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Research article

Floristic composition and ecological characteristics of the forest vegetation in the sub-mountainous hills of Punjab, India

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Abstract

Baseline data is crucial for assessing forest vegetation in a specific region. We found 297 species across 229 genera and 72 families, revealing an uneven distribution among them. Poaceae led with 29 genera and 40 species and followed closely by Fabaceae with 28 genera and 37 species. Herbaceous plants and trees accounted for the greatest number of plant species (81) and made up 27.27% of all species. The majority of the species, about 21.21%, were nanophanerophytes, which were followed by 59 species of hemicryptophytes and mesophanerophytes (19.87%). Microphyll accounted for 88 species (29.63%) of the total leaf spectrum, while nanophyll had 80 species (26.94%). The study area had 198 native species (66.66%) and 99 foreign species (33.33%) according to the phytogeographical analysis. A significant 77.10% of species are still unclassified, highlighting the necessity of thorough IUCN status assessments. Among all the plant species encountered, 32.66% flourished in natural forest, 15.82% in shrubberies, 12.12% in areas with water and dry slopes, 6.06% in areas with shade and 17.51% in plantations or cultivated areas. The data could aid in crafting management strategies for more effective and sustainable use of the forest landscapes in this sub-mountainous region.

Keywords: Biogeographical area, Ecological community, Ecosystem, Forest landscapes, Forest vegetation, Habitat.

Introduction

Ecosystems heavily rely on floristic diversity, encompassing the array of plant species within a specific area that mirrors the local flora (Hua *et al*., 2022). The study of taxonomy, which involves species identification and classification, is crucial for understanding this diversity (Barkley *et al*., 2004). Detailed studies in this field provide valuable insights into various ecosystem aspects, including distribution, nomenclature, ecology and the practical applications of plant species (Haq *et al*., 2022). Despite the availability of online checklists for different regions, a comprehensive floristic study remains indispensable for documenting the plant diversity within an area (Noss, 1983). The absence of such studies poses a significant impediment to plant research and limits our understanding of plant community distribution and structure (Kier *et al*., 2005). Grazing pressure, land-use practices, environmental gradients and human dependence on vegetation resources shape floristic diversity and composition in forest ecosystems. Sustainable management, including controlled grazing and restoration measures, is essential to conserve biodiversity and maintain ecosystem stability (Islam *et al*., 2025).

Numerous biotic and abiotic factors influence critical ecological traits within plant communities, impacting their floristic composition and ecological diversity (Khan *et al*., 2018; Solefack *et al*., 2018). Understanding the interplay between plant diversity and ecological functions is crucial for comprehending how plant communities adapt to specific habitats (Altaf *et al*., 2022). Physiognomic attributes such as life form and habit are significant in vegetation research (Haq *et al*., 2019a). Studying the functional traits of plants in a specific area can reveal the unique biological roles of individual species and shed light on how environmental factors influence the composition and distribution of plant communities (Vakhlamova *et al*., 2016).

The Shivalik foothills in Punjab, situated in the extreme north-eastern part of the state, also known as the Kandi region, host significant biodiversity. The Kandi region, which covers around 10% of Punjab and spans five districts (Pathankot, Hoshiarpur, SBS Nagar, Ropar, and SBS Nagar), is characterized by submontane areas.

Punjab allocates 84% of its total geographical area to agriculture and only 6.07% is designated as forest (Kaur *et al.*, 2017). Most of the forest areas in the state are concentrated as block forests in the Shivalik hills or the Kandi region, accounting for 52% of the total forest area. The Shivalik areas boast abundant wild medicinal plants and non-timber forest produce (NTFP), supporting the livelihoods of local communities in approximately 300 villages. These bio-resources are obtained from both forests and uncultivated areas. Given that unidentified species may disappear without acknowledgment of their existence, it is imperative to identify, document, and raise awareness about plant species in the Kandi region of Punjab. This information will serve as a foundational resource for managers, conservationists and researchers to recognize the importance of medicinal plants in the region and develop strategies for their conservation and sustainable use.

Materials and Methods

Study area**:** The present study was conducted in the lower Shivalik foothills of Punjab, spanning from 30°44′ to 32°32′ N latitude and 75°52′ to 76°43′ E longitude, at elevations ranging from 300 to 500 m above mean sea level. This region features a semi-arid to sub-humid climate. Average annual rainfall measures 1051 mm, with the majority occurring from June to September, comprising about 80% of total annual rainfall. Average temperature ranges from 5.1 to 40°C during December-January to May-June, respectively.

Three blocks were selected for study: Nurpur Bedi (district Roopnagar), Gharshankar (district Hoshiarpur), and Balachaur (district SBS Nagar). The Nurpur Bedi Range, along with a small portion of the Anandpur Sahib Range, is situated on the right side of the Sutlej River. On the left side of the river, other ranges include the major part of Anandpur Sahib, the entire Rupnagar and Chamkaur Sahib. In Nurpur Bedi, the Block and Strip Forest areas cover 525.16 and 41.08 ha, respectively. The Garhshankar and Balachaur blocks fall under the jurisdiction of the Garhshankar Territorial Forest Divisions, with forest areas of 195.20 and 440.50 ha, respectively. The natural vegetation in the region is classified into two forest types. Firstly, the scrub forest in hill and foothill areas aligns with Champion and Seth's forest type 5B/C2 (northern dry deciduous forests) and occasionally transitions to 5B/DS2 (dry deciduous scrub forests). Secondly, Khair and Sissoo Forests in the foothills and riverine areas conform to Champion and Seth's forest type 5B/IS2 (Champion and Seth, 1968).

To determine the habitat types, administrative boundaries, forest vegetation, and geographical location of the study areas, we analyzed the forest working plan. Extensive surveys were conducted regularly from 2019 to 2021 to gain a deeper knowledge of the study area and collection of field data. The random sampling method was employed to select sites, ensuring equitable representation of plant species across different habitats. The quadrat technique was used to document functional characteristics and floristic composition, thereby enhancing vegetation documentation (Haq *et al.*, 2020). A total of 36 plots were established, measuring 0.1 hectares each for sampling across diverse habitats. Within each 0.1 hectare plot, two 5 m^2 plots in opposite corners were positioned to assess shrub diversity. For herbaceous plants, 5 plots measuring 1 square meter each were arranged with one in the center and four in each corner of the 0.1 hectare plot. Field data for each plant specimen were meticulously recorded during the surveys.

The plant specimens were processed into herbariums following conventional procedures (Bridson, 1999). Plant identification relied on field characteristics observed during collection, as well as reference to standard floras of neighbouring regions in India and various monographic and revisionary works. Updated nomenclature was cross-referenced using The Plant List (2013; www.theplantlist.org). The identification of specimens was done by matching with the authentic specimens of the herbarium maintained at the University of Horticulture and Forestry, Nauni, and problematic specimens were cross-verified with the herbarium at Forest Research of India, Dehradun. After the identification process, an inventory was created, in which names of the plants- both generic and specific were listed first, then synonyms, common names, the location from where specimens were collected, their distribution and habitat, a synopsis of the systematic account, and the time of year they bloomed or fruited. Nomenclature was updated with recent taxonomic literature (Bennet, 1987).

Biological spectrum**:** The field studies in the research area captured the distinct characteristics of four seasons. Comprehensive observations of the ecological characteristics of every species were recorded as per Raunkiaer (1934), Perez *et al.* (2013) and Muzafar *et al.* (2018). Ecological features relating to habitat were classified into the following groups: WP: Water courses/ Wet places, NF: Natural forest, DS: Dry slopes, SP: Shady places, RS: Roadside, W: Wastelands, C: Crop field, S: Shrubberies and P: Plantation.

Phytogeographic analysis**:** Secondary resources included specialized online platforms like the Germplasm Resource Information Network (GRIN), manuals, floras and recent scientific publications (Muzafar *et al.*, 2018; Mehraj *et al.*, 2018). These sources aided in establishing the native phyto-geographical range of plant species gathered from the research area, alongside the website www.efloras.org. Using this data, plant species were categorized as either native or alien.

***Data analysis*:** Statistical methods were employed to analyze vegetation data and explore the relationship between ecological parameters and plant composition. The PAST software (Hammer and Rayan, 2001) facilitated matrix plot and cluster analysis using presence/absence (1/0) data. Diversity indices, including Shannon and Simpson, species richness, were calculated based on the presence or absence of species across environments and plots.

Results and Discussion

Vegetation composition and functional diversity: In the current study, 297 plant species were documented, spanning across 72 families and 229 genera (Table 1). Among these, 295 species belonged to Angiosperms, encompassing 70 families and 227 genera. Additionally, there was one Gymnosperm and one Pteridophyte reported. Monocots among Angiosperms were represented by 56 species, distributed across 41 genera and 10 families, while dicots contributed 239 species, representing 186 genera and 60 families (Table 2). Analyzing floral composition is vital for understanding plant diversity and organization, especially concerning functional attributes, as highlighted by Haq *et al.* (2019b). Understanding the intricate relationship between diversity and function is crucial for assessing the future trajectory of plant communities under human impacts (Cadotte *et al.*, 2011). Systematically mapping the distribution of floristic diversity serves as the initial step in plant conservation, as advocated by Myers *et al.* (2000). This approach establishes a foundational framework for informed conservation strategies, enabling proactive measures to safeguard the delicate balance of plant life amidst evolving environmental challenges.

The species richness is consistent with findings in various Himalayan regions as reported by Dar *et al.* (2018). Kaur *et al.* (2017) also identified a diverse collection of 464 species in the Doaba region of Punjab, while Rawat *et al.* (2013) recorded 176 plant species in the Kandi Region of Hoshiarpur, Punjab.

Species-family relationship: In the study area, the distribution of species across 72 families showed an uneven pattern, where 10 families accounted for half of the total species, while the remaining 62 families shared the other half. Additionally, there were approximately thirty-three monotypic families. Notably, Poaceae emerged as the most dominant family, comprising 29 genera and 40 species, followed by Fabaceae (28 genera and 37 species), Asteraceae (14 genera and 17 species), Lamiaceae (11 genera and 12 species), Malvaceae (11 genera and 15 species), and Apocynaceae (9 genera and 10 species). The majority of families were represented by only one or two genera and species (Fig 1).

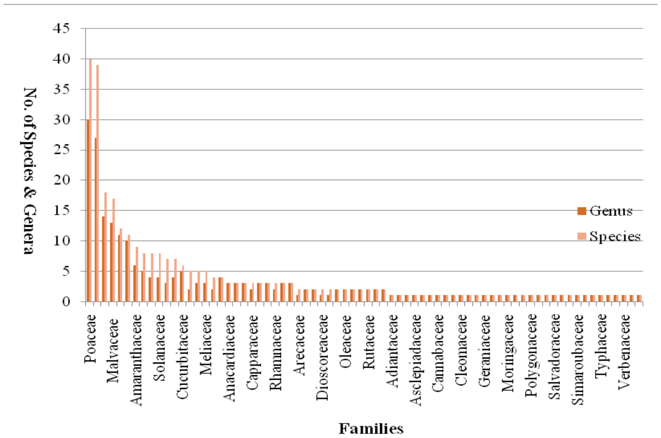

Fig 1. Species-genera -family relationship of flora in the lower Shiwalik hills of Punjab, India

Kaur *et al.* (2017) identified Fabaceae as dominant, followed by Asteraceae and Poaceae, among others, in the Kandi region of Hoshiarpur, Punjab. Similar distributions were reported by Rawat *et al.* (2013) in the Kandi Region of Hoshiarpur, Punjab and Kabeer *et al.* (2018) in the Nilgiri Biosphere Reserve, where Poaceae was identified as the dominant family. Srivastav *et al.* (2015) found Poaceae to be the largest family in their study, comprising 16 genera and 17 species, followed by Rosaceae (nine genera, 13 species) and Asteraceae (eight genera, eight species). The floristic analysis revealed 33 monotypic families and uneven species distribution, consistent with prior research in various Himalayan locations. These findings aligned with the findings of Pal *et al.* (2014) from diverse Himalayan regions.

Species distribution among growth form types: Herbaceous plants and trees accounted for the greatest number of plant species (81) in the present study, constituting 27.27% of all species. This was followed by 52 shrubs (17.51%), thirty-nine species of grasses (13.03%), thirty climbers (10.10%), seven under shrubs (2.36%), six sedges (2.02%) and one fern (0.34%) (Table 3).

Similar patterns were observed in the sub-mountainous zone of Punjab, as reported by Kaur *et al.* (2017), where recorded species included 255 herbs, 65 shrubs, 85 trees, and 59 climbers in the Doaba region of Punjab. Rawat *et al.* (2013) identified trees (36.9%) as the dominant life form, followed by shrubs (22.7%), grasses (17.1%), herbs (13.6%), climbers (8.5%) and sedges (1.1%) in Hoshiarpur, Punjab. The study's findings highlight the diverse plant life in the Kandi region of Punjab, with herbs and trees being the predominant life forms. This aligned with broader observations in northwestern Himalaya, where herbaceous growth forms and trees have been consistently noted as dominant (Saygin *et al*., 2025; Oussein *et al*., 2025; Mhaiskar et al., 2025; Haq *et al*., 2021a; Haq *et al*., 2019 b).

Table 1. Floristic composition and life span trait of the vegetation in lower shivalik hills of Punjab

S.No	Scientific name	Family	Nativity	IUCN status	Leaf size	Life span	Raunkiaer life form
1	*Abrus precatorius* Linn	Fabaceae	N	NE	Leptophyll	Perennial	NOP
2	*Abutilon indicum* Sw.	Malvaceae	N	NE	Mesophyll	Perennial	HCP
3	*Acacia catechu* Willd.	Fabaceae	N	NT	Leptophyll	Perennial	MSP
4	*Acacia leucophloea* (Roxb.) Willd.	Fabaceae	N	LC	Leptophyll	Perennial	MSP
5	*Acacia modesta* Willd.	Fabaceae	N	NE	Leptophyll	Perennial	MCP
6	*Acacia nilotica* (L.) Willd. ex Del.	Fabaceae	N	LC	Leptophyll	Perennial	MSP
7	*Achyranthus aspera* Linn.	Amaranthaceae	N	NE	Nanophyll	Perennial	NOP
8	*Acrachne racemosa* (B.Heyne ex Roth) Ohwi	Poaceae	E	LC	Nanophyll	Perennial	HCP
9	*Adiantum incisum* C.Presl	Adiantaceae	N	LC	Nanophyll	Perennial	CHA
10	*Aegle marmelos* Correa ex. Roxb.	Rutaceae	N	NT	Mesophyll	Perennial	MCP
11	*Aerva javanica* Juss ex Schult.	Amaranthaceae	E	NE	Leptophyll	Perennial	CHA
12	*Aerva lanata* Juss ex Schult.	Amaranthaceae	N	NE	Leptophyll	Perennial	HCP
13	*Aerva pseudotomentosa* Biatt & Halib.	Amaranthaceae	N	NE	Leptophyll	Perennial	HCP
14	*Agave cantala (Haw.)* Roxb. ex Salm-Dyck	Asparagaceae	E	LC	Aphyllous	Perennial	NOP
15	*Ageratum conyzoides* Linn.	Asteraceae	E	LC	Mesophyll	Annual	THE
16	*Ageratum houstonianum* Mill.	Asteraceae	E	LC	Mesophyll	Annual	THE
17	*Ailanthus excelsa* Roxb.	Simaroubaceae	N	NE	Mesophyll	Perennial	MSP
18	*Albizia lebbek* Benth.	Fabaceae	N	LC	Leptophyll	Perennial	MSP
19	*Albizia procera* (Roxb.) Benth.	Fabaceae	N	LC	Leptophyll	Perennial	MSP
20	*Alloteropsis cimicina* (L.) Stapf	Poaceae	N	NE	Nanophyll	Annual	THE
21	*Aloe vera* (L.) Burm.f.	Xanthorrhoeaceae	E	NE	Mesophyll	Perennial	HCP
22	*Alstonia scholaris* (L.) R. Br.	Apocynaceae	N	LC	Mesophyll	Perennial	MGP
23	*Alternanthera paronychioides* A. St.-Hil.	Amaranthaceae	E	NE	Nanophyll	Perennial	CRP
24	*Alternanthera sessilis* (L.) R. Br. ex DC.	Amaranthaceae	N	LC	Nanophyll	Perennial	CHA
25	*Alysicarpus rugosus* (Willd.)DC.	Fabaceae	N	NE	Leptophyll	Perennial	CHA
26	*Ampelocissus latifolia* Planch.	Vitaceae	N	NE	Mesophyll	Perennial	THE
27	*Anagallis arvensis* L.	Primulaceae	N	NE	Nanophyll	Annual	CHA
28	*Anisomeles indica* (L.) Kuntze	Lamiaceae	N	NE	Microphyll	Perennial	HCP
29	*Anogeissus latifolia* (DC.) Wallich ex Guill. & Perr.	Combretaceae	N	NE	Mesophyll	Perennial	MSP
30	*Apluda mutica* Linn.	Poaceae	N	NE	Nanophyll	Perennial	HCP
31	*Argemone mexicana* L.	Papaveraceae	E	NE	Microphyll	Annual	THE
32	*Aristida setacea* Retz.	Poaceae	N	NE	Leptophyll	Perennial	HCP
33	*Artemisia scoparia* Waldst. & Kitam	Asteraceae	E	NE	Nanophyll	Perennial	THE
34	*Arthraxon lancifolius* (Trin.) Hochst.	Poaceae	N	NE	Leptophyll	Annual	THE
35	*Artocarpus lacucha* Buch.-Ham	Moraceae	N	NE	Mesophyll	Perennial	MSP
36	*Arundo donax* Linn.	Poaceae	N	LC	Microphyll	Perennial	MCP
37	*Asparagus racemosus* Willd.	Asparagaceae	N	LC	Leptophyll	Perennial	CRP
38	*Asphodelus tenuifolius* Cav.	Xanthorrhoeaceae	E	LC	Leptophyll	Annual	THE
39	*Avena fatua* L.	Poaceae	N	NE	Microphyll	Annual	THE
40	*Azadirachta indica* Juss.	Meliaceae	N	LC	Microphyll	Perennial	MSP
41	*Bambusa arundinacea* Willd.	Poaceae	N	NE	Microphyll	Perennial	MCP

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42	*Bambusa vulgaris* Schrad. ex J.C.Wendl	Poaceae	E	NE	Microphyll	Perennial	MCP
43	*Barleria cristata* Linn.	Acanthaceae	N	NE	Leptophyll	Perennial	HCP
44	*Bauhinia racemosa* Lam.	Fabaceae	N	NE	Mesophyll	Perennial	MCP
45	*Bauhinia vahlii* W. & A.	Fabaceae	N	VU	Megaphyll	Perennial	MSP
46	*Bauhinia variegata* Linn.	Fabaceae	N	LC	Mesophyll	Perennial	MCP
47	*Bidens bipinnata* Linn.	Asteraceae	E	NE	Nanophyll	Annual	THE
48	*Bidens pilosa* Linn.	Asteraceae	E	NE	Nanophyll	Annual	THE
49	*Boehmeria platyphylla* D. Don	Urticaceae	N	NE	Mesophyll	Perennial	NOP
50	*Boerhavia diffusa* L.	Nyctaginaceae	N	NE	Nanophyll	Perennial	HCP
51	*Bombax ceiba* L.	Malvaceae	N	LC	Microphyll	Perennial	MSP
52	*Bougainvillea spectabilis* Willd.	Nyctaginaceae	E	NE	Microphyll	Perennial	MCP
53	*Brachiaria reptans* (L.) C.A.Gardner & C.E.Hubb	Poaceae	N	NE	Leptophyll	Annual	THE
54	*Broussonetia papyrifera* (L.) Vent.	Moraceae	N	LC	Megaphyll	Perennial	MSP
55	*Bryonia laciniosa* L.	Cucurbitaceae	N	NE	Nanophyll	Perennial	HCP
56	*Butea monosperma* (Lamk.) Taub.	Fabaceae	N	LC	Mesophyll	Perennial	MSP
57	*Caesulia axillaris* Roxb.	Asteraceae	N	NE	Nanophyll	Annual	HCP
58	*Cajanus scarabaeoides* (L.)Thouars	Fabaceae	N	NE	Nanophyll	Perennial	HCP
59	*Calotropis procera* (Aiton) W.T.Aiton	Apocynaceae	E	LC	Mesophyll	Perennial	NOP
60	*Cannabis sativa* Linn.	Cannabaceae	E	NE	Microphyll	Perennial	NOP
61	*Capparis decidua* (Forssk.) Edgew.	Capparaceae	N	NE	Leptophyll	Perennial	MCP
62	*Capparis sepiaria* Linn.	Capparaceae	N	NE	Leptophyll	Perennial	THE
63	*Cardiospermum halicacabum* L.	Sapindaceae	E	NE	Nanophyll	Perennial	NOP
64	*Carissa carandas* L.	Apocynaceae	N	NE	Microphyll	Perennial	NOP
65	*Carissa spinarum* Linn. Syn Carissa opaca Stapf ex Haines	Apocynaceae	N	LC	Microphyll	Perennial	NOP
66	*Cascabela thevetia* (L.) H. Lippold	Apocynaceae	E	LC	Microphyll	Perennial	NOP
67	*Casearia tomentosa* Roxb.	Salicaceae	N	NE	Mesophyll	Perennial	MCP
68	*Cassia fistula* L.	Fabaceae	N	LC	Mesophyll	Perennial	MSP
69	*Cassia sophera* Linn.	Fabaceae	E	NE	Nanophyll	Perennial	NOP
70	*Cassia tora* Linn.	Fabaceae	E	NE	Microphyll	Annual	NOP
71	*Casuarina equisetifolia* L.	Casuarinaceae	E	NE	Leptophyll	Perennial	MSP
72	*Catharanthus roseus* (L.) G. Don	Apocynaceae	E	NE	Mesophyll	Perennial	NOP
73	*Celastrus paniculata* Willd.	Celastraceae	N	VU	Microphyll	Perennial	THE
74	*Chenopodium album* L.	Amaranthaceae	E	NE	Nanophyll	Annual	THE
75	*Chrysopogon fulvus* Choiv.	Poaceae	N	NE	Leptophyll	Perennial	HCP
76	*Cirsium arvense* (L.) Scop.	Asteraceae	E	NE	Microphyll	Perennial	CHA
77	*Cissampelos pareira* L.	Menispermaceae	N	NE	Mesophyll	Perennial	HCP
78	*Citrullus colocynthis* (L.) Schrader	Cucurbitaceae	E	NE	Nanophyll	Perennial	HCP
79	*Cleome viscosa* L.	Cleomaceae	E	NE	Microphyll	Annual	THE
80	*Colebrookia oppositifolia* J. E. Smith	Lamiaceae	N	NE	Mesophyll	Perennial	NOP
81	*Commelina benghalensis* Linn.	Commelinaceae	N	LC	Microphyll	Annual	CRP
82	*Convolvulus arvensis* L.	Convolvulaceae	N	NE	Microphyll	Perennial	HCP
83	*Corchorus olitorius* L.	Malvaceae	N	NE	Microphyll	Annual	CRP
84	*Cordia dichotoma* G. Forst	Boraginaceae	N	NE	Mesophyll	Perennial	MCP
85	*Crataeva nurvala* Buch.-Ham.	Capparaceae	N	NE	Mesophyll	Perennial	MSP
86	*Croton tiglium* L.	Euphorbiaceae	N	NE	Microphyll	Perennial	NOP

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87	*Cryptolepis buchanani* Roemer & Schultes A	Asclepiadaceae	N	NE	Mesophyll	Perennial	THE
88	*Cucumis maderaspatanus* L.	Cucurbitaceae	N	NE	Nanophyll	Perennial	HCP
89	*Cuscuta reflexa* Roxb.	Convolvulaceae	E	LC	Aphyllous	Perennial	PAR
90	*Cyathula tomentosa* (Roth) Moq.	Amaranthaceae	N	NE	Microphyll	Perennial	HCP
91	*Cymbopogon citratus* (DC.) Stapf.	Poaceae	N	NE	Leptophyll	Perennial	HCP
92	*Cymbopogon martini* (Roxb.) Wats.	Poaceae	N	NE	Leptophyll	Perennial	HCP
93	*Cynodon dactylon* Pers.	Poaceae	N	NE	Leptophyll	Perennial	HCP
94	*Cyperus esculentus* Linn.	Cyperaceae	E	LC	Nanophyll	Perennial	CRP
95	*Cyperus niveus* Retz.	Cyperaceae	N	NE	Nanophyll	Perennial	CRP
96	*Cyperus rotundus* L.	Cyperaceae	N	LC	Nanophyll	Perennial	CRP
97	*Dactyloctenum aegyptium* (Linn.) P. Beauv.	Poaceae	E	NE	Nanophyll	Annual	CRP
98	*Dalbergia sissoo* Roxb.	Fabaceae	N	LC	Microphyll	Perennial	MSP
99	*Datura innoxia* P. Miller	Solanaceae	E	NE	Mesophyll	Annual	THE
100	*Datura stramonium* Linn.	Solanaceae	E	NE	Mesophyll	Annual	THE
101	*Delonix regia* (Hook.)Raf.	Fabaceae	E	LC	Nanophyll	Perennial	MSP
102	*Dendrocalamus hamiltonii* Nees & Arn. ex Munro	Poaceae	N	NA	Microphyll	Perennial	MSP
103	*Dendrocalamus strictus* Bl.	Poaceae	N	NE	Microphyll	Perennial	MSP
104	*Dendrophthoe falcata* (L.f.) Ettingsh.	Loranthaceae	N	NE	Microphyll	Perennial	NOP
105	*Dicanthium annulatum* Stapf.	Poaceae	N	NE	Nanophyll	Perennial	HCP
106	*Dicliptera bupleuroides* Nees	Acanthaceae	N	NE	Microphyll	Perennial	CHA
107	*Dicliptera paniculata* (Forssk.) I.Darbysh.	Acanthaceae	N	NE	Microphyll	Perennial	CHA
108	*Digera arvensis* Forssk.	Amaranthaceae	E	NE	Microphyll	Annual	THE
109	*Digitaria abludens* (Roth. & Schult) Veldk.	Poaceae	N	NE	Nanophyll	Annual	CHA
110	*Digitaria ciliaris* Koel	Poaceae	N	NE	Nanophyll	Annual	CHA
111	*Digitaria compacta* (Roth) Veldkamp	Poaceae	N	NE	Nanophyll	Annual	CHA
112	*Digitaria longiflora* (Retz.) Pers.	Poaceae	E	NE	Nanophyll	Annual	CHA
113	*Digitaria sanguinalis* (L.) Scop.	Poaceae	E	NE	Leptophyll	Annual	CHA
114	*Digitaria stricta* Roth. ex Roem. & Schult.	Poaceae	N	NE	Leptophyll	Annual	CHA
115	*Dioscorea belophylla* Voigt	Dioscoreaceae	N	NE	Mesophyll	Perennial	HCP
116	*Dioscorea deltoidea* Wall.	Dioscoreaceae	N	NE	Mesophyll	Perennial	HCP
117	*Diospyros cordifolia* Roxb.	Ebenaceae	N	NE	Microphyll	Perennial	MCP
118	*Diospyros tomentosa* Roxb.	Ebenaceae	N	NE	Microphyll	Perennial	MCP
119	*Dodonaea viscosa* (Linn.) Jacq.	Sapindaceae	E	LC	Nanophyll	Perennial	NOP
120	*Eclipta prostrata* (L.)	Asteraceae	E	LC	Microphyll	Annual	THE
121	*Ehretia laevis* Roxb.	Boraginaceae	N	NE	Mesophyll	Perennial	NOP
122	*Elaeodendron roxburghii* Wt. & Arn.	Celastraceae	N	NE	Microphyll	Perennial	MCP
123	*Eleusine indica*	Poaceae	N	LC	Nanophyll	Annual	THE
124	*Eragrostis tenella* (L.) P.Beauv. ex Roem. & Schult.	Poaceae	N	LC	Nanophyll	Annual	HCP
125	*Erigeron canadensis* L.	Asteraceae	E	NE	Nanophyll	Annual	THE
126	*Eriophorum comosum* (Wall.) Nees	Cyperaceae	N	NE	Nanophyll	Perennial	HCP
127	*Eucalyptus tereticornis* Sm.	Myrtaceae	E	LC	Microphyll	Perennial	MGP
128	*Eulaliopsis binata* Hubbard	Poaceae	N	NE	Nanophyll	Perennial	HCP
129	*Euphorbia heterophylla* L.	Euphorbiaceae	E	LC	Nanophyll	Annual	CHA

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130	*Euphorbia hirta* Linn.	Euphorbiaceae	N	NE	Nanophyll	Annual	THE
131	*Euphorbia royleana* Boiss.	Euphorbiaceae	N	NE	Microphyll	Perennial	NOP
132	*Euphorbia thymifolia* L.	Euphorbiaceae	E	NE	Nanophyll	Annual	CHA
133	*Ficus benghalensis* L.	Moraceae	N	NE	Mesophyll	Perennial	MGP
134	*Ficus carica* L.	Moraceae	E	NE	Macrophyll	Perennial	MCP
135	*Ficus palmata* Forssk.	Moraceae	N	NE	Mesophyll	Perennial	MCP
136	*Ficus glomerata* Roxb.	Moraceae	N	LC	Macrophyll	Perennial	MCP
137	*Ficus religiosa* Linn.	Moraceae	N	LC	Mesophyll	Perennial	MGP
138	*Fimbristylis miliacea* (L.) Vahl	Cyperaceae	E	NE	Nanophyll	Annual	HCP
139	*Flacourtia indica* (Burm. f.) Merr.	Salicaceae	N	NE	Microphyll	Perennial	MCP
140	*Flueggea virosa* (Roxb. ex Willd.) Royle	Phyllanthaceae	E	NE	Mesophyll	Perennial	NOP
141	*Fumaria indica* (Hausskn.) Pugsley	Papaveraceae	N	NE	Nanophyll	Annual	CHA
142	*Geranium mascatense* Boiss. *var. himalaicum Babu*	Geraniaceae	E	NE	Nanophyll	Annual	THE
143	*Gmelina arborea* Roxb.	Lamiaceae	N	DD	Mesophyll	Perennial	MSP
144	*Grevillea robusta* A. Cunn. ex R. Br.	Proteaceae	E	NE	Nanophyll	Perennial	MSP
145	*Grewia optiva* J.R.Drumm. ex Burret	Malvaceae	N	VU	Mesophyll	Perennial	MSP
146	*Grona triflora* (L.) H.Ohashi & K.Ohashi	Fabaceae	E	NE	Nanophyll	Perennial	HCP
147	*Helicteres isora* L.	Malvaceae	N	NT	Microphyll	Perennial	NOP
148	*Heteropogon contortus* (L.) P. Beauv.	Poaceae	M	NE	Nanophyll	Perennial	HCP
149	*Hibiscus rosa-sinensis* L.	Malvaceae	N	NE	Mesophyll	Perennial	HCP
150	*Holarrhena antidysenterica* (L.) Wall. ex DC.	Apocynaceae	N	LC	Mesophyll	Perennial	MSP
151	*Holoptelea integrifolia* Planch.	Ulmaceae	N	NE	Mesophyll	Perennial	MSP
152	*Hymenodictyon excelsum* Wall.	Rubiaceae	N	NE	Mesophyll	Perennial	MSP
153	*Ichnocarpus frutescens* Br.	Apocynaceae	N	NE	Mesophyll	Perennial	HCP
154	*Indigofera cassiodes* Rottl. Ex DC.	Fabaceae	N	LC	Microphyll	Perennial	NOP
155	*Ipomoea carnea* Jacq.	Convolvulaceae	E	NE	Nanophyll	Perennial	NOP
156	*Ipomoea obscura* (L.) Ker Gawler	Convolvulaceae	E	NE	Microphyll	Perennial	HCP
157	*Ipomoea pes-tigridis* L.	Convolvulaceae	E	NE	Microphyll	Perennial	HCP
158	*Ipomoea purpurea* (Linn.) Roth	Convolvulaceae	E	NE	Mesophyll	Perennial	HCP
159	*Jacaranda mimosifolia* D. Don	Bignoniaceae	E	NE	Nanophyll	Perennial	MSP
160	*Jasminum sambac* (L.) Aiton	Oleaceae	N	NE	Mesophyll	Perennial	NOP
161	*Jatropha curcas* Linn.	Euphorbiaceae	E	NE	Mesophyll	Perennial	NOP
162	*Justicia prostrata*(Roxb. Ex C. B.Cl.) Gamble, Fl	Acanthaceae	N	NE	Microphyll	Perennial	HCP
163	*Justicia adhatoda* L.	Acanthaceae	N	NE	Microphyll	Perennial	NOP
164	*Justicia gendarussa* Burm. F.	Acanthaceae	N	NE	Microphyll	Perennial	NOP
165	*Justicia procumbens* L.	Acanthaceae	N	NE	Microphyll	Perennial	HCP
166	*Kalanchoe pinnata* (Lam.) Pers.	Crassulaceae	E	NE	Aphyllous	Perennial	CHA
167	*Kigelia pinnata* (Jacq.) DC.	Bignoniaceae	E	LC	Mesophyll	Perennial	MSP
168	*Lactuca dissecta* D.Don	Asteraceae	E	NE	Microphyll	Annual	CHA
169	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	N	LC	Microphyll	Perennial	MSP
170	*Lantana camara* Linn.	Verbenaceae	E	NE	Mesophyll	Perennial	NOP
171	*Launaea nudicaulis* (L.) Hook.f.	Asteraceae	N	NE	Nanophyll	Annual	CHA
172	*Lepidium didymum* L.	Brassicaceae	E	NE	Leptophyll	Annual	CHA

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173	*Leptochloa chinensis* (L.) Nees	Poaceae	N	NE	Nanophyll	Annual	THE
174	*Leucaena leucocephala* (Lam.)de Wit	Fabaceae	E	NE	Microphyll	Perennial	MSP
175	*Madhuca longifolia* (Koenig) Macbride	Sapotaceae	N	NE	Mesophyll	Perennial	MSP
176	*Mallotus philippensis* (Lam.) Müll. Arg.	Euphorbiaceae	N	NE	Microphyll	Perennial	MSP
177	*Malva parviflora* L.	Malvaceae	N	NE	Microphyll	Perennial	CHA
178	*Malvastrum coromandelianum* (L.) Garcke	Malvaceae	E	NE	Nanophyll	Perennial	HCP
179	*Mangifera indica* Linn.	Anacardiaceae	N	DD	Mesophyll	Perennial	MSP
180	*Medicago polymorpha* L.	Fabaceae	E	NE	Nanophyll	Annual	CHA
181	*Melaleuca citrina* (Curtis) Dum.Cours.	Myrtaceae	E	NE	Nanophyll	Perennial	MCP
182	*Melia azedarach* Linn. sub spp *compacta*	Meliaceae	N	NE	Mesophyll	Perennial	MSP
183	*Melia azedarach* Linn.	Meliaceae	N	NE	Mesophyll	Perennial	MSP
184	*Melia composita* Willd.	Meliaceae	N	NE	Mesophyll	Perennial	MSP
185	*Melilotus albus* Medik.	Fabaceae	E	NE	Nanophyll	Annual	THE
186	*Melilotus indicus* (L.)All.	Fabaceae	N	NE	Nanophyll	Annual	THE
187	*Merremia aegyptia* (Linn.) Urban	Convolvulaceae	E	NE	Microphyll	Annual	THE
188	*Mimosa himalayana* Gamble	Fabaceae	N	NE	Leptophyll	Perennial	NOP
189	*Mimusops elengi* L.	Sapotaceae	N	NE	Mesophyll	Perennial	MSP
190	*Mitragyna parvifolia* Korth.	Rubiaceae	N	NE	Microphyll	Perennial	MSP
191	*Momordica charantia* Descourt	Cucurbitaceae	N	NE	Mesophyll	Perennial	NOP
192	*Momordica dioica* Roxb. ex Willd.	Cucurbitaceae	N	NE	Mesophyll	Perennial	NOP
193	*Moras alba* Linn.	Moraceae	N	NE	Mesophyll	Perennial	MSP
194	*Moringa oleifera* Lamk.	Moringaceae	N	NE	Nanophyll	Perennial	MSP
195	*Mucuna pruriens* (L.)DC.	Fabaceae	N	VU	Microphyll	Perennial	NOP
196	*Murraya koengii* (Linn.) Spreng	Rutaceae	N	NE	Nanophyll	Perennial	NOP
197	*Nerium indicum* Mill.	Apocynaceae	N	NE	Microphyll	Perennial	NOP
198	*Nyctanthes arbor-tristis* Linn.	Oleaceae	N	NE	Mesophyll	Perennial	NOP
199	*Ocimum basilicum* Linn.	Lamiaceae	N	NE	Microphyll	Perennial	NOP
200	*Ocimum gratissimum* L.	Lamiaceae	E	NE	Microphyll	Perennial	NOP
201	*Oplismenus burmannii* (Retz.) Beauv.	Poaceae	E	NE	Nanophyll	Annual	THE
202	*Oplismenus compositus* (Linn.) P. Beauv.	Poaceae	E	NE	Nanophyll	Annual	THE
203	*Opuntia dillenii* (Ker Gawl.) Haw.	Cactaceae	E	LC	Aphyllous	Perennial	NOP
204	*Oroxylum indicum* Vent.	Bignoniaceae	N	NT	Mesophyll	Perennial	MSP
205	*Ougeinia oojeinensis* (Roxb.) Hochr.	Fabaceae	N	NE	Microphyll	Perennial	MCP
206	*Oxalis corniculata* Linn.	Oxalidaceae	E	LC	Nanophyll	Perennial	CHA
207	*Oxlis martiana* Zucc.	Oxalidaceae	E	NE	Nanophyll	Perennial	CHA
208	*Panicum maximum* Jacq	Poaceae	E	NE	Nanophyll	Perennial	HCP
209	*Parkinsonia aculeate* Linn.	Fabaceae	E	NE	Leptophyll	Perennial	MCP
210	*Parthenium hysterophorus* Linn.	Asteraceae	E	NC	Mesophyll	Annual	THE
211	*Peltophorum pterocarpum* (DC.) K.Heyne	Fabaceae	E	NE	Leptophyll	Perennial	MSP
212	*Perilla frutescens* (Linn.) Brittom	Lamiaceae	N	NE	Nanophyll	Perennial	HCP
213	*Phoenix loureiroi* Kunth	Arecaceae	N	NE	Microphyll	Perennial	NOP
214	*Phoenix sylvestris* Roxb.	Arecaceae	N	NE	Microphyll	Perennial	MSP

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215	*Phyllanthus emblica* L.	Phyllanthaceae	N	NE	Leptophyll	Perennial	MSP
216	*Phyllanthus niruri* L.	Phyllanthaceae	E	NE	Leptophyll	Annual	THE
217	*Phyllanthus urinaria* L.	Phyllanthaceae	N	NE	Leptophyll	Annual	THE
218	*Physalis minima* L.	Solanaceae	N	LC	Mesophyll	Perennial	HCP
219	*Pinus roxburghgii* Sarg.	Pinaceae	N	LC	Nanophyll	Perennial	MGP
220	*Pistacia integerrima* J.L.Stewart ex Brandis	Anacardiaceae	N	NE	Microphyll	Perennial	MSP
221	*Plectranthus barbatus* Andrews	Lamiaceae	N	NE	Microphyll	Perennial	HCP
222	*Poa annua* Linn.	Poaceae	E	NE	Nanophyll	Annual	THE
223	*Pogostemon benghalensis* (Burm.f.) Kuntze	Lamiaceae	N	NE	Microphyll	Perennial	NOP
224	*Polyalthia longifolia* (Sonn.) Thwaites	Annonaceae	N	NE	Mesophyll	Perennial	MSP
225	*Polygonum plebeium* R.Br.	Polygonaceae	N	NE	Nanophyll	Annual	THE
226	*Pongamia pinnata* (L.)Pierre	Fabaceae	N	LC	Microphyll	Perennial	MSP
227	*Populus deltoides* W.Bartram ex Marshall	Salicaceae	E	NE	Mesophyll	Perennial	MSP
228	*Premna mollissima* Roth	Lamiaceae	E	NE	Microphyll	Perennial	MCP
229	*Prosopis cineraria*(L.) Druce	Fabaceae	N	NE	Leptophyll	Perennial	MCP
230	*Prosopis juliflora* (Sw.) DC.	Fabaceae	E	NE	Leptophyll	Perennial	NOP
231	*Pterospermum acerifolium* (L.) Willd.	Malvaceae	N	NE	Mesophyll	Perennial	MGP
232	*Pueraria tuberosa* DC.	Fabaceae	N	NE	Microphyll	Perennial	NOP
233	*Putranjiva roxburghii* Wall.	Putranjivaceae	N	NE	Mesophyll	Perennial	MSP
234	*Rauvolfia serpentina* (L.) Benth. ex Kurz	Apocynaceae	N	T	Mesophyll	Perennial	HCP
235	*Rhamnus triquetra* Wall.	Rhamnaceae	N	NE	Microphyll	Perennial	NOP
236	*Ricinus communis* Linn.	Euphorbiaceae	N	NE	Mesophyll	Perennial	NOP
237	*Roylea cinerea* (D. Don) Baillon	Lamiaceae	N	NE	Nanophyll	Perennial	NOP
238	*Saccharum benghalensis* Ret z.	Poaceae	N	NE	Mesophyll	Perennial	HCP
239	*Saccharum spontaneum* Linn.	Poaceae	E	LC	Microphyll	Perennial	HCP
240	*Salix tetrasperma* Roxb.	Salicaceae	N	NE	Microphyll	Perennial	MCP
241	*Salvadora oleoides* Decne	Salvadoraceae	N	LC	Nanophyll	Perennial	NOP
242	*Santalum album* L.	Santalaceae	N	VU	Microphyll	Perennial	MSP
243	*Sapindus mukorossi* Gaertn.	Sapindaceae	N	LC	Mesophyll	Perennial	MSP
244	*Senna occidentalis* (L.)Link	Fabaceae	E	NE	Microphyll	Perennial	NOP
245	*Senna siamea* (Lam.)H.S.Irwin & Barneby	Fabaceae	N	NE	Microphyll	Perennial	MSP
246	*Setaria glauca* (Linn.) P. Beauv.	Poaceae	N	NE	Nanophyll	Perennial	THE
247	*Setaria verticillata* (Linn.) P. Beauv.	Poaceae	E	NE	Nanophyll	Perennial	HCP
248	*Setaria viridis* (L.) P. Beauv.	Poaceae	N	NE	Nanophyll	Perennial	THE
249	*Sida acuta* Burm. F.	Malvaceae	E	NE	Microphyll	Perennial	HCP
250	*Sida cordata* Borss.-Waalkes	Malvaceae	N	NE	Microphyll	Perennial	HCP
251	*Sida cordifolia* Linn.	Malvaceae	N	NE	Microphyll	Perennial	HCP
252	*Sida ovata* Forssk.	Malvaceae	N	NE	Microphyll	Perennial	HCP
253	*Sida rhombifolia* L.	Malvaceae	N	NE	Microphyll	Perennial	HCP
254	*Silybum marianum* (L.) Gaertn.	Asteraceae	E	NE	Mesophyll	Annual	HCP
255	*Smilax parvifolia* Wall.	Smilacaceae	E	NE	Mesophyll	Perennial	CHA
256	*Solanum aculeatissimum* Jacq.	Solanaceae	E	NE	Microphyll	Perennial	NOP
257	*Solanum erianthum* D.Don	Solanaceae	E	NE	Microphyll	Perennial	NOP

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258	*Solanum nigrum* L.	Solanaceae	N	NE	Microphyll	Perennial	HCP
259	*Solanum virginianum* L.	Solanaceae	E	NE	Nanophyll	Perennial	NOP
260	*Sonchus asper* L.	Asteraceae	E	NE	Microphyll	Annual	THE
261	*Sonchus oleraceus* L.	Asteraceae	E	NE	Microphyll	Annual	THE
262	*Sorghum halepense* (L.) Pers.	Poaceae	N	NE	Nanophyll	Annual	THE
263	*Spergula arvensis* L.	Caryophyllaceae	N	NE	Leptophyll	Annual	THE
264	*Stephania japonica* (Thunb.) Miers	Menispermaceae	N	NE	Mesophyll	Perennial	NOP
265	*Syzygium cumini* Skeels	Myrtaceae	N	LC	Mesophyll	Perennial	MSP
266	*Tamarix dioica* Roxb.	Tamaricaceae	N	NE	Leptophyll	Perennial	NOP
267	*Tateishia concinna* (DC.) H.Ohashi & K.Ohashi	Fabaceae	N	NE	Leptophyll	Perennial	NOP
268	*Tectona grandis* L.f.	Lamiaceae	N	NE	Megaphyll	Perennial	MSP
269	*Tephrosia purpurea* (L.)Pers.	Fabaceae	N	NE	Nanophyll	Perennial	HCP
270	*Terminalia alata* Heyne.	Combretaceae	N	LC	Mesophyll	Perennial	MSP
271	*Terminalia arjuna* Wt. & Arn.	Combretaceae	N	NE	Mesophyll	Perennial	MSP
272	*Terminalia bellirica* Roxb.	Combretaceae	N	LC	Mesophyll	Perennial	MSP
273	*Terminalia chebula* Retz.	Combretaceae	N	LC	Macrophyll	Perennial	MSP
274	*Themeda anathera* Hack.	Poaceae	N	NE	Leptophyll	Perennial	HCP
275	*Tinospora cordifolia* (Willd.) Miers	Menispermaceae	N	NE	Leptophyll	Perennial	NOP
276	*Toona ciliata* M. Roem.	Meliaceae	N	LC	Mesophyll	Perennial	MSP
277	*Trianthema portulacastrum* L.	Aizoaceae	E	NE	Nanophyll	Perennial	HCP
278	*Tribulus terrestris* L.	Zygophyllaceae	E	NE	Microphyll	Annual	THE
279	*Trichodesma indicum* (L.) R. Br.	Boraginaceae	N	NE	Nanophyll	Annual	THE
280	*Trichosanthes cucumerina* Buch.-Ham. ex Wall.	Cucurbitaceae	N	NE	Mesophyll	Perennial	THE
281	*Tridax procumbens* L.	Asteraceae	E	NE	Microphyll	Perennial	HCP
282	*Triumfetta rhomboidea* Jacq.	Malvaceae	E	NE	Microphyll	Perennial	NOP
283	*Typha elephantina* Roxb.	Typhaceae	E	NE	Mesophyll	Perennial	CRP
284	*Urena lobata* L.	Malvaceae	N	LC	Microphyll	Perennial	NOP
285	*Vallaris solenacea* Ktze.	Apocynaceae	E	NE	Microphyll	Perennial	NOP
286	*Verbascum thapsus* Linnaeus	Scrophulariaceae	N	NE	Mesophyll	Perennial	NOP
287	*Verbesina encelioides* (Cav.) Benth. & Hook.f. ex A.Gray	Asteraceae	E	NE	Nanophyll	Annual	THE
288	*Vicia hirsuta* (L.)Gray	Fabaceae	E	NE	Nanophyll	Annual	THE
289	*Vicia sativa* L.	Fabaceae	N	NE	Nanophyll	Annual	THE
290	*Vitex negundo* L.	Lamiaceae	N	LC	Microphyll	Perennial	NOP
291	*Waltheria indica* L.	Malvaceae	N	DD	Nanophyll	Perennial	HCP
292	*Wendlandia heynei* Sant. & Merch.	Rubiaceae	N	NE	Mesophyll	Perennial	NOP
293	*Withania somnifera* (L.) Dunal	Solanaceae	N	NE	Microphyll	Perennial	NOP
294	*Woodfordia fruticosa* Kurz.	Lythraceae	N	LC	Mesophyll	Perennial	NOP
295	*Xanthium strumarium* Linn.	Asteraceae	E	NE	Mesophyll	Annual	THE
296	*Ziziphus mauritiana* Lamk.	Rhamnaceae	N	LC	Microphyll	Perennial	MCP
297	*Ziziphus nummularia* (Burm. f.) W. A.	Rhamnaceae	N	NE	Nanophyll	Perennial	NOP

N: Native; E: Exotic; NE: Not evaluated; DD: Data deficient; LC: Least concern; T: Threatened; NT: Near threatened; VU: Vulnerable; NOP: Nanophanerophytes; HCP: Hemicryptophytes; MSP: Mesophanerophytes; THE: Therophytes; CHA: Chamaephytes; MCP: Microphanerophytes; CRP: Cryptophytes; MGP: Megaphanerophytes; PAR: Parasitic; N: Native; E: Exotic

Table 2. Number of families, genera and species documented from the study area and their respective per cent representation

Sr. No.	Plant group/division/taxon	Families		Genera		Species	
		Total	**Percent of total**	**Total**	**Percent of total**	**Total**	**Percent of total**
1	Angiosperms	70	97.22	227	99.13	295	99.33
	a) Dicotyledons	60	83.33	186	81.22	239	80.47
	b) Monocotyledons	10	13.89	41	17.90	56	18.86
2	Gymnosperms	1	1.39	1	0.44	1	0.34
3	Pteridophytes (Ferns and fern allies)	1	1.39	1	0.44	1	0.34
Grand total		72	100	229	100	297	100

Likewise, higher diversity in silvipastures compared to grasslands along altitudinal gradients (Bhutia *et al.*, 2024) and improved species diversity under exclosures (Debeko *et al.*, 2024) emphasize the role of management. Conversely, invasion by *Prosopis juliflora* and overgrazing have degraded floristic composition in Banni grasslands (Manjunatha *et al.*, 2025).

Species distribution among life form trait: Approximately 21.21% of the species were nanophanerophytes, constituting the dominant life form, followed by 59 species of hemicryptophytes and mesophanerophytes (19.87%). Therophytes were represented by 49 species, chamaephytes by 26 species (8.75%), microphanerophytes by 25 species (8.42%), cryptophytes by 9 species (3.03%), megaphanerophytes by 6 species (2.02%), and parasitic species with a single occurrence (0.34%) (Fig. 2; Table 1). The biological spectrum, a vital tool for vegetation studies, revealed how plants respond to micro- and macroclimates. The composition of living forms within the community illustrates species adaptation to local climates, allowing inference of climates and soil types from the diversity of life forms (Khan *et al.*, 2018). Nanophanerophytes, being the predominant life form, serve as indicators of human disturbances, typically associated with unfavorable dry environmental conditions, warmth and humidity (Verdinelli *et al.*, 2022; Nafeesa *et al.*, 2021). A high percentage of therophytes in a specific region signals an arid climate and disturbed habitats. These findings aligned with previous studies, which also reported the dominance of therophytes and nanophanerophytes in their study areas (Rahman *et al.*, 2018).

Table 3. Analysis of habit-forms of the flora of the study area

S. No.	Habit-form	No. of species	Percent of total
1	Trees	81	27.27
2	Shrubs	52	17.51
3	Under shrubs	7	2.36
	a) Annuals	1	0.34
	b) Perennials	6	2.02
4	Herbs	81	27.27
	a) Annuals	43	14.48
	b) Perennials	38	12.79
5	Climbers	30	10.10
	a) Woody	14	4.71
	b) Non-woody	16	5.39
6	Grasses	39	13.13
	a) Grasses	35	11.78
	b) Bamboo	4	1.35
7	Sedges	6	2.02
8	Fern	1	0.34
Total		**297**	100.00

Leaf size spectra: Microphyll accounted for 88 species (29.63%) of total leaf spectrum, while nanophyll had 80 species (26.94%), mesophyll with 79 species (26.60%), leptophyll with 40 species (13.47%), aphyllous with 4 species (1.35%), and megaphyll and macrophyll each with 3 species (1.01%) (Fig. 3; Table 1). The floristic study

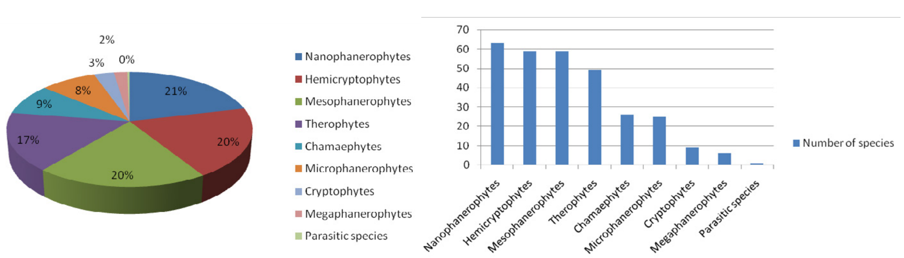

Fig 2. Distribution of species among life form traits expressed in terms of percentage (%) and number of species.

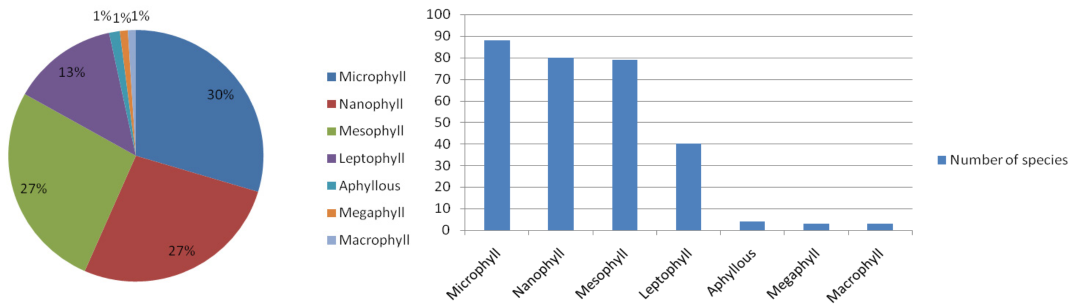

Fig 3. Distribution of species among leaf size spectra expressed in terms of percentage (%) and number of species.

revealed microphyll species as predominant in leaf-size spectra, with nanophyll and mesophyll following. The abundance of micro- and nanophylls suggests a semi-arid, sub-humid climate. Haq *et al.* (2021a) observed a prevalence of microphylls in Dachigam National Park in the Himalayas. Ali *et al.* (2016) found mesophylls predominant in the Chail valley in Pakistan. Similarly, in the Shawilks Mountain range of the Western Himalayas, Haq *et al.* (2022) discovered microphylls and mesophylls as predominant leaf sizes.

Phytogeographical analysis: In the study region, native species totalled 198, representing 66.66%, while 99 alien species accounted for 33.33%. Among these, various floral groups of alien species were identified, with Asteraceae leading as the dominant family (16 species), followed by Poaceae and Fabaceae (11 species each), Convolvulaceae (6), and Solanaceae (5). *Ageratum conyzoides, Solanum virginianum* L. Syn, *Ricinus communis, Lantana camara, Argemone mexicana* L., *Datura innoxia, Solanum xanthocarpum* Schrad. & J.C.Wendl. and *Parthenium hysterophorus* emerged as the most frequently encountered invasive species in the study area (Fig. 4; Table 1). In the intricate web of the research region's life cycle, a fascinating revelation comes to light: a significant 78.79% of the identified species exist as perennial entities, grounded in enduring cycles of existence. Simultaneously, a notable 21.21% present themselves as annual species, representing the transient yet equally crucial threads of life's continuum. This juxtaposition creates a vivid portrait of biodiversity, with each percentage serving as a brushstroke on the canvas of nature's grandeur within the boundaries of our examined domain (Table 1).

The IUCN status of the identified species exhibits significant diversity, with a substantial distribution across various classifications. A notable 77.10% of species remain unassessed, underscoring the imperative for comprehensive evaluations. In contrast, 19.53% were categorized as least concern, signifying a relatively stable status. However, 1.68% was considered vulnerable, highlighting the urgency of conservation efforts. Furthermore, 1.35% falls under the near-threatened category, emphasizing the need for attention to prevent further decline. The data deficiency for 1.01% of species underscores the critical need for additional information. Finally, 0.34% of species were classified as threatened, underscoring the immediate need for conservation actions to mitigate risks and ensure their survival (Fig 5; Table 1). Diverse forest settings exhibited varying invasion levels, with dramatic variations in invasive species diversity between ecosystems, indicating differing sensitivities to invaders. About one-third of the examined species were foreign, thriving predominantly in human-made environments rather than slightly fragmented forest ecosystems. Alien plant species, owing to their higher phenotypic plasticity than native plants, tend to colonize disturbed environments regardless of their life history approach. Alien species distribution

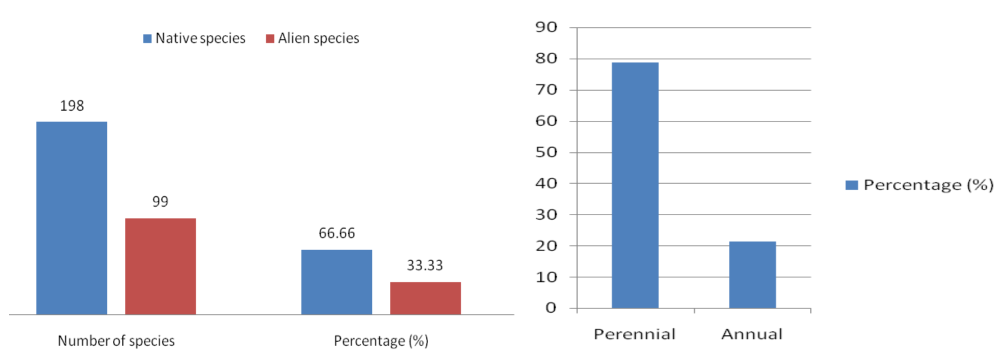

Fig 4. Distribution of species phytogeographical analysis and life cycle expressed in terms of percentage (%) and number of species

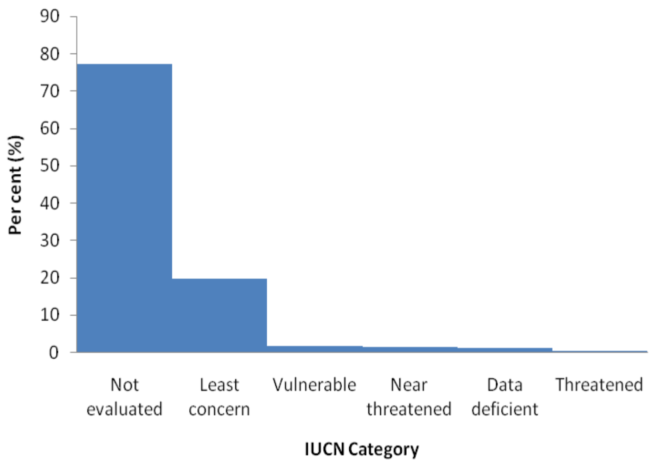

Fig 5. IUCN status-wise percentage distribution of recorded species

Table 4. Variation in diversity indices between habitat types in lower Shiwalik hills of Punjab

Habitat	Richness	Simpson	Shannon_H
Croplands	52	0.95	3.95
Dry slopes	45	0.95	3.81
Natural forests	122	0.99	4.8
Plantations	60	0.96	4.09
Road side	85	0.98	4.44
Shrubberies	62	0.96	4.13
Shady places	22	0.92	3.09
Waste lands	88	0.98	4.48
Water courses	48	0.95	3.87

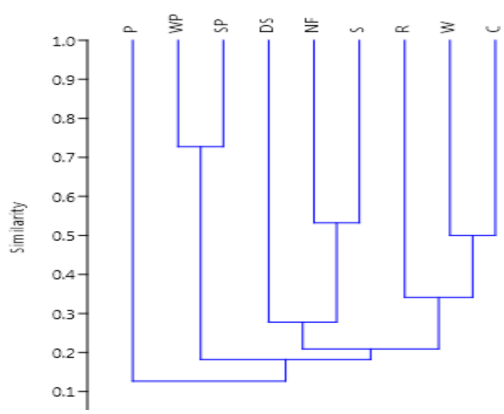

Fig 6. Habitat filtering based on species compositional similarity in different habitats form in lower Shiwaliks hills, Punjab, India

varied among groups, with Asteraceae being the most common, aligning with findings of Haq *et al.* (2021b) in the Indian Himalayas, where Asteraceae dominated weed species, reflecting their ecological adaptability. Initial forest invasions might facilitate subsequent invasions, creating conditions favouring invaders over natives, thereby facilitating biological invasions. The main ecological factors influencing plant growth in an area are constantly evolving units shaped by accessible habitats.

Habitat-wise distribution: Among all the plant species encountered, 32.66% thrived in natural forests, 15.82% in shrubberies, 12.12% in water bodies and dry slopes, 6.06% in shaded areas, and 17.51% in plantations or cultivated areas. The remaining species were distributed across diverse habitats: 24.24% in wastelands, 22.56% along roadsides, and 13.80% in croplands. Cluster-1 included water courses and shaded areas, while cluster-2 comprised dry slopes, natural forests, and shrubberies. Cluster-3 encompassed roadsides, wastelands, and croplands. Cluster-4, depicted as a separate limb in the dendrogram (Fig. 6), consisted of plantations. Habitats within clusters 1 and 2 showed greater similarity to each other than to cluster 4, which exhibited the highest dissimilarity with respect to other habitat types.

In estimated diversity indices, natural forests exhibited the highest values across all three indices. With a Shannon index of 4.70 and Simpson's index of 0.99, it hosted a total of 122 species. Wastelands and roadside areas followed with 88 and 85 species, respectively (Shannon indices: 4.48 and 4.44; Simpson indices: 0.98 and 0.98). Dry slopes and shady places recorded the lowest values (Table 4).
Habitat destruction, fragmentation and degradation due to human-induced disturbances impact the structure and composition of forest communities. Environmental filtering, evidenced by similar ecosystems affected by human activity, like damaged slopes, roadsides, and pedestrian zones, was observed in the area. Community patterns changed due to the close relationship, at small spatial scales, between biotic interactions (plant invasion) and abiotic environmental influences. Sharma and Kant (2014) found that northern dry mixed deciduous woods, comprising 27.3% of the study area, exhibited higher values for Shannon-Wiener's index and Simpson's index of dominance, indicating the highest levels of species richness and variety. Given the impact of human disturbances on most forest landscapes, urgent conservation action plans are necessary to ensure sustainable use and improved forest management. This project inventoried forests in Punjab's lower Shiwalik Hills to gather biodiversity information. While some crucial variables, such as climatic parameters, are still missing in examining the ecological characteristics of forest vegetation, they could help explain the diversity and composition of plant communities further. Despite these limitations, our examination of qualitative traits provides insightful, objectively corroborated information about the area's climate.

Conclusion

This study is a vital resource for understanding and conserving the diverse plant life in Punjab's lower

Shiwalik hills. It's the first comprehensive attempt to document the flora, functional complexity and habitat specifics of this area. Our findings highlight species' remarkable adaptability to environmental stresses, emphasizing the role of habitat filtration in shaping plant communities. We also identified significant ecological shifts, including habitat fragmentation from linear developments like roads and transmission lines. The potential dominance of Asteraceae in disturbed areas is concerning, as is the clustering of species within limited families. We observed an increased prevalence of certain plant types due to anthropogenic disruptions. By employing a functional diversity approach, we enhanced our understanding of ecosystem behaviour and the valuable services forests provide. This strategic framework promotes sustainable development that preserves biodiversity and ecosystem functioning in the fragile Himalayan region. Ultimately, our study guides conscientious development practices that align with the unique ecological dynamics of this important area.

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