Assessing plant species diversity and its ecological contributions in the urban landscapes of Sirsa, Haryana, India: an exploratory study

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Abstract
Urban biodiversity serves as the foundation for ecological stability, resilience and sustainable development within the urban ecosystem. Progressive development and rapid growth in urbanization have posed the significant threat to green spaces and have prompted to conduct diversity studies to plan effective conservation measures and strategies. This study assessed the plant species diversity across eight urban sites in Sirsa, Haryana. The phytosociological parameters like abundance, density, frequency and Importance Value Index (IVI), along with statistical calculation of Shannon-Wiener and Simpson indices were determined to gain insight about species dominance, evenness and richness. The result obtained from the study showed significant spatial variation, as plot A (Shaheed Bhagat Singh Stadium) reported the highest biodiversity because of the effective maintenance, whereas plots in smaller size such as home gardens showed reduced biodiversity.

The study also highlighted the dominance of invasive species like Cannabis sativa, which is a significant threat to biodiversity and requires immediate management efforts for its mitigation. These findings highlight the cultural, ecological and socio-economic importance of urban green spaces and advocate for the integration of biodiversity conservation strategies into urban planning frameworks to promote sustainable development.

Keywords: Biodiversity management, Conservation strategies, Environmental resilience, Plant species diversity, Urban biodiversity, Urban planning.

Introduction
Urban parks are important biodiversity reservoirs within city landscapes, which not only aid in preserving biodiversity in urban areas but also allow the people to interact with nature[59]. As over 55% of the population globally now resides in urban areas, it has become necessary to make the green spaces accessible for human interaction to foster public appreciation and support for conservation of biodiversity[1,11]. These urban parks foster rare species and provide essential habitat for vulnerable species population. Furthermore, they also function as vital ecological corridors that promote habitat connectivity and dispersal for metapopulations, thus contributing to broader ecological network of urban environments[43]. These interrelations align with ethical responsibilities that enable communities to actively engage in environmental stewardship and protect these spaces as shared assets[10].

Within this urban ecosystem, plant diversity is key component which plays critical role in maintaining stability and resilience of terrestrial ecosystems[30]. The diverse plant flora supports essential ecological functions like enhancement of soil fertility, moderation of weather, slope stabilization and provide habitats for wildlife[16,26]. Lately, the sustainable conservation of such biodiversity has become the priority as it has been recognized that plant diversity not only suffice basic human needs such as food and medicine, but it also significantly contributes to human well-being[15,51]. Thus, biodiversity assessment which involves the cataloguing of plant species along with the attributes like abundance and the Importance Value Index (IVI), has become important for understanding the socio-economic and ecological values of plant diversity.

It can also be understood by the fact that around 30000 edible plant species are available globally but only a small proportion is widely used, which highlights the urgency of conducting detailed biodiversity assessments[12,34]. Further, rapid urbanization and land-use changes are severely impacting the biodiversity in urban green spaces, particularly in regions growing rapidly. India, being the most rapidly urbanizing nations globally, is witnessing a steady decline in the urban green spaces[50]. In Haryana, where forest cover only 3.59% of the geographical area which is quite below the national target of 33% is facing challenges of loss of biodiversity and insufficient carbon sequestration[36,58]. In spite of these challenges, studies on plant diversity and their ecological contributions in small-sized cities like Sirsa remain limited. This highlights the critical gap for the development of region-specific biodiversity conservation plans.

However, urban vegetation encompassing grasses, shrubs and trees in gardens, green roofs and parks serves as a viable alternative to above challenges. Moreover, urban vegetation also reduces energy usage by naturally regulating the temperature, supports biodiversity by providing habitat to different species, mitigates the urban heat effect, improves air quality index and promotes physical and mental health by promoting physical activity and reducing stress[25,32,38,52,56].

Even published literature suggests that urban areas even being heavily developed can harbour substantial biodiversity and, in some cases, surpass surrounding rural landscapes because of human interference[5,9,14]. This highlights urban biodiversity as effective complementary solution to Haryana's limited forest resources in advancing ecological resilience and carbon sequestration.

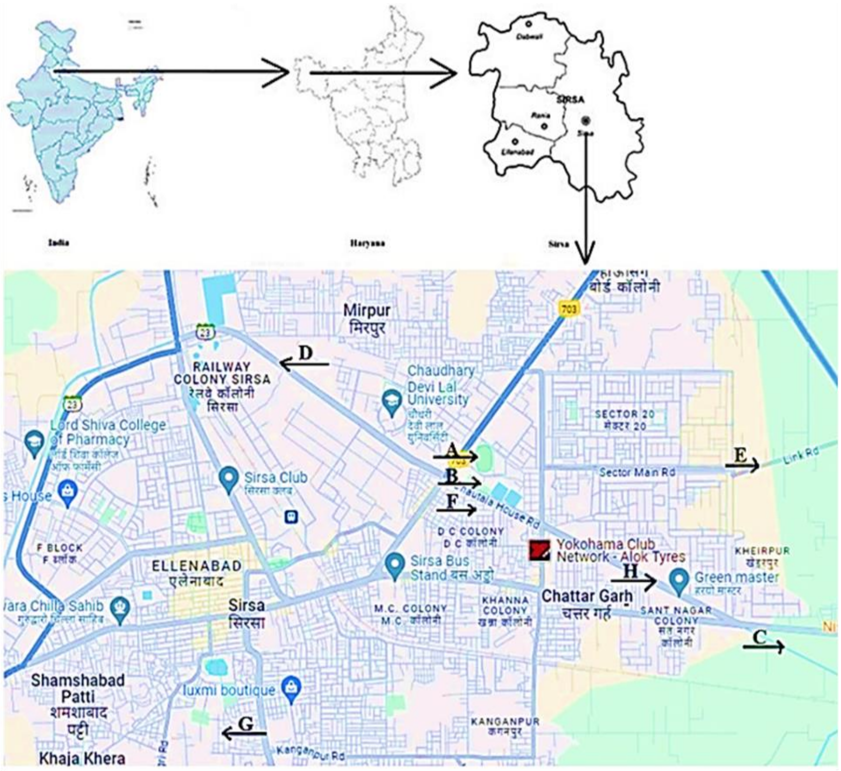
The present study aims to assess the plant diversity and their ecological contributions in urban landscape of Sirsa region by analyzing green spaces of varied structures and functions. Further, this study aims to understand how biodiversity aids in improving carbon sequestration, ecosystem services and advancing sustainable urban planning. This study aims to address the gaps in regional biodiversity strategies and create foundation for the development of policies that integrate biodiversity conservation into urban planning framework.

Material and Methods

Study Area: Sirsa district lies in the westernmost corner of Haryana State, which shares its border with Bathinda and Faridkot district of Punjab State to the North-East and North region, Hanumangarh and Ganganagar district of Rajasthan State in the South and West region and Fatehabad district of Haryana in the East region. Thus, it forms interstate boundaries on three sides and connects to Haryana only from Eastern side. Geographically, the district is situated between 29º 14' to 30ºN latitudes and 74º 29' to 75º 18'E longitudes encompassing an area of 4,268.20 km² [33].

The Sirsa district terrain can be topographically divided into three major regions i.e. Hayana plain, Ghaggar/Nali alluvial bed and sand dune tract. Additionally, this district receives an average rainfall of 186.3 mm annually and peak temperature has been recorded within the range of 41°C to 46°C in the month of May and June, with lowest temperature of 27°C and highest temperature of 48°C [37]. The figure 1 illustrates the locations of the study area.

Selection of Sampling Sites: The study of urban vegetation in Sirsa district involved the selection of diverse sampling sites including comprehensive range of varied habitats and urban landscapes. The sampling locations include both artificial and natural landscapes like Shaheed Bhagat Singh Stadium (Latitude 29.5428°N, Longitude 75.0519°E), Chaudhary Devi Lal Park (Latitude 29.5413°N, Longitude 75.0508°E), Sirsa Minor (Latitude 29.5259°N, Longitude 75.0855°E), Municipality Park (Latitude 29.5350°N, Longitude 75.0240°E), HUDA Unhabituated Area (Latitude 29.5498°N, Longitude 75.0741°E), Home Garden 1 (Latitude 29.5395°N, Longitude 75.0502°E), Home Garden 2 (Latitude 29.5268°N, Longitude 75.0336°E) and Mini-bypass Sirsa (Latitude 29.5373°N, Longitude 75.0328°E). These areas encompassed different urban vegetation types including forested municipal areas, private home gardens, roadside vegetation and recreational parks.



A: Shaheed Bhagat Singh Stadium ; B: Chaudhary Devi Lal Park; C: Sirsa Minor; D: Municipality Park; E: HUDA Unhabituated Area; F:Home Garden 1; G: Home Garden 2 and H: Mini-bypass Sirsa

Figure 1: The location map of study area of District Sirsa, Haryana.

Further, the field was researched by employing phytosociological techniques to analyse the parameters like abundance of vascular plant, density and frequency. The quadrant method was used to ensure standardized quantitative analysis.

Data Collection and Statistical Analysis: The study used the stratified random sampling with quadrats of varying sizes for herbs, shrubs and trees to analyse the vegetation across 8 study sites[13,18,21]. The sampling of easily available, mature and disturbed vegetation was done at each site. The quadrats measuring 1×1 m for herbs, 5×5 m for shrubs and 10×10 m for trees were formed using simple tools like rods, rope and measuring tape in this study. Data collection from each site involved the establishing of three quadrats at four different points for sampling floristic data across three vegetation layers i.e. herb layer which encompasses herbaceous flora with height of < 1m, shrub layer which encompasses woody flora with height between 1-5 m and tree layer which encompasses woody plants with height > 5m[4].

The attributes like size, fruit/seed morphology, plant habit and leaf arrangement were accorded for each sample site[48,53]. Additionally, the key phytosociological parameters assessed at different sites viz. abundance, density, frequency, relative abundance, relative density, relative dominance, relative frequency and IVI were calculated using the following formulas [4,39,45]:

a) $\text{Abundance} = \frac{\text{No.of individuals of a species in all quadrats}}{\text{No.of quadrats in which species occur}}$

b) $\text{Density} = \frac{\text{Total no. of a single species in all plots}}{\text{Total of studied plots}}$

c) $\text{Frequency} = \frac{\text{No.of plots in which species grow}}{\text{Total of studied plots}} * 100$

d) $\text{Relative Abundance (\%)} = \frac{\text{Abundance of one species}}{\text{Sum of abundance of all species}} * 100$

e) $\text{Relative Density (\%)} = \frac{\text{Density of any particular species}}{\text{Total of densities of all studied species}} * 100$

f) $\text{Relative Dominance} = \frac{\text{Total basal cover of a species}}{\text{Total basal cover of all the species}} * 100$

g) $\text{Relative Frequency (\%)} = \frac{\text{Frequency of any particular species}}{\text{Total of frequency of all studied species}} * 100$

h) IVI = Relative Density + Relative Frequency + Relative Dominance

The specimens of all the plant species were collected from all sites. The plant specimens were dried, processed and mounted on the standard herbarium sheets. All plant species were identified and verified by taxonomists at Forest Research Institute of India (Dehradun) and Jammu University (Jammu). Further for the assessment of species diversity across the parks, Shannon-Wiener Index and Simpson Index were calculated using the following formulas:[57]

$$Shannon - Wiener\ Index\ (H') = -\sum(pi \cdot ln(pi))$$

and $Simpson\ Index\ (D) = 1 - \sum(pi^2)$

where $pi = \frac{Individuals\ of\ species\ i}{Total\ individuals}$

Results and Discussion

Plant Diversity and Distribution in Urban Areas: A total of 98 plant species belonging to 45 families were identified across eight urban plots representing the rich biodiversity of the Sirsa region (Table 1). The *Fabaceae* family was found to be highly dominant as it included 12 species like *Acacia catechu*, *Dalbergia sissoo* and *Vachellia nilotica*, unveiled during biodiversity assessment (Figure 2). This assessment highlighted about their ecological significance in improving soil fertility and nitrogen fixation[23,31]. The family *Apocynaceae* and *Asparagaceae* showed the prominence in the urban setting after *Fabaceae* family. Other families like *Asteraceae* and *Poaceae* with species like *Tagetes erecta* and *Saccharum spontaneum* were also recorded which demonstrate their flexibility and adaptability to urban environment[19,46].

Further, the presence of species like *Azadirachta indica* (Neem) and *Ficus religiosa* (Pipal) represented the convergence of ecological functionality and cultural heritage, highlighting the cordial integration of biodiversity and human traditions in urban settings [7]. Additionally, the presence of ornamental species like *Bougainvillea glabra* and *Catharanthus roseus* contributes to the aesthetic appeal of urban spaces [40]. On contrary, the presence of invasive species like *Cannabis sativa* highlights the need of effective management [28]. Few of the plant species documented during biodiversity assessment are illustrated in figure 3.

The findings of study align with the global status of the *Fabaceae* family as it the holds the position of third-largest plant family, after *Asteraceae* and *Orchidaceae* family as they encompass 770 genera and approximately 19,500 species[8,22]. Moreover, the current study also underlines the equilibrium between native and urban-adapted species that are maintaining the ecological stability in urban areas.

Spatial Variation in Biodiversity: The spatial variation of plant species biodiversity across the eight urban plots highlights the influence of anthropogenic activity land-use practices, plot size and maintenance. The plot A (Shaheed Bhagat Singh Stadium) recorded the highest species richness with 35 species. This can be attributed to its extensive area, effective management, diverse microhabitats providing ecological services like carbon sequestration and shade [24]. The plot B (Chaudhary Devi Lal Park) holds the second position with 29 species. This can be attributed to consistent maintenance and limited human interference as parks are

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planned to promote aesthetics and provide serene spaces for public use as well as ecological benefits. The key species that contributes in the biodiversity includes *Azadirachta indica* and *Ficus religiosa*, well-known for their cultural and ecological importance[7].

Table 1
Phytosociological parameters analysis of 8 sites of Sirsa Region

S.N.	Botanical Name	Common Name	Family	Individuals found	Found in no. of plots (Plot Code)	Relative Density	Relative Frequency	Relative Abundance	IVI
1	*Acacia cetechu*	Kher	*Fabaceae*	1	1 (A)	0.1248439	0.5319149	0.2560929	0.912852
2	*Achyranthes aspera*	Puth kanta	*Amaranthaceae*	6	1 (H)	0.7490637	0.5319149	1.5365573	2.817536
3	*Aegle marmelos*	Bellpatar	*Rutaceae*	2	2 (B, F)	0.2496879	1.0638298	0.2560929	1.569611
4	*Aerva javanica*	Bui	*Amaranthaceae*	11	3 (C, E, H)	1.3732834	1.5957447	0.9390072	3.908035
5	*Agave desmettiana*	Dwarf Century Plant	*Asparagaceae*	5	2 (F, G)	0.6242197	1.0638298	0.6402322	2.328282
6	*Albizia lebbeck*	Sarinh	*Fabaceae*	6	3 (B, C, E)	0.7490637	1.5957447	0.5121858	2.856994
7	*Alkanna tinctoria*	Ratanjot	*Boraginaceae*	1	1 (A)	0.1248439	0.5319149	0.2560929	0.912852
8	*Aloe barbadensis*	Aloe vera	*Asphodelaceae*	8	3 (D, F, G)	0.9987516	1.5957447	0.6829143	3.277411
9	*Alstonia scholaris*	Saptparni	*Apocynaceae*	5	2 (A, B)	0.6242197	1.0638298	0.6402322	2.328282
10	*Amaranthus hypochondriacus*	Pigweed	*Amaranthaceae*	7	2 (C, H)	0.8739076	1.0638298	0.8963251	2.834062
11	*Araucaria araucana*	Aerocaria	*Araucariaceae*	3	2 (F, G)	0.3745318	1.0638298	0.3841393	1.822501
12	*Azadirachta indica*	Neem	*Meliaceae*	15	5 (A, B, C, D, H)	1.8726592	2.6595745	0.7682786	5.300512
13	*Bauhinia variegata*	Kachnar	*Fabaceae*	5	2 (A, B)	0.6242197	1.0638298	0.6402322	2.328282
14	*Beaucarnea recurvata*	Lolina	*Asparagaceae*	2	1 (F)	0.2496879	0.5319149	0.5121858	1.293789
15	*Bougainvillea glabra*	Bougainvillea	*Nyctaginaceae*	16	1 (E)	1.9975031	0.5319149	4.097486	6.626904
16	*Bougainvillea peruviana*	Yellow Bougainville	*Nyctaginaceae*	7	1 (E)	0.8739076	0.5319149	1.7926501	3.198473
17	*Bryophyllum pinnatum*	Patharchat	*Crassulaceae*	1	1 (F)	0.1248439	0.5319149	0.2560929	0.912852
18	*Callistemon citrinus*	Bottlebrush	*Myrtaceae*	7	2 (A, B)	0.8739076	1.0638298	0.8963251	2.834062
19	*Calotropis procera*	Aak	*Apocynaceae*	32	2 (E, H)	3.9950062	1.0638298	4.097486	9.156322
20	*Canna lily*	Keli Lal	*Cannaceae*	13	1 (E)	1.6229713	0.5319149	3.3292074	5.484094
21	*Cannabis sativa*	Bhang	*Cannabaceae*	59	2 (C, H)	7.3657928	1.0638298	7.5547399	15.98436
22	*Capsicum annuum*	Green chilli	*Solanaceae*	2	1 (F)	0.2496879	0.5319149	0.5121858	1.293789
23	*Cassia fistula*	Amaltas	*Fabaceae*	8	4 (A, B, D, E)	0.9987516	2.1276596	0.5121858	3.638597
24	*Catharanthus roseus*	Sadabahar	*Apocynaceae*	21	3 (A, B, F)	2.6217228	1.5957447	1.7926501	6.010118
25	*Chlorophytum comosum*	Spider plant	*Asparagaceae*	6	2 (F, G)	0.7490637	1.0638298	0.7682786	2.581172
26	*Chrysanthemum indicum*	Guldaudi	*Asteraceae*	7	2 (A, B)	0.8739076	1.0638298	0.8963251	2.834062

27	*Chukrasia velutina*	Chukrasia	*Meliaceae*	1	1 (A)	0.1248439	0.5319149	0.2560929	0.912852
28	*Citrus × limon*	Nimbu	*Rutaceae*	4	2 (D, E)	0.4993758	1.0638298	0.5121858	2.075391
29	*Codiaeum variegatum*	Croton	*Euphorbiaceae*	5	1 (G)	0.6242197	0.5319149	1.2804644	2.436599
30	*Cordia dichotoma*	Lehsua	*Boraginaceae*	2	1 (E)	0.2496879	0.5319149	0.5121858	1.293789
31	*Cuscuta reflexa*	Amarbael	*Convonvulaceae*	2	1 (E)	0.2496879	0.5319149	0.5121858	1.293789
32	*Cycas revoluta*	Palm-Kanghi	*Cycadaceae*	5	2 (C, E)	0.6242197	1.0638298	0.6402322	2.328282
33	*Dahlia pinnata*	Dahlia	*Asteraceae*	4	1 (B)	0.4993758	0.5319149	1.0243715	2.055662
34	*Dalbergia sissoo*	Shisham	*Fabaceae*	24	6 (A, B, C, D, E, H)	2.9962547	3.1914894	1.0243715	7.212116
35	*Datura innoxia*	Datura	*Solanaceae*	36	3 (C, D, H)	4.494382	1.5957447	3.0731145	9.163241
36	*Dolichos lablab*	Papdi	*Fabaceae*	36	5 (A, B, D, E, H)	4.2446941	2.6595745	1.7414316	8.6457
37	*Dracaena anglolensis*	Cylindrical snake plant	*Asparagaceae*	8	2 (F, G)	0.9987516	1.0638298	1.0243715	3.086953
38	*Dracaena trifasciata*	Snake plant	*Asparagaceae*	11	2 (F, G)	1.3732834	1.0638298	1.4085108	3.845624
39	*Dypsis lutescens*	Erica Palm	*Arecaceae*	9	3 (B, E, F)	1.1235955	1.5957447	0.7682786	3.487619
40	*Echinocactus grusonii*	Barrel cactus	*Cactaceae*	1	1 (F)	0.1248439	0.5319149	0.2560929	0.912852
41	*Elaeocarpus ganitrus*	Rudrakash	*Elaeocarpaceae*	1	1 (F)	0.1248439	0.5319149	0.2560929	0.912852
42	*Epipremnum aureum*	Moneyplant	*Araceae*	1	1 (F)	0.1248439	0.5319149	0.2560929	0.912852
43	*Eucalyptus globulus*	Safeda	*Myrtaceae*	11	1 (C)	1.3732834	0.5319149	2.8170216	4.72222
44	*Ficus benjamina*	Ficus	*Moraceae*	12	3 (A, B, C)	1.4981273	1.5957447	1.0243715	4.118244
45	*Ficus racemose*	Anjeer	*Moraceae*	3	2 (A, E)	0.3745318	1.0638298	0.3841393	1.822501
46	*Ficus religiosa*	Pipal	*Moraceae*	12	4 (A, B, C, H)	1.4981273	2.1276596	0.7682786	4.394066
47	*Grevillea robusta*	Silver oak	*Proteaceae*	1	1 (A)	0.1248439	0.5319149	0.2560929	0.912852
48	*Hibiscus rosa-sinensis*	China Rose	*Malvaceae*	3	1 (B)	0.3745318	0.5319149	0.7682786	1.674725
49	*Indian jujube*	Beri	*Rhamnaceae*	10	4 (A, D, E, H)	1.2484395	2.1276596	0.6402322	4.016331
50	*Jasminum arborescens*	Chameli	*Oleaceae*	4	2 (A, F)	0.4993758	1.0638298	0.5121858	2.075391
51	*Jasminum sambac*	Jasmine	*Oleaceae*	3	1 (G)	0.3745318	0.5319149	0.7682786	1.674725
52	*Jatropha curcas*	Jatropha	*Euphorbiaceae*	6	1 (A)	0.7490637	0.5319149	1.5365573	2.817536
53	*Kigelia africana*	Kigelia	*Bignoniaceae*	4	2 (E, H)	0.4993758	1.0638298	0.5121858	2.075391
54	*Magnolia champaca*	Champak	*Magnoliaceae*	10	2 (A, B)	1.2484395	1.0638298	1.2804644	3.592734
55	*Mangifera indica*	Aam	*Anacardiaceae*	2	2 (B, D)	0.2496879	1.0638298	0.2560929	1.569611
56	*Manilkara zapota*	Chiku	*Sapotaceae*	1	1 (D)	0.1248439	0.5319149	0.2560929	0.912852
57	*Melia azedarach*	Bakain	*Meliaceae*	5	3 (A, C, D)	0.6242197	1.5957447	0.4268215	2.646786
58	*Monstera deliciosa*	Fruit salad plant	*Araceae*	3	1 (F)	0.3745318	0.5319149	0.7682786	1.674725
59	*Moringa oleifera*	Sohanjana	*Moringaceae*	5	2 (A, B)	0.6242197	1.0638298	0.6402322	2.328282
60	*Morus alba*	Shehtoot	*Moraceae*	4	3 (A, C, D)	0.4993758	1.5957447	0.3414572	2.436578
61	*Murraya koenigii*	Curri plant	*Rutaceae*	1	1 (F)	0.1248439	0.5319149	0.2560929	0.912852
62	*Musa paradisiaca*	Banana	*Musaceae*	3	1 (D)	0.3745318	0.5319149	0.7682786	1.674725
63	*Nerium oleander*	Kaner	*Apocynaceae*	25	4 (A, B, E, H)	3.1210986	1.5957447	2.1341073	6.850951
64	*Nyctanthes arbor-tristis*	Harshingar	*Oleaceae*	3	1 (A)	0.3745318	0.5319149	0.7682786	1.674725
65	*Papaver somniferum*	Poppyflower	*Papaveraceae*	5	1 (B)	0.6242197	0.5319149	1.2804644	2.436599

66	*Parthenium hysterophorus*	Congress grass	*Asteraceae*	12	2 (C, H)	1.4981273	1.0638298	1.5365573	4.098514
67	*Petunia × atkinsiana*	Petunia	*Solanaceae*	3	2 (B, G)	0.3745318	0.5319149	0.7682786	1.674725
68	*Phalaris minor*	Guli Danda Ghass	*Poaceae*	4	1 (C)	0.4993758	0.5319149	1.0243715	2.055662
69	*Philodendron Xanadu*	Philodendron Xanadu	*Araceae*	1	1 (F)	0.1248439	0.5319149	0.2560929	0.912852
70	*Phyllanthus emblica*	Amla	*Phyllanthaceae*	2	1 (D)	0.2496879	0.5319149	0.5121858	1.293789
71	*Pinus roxburghii*	Indian pine	*Pinaceae*	2	1 (B)	0.2496879	0.5319149	0.5121858	1.293789
72	*Platycladus orientalis*	Platypladus	*Cupressaceae*	2	1 (G)	0.2496879	0.5319149	0.5121858	1.293789
73	*Polyscias fruticosa*	Aralia	*Araliaceae*	1	1 (A)	0.1248439	0.5319149	0.2560929	0.912852
74	*Prosopis cineraria*	Janti	*Fabaceae*	4	4 (A, C, D, H)	0.4993758	1.5957447	0.3414572	2.436578
75	*Prosopis juliflora*	Pahadi Keekar	*Fabaceae*	6	3 (C, E, H)	0.7490637	1.5957447	0.5121858	2.856994
76	*Prunus persica*	Aadu	*Fabaceae*	3	1 (E)	0.3745318	0.5319149	0.7682786	1.674725
77	*Psidium guajava*	Amrood	*Myrtaceae*	4	2 (C, D)	0.4993758	1.0638298	0.5121858	2.075391
78	*Pterospermum acerifolium*	Kanak champa	*Malvaceae*	3	1 (A)	0.3745318	0.5319149	0.7682786	1.674725
79	*Punica granatum*	Anar	*Lythraceae*	1	1 (D)	0.1248439	0.5319149	0.2560929	0.912852
80	*Ricinus communis*	Arind	*Euphorbiaceae*	30	3 (C, E, H)	3.7453184	1.5957447	2.5609288	7.901992
81	*Rosa indica*	Rose	*Rosaceae*	14	2 (B, D)	1.7478152	1.0638298	1.7926501	4.604295
82	*Rosa rubigionosa*	English Rose	*Rosaceae*	2	1 (F)	0.2496879	0.5319149	0.5121858	1.293789
83	*Royal Poinciana*	Gulmohar	*Fabaceae*	3	1 (A)	0.3745318	0.5319149	0.7682786	1.674725
84	*Saccharum spontaneum*	Kans	*Poaceae*	5	1 (C)	0.6242197	0.5319149	1.2804644	2.436599
85	*Saraca asoca*	Ashoka	*Fabaceae*	20	5 (A, B, E, F, G)	2.4968789	2.6595745	1.0243715	6.180825
86	*Syngonium podophyllum*	Signoia	*Araceae*	1	1 (F)	0.1248439	0.5319149	0.2560929	0.912852
87	*Syzygium cumini*	Jamun	*Myrtaceae*	8	5 (A, B, C, D, H)	0.9987516	2.6595745	0.4097486	4.068075
88	*Tabernaemontana divaricata*	Chandni	*Apocynaceae*	31	4 (A, B, F, G)	3.8701623	2.1276596	1.9847198	7.982542
89	*Tagetes erecta*	Genda	*Asteraceae*	40	2 (B, D)	4.9937578	1.5957447	3.4145717	10.00407
90	*Tecoma stans*	Yellow trumpet	*Bignoniaceae*	5	1 (A)	0.6242197	0.5319149	1.2804644	2.436599
91	*Tecomella undulata*	Rohida	*Bignoniaceae*	1	1 (B)	0.1248439	0.5319149	0.2560929	0.912852
92	*Terminalia arjuna*	Arjun	*Combretaceae*	3	1 (A)	0.3745318	0.5319149	0.7682786	1.674725
93	*Tinospora cordifolia*	Giloy	*Menispermaceae*	3	2 (D, F)	0.3745318	1.0638298	0.3841393	1.822501
94	*Trachycarpus fortunei*	Chinese windmill palm	*Arecaceae*	8	2 (C, F)	0.9987516	1.0638298	1.0243715	3.086953
95	*Tradescantia pallida*	Purple queen	*Commelinaceae*	2	1 (F)	0.2496879	0.5319149	0.5121858	1.293789
96	*Tradescantia zebrina*	Inch plant	*Commelinaceae*	3	1 (F)	0.3745318	0.5319149	0.7682786	1.674725
97	*Vachellia nilotica*	Kikar	*Fabaceae*	24	3 (A, C, H)	2.9962547	1.5957447	2.048743	6.640742
98	*Withania somnifera*	Ashwagandha	*Solanaceae*	10	2 (C, H)	1.2484395	1.0638298	1.2804644	3.592734

A: Shaheed Bhagat Singh Stadium; B: Chaudhary Devi Lal Park; C: Sirsa Minor; D: Municipality Park; E: HUDA Unhabituated Area; F: Home Garden 1; G: Home Garden 2 and H: Mini-bypass Sirsa.

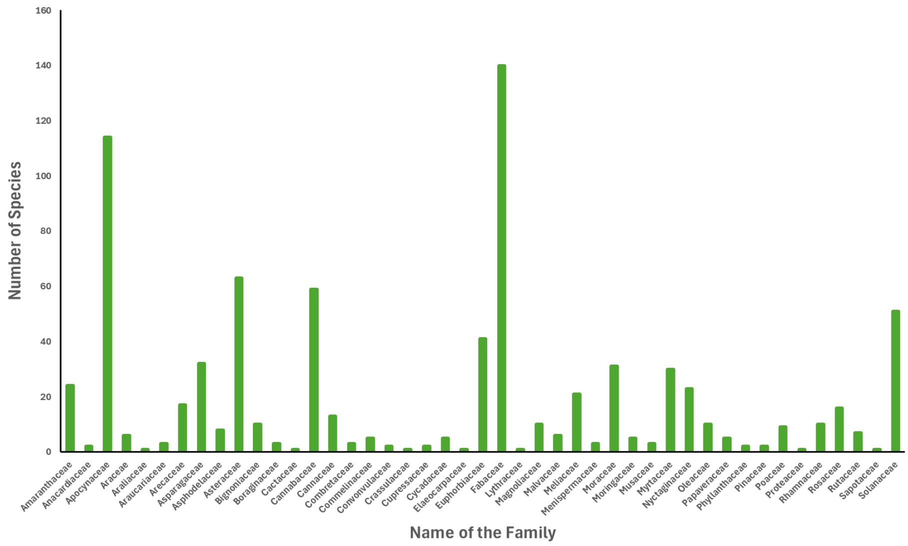

Figure 2: Bar Chart illustrating the distribution of number of species among plant families.

The moderate richness was recorded for plot C (Sirsa Minor) and F (House Garden 1) with 24 and 27 species respectively. The plot G (Home Garden 2) recorded the lowest species richness with 12 species. This is primarily because of the small size and infrequent maintenance. Additionally, household garden predominantly cultivates the ornamental and edible plants like *Mangifera indica* (Mango) and *Psidium guajava* (Guava)[60]. Thus, restricted areas of homes and selective planting limit the overall biodiversity and ecological connectivity[20]. The findings of our study were found to corroborate with the findings for urban biodiversity studies conducted in regions like Adama city (Central Ethiopia), Cilegon City (Indonesia), Portland (Oregon) and Punjab (Pakistan), as they also reported about the higher plant diversity in well-managed urban areas.

Conversely, they also stated that unmanaged small plots show reduced biodiversity due to inadequate conservation measures/efforts and habitat fragmentation[4,31,40,57]. These findings underscore the significance of integrated conservation strategies into urban planning to preserve biodiversity and maintain environmental resilience.

Ecological Indices and Species Dominance: The phytosociological parameters like relative abundance (RA), relative density (RD), relative frequency (RF) and importance value index (IVI) have been calculated for all the species in order to gain insights about species dominance and their ecological significance (Table 1). Based on the data, *Cannabis sativa* showed the highest IVI value i.e. 15.98, highlighting its dominance in urban vegetation of Sirsa region, especially in plot C and H. It also showed the highest RA (7.55) and RD (7.37) indicating its massive presence and adaptiveness to the urban conditions [28,29].

Likewise, *Tagetes erecta* showed the IVI value of 10, RA value of (3.41) and RD value of (4.99), demonstrating its cultural and ornamental importance as well as significant dominance in plot B and D[17,49]. Among native species, *Dalbergia sissoo* and *Vachellia nilotica* showed their prominent presence with IVI value of 7.21 and 6.64 respectively. They were determined to be present in multiple plots (A, B, C, D, E, H for *Dalbergia sissoo* and A, C, H for *Vachellia nilotica*), highlighting their ecological roles in carbon sequestration and soil stabilization [6,47,55]. Additionally, culturally significant and medicinal importance plant species like *Azadirachta indica*, *Calotropis procera, Ficus religiosa and Tabernaemontana divaricate* showed the IVI values of 5.30, 9.16, 4.39 and 7.98 respectively. Further, RF value of these species (2.66 for *Azadirachta indica*, 1.06 for *Calotropis procera*, 2.13 for *Ficus religiosa and* 2.13 for *Tabernaemontana divaricate*) revealing their adaptability to urban environment and reinforcing the merging of biodiversity with human well-being and cultural heritage[7,27,54].

These findings unveil about the contribution of urban vegetation in Sirsa region in various environmental services like air quality improvement, biodiversity conservation, carbon sequestration and thermal regulation. Additionally, it also highlights that species dominance and human intervention affect the species presence and dominance. This aligns with the other studies which demonstrated that species composition depends on the intensity of human activities[19,46]. As stated above, the presence of invasive species like *Cannabis sativa* and *Parthenium hysterophorus* highlights the significant challenges of urban biodiversity management. The invasive nature of the plants species has also been reported by different studies to highlight their adaptive nature to diverse environmental conditions[2,28]. This necessitates the implementation of proactive strategies like habitat restoration and invasive species mitigation.

The findings of our study reveal that urban parks and garden act as the biodiversity hotspots (especially plot A and E) due to their extensive role in providing services like habitat for animal species, shade and carbon sequestration.

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Agave desmettiana
(Dwarf Century Plant)

Saraca asoca
(Ashoka)

Melia azedarach
(Bakain)

Ficus benghalensis
(Bargad)

Callistemon citrinus
(Bottlebrush)

Echinocactus grusonii
(Cactus)

Jasminum sambac
(Chameli)

Magnolia champaca
(Champak)

Nyctanthes arbor-tristis
(Harshingar)

Syzygium cumini
(Jamun)

Nerium oleander
(Kaner)

Vachellia nilotica
(Kikar)

Cordia dichotoma
(Lehsua)

Mangifera indica
(Mango)

Jasminum sambac
(Mogra)

Azadirachta indica
(Neem)

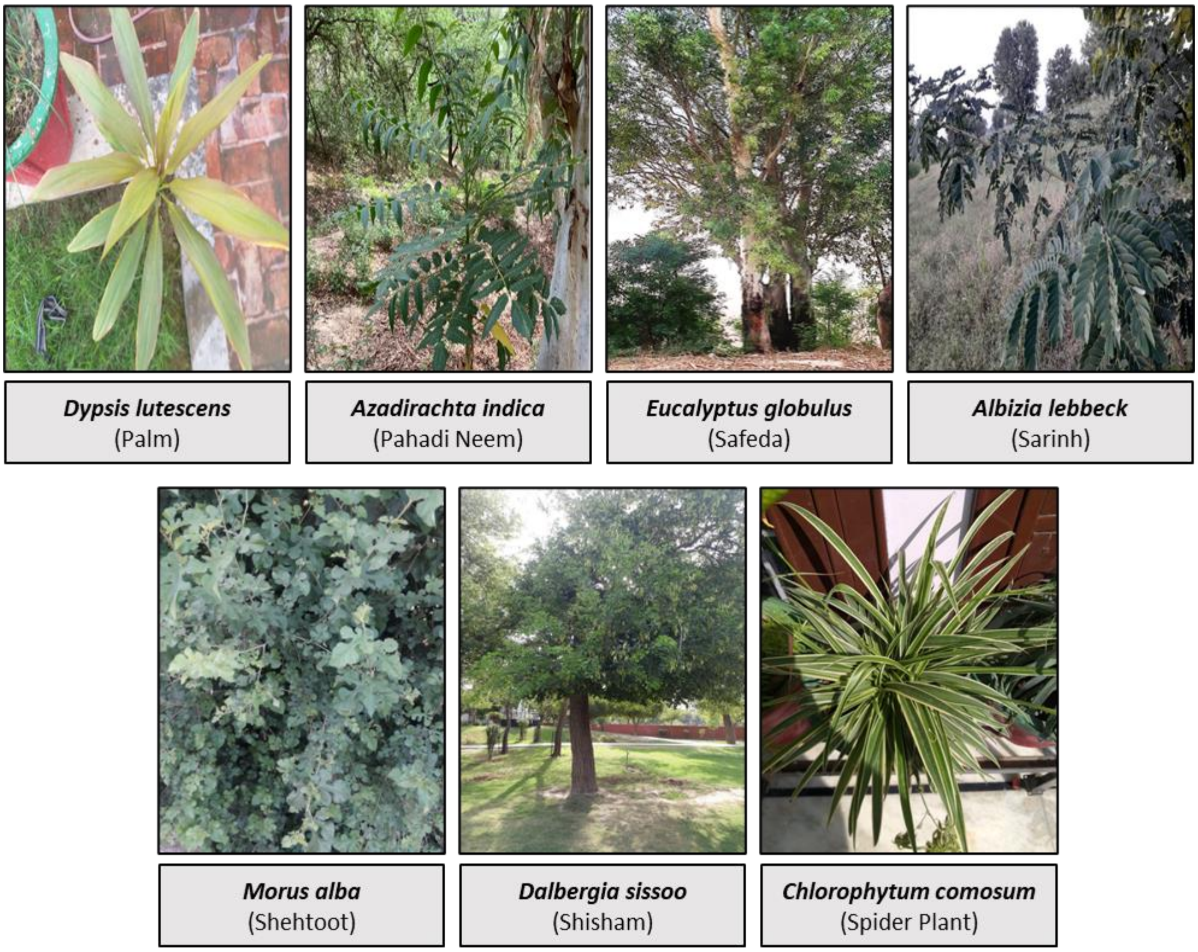


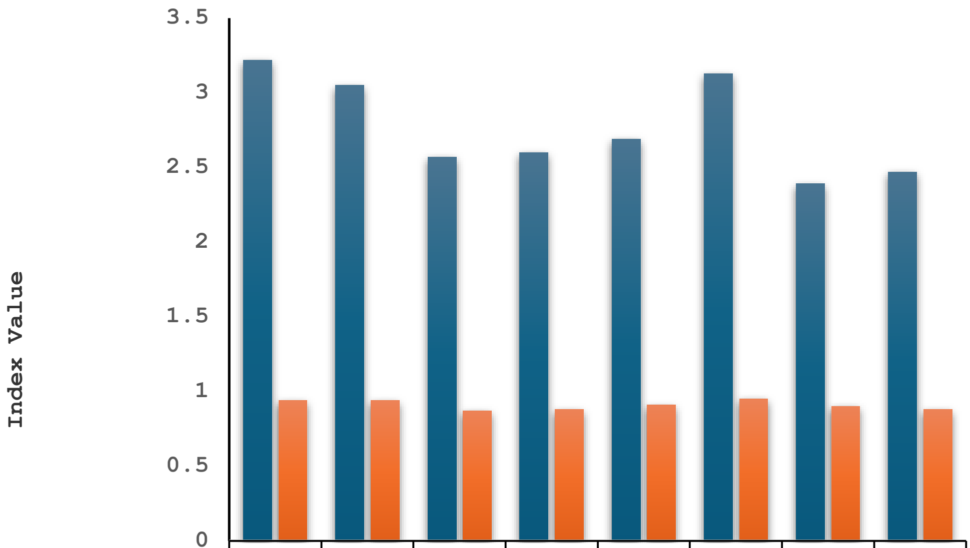
Figure 3: Photographs of explored plant species during biodiversity assessment illustrating the diversity of cultural, ornamental and ecologically important species in urban ecosystems

Table 2
Diversity Indices of each plot in Sirsa region

Site Name	Plot Code	Total Individuals	Shannon-Wiener Index (H')	Simpson Index (D)
Shaheed Bhagat Singh Stadium	A	136	3.22	0.94
Chaudhary Devi Lal Park	B	113	3.05	0.94
Sirsa Minor	C	119	2.57	0.87
Municipality Park	D	62	2.6	0.88
HUDA Unhabituated Area	E	155	2.69	0.91
Home Garden 1	F	53	3.13	0.95
Home Garden 2	G	36	2.39	0.90
Mini-bypass Sirsa	H	129	2.47	0.88

These findings align with the results of Nagendra and Gopal[42] in which they highlighted that urban parks serve as a vital biodiversity hotspot in densely populated, concrete-dominated urban landscapes. Conclusively, promoting native species, enhancing green space management and regulating the growth of invasive plant species are few vital measures for maintaining overall urban ecological balance[7,23].

Statistical Analysis: The biodiversity of plant species was assessed across the different sites in the Sirsa region using Shannon-Wiener Index (H') and Simpson Index (D). These two index metrices provided valuable insights about evenness and species richness. Table 2 provides the summary of the result covering total individuals and diversity index values of respective sites. The Shannon-Wiener Index (H') values showed variation across the different sites ranging from 2.39 to 3.22 indicating the differences in species diversity. The plot A (Shaheed Bhagat Singh Stadium) showed the highest value of H' i.e. 3.22, indicating the presence of diverse plant species in comparison to other sites. This high value indicates that there are large number of species and individual species which are evenly distributed.



	A	B	C	D	E	F	G	H
Shannon-Wiener Index (H')	3.22	3.05	2.57	2.6	2.69	3.13	2.39	2.47
Simpson Index (D)	0.94	0.94	0.87	0.88	0.91	0.95	0.9	0.88

Figure 4: Comparison of Shannon-Wiener (H') and Simpson (D) indices across different sites in Sirsa region

On contrary, the plot G (Home Garden 2) exhibited the lowest value of H' i.e. 2.39, indicating the presence of fewer species or uneven or skewed distribution of the individuals. Other than that, the plot C (Sirsa Minor) and D (Municipality Park) showed the H' value of 2.57 and 2.6, respectively, indicating the moderate diversity at these sites. The remaining sites showed the H' value within the range of 2.39 to 3.13, indicating the moderate level species diversity but not as high as observed for plot A. The Shannon-Wiener index of our study was found within the range of 2.39 to 3.22 which aligns with the results for urban areas in the USA (range 2.1 to 3.9), Nigeria (range 2.24 to 3.56) and Bangalore, India (2.68)[3,41,44].

Compared to Shannon-Weiner Index (H'), the Simpson Index (D) showed less variation with values ranging from 0.87 to 0.95. The value of D aids in determining the dominance of species within a community, where lower values signify higher diversity. The plot F (Home Garden 1) showed the highest value of D i.e. 0.95, indicating even distribution of species and less dominance by any individual species. Both the plot A (Shaheed Bhagat Singh Stadium) and B (Chaudhary Devi Lal Park) showed the same value of D i.e. 0.94, indicating balanced distribution of the species.

On the contrary, plots C (Sirsa Minor), D (Municipality Park) and H (Mini-bypass Sirsa) showed the D values of 0.87, 0.88 and 0.88 respectively, indicating that these sites have uneven species distribution with certain species being dominant. This result has been found to be consistent with H' values of these sites showing reduced overall diversity.

The Simpson Index of our study was found to within the range of 0.87 to 0.95 which aligns with the results for urban areas in the Portland, Oregon (range 0.62 to 0.95) and Novi Sad, Serbia (range 0.92 to 0.96) [35,57]. These two index metrices provide value information about species richness as well as evenness (Figure 4).

Conclusion and Recommendations

The current study highlights the critical role of urban vegetation in maintaining biodiversity and ecological resilience in Sirsa, Haryana. The research showed notable spatial variation in plant diversity across different urban plots influenced by factors like human activities, maintenance practices and plot sizes. The plot A (Shaheed Bhagat Singh Stadium) emerged as the site with high plant species diversity highlighting the positive impact of effective maintenance of the green spaces. On the contrary, home gardens showed the lower species diversity because of selective cultivation and limited space. The utilization of ecological indices like the Shannon-Wiener and Simpson Index revealed deep insights about the species distribution and richness across different sites.

The dominance of *Cannabis sativa* and *Parthenium hysterophorus* poses a threat to biodiversity conservation and highlight the need of immediate intervention to control the growth of these species. Based on these findings, there is dire need for planting of native species which will aid maintaining ecological balance and persevering cultural heritage. Additionally, regular maintenance, sustainable management practices and habitat restoration are required to improve species richness and distribution in urban spaces. Moreover, involving local communities in awareness programs can improve their understanding of the environmental and socio-economic benefits of urban greenery. Further research on urban diversity will offer valuable insights that will help in framing policies for the sustainable growth of urban ecosystem in the long run.

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