted in this study and are discussed in detail in the following sections (Fig. 1).

Description of the study site: Tripura is the second-smallest state in northeast India and the third-smallest in the country, with a geographical area of 10,491 km^2. It belongs to the biogeographic zone of 9B. The study area lies between 23°22' to 23°42' N and 91°43′ to 91°58' E, and is the watershed area of the Dumbur reservoir falling under two administrative districts of Tripura *viz.,* Dhalai and Gomati. The basin areas obtained after delineation with GIS dataset and census data is estimated at 550.70 sq. km (Selvan and Dasgupta 2018). The elevation ranges between 40 to 300m above the mean sea level. The climate of this area is generally moist and humid. The minimum and maximum temperatures of the area are between 4 and 33°C during the winter. In summer, the temperature ranges from 21 to 38°C. The average annual rainfall varies between 1922 and 2855 mm and increases from southwest to northeast monsoon. This study was conducted in the adjoining forest landscapes of the Dumbur Reservoir, which falls under the Gumti Wildlife Sanctuary, Tripura.

Sampling procedure: Eleven line transects of 500 m each were laid around the reservoir in such a way that the starting point of the transect started from the nearby waterbody area and it moved towards a higher altitude towards the natural forests (Table 1). The vegetation was studied using a random sampling method to obtain the most representative vegetation composition. The fieldwork was conducted using the nested quadrat design (Peet et al., 1998, Barnett et al., 2019) with slight modifications by removing the centre

Fig. 1. Scheme of work

Table 1. Location details of study area

Transact name	Site/ Locality	Start point		End point	
		Latitude	Longitude	Latitude	Longitude
T1	Monadhan Para	23°33'18.32°N	91°49'42.73°E	23°34'°4.65°N	91°50'27.98°E
T2	Rupadhan Para	23°33'35.79°N	91°49'44.97°E	23°35'06.97°N	91°49'57.17°E
T3	Jagaram Para	23°29'54.08°N	91°51'38.13°E	23°29'51.51°N	91°51'43.73°E
T4	Nakku-Indrajoy Para	23°30'°6.84°N	91°48'31.38°E	23°32'18.95°N	91°48'°3.37°E
T5	Bhakta Para	23°31'40.23°N	91°50'53.56°E	23°33'04.05°N	91°51'48.96°E
T6	Chaplingchara	23°24'°3.67°N	91°50'09.08°E	23°24'03.78°N	91°49'46.03°E
T7	Mandirghat	23°25'17.75°N	91°49'07.15°E	23°25'17.09°N	91°49'15.74°E
T8	Gudhamjoy Para	23°25'35.38°N	91°52'21.34°E	23°25'26.73°N	91°52'42.59°E
T9	Bijoy Para	23°30'39.36°N	91° 52'57.05°E	23°31'15.24°N	91°53'16.78°E
T10	Mandul kami	23°34'04.91°N	91°48'10.41°E	23°35'33.75°N	91°46'38.32°E
T11	Mitrahum Para	23°34'24.18°N	91°51'09.92°E	23°35'02.25°N	91°51'09.76°E

quadrat to make the fieldwork more manageable. Total forty-four (44) quadrats of size 20 x 20 m were laid along the 11 transect lines, each transect having four quadrats (Fig. 2). Quadrats were laid alternatively along the transect lines, that is, two quadrats on the left and two quadrats on the right of the transect line. These sampled quadrates were used for necessary measurements of the tree samples. In each 20 × 20 m quadrat, two quadrats of size 5 × 5 m at the opposite corners for shrub species, and four quadrats of size 1 × 1 m were laid out for herb species. The total 44 quadrats for trees, 88 quadrats for shrub species, and 176 quadrats for herb species were laid.

Assessment of the vegetational diversity: Vegetation composition was evaluated by analyzing the frequency, density, abundance, importance value index (IVI), and A/F value (Mishra 1968, Tripathi 2004). Species were identified using the Flora of the State Tripura, Flora of Assam, and other secondary literatures (Kanjilal et al., 1938, Deb 1981, 1983).

Data analysis and compilation: Based on the number of species and individuals recorded in different quadrats, vegetation data were analyzed quantitatively for estimating relative frequency, relative density, relative abundance, and their sum as the IVI (Curtis and McIntosh 1950, Naidu and Kumar 2016). The Simpson index, Shannon-Weiner index, Margalef index, and evenness index were determined following standard methodology (Simpson 1949, Shannon and Weiner 1963, Pielou 1966, Margalef 1968). Diversity indices were analyzed using the Past 4.09 software. Microsoft Office Excel software was used to compile and calculate the collected data using the aforementioned equations.

RESULTS AND DISCUSSION

Composition and structure of vegetation: The present study recorded 221 species, of which, 112 species were herbs, 45 were shrubs, and 64 were tree species belonging to 76 families. The highest number of species was 22 in the family Fabaceae, followed by 13 species each in Asteraceae and Euphorbiaceae, and 11 species in Poaceae (Table 2). The total number of 7328 individuals was reported in the current study, of which 4665 were herbs, 2193 were shrubs, and 470 were trees. The highest number of individuals was 1580 in the family Poaceae, followed by Asteraceae and Fabaceae. Of the total vegetation, the percentage of species in herb lifeform was the highest (51%), followed by trees (29%), and shrubs (20%). Similarly, the percentage of individuals was found to be highest in herb (64%), followed by shrub (30%), and tree lifeforms (6%).

Herb vegetation: A total of 4665 individuals from 112 herb species belonging to 53 families were identified. The Asteraceae family showed the highest number of species (10), followed by Zingiberaceae and Poaceae (Table 2). Poaceae showed the highest number of individuals (1253), followed by Fabaceae and Asteraceae. The highest frequency (50) was in *Cyrtococcum oxyphyllum*, followed by *Imperata cylindrica*, and *Mimosa pudica.* The density was

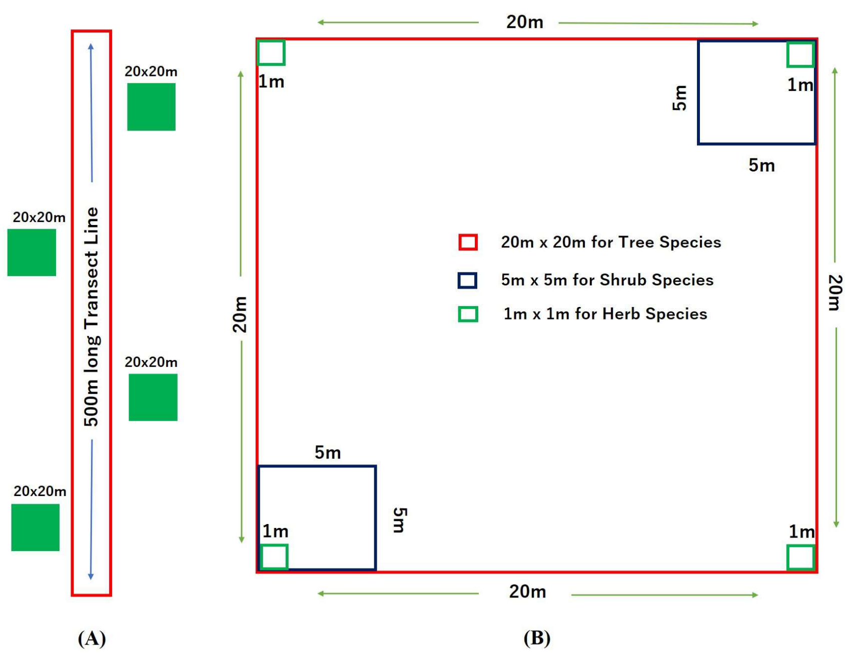

Fig. 2. Layout map of sampling: (A) 500m Line Transect (B) 20 x 20 m Quadrat with different components

Table 2. Family wise species and numbers in each habit (life form)

Family	Herb		Shrub		Tree	
	Species	Individual	Species	Individual	Species	Individual
Acanthaceae	01	42	-	-	-	-
Adiantaceae	01	04	-	-	-	-
Alangiaceae	-	-	-	-	01	01
Amaranthaceae	03	33	-	-	-	-
Anacardiaceae	-	-	-	-	02	9
Apiaceae	02	220	-	-	-	-
Apocynacae	01	8	02	20	02	15
Araceae	03	55	-	-	-	-
Araliaceae	-	-	-	-	01	01
Asteraceae	10	279	03	541	-	-
Athyriaceae	01	48	-	-	-	-
Bignoniaceae	-	-	-	-	03	27
Bombacaceae	-	-	-	-	01	02
Boraginaceae	01	9	-	-	-	-
Bromeliaceae	01	15	-	-	-	-
Buddlejaceae	01	05	-	-	-	-
Burseraceae	-	-	-	-	02	05
Cannabaceae	-	-	-	-	01	12
Cariaceae	-	-	-	-	01	2
Combretaceae	-	-	01	03	01	6
Commelinaceae	02	53	-	-	-	-
Convolvulaceae	06	97	-	-	-	-
Costaceae	01	39	-	-	-	-
Crassulaceae	01	5	-	-	-	-
Cucurbitaceae	02	33	-	-	-	-
Cyperaceae	03	85	-	-	--	-
Dilleniaceae	-	-	-	-	02	8
Dioscoreaceae	05	276	-	-	-	-
Dryopteridaceae	02	28	-	-	-	-
Euphorbiaceae	02	35	03	34	08	68
Fabaceae	05	386	09	131	08	53
Gleicheniaceae	01	33	-	-	-	-
Hypoxidaceae	03	158	-	-	-	-
Lamiaceae	01	97	05	302	02	58
Lecythidaceae	-	-	-	-	01	01
Leeaceae	-	-	01	01	-	-
Linderniaceae	01	98	-	-	-	-
Loranthaceae	-	-	01	02	-	-
Lycopodiaceae	01	3	-	-	-	-
Lygodiaceae	02	88	-	-	-	-
Lythraceae	01	8	-	-	02	60
Malvaceae	02	112	02	250	04	32

Cont...

Table 2. Family wise species and numbers in each habit (life form)

Family	Herb		Shrub		Tree	
	Species	Individual	Species	Individual	Species	Individual
Marantaceae	01	13	-	-	-	-
Melastomaceae	-	-	02	119	-	-
Meliaceae	-	-	-	-	01	09
Menispermaceae	02	64	-	-	-	-
Moraceae	-	-	-	-	10	36
Musaceae	02	38	-	-	-	-
Myrsinaceae	-	-	01	05	-	-
Myrtaceae	-	-	-	-	03	12
Nyctaginaceae	01	12	-	-	-	-
Onagraceae	02	34	-	-	-	-
Orchidaceae	02	16	-	-	-	-
Oxalidacece	01	46	-	-	-	-
Palmae	-	-	02	06	-	-
Papaveraceae	01	2	-	-	-	-
Passifloraceae	01	25	-	-	-	-
Phyllanthaceae	-	-	-	-	01	2
Piperaceae	01	30	-	-	-	-
Plantaginaceae	01	33	-	-	-	-
Poaceae	07	1253	04	327	-	-
Polygonaceae	03	61	-	-	-	-
Polypodiaceae	01	5	-	-	-	-
Rhamnaceae		-	01	08	01	04
Rubiaceae	02	229	02	21	01	15
Rutaceae		-	02	25	02	2
Scrophulariaceae	01	160	-	-	-	-
Solanaceae	02	73	01	96	-	-
Stemonaceae	01	03	-	-	-	-
Sterculiaceae	-	-	01	21	-	-
Thelypteridaceae	01	03	-	-	-	-
Tiliaceae	-	-	-	-	01	02
Urticaceae	01	12	01	11	-	
Verbenaceae	01	57	01	270	02	28
Vitaceae	02	23	-	-	-	-
Vittariaceae	01	03	-	-	-	-
Zingiberaceae	08	118	-	-	-	-
Total	112	4665	45	2193	64	470

highest in *I. cylindrica* (11.20), followed by *C. oxyphyllum* and *Spermacoce latifolia*, while abundance was highest in *Centella asiatica* (44.25), followed by *Stachytarpheta australis* and *I. cylindrica.* The highest IVI was 17.24 in *I. cylindrica,* followed by *C. oxyphyllum Centella asiatica* (Table 3).

Shrub vegetation: A total of 45 shrub species, consisting of 2193 individuals belonging to 20 families, were reported in this study. The Fabaceae family showed the highest number of species (9), followed by Lamiaceae and Poaceae (Table 2). The family Asteraceae had the highest number of individuals (541), followed by Poaceae and Lamiaceae. The

Table 3. Diversity indices of herb species

Species name	Family	F	RF	D	RD	A	RA	IVI	A/F
Achyranthes aspera L.	Amaranthaceae	9.09	0.77	0.43	0.41	4.75	0.55	1.72	0.52
Acmella oleracea (L.) R.K. Jansen	Asteraceae	2.27	0.19	0.16	0.15	7.00	0.80	1.15	3.08
Adiantum caudatum L.	Adiantaceae	2.27	0.19	0.09	0.09	4.00	0.46	0.74	1.76
Ageratum conyzoides L.	Asteraceae	22.73	1.92	1.52	1.44	6.70	0.77	4.13	0.29
Alocasia indica (Lour.) Spach	Araceae	2.27	0.19	0.05	0.04	2.00	0.23	0.46	0.88
Alpinia allughas (Retz.) Roscoe	Zingiberaceae	4.55	0.38	0.45	0.43	10.00	1.15	1.96	2.20
Alpinia malaccensis (Burm.f.) Roscoe.	Zingiberaceae	13.64	1.15	1.02	0.96	7.50	0.86	2.98	0.55
Amaranthus spinosus L.	Amaranthaceae	2.27	0.19	0.07	0.06	3.00	0.34	0.60	1.32
Ammannia baccifera L.	Lythraceae	2.27	0.19	0.18	0.17	8.00	0.92	1.28	3.52
Amorphophallus bulbifer (Roxb.) Blume	Araceae	22.73	1.92	0.95	0.90	4.20	0.48	3.31	0.18
Ananas comosus (L.) Merr.	Bromeliaceae	4.55	0.38	0.34	0.32	7.50	0.86	1.57	1.65
Argemone mexicana L.	Papaveraceae	2.27	0.19	0.05	0.04	2.00	0.23	0.46	0.88
Arundo donax L.	Poaceae	6.82	0.58	0.11	0.11	1.67	0.19	0.88	0.24
Axonopus compressus (Sw.) P.Beauv.	Poaceae	13.64	1.15	2.70	2.55	19.83	2.28	5.98	1.45
Blumea lanceolaria (Roxb.) Druce	Asteraceae	2.27	0.19	0.07	0.06	3.00	0.34	0.60	1.32
Boehmeria nivea (L.) Gaudich.	Urticaceae	6.82	0.58	0.27	0.26	4.00	0.46	1.29	0.59
Boerhavia diffusa L.	Nyctaginaceae	4.55	0.38	0.27	0.26	6.00	0.69	1.33	1.32
Buddleja asiatica Lour.	Buddlejaceae	4.55	0.38	0.11	0.11	2.50	0.29	0.78	0.55
Cayratia trifolia (L.) Domin	Vitaceae	2.27	0.19	0.18	0.17	8.00	0.92	1.28	3.52
Centella asiatica (L.) Urb.	Apiaceae	9.09	0.77	4.02	3.79	44.25	5.08	9.64	4.87
Chenopodium album L.	Amaranthaceae	2.27	0.19	0.25	0.24	11.00	1.26	1.69	4.84
Coccinia grandis (L.) Voigt	Cucurbitaceae	13.64	1.15	0.57	0.54	4.17	0.48	2.17	0.31
Colocasia esculenta (L.) Schott.	Araceae	2.27	0.19	0.25	0.24	11.00	1.26	1.69	4.84
Commelina paludosa Blume	Commelinaceae	6.82	0.58	0.75	0.71	11.00	1.26	2.55	1.61
Costus speciosus (J.König) Sm.	Costaceae	20.45	1.73	0.89	0.84	4.33	0.50	3.06	0.21
Curculigo latifolia Dryand. ex W.T.Aiton	Hypoxidaceae	13.64	1.15	1.45	1.37	10.67	1.22	3.75	0.78
Curculigo orchioides Gaertn.	Hypoxidaceae	20.45	1.73	2.00	1.89	9.78	1.12	4.74	0.48
Curculigo recurvata Dryand.	Hypoxidaceae	2.27	0.19	0.14	0.13	6.00	0.69	1.01	2.64
Curcuma longa L.	Zingiberaceae	2.27	0.19	0.30	0.28	13.00	1.49	1.96	5.72
Curcuma zedoaria (Christm.) Roscoe	Zingiberaceae	2.27	0.19	0.09	0.09	4.00	0.46	0.74	1.76
Cuscuta reflexa Roxb.	Convolvulaceae	2.27	0.19	0.02	0.02	1.00	0.11	0.33	0.44
Cyclea barbata Miers.	Menispermaceae	11.36	0.96	0.66	0.62	5.80	0.67	2.25	0.51
Cyclosorus unitus (L.) Ching	Thelypteridaceae	2.27	0.19	0.07	0.06	3.00	0.34	0.60	1.32
Cymbidium aloifolium (L.) Sw.	Orchidaceae	6.82	0.58	0.18	0.17	2.67	0.31	1.05	0.39
Cynodon dactylon (L.) Pers.	Poaceae	13.64	1.15	2.52	2.38	18.50	2.12	5.66	1.36
Cyperus pilosus Vahl.	Cyperaceae	6.82	0.58	0.75	0.71	11.00	1.26	2.55	1.61
Cyrtococcum oxyphyllum (Steud.) Stapf	Poaceae	50.00	4.23	9.02	8.51	18.05	2.07	14.81	0.36
Dendrobium transparens Wall. ex Lindl.	Orchidaceae	6.82	0.58	0.18	0.17	2.67	0.31	1.05	0.39
Dicranopteris linearis (Burm.f.) Underw.	Gleicheniaceae	15.91	1.35	0.75	0.71	4.71	0.54	2.59	0.30
Dioscorea bulbifera L.	Dioscoreaceae	2.27	0.19	0.09	0.09	4.00	0.46	0.74	1.76
Dioscorea deltoidei Wall. ex Grisep.	Dioscoreaceae	15.91	1.35	0.64	0.60	4.00	0.46	2.41	0.25
Dioscorea glabra Roxb.	Dioscoreaceae	18.18	1.54	0.91	0.86	5.00	0.57	2.97	0.28
Dioscorea hamiltonii Hook. f.	Dioscoreaceae	20.45	1.73	2.25	2.12	11.00	1.26	5.12	0.54
Dioscorea villosa L.	Dioscoreaceae	27.27	2.31	2.39	2.25	8.75	1.00	5.56	0.32
Diplazium esculentum (Retz.) Sw.	Athyriaceae	13.64	1.15	1.09	1.03	8.00	0.92	3.10	0.59
Drynaria quercifolia (L.) J. Sm.	Polypodiaceae	4.55	0.38	0.11	0.11	2.50	0.29	0.78	0.55
Dryopteris affinis Fraser-Jenk.	Dryopteridaceae	2.27	0.19	0.09	0.09	4.00	0.46	0.74	1.76
Etlingera linguiformis (Roxb.) R.M.Sm.	Zingiberaceae	4.55	0.38	0.20	0.19	4.50	0.52	1.09	0.99
Euphorbia hirta L.	Euphorbiaceae	4.55	0.38	0.55	0.51	12.00	1.38	2.28	2.64
Evolvulus nummularius L.	Convolvulaceae	6.82	0.58	0.86	0.81	12.67	1.45	2.85	1.86
Fimbristylis aestivalis Vahl.	Cyperaceae	6.82	0.58	0.64	0.60	9.33	1.07	2.25	1.37
Floscopa scandens Lour.	Commelinaceae	6.82	0.58	0.45	0.43	6.67	0.77	1.77	0.98
Globba racemose sm.	Zingiberaceae	2.27	0.19	0.07	0.06	3.00	0.34	0.60	1.32
Heliotropium indicum L.	Boraginaceae	4.55	0.38	0.20	0.19	4.50	0.52	1.09	0.99
Hydrocotyle sibthorpioides Lam.	Apiaceae	4.55	0.38	0.98	0.92	21.50	2.47	3.77	4.73
Hypolytrum nemorum (Vahl.) Spreng	Cyperaceae	9.09	0.77	0.55	0.51	6.00	0.69	1.97	0.66
Imperata cylindrica (L.) Raeusch.	Poaceae	45.45	3.85	11.20	10.57	24.65	2.83	17.24	0.54

Cont...

Table 3. Diversity indices of herb species

Species name	Family	F	RF	D	RD	A	RA	IVI	A/F
Ipomoea carnea Jacq.	Convolvulaceae	4.55	0.38	0.43	0.41	9.50	1.09	1.88	2.09
Ipomoea heterotricha Didr.	Convolvulaceae	2.27	0.19	0.16	0.15	7.00	0.80	1.15	3.08
Kalanchoe pinnata (Lam.) Pers.	Crassulaceae	2.27	0.19	0.11	0.11	5.00	0.57	0.87	2.20
Lepistemon binectariferum (Wall.) Kuntze	Convolvulaceae	15.91	1.35	0.57	0.54	3.57	0.41	2.29	0.22
Lindernia antipoda (L.) Alston.	Linderniaceae	18.18	1.54	2.23	2.10	12.25	1.41	5.05	0.67
Ludwigia perennis L.	Onagraceae	4.55	0.38	0.23	0.21	5.00	0.57	1.17	1.10
Ludwigia prostrata Roxb.	Onagraceae	4.55	0.38	0.55	0.51	12.00	1.38	2.28	2.64
Lycopodium cernuum L.	Lycopodiaceae	2.27	0.19	0.07	0.06	3.00	0.34	0.60	1.32
Lygodium flexuosum (L.) Sw.	Lygodiaceae	29.55	2.50	1.93	1.82	6.54	0.75	5.07	0.22
Lygodium scandens (L.) Sw.	Lygodiaceae	2.27	0.19	0.07	0.06	3.00	0.34	0.60	1.32
Melochia corchorifolia L.	Malvaceae	9.09	0.77	0.66	0.62	7.25	0.83	2.22	0.80
Merremia vitifolia (Burm.f.) Hallier f.	Convolvulaceae	4.55	0.38	0.16	0.15	3.50	0.40	0.94	0.77
Mesosphaerum suaveolens (L.) Kruntze	Lamiaceae	18.18	1.54	2.20	2.08	12.13	1.39	5.01	0.67
Mikania scandens (L.) Willd	Asteraceae	31.82	2.69	2.36	2.23	7.43	0.85	5.77	0.23
Mimosa pudica L.	Fabaceae	40.91	3.46	3.48	3.28	8.50	0.98	7.72	0.21
Mucuna bracteata L.	Fabaceae	6.82	0.58	0.23	0.21	3.33	0.38	1.17	0.49
Musa balbisiana Colla	Musaceae	11.36	0.96	0.43	0.41	3.80	0.44	1.81	0.33
Musa x paradIsiaca L.	Musaceae	9.09	0.77	0.43	0.41	4.75	0.55	1.72	0.52
Mussaenda erosa Champ. ex Benth.	Rubiaceae	15.91	1.35	0.64	0.60	4.00	0.46	2.41	0.25
Nelsonia canescens (Lam.) Spreng.	Scrophulariaceae	31.82	2.69	3.64	3.43	11.43	1.31	7.43	0.36
Oxalis corniculata L.	Oxalidacece	9.09	0.77	1.05	0.99	11.50	1.32	3.08	1.27
Parthenium hysterophorus L.	Asteraceae	9.09	0.77	0.57	0.54	6.25	0.72	2.02	0.69
Paspalum conjugatum P.J. Bergius	Poaceae	11.36	0.96	1.91	1.80	16.80	1.93	4.69	1.48
Passiflora foetida L.	Passifloraceae	18.18	1.54	0.57	0.54	3.13	0.36	2.43	0.17
Peperomia pellucida (L.) Kunth	Piperaceae	4.55	0.38	0.68	0.64	15.00	1.72	2.75	3.30
Phrynium pubinerve Blume	Marantaceae	4.55	0.38	0.30	0.28	6.50	0.75	1.41	1.43
Phyllanthus urinaria L.	Euphorbiaceae	4.55	0.38	0.25	0.24	5.50	0.63	1.25	1.21
Physalis minima L.	Solanaceae	15.91	1.35	1.07	1.01	6.71	0.77	3.12	0.42
Polygonum hydropiper L.	Polygonaceae	4.55	0.38	1.02	0.96	22.50	2.58	3.93	4.95
Polystichum acrostichoides (Michx.) Schott.	Dryopteridaceae	11.36	0.96	0.55	0.51	4.80	0.55	2.03	0.42
Pueraria phaseoloides (Roxb.) Benth.	Fabaceae	9.09	0.77	0.32	0.30	3.50	0.40	1.47	0.39
Pueraria tuberosa (Willd.) DC.	Fabaceae	25.00	2.12	1.32	1.24	5.27	0.61	3.96	0.21
Rauwolfia serpentina (L.) Benth.	Apocynacae	6.82	0.58	0.18	0.17	2.67	0.31	1.05	0.39
Rumex maritimus L.	Polygonaceae	4.55	0.38	0.30	0.28	6.50	0.75	1.41	1.43
Rumex nepalensis Spreng.	Polygonaceae	2.27	0.19	0.07	0.06	3.00	0.34	0.60	1.32
Scoparia dulcis L.	Plantaginaceae	13.64	1.15	0.75	0.71	5.50	0.63	2.49	0.40
Senna tora (L.) Roxb.	Fabaceae	18.18	1.54	3.43	3.24	18.88	2.17	6.94	1.04
Sida acuta Burm.f.	Malvaceae	25.00	2.12	1.89	1.78	7.55	0.87	4.76	0.30
Solanum nigrum L.	Solanaceae	11.36	0.96	0.59	0.56	5.20	0.60	2.12	0.46
Spermacoce latifolia Aubl.	Rubiaceae	27.27	2.31	4.57	4.31	16.75	1.92	8.54	0.61
Spilanthes acmella L.	Asteraceae	2.27	0.19	0.27	0.26	12.00	1.38	1.83	5.28
Spilanthes paniculata Wall. ex DC	Asteraceae	2.27	0.19	0.18	0.17	8.00	0.92	1.28	3.52
Spilanthes radicans Schrad. ex DC	Asteraceae	4.55	0.38	0.41	0.39	9.00	1.03	1.80	1.98
Stachytarpheta australis Moldenke	Verbenaceae	4.55	0.38	1.30	1.22	28.50	3.27	4.88	6.27
Stemona tuberosa Lour.	Stemonaceae	2.27	0.19	0.07	0.06	3.00	0.34	0.60	1.32
Synedrella nodiflora (L.) Gaertn	Asteraceae	4.55	0.38	0.55	0.51	12.00	1.38	2.28	2.64
Tetrastigma harmandii Planch	Vitaceae	11.36	0.96	0.34	0.32	3.00	0.34	1.63	0.26
Thladiantha calcarata (Wall.) C.B. Clarke	Cucurbitaceae	6.82	0.58	0.18	0.17	2.67	0.31	1.05	0.39
Thunbergia grandiflora Roxb.	Acanthaceae	25.00	2.12	0.95	0.90	3.82	0.44	3.45	0.15
Thysanolaena latifolia (Roxb. ex Hornem.) Honda	Poaceae	27.27	2.31	1.00	0.94	3.67	0.42	3.67	0.13
Tinospora cordifolia (Willd.) Miers	Menispermaceae	20.45	1.73	0.80	0.75	3.89	0.45	2.93	0.19
Vittaria elongata Sw.	Vittariaceae	2.27	0.19	0.07	0.06	3.00	0.34	0.60	1.32
Xanthium strumarium L.	Asteraceae	6.82	0.58	0.25	0.24	3.67	0.42	1.23	0.54
Zingiber chrysanthum Roscoe	Zingiberaceae	13.64	1.15	0.43	0.41	3.17	0.36	1.92	0.23
Zingiber rubens Roxb.	Zingiberaceae	2.27	0.19	0.11	0.11	5.00	0.57	0.87	2.20
Total		1181.82	100	106.02	100	871.15	100	300.00	150.52

F=Frequency, RF=Relative frequency, D=Density, RD=Relative Density, A=Abundance, RA=Relative Abundance, IVI=Important Value Index, A/F= Abundance to Frequency ratio highest frequency (77.27) was for *Chromolaena odorata* followed by *Clerodendrum viscosum* and *Lantana camara*. Density was also the highest (11.77) in *C. odorata* followed by *L. camara* and *Melocanna bacifera.* Abundance was the highest in *Bambusa polymorpha* (21.50), followed by *M. bacifera*, and *C. odorata.* The highest IVI value (42.48) was in *C. odorata* followed by *L. camara* and *C. viscosum* (Table 4).

Tree vegetation: A total of 64 tree species comprising 470 individuals belonging to 26 families were identified in this study. The Moraceae family showed the highest number of species (10), followed by the Euphorbiaceae and Fabaceae families. The family Euphorbiaceae recorded the highest number of individuals (68), followed by Lythraceae and Lamiaceae (Table 2). Similar kinds of result was found by . The highest frequency was in *Lagerstroemia parviflora* (40.91), followed by *Albizia procera*. The density was highest in *L. parviflora* (1.34), followed by *Tectona grandis* and *Hevea brasiliensis*. The highest abundance was in *H. brasiliensis* (36), followed by *T. grandis* and *Pterospermum acerifolium*. The reason for the distinct abundance of *H. brasiliensis* is that it is a monocultured tree. The value of IVI was highest in *L. parviflora* (21.90), followed by *Ficus auriculata* and *A. procera* (Table 5). IVI is an index that represents the social standing of a species in a community and can be understood as the pattern of affiliation of the dominant species of that specific community (Sharma et al., 2023). Greater IVI values indicate a broad ecological amplitude, adaptability, and strong regeneration capability.

Distribution pattern: The ratio of abundance to frequency (A/F) or distribution pattern in herbs was highest in *Stachytarpheta australis* (6.27), followed by *Curcuma longa*, *Spilanthes acmella* and lowest in *Thysanolaena latifolia* (0.13). Among the shrubs, the A/F value was highest in *Bambusa polymorpha* (4.73), followed by *Parthenium hysterophorus* and *Sesbania cannabina*), whereas *Ziziphus oenoplia* (0.10) recorded the lowest A/F value. Among the tree species, the A/F value was highest in *H. brasiliensis* (15.84) and lowest in *Albizia procera,* (0.06). The distribution pattern for herbs, shrubs, and trees in all the 11 transects studied (Table 3, 4 & 5 respectively) was a contagious distribution, that is, A/F value (more than 0.05) ranging from 0.15 (*Thunbergia grandiflora*) to 6.27 (*S. australis*) in herbs, 0.10 (*Ziziphus oenoplia*) to 4.73 (*Bambusa polymorpha*) in shrubs and 0.06 (*A. procera*) to 15.84 (*H. brasiliensis*) in trees.

Plant diversity parameters and diversity indices: The highest mean frequency in all life forms was fin shrubs *i.e.,* 13.94, followed by herbs and tree species). Similarly mean density was highest among shrubs (1.11), followed by herbs and tree species. Both mean abundance and mean A/F value were the highest among herbs (7.78 and 1.34, respectively), followed by shrubs and trees. Mean IVI was highest among shrubs (6.67), followed by trees and herbs (Table 6). The diversity analysis of herbs, shrubs, and trees across all transects shows a clear stratified pattern of species distribution. The herb layer exhibited the highest species richness, with an average of 30.82 species and approximately 415 individuals, indicating a highly diverse and stable ground-layer community. Low dominance (D = 0.08), coupled with high Simpson diversity (1–D = 0.92) and a relatively high Shannon index (H = 2.95), suggests that no single species dominates the herbaceous vegetation. The evenness value (E^H = 0.68) further reflects a fairly balanced distribution of individuals among species, while the high Margalef index (4.99) points to significant contributions of species richness across the transects. These results together indicate that the herb layer is the most ecologically balanced and species-rich stratum in the study area, likely benefiting from favourable microhabitat conditions and reduced competitive exclusion. In contrast, the shrub layer showed moderate levels of diversity, with an average of 16 species and about 199 individuals. Dominance was slightly higher (D = 0.17) than in the herb layer, indicating that a few species occur more frequently. The Simpson index (1–D = 0.83) and Shannon diversity (H = 2.15) reflect moderate taxonomic diversity, while the evenness (E^H = 0.64) suggests that some shrub species are far more abundant than others. The Margalef index of 2.83 confirms that shrub richness is present but not as strong as in herbs. Overall, the shrub community appears to be in a transitional state, likely influenced by canopy cover, succession, or human disturbance, resulting in a moderately diverse but uneven distribution of species. The tree layer recorded the lowest diversity among the three strata, with an average species richness of 13.73 and roughly 43 individuals. Dominance was comparatively higher (D = 0.19), indicating that only a few canopy species are ecologically influential. Diversity values, including Simpson's index (1–D = 0.81) and Shannon H (2.12), show that the tree layer is less diverse than the lower vegetation strata. Although the evenness value (E^H = 0.73) appears relatively high, this largely reflects low overall richness rather than a genuinely diverse community, since individuals are distributed among fewer tree species. The Margalef index (3.35) indicates moderate richness typical of forest canopies but still lower than the herb layer. These patterns suggest that the tree stratum is either in an early successional stage, recovering from disturbance, or naturally dominated by a limited number of species. The results reveal gradient of decreasing diversity from herbs to shrubs to trees. Herbs form the most diverse and evenly distributed layer,

Table 4. Diversity indices of shrub species

Species name	Family	F	RF	D	RD	A	RA	IVI	A/F
Abrus precatorius L.	Fabaceae	6.82	1.09	0.14	0.27	2.00	0.86	2.22	0.29
Bambusa polymorpha Munro	Poaceae	4.55	0.72	0.98	1.96	21.50	9.22	11.91	4.73
Bambusa tulda Roxb.	Poaceae	6.82	1.09	0.50	1.00	7.33	3.15	5.24	1.08
Byttneria pilosa Roxb.	Sterculiaceae	15.91	2.54	0.48	0.96	3.00	1.29	4.78	0.19
Calamus heteracanthus Zipp. ex Blume	Palmae	4.55	0.72	0.09	0.18	2.00	0.86	1.77	0.44
Calamus leptospadix griff.	Palmae	2.27	0.36	0.05	0.09	2.00	0.86	1.31	0.88
Calotropis gigantea (L.) Dryand.	Apocynaceae	13.64	2.17	0.39	0.78	2.83	1.22	4.16	0.21
Cassia occidentalis L.	Fabaceae	20.45	3.26	0.82	1.64	4.00	1.72	6.62	0.20
Chassalia curviflora (Wall.) Thwaites	Rubiaceae	4.55	0.72	0.16	0.32	3.50	1.50	2.55	0.77
Chromolaena odorata (L.) R.M.King & H.Rob.	Asteraceae	77.27	12.32	11.77	23.62	15.24	6.54	42.48	0.20
Citrus limon (L.) Burm. f.	Rutaceae	2.27	0.36	0.05	0.09	2.00	0.86	1.31	0.88
Clerodendrum indicum (L.) Kuntze	Lamiaceae	4.55	0.72	0.23	0.46	5.00	2.14	3.33	1.10
Clerodendrum japonicum (Thunb.) Sweet	Lamiaceae	6.82	1.09	0.41	0.82	6.00	2.57	4.48	0.88
Clerodendrum philippinum Schauer	Lamiaceae	6.82	1.09	0.27	0.55	4.00	1.72	3.35	0.59
Clerodendrum viscosum Vent.	Lamiaceae	50.00	7.97	5.39	10.81	10.77	4.62	23.40	0.22
Clerodendrum wallichii Merr.	Lamiaceae	11.36	1.81	0.57	1.14	5.00	2.14	5.10	0.44
Coffea bengalensis Roxb. ex Schult.	Rubiaceae	9.09	1.45	0.32	0.64	3.50	1.50	3.59	0.39
Combretum indicum (L.) DeFilipps	Combretaceae	2.27	0.36	0.07	0.14	3.00	1.29	1.79	1.32
Dendrocalamus longispathus Kurz	Poaceae	9.09	1.45	0.82	1.64	9.00	3.86	6.95	0.99
Desmodium triquetrum (L.) DC.	Fabaceae	4.55	0.72	0.16	0.32	3.50	1.50	2.55	0.77
Desmodium velutinum (Willd.) DC.	Fabaceae	4.55	0.72	0.16	0.32	3.50	1.50	2.55	0.77
Ervatamia coronaria (Jacq.) Stapf	Apocynaceae	2.27	0.36	0.07	0.14	3.00	1.29	1.79	1.32
Flemingia strobilifera (L.) W.T. Aiton	Fabaceae	18.18	2.90	0.61	1.23	3.38	1.45	5.58	0.19
Helixanthera parasitica Lour.	Loranthaceae	2.27	0.36	0.05	0.09	2.00	0.86	1.31	0.88
Jatropha curcas L.	Euphorbiaceae	2.27	0.36	0.05	0.09	2.00	0.86	1.31	0.88
Lantana camara L.	Verbenaceae	50.00	7.97	6.14	12.31	12.27	5.26	25.55	0.25
Leea guineensis f. comoriensis Desc.	Leeaceae	2.27	0.36	0.02	0.05	1.00	0.43	0.84	0.44
Maesa indica (Roxb.) A. DC.	Myrsinaceae	6.82	1.09	0.11	0.23	1.67	0.71	2.03	0.24
Manihot esculenta Crantz	Euphorbiaceae	9.09	1.45	0.55	1.09	6.00	2.57	5.12	0.66
Melastoma malabathricum L.	Melastomaceae	31.82	5.07	2.36	4.74	7.43	3.19	13.00	0.23
Melocanna baccifera (Roxb.) Kurz	Poaceae	31.82	5.07	5.14	10.31	16.14	6.92	22.30	0.51
Meriandra strobilifera Benth.	Asteraceae	13.64	2.17	0.36	0.73	2.67	1.14	4.05	0.20
Mezoneuron cucullatum (Roxb.) Wight. & Arn.	Fabaceae	15.91	2.54	0.55	1.09	3.43	1.47	5.10	0.22
Microcos paniculata L.	Malvaceae	11.36	1.81	0.70	1.41	6.20	2.66	5.88	0.55
Micromelum integerrimum (Buch.-Ham. ex DC.) Wight & Arn. ex M. Roem.	Rutaceae	11.36	1.81	0.52	1.05	4.60	1.97	4.83	0.40
Mimosa himalayana Gamble	Fabaceae	4.55	0.72	0.05	0.09	1.00	0.43	1.24	0.22
Osbeckia chinensis L.	Melastomaceae	6.82	1.09	0.34	0.68	5.00	2.14	3.92	0.73
Parthenium hysterophorus L.	Asteraceae	2.27	0.36	0.16	0.32	7.00	3.00	3.68	3.08
Ricinus communis L.	Euphorbiaceae	9.09	1.45	0.18	0.36	2.00	0.86	2.67	0.22
Sarcochlamys pulcherrima Gaudich.	Urticaceae	9.09	1.45	0.25	0.50	2.75	1.18	3.13	0.30
Senna alata (L.) Roxb.	Fabaceae	11.36	1.81	0.39	0.78	3.40	1.46	4.05	0.30
Sesbania cannabina (Retz.) Pers.	Fabaceae	2.27	0.36	0.11	0.23	5.00	2.14	2.74	2.20
Solanum torvum Sw.	Solanaceae	38.64	6.16	2.18	4.38	5.65	2.42	12.96	0.15
Urena lobata L.	Malvaceae	52.27	8.33	4.98	9.99	9.52	4.08	22.40	0.18
Ziziphus oenopolia (L.) Mill.	Rhamnaceae	13.64	2.17	0.18	0.36	1.33	0.57	3.11	0.10
Total		627.27	100	49.84	100	233.11	100	300.00	31.75

Table 5. Diversity indices of tree species

Scientific name	Family	F	RF	D	RD	A	RA	IVI	A/F
Aegle marmelos (L.) Correa	Rutaceae	2.27	0.44	0.02	0.21	1.00	0.68	0.86	0.44
Alangium chinense (Lour.) Harms	Alangiaceae	2.27	0.44	0.02	0.21	1.00	0.68	1.25	0.44
Albizia chinensis (Osbeck) Merr.	Fabaceae	11.36	2.22	0.18	1.70	1.60	1.09	4.73	0.14
Albizia lebbek (L.) Benth	Fabaceae	2.27	0.44	0.05	0.43	2.00	1.37	1.79	0.88
Albizia procera (Roxb.) Benth	Fabaceae	29.55	5.78	0.55	5.11	1.85	1.26	13.92	0.06
Alstonia scholaris (L.) R. Br.	Apocynaceae	6.82	1.33	0.09	0.85	1.33	0.91	2.57	0.20
Anthocephalus cadamba (Roxb.) Miq.	Moraceae	4.55	0.89	0.05	0.43	1.00	0.68	4.20	0.22
Antidesma ghaesembilla Gaerth	Euphorbiaceae	2.27	0.44	0.02	0.21	1.00	0.68	1.01	0.44
Artocarpus chaplasha Roxb.	Moraceae	4.55	0.89	0.14	1.28	3.00	2.05	3.69	0.66
Artocarpus heterophyllus Lam.	Moraceae	6.82	1.33	0.18	1.70	2.67	1.82	7.16	0.39
Artocarpus lakoocha Roxb.	Moraceae	2.27	0.44	0.07	0.64	3.00	2.05	3.68	1.32
Bombax ceiba L.	Bombacaceae	4.55	0.89	0.05	0.43	1.00	0.68	3.21	0.22
Callicarpa arborea Roxb.	Verbenaceae	20.45	4.00	0.41	3.83	2.00	1.37	10.02	0.10
Callistemon linearis (Schrad. & J.C.Wendl.) Colv. ex Sweet	Myrtaceae	2.27	0.44	0.02	0.21	1.00	0.68	1.10	0.44
Careya arborea Roxb.	Lecythidaceae	2.27	0.44	0.02	0.21	1.00	0.68	2.07	0.44
Carica papaya L.	Cariaceae	4.55	0.89	0.05	0.43	1.00	0.68	1.69	0.22
Citrus sinensis (L.) Osbeck	Rutaceae	2.27	0.44	0.02	0.21	1.00	0.68	1.01	0.44
Delonix regia (Hook.) Raf.	Fabaceae	2.27	0.44	0.02	0.21	1.00	0.68	1.97	0.44
Dillenia indica L.	Dilleniaceae	2.27	0.44	0.02	0.21	1.00	0.68	2.04	0.44
Dillenia pentagyna Roxb.	Dilleniaceae	9.09	1.78	0.16	1.49	1.75	1.20	5.59	0.19
Erythrina fusca Lour.	Fabaceae	2.27	0.44	0.02	0.21	1.00	0.68	2.11	0.44
Fernandoa adenophylla (Wall. ex G.Don) Steenis	Bignoniaceae	2.27	0.44	0.05	0.43	2.00	1.37	1.96	0.88
Ficus auriculata Lour.	Moraceae	4.55	0.89	0.07	0.64	1.50	1.02	18.03	0.33
Ficus benghalensis L.	Moraceae	2.27	0.44	0.02	0.21	1.00	0.68	1.63	0.44
Ficus hispida L.f.	Moraceae	13.64	2.67	0.18	1.70	1.33	0.91	7.66	0.10
Ficus racemose L.	Moraceae	2.27	0.44	0.02	0.21	1.00	0.68	2.76	0.44
Ficus semicordata Buch.-Ham. ex Sm.	Moraceae	6.82	1.33	0.07	0.64	1.00	0.68	3.16	0.15
Firmiana colorata (Roxb.) R.Br.	Malvaceae	13.64	2.67	0.23	2.13	1.67	1.14	6.35	0.12
Garuga pinnata Roxb.	Burseraceae	2.27	0.44	0.02	0.21	1.00	0.68	2.56	0.44
Gmelina arborea Roxb.	Lamiaceae	18.18	3.56	0.45	4.26	2.50	1.71	8.93	0.14
Grewia serrulata	Tiliaceae	2.27	0.44	0.05	0.43	2.00	1.37	1.40	0.88
Hevea brasiliensis (Willd. ex A.Juss.) Müll.Arg.	Euphorbiaceae	2.27	0.44	0.82	7.66	36.00	24.59	8.76	15.84
Holarrhena antidysenterica (L.) Wall.	Apocynaceae	13.64	2.67	0.25	2.34	1.83	1.25	6.29	0.13
Jatropha curcas L.	Euphorbiaceae	2.27	0.44	0.09	0.85	4.00	2.73	1.55	1.76
Lagerstroemia microcarpa Wight	Lythraceae	2.27	0.44	0.02	0.21	1.00	0.68	1.41	0.44
Lagerstroemia parviflora Roxb.	Lythraceae	40.91	8.00	1.34	12.55	3.28	2.24	21.90	0.08
Lannea coromandelica (Houtt.) Merr.	Anacardiaceae	4.55	0.89	0.05	0.43	1.00	0.68	3.46	0.22
Macaranga denticulata (Blume) Mull.Arg.	Euphorbiaceae	2.27	0.44	0.05	0.43	2.00	1.37	1.33	0.88
Macaranga peltata (Roxb.) Mull.Arg.	Euphorbiaceae	20.45	4.00	0.32	2.98	1.56	1.06	7.55	0.08
Mallotus tetracoccus (Roxb.) Kurz	Euphorbiaceae	6.82	1.33	0.09	0.85	1.33	0.91	2.99	0.20
Mangifera indica L.	Anacardiaceae	6.82	1.33	0.16	1.49	2.33	1.59	3.94	0.34
Microcos paniculata L.	Malvaceae	2.27	0.44	0.07	0.64	3.00	2.05	1.79	1.32

Cont...

Table 5. Diversity indices of tree species

Scientific name	Family	F	RF	D	RD	A	RA	IVI	A/F
Mitragyna tubulosa (Arn.) Kuntze	Rubiaceae	20.45	4.00	0.34	3.19	1.67	1.14	7.53	0.08
Oroxylum indicum (L.) Kurz	Bignoniaceae	11.36	2.22	0.14	1.28	1.20	0.82	4.07	0.11
Parkia speciosa Hassk.	Fabaceae	2.27	0.44	0.05	0.43	2.00	1.37	1.28	0.88
Phyllanthus emblica L.	Phyllanthaceae	2.27	0.44	0.05	0.43	2.00	1.37	1.38	0.88
Protium serratum (Wall. ex Colebr.) Engl.	Burseraceae	2.27	0.44	0.09	0.85	4.00	2.73	2.68	1.76
Psidium guajava L.	Myrtaceae	2.27	0.44	0.02	0.21	1.00	0.68	2.25	0.44
Pterospermum acerifolium (L.) Willd	Malvaceae	2.27	0.44	0.09	0.85	4.00	2.73	2.51	1.76
Sapium baccatum Roxb.	Euphorbiaceae	11.36	2.22	0.11	1.06	1.00	0.68	3.97	0.09
Securinega virosa (Roxb. ex Willd.) Baill.	Euphorbiaceae	2.27	0.44	0.05	0.43	2.00	1.37	1.46	0.88
Senna siamea (Lam.) H.S.Irwin & Barneby	Fabaceae	11.36	2.22	0.27	2.55	2.40	1.64	5.81	0.21
Sterculia villosa Roxb.	Malvaceae	20.45	4.00	0.34	3.19	1.67	1.14	8.97	0.08
Stereospermum personatum (Hassk.) Chatterjee	Bignoniaceae	20.45	4.00	0.43	4.04	2.11	1.44	10.54	0.10
Streblus asper Lour.	Moraceae	2.27	0.44	0.02	0.21	1.00	0.68	0.99	0.44
Syzygium cumini (L.) Skeels	Myrtaceae	13.64	2.67	0.23	2.13	1.67	1.14	6.69	0.12
Tamarindus indica L.	Fabaceae	4.55	0.89	0.07	0.64	1.50	1.02	6.98	0.33
Tectona grandis L.f.	Lamiaceae	15.91	3.11	0.86	8.09	5.43	3.71	12.98	0.34
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	13.64	2.67	0.14	1.28	1.00	0.68	5.96	0.07
Toona ciliata M.Roem.	Meliaceae	13.64	2.67	0.20	1.91	1.50	1.02	6.32	0.11
Trema orientalis (L.) Blume	Cannabaceae	13.64	2.67	0.27	2.55	2.00	1.37	5.88	0.15
Trevesia palmata (Roxb. ex Lindl.) Vis.	Araliaceae	2.27	0.44	0.02	0.21	1.00	0.68	1.01	0.44
Vitex altissima L.f.	Verbenaceae	15.91	3.11	0.23	2.13	1.43	0.98	6.65	0.09
Ziziphus jujuba Mill.	Rhamnaceae	6.82	1.33	0.09	0.85	1.33	0.91	2.99	0.20
Total		511.36	100	10.68	100	146.43	100	300	43.32

F=Frequency, RF=Relative frequency, D=Density, RD=Relative Density, A=Abundance, RA=Relative Abundance, IVI=Important Value Index, A/F= Abundance to Frequency ratio

contributing substantially to overall vegetation heterogeneity. Shrubs exhibit intermediate diversity with signs of species dominance, while the tree layer is the least diverse and most dominated. This structure reflects ecological conditions that favour herbaceous species richness and suggests varying levels of disturbance, succession, or competitive interactions across vegetation strata in the study area.

Vegetation dynamics: The comprehensive study of the forest understory, shrub layer, and canopy revealed distinct patterns in biodiversity and species dominance across different life forms. In total, the study documented 4,665 individual herbs, 2,193 shrubs, and 470 trees, highlighting the complex, multi-layered nature of the ecosystem. For the herbaceous layer, the Asteraceae family was the most species-rich, while Poaceae dominated in terms of individual count. This dichotomy between species diversity and numerical dominance is a common ecological pattern. The grass *Imperata cylindrica* exhibited the highest Importance Value Index (IVI) (17.24), confirming its significant influence on the community structure. As noted by Sharma et al. (2023), higher IVI values indicate broad ecological amplitude and adaptability, suggesting *I. cylindrica* is well-suited to the local conditions and plays a foundational role. Within the shrub community, 45 species across 20 families were identified. The invasive species *Chromolaena odorata* showed remarkable dominance, leading in frequency, density, and IVI (42.48). This high IVI suggests *C. odorata* has strong regeneration capability and a significant competitive advantage over native species, a typical behavior for successful invasive plants which often form dense thickets. Tree layers identified 64 species from 26 families. Moraceae had the highest species richness, while Euphorbiaceae recorded the most individuals. *Lagerstroemia parviflora* had the highest IVI. A specific observation highlighted the distinct abundance of *Hevea brasiliensis* (rubber tree), attributed to its monocultured status within parts of the study area. This finding illustrates how anthropogenic activities, such as establishing monocultures, can dramatically alter natural community composition and abundance patterns, influencing overall forest structure and function. The vegetation in this area has a contiguous distribution. Regular and random distributions were not observed in this study. The dominance of contiguous distribution may be because most species reproduce vegetatively in addition to their normal seed/spore production. In natural conditions, contagious distribution is the most common (Singh et al., 2016). The reason for the higher number of species could be the availability of soil moisture and other environmental factors present in this area due to more vegetation cover higher forest density promotes higher species diversity (Yaqoob et al., 2014). Overall, the data demonstrates that dominant species, identified through high IVI values, dictate the social standing and structure of their respective communities, reflecting a mix of natural adaptability (*I. cylindrica*, *L. parviflora*) and human influence (*H. brasiliensis* monoculture, invasive *C. odorata*).

Biodiversity in HEP sites: The high diversity index indicates a forest with high species diversity, abundance, and richness (Adekunle et al., 2013, Naidu and Kumar 2016). In the present study, the Simpson dominance index for herbs, shrubs, and trees fell within the range of 0.61 to 0.96, which is higher than the value obtained in previous studies (Singh et al., 2011). Similarly, the Shannon diversity index for Herbs, Shrubs and Trees was found to be within the range of 1.01 and 3.47, which falls in the range of typical Indian forests (Singh et al., 2011, Shahid and Joshi 2016, Sharma et al., 2023) and is less than the index value of the Pachamalai Reserve Forest (Kanagaraj et al., 2017) and tropical forests in Eastern Ghat, Andhra Pradesh (Naidu and Kumar 2016). However, the value of Shannon diversity can be higher in high-altitude regions such

Table 6. Frequency, density, abundance, IVI, and distribution pattern of different life form (Mean±SE)

Parameters studied	Herb	Shrub	Tree
Frequency	10.55±0.919	13.94±2.430	7.99±0.979
Density	0.95±0.146	1.11±0.332	0.17±0.029
Abundance	7.78±0.597	5.18±0.638	2.29±0.547
Important Value Index	2.68±0.245	6.67±1.232	4.69±0.644
Distribution pattern	1.34±0.129	0.71±0.124	0.68±0.246

Table 7. Diversity indices of herb, shrub and tree of adjoining areas of Dumbur HEP

Transect	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Average
Herb												
Taxa (S)	25	19	11	17	34	32	31	46	43	31	50	30.82
Individuals	652	549	354	341	307	386	208	465	441	466	395	414.91
Dominance (D)	0.08	0.11	0.15	0.18	0.07	0.05	0.05	0.07	0.05	0.04	0.05	0.08
Simpson (1-D)	0.92	0.89	0.85	0.82	0.93	0.95	0.95	0.93	0.95	0.96	0.95	0.92
Shannon (H)	2.81	2.51	2.09	2.19	3.09	3.20	3.13	3.31	3.35	3.27	3.47	2.95
Evenness e^H/S	0.66	0.65	0.74	0.53	0.65	0.76	0.74	0.60	0.66	0.85	0.64	0.68
Margalef index	3.70	2.85	1.70	2.74	5.76	5.21	5.62	7.33	6.90	4.88	8.20	4.99
Shrub												
Taxa (S)	7	9	5	9	8	18	18	27	23	30	22	16
Individuals	152	223	252	171	156	132	162	224	235	220	266	199.36
Dominance (D)	0.18	0.23	0.31	0.22	0.21	0.15	0.14	0.10	0.10	0.10	0.12	0.17
Simpson (1-D)	0.82	0.77	0.69	0.78	0.79	0.85	0.86	0.90	0.91	0.90	0.88	0.83
Shannon (H)	1.81	1.68	1.34	1.85	1.75	2.29	2.32	2.64	2.67	2.84	2.44	2.15
Evenness e^H/S	0.87	0.60	0.76	0.71	0.72	0.55	0.56	0.52	0.62	0.57	0.52	0.64
Margalef index	1.19	1.48	0.72	1.56	1.39	3.48	3.34	4.80	4.03	5.38	3.76	2.83
Tree												
Taxa (S)	3	15	4	14	17	15	10	22	21	15	15	13.73
Individuals	12	73	11	34	58	53	46	44	49	43	47	42.73
Dominance (D)	0.39	0.27	0.26	0.10	0.12	0.24	0.36	0.06	0.07	0.11	0.12	0.19
Simpson (1-D)	0.61	0.73	0.74	0.90	0.88	0.76	0.64	0.94	0.93	0.89	0.88	0.81
Shannon (H)	1.01	1.93	1.37	2.44	2.44	2.03	1.49	2.97	2.81	2.45	2.38	2.12
Evenness e^H/S	0.92	0.46	0.99	0.82	0.68	0.51	0.45	0.88	0.79	0.77	0.72	0.73
Margalef index	0.80	3.26	1.25	3.69	3.94	3.53	2.35	5.55	5.14	3.72	3.64	3.35

T1, T2, T3……T11 represent locations of the study areas as mentioned in Table 1 as the Indian Eastern Himalayas (Sharma et al., 2019). The evenness of all Herbs, Shrubs and Trees in this study ranges from 0.45 0.99. Other authors have also found evenness within the range of the present study (Shahid and Joshi 2016). The average value of the Margalef index in the present study was 3.72, ranging from 0.80 to 8.2, which is slightly lower than the range of values for tropical forests reported by previous researchers (Kumar et al., 2010, Singh et al., 2011, Naidu and Kumar 2016). Plant species richness can influence the physical structure. Hence, it is helpful in determining plant community structure and a critical indicator of the microclimatic conditions in an area (Schuldt et al., 2019).

The vegetation of the study area is vital for sustaining the livelihoods of the local people, as most of the surrounding communities are forest-dwelling communities (Naidu and Kumar 2016). It is interesting to note that almost a thousand planned HEPs have been proposed in areas of biodiversity importance that are characterized by the presence of high endemics and threatened biodiversity. Post-project areas may show lower biodiversity due to the impacts of inundation, compaction, trampling, etc., and the creation of artificial lakes due to hydel-power projects may cause inundation of farming land, resulting in forest biodiversity loss. Moreover, creating a reservoir can cause the loss of terrestrial species due to habitat loss, which may persist until the final life of the HEP. opined that reservoir-based hydropower projects contradicts the United Nations' SDG 6 on Clean Water and SDG 15 on Life on Land, as such projects have often been linked with negative impacts on biodiversity. Urgent action must be taken by all stakeholders to perpetually obtain ecosystem services and conserve existing biodiversity without harming the local ecosystem. Furthermore, if the Dumber HEP is halted because of low energy generation, there would be many issues, ranging from resettlement, compensation, and livelihood, which can only be achieved through nature-based solutions for alternative livelihood activities (Panmei and Selvan 2024). The underlying values within a society can be represented through scenarios and require further research and broader discourse for a par-excellence scenario suitable for communities in the Dumbur HEP area. CBD regulations can protect access to bioresources. In the Local Biodiversity Outlooks 2, several studies on 'Biodiversity, climate change and sustainable development,' 'Transition towards living in harmony with nature,' and the 2050 vision for 'Nature and culture transitions' can be applied to the socio-economically weaker indigenous peoples in the Dumber HEP. The key messages in the document mentioned above pointed out that Aichi Biodiversity Target 18 of the Strategic Plan for Biodiversity 2011-2020, pertaining to traditional knowledge and customary sustainable use of biodiversity, has not been realized, and there is continued dismissal of the vital contributions of indigenous peoples to biodiversity conservation and sustainable use.

CONCLUSION

The present study revealed that the vegetation of the area is contagiously distributed, thereby indicating that the area is regenerated almost entirely through natural means. The present status of biodiversity in the area suggests that the future scenario is favourable when working together with communities for their livelihood and government-assisted community-based conservation. Hence, the outcome of this study calls for an urgent conservation initiative to conserve biological diversity, while ensuring food security, livelihood, and sustainable development.

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