

**Herbaceous species diversity, composition and anthropogenic disturbances at Gautala
Autramghat Wildlife Sanctuary (GAWLS), Maharashtra, Western India**

UNDER PEER REVIEW

ABSTRACT

Herbaceous flora plays a crucial role in maintaining ecosystem functions, yet comprehensive studies on their diversity and ecological significance remain limited. This study assesses the species richness, density, frequency, abundance, and Importance Value Index (IVI) of herbaceous plants within the GAWLS Sanctuary. A total of 33 herb species, belonging to 33 genera and 18 families, were documented. Asteraceae emerged as the dominant family with six species, followed by Fabaceae (five species) and Acanthaceae (four species), indicating their prominence in the herbaceous layer. Density analysis identified *Senna tora* (L.) Roxb. as the most dominant species, with 176.39 individuals per hectare (14.77%), followed by *Mesosphaerum suaveolens* (L.) Kuntze (11.86%) and *Hemidesmus indicus var. indicus* (11.63%). Frequency analysis revealed *Hemidesmus indicus var. indicus* as the most frequent species (44.44%), contributing 13.73% to the relative frequency, while *Euphorbia thymifolia* L. and *Mesosphaerum suaveolens* (L.) Kuntze exhibited notable frequencies of 33.33% and 29.17%, respectively. In terms of abundance, *Senna tora* (L.) Roxb. recorded the highest abundance (6.35 individuals per plot), followed by *Ageratum conyzoides* L. and *Corchorus trilocularis* Auct. (6.25 each). The IVI analysis confirmed *Senna tora* (L.) Roxb. as the most ecologically significant species (IVI = 38.12), followed by *Hemidesmus indicus var. indicus* (IVI = 36.99) and *Mesosphaerum suaveolens* (L.) Kuntze (IVI = 32.73). Anthropogenic disturbances, including livestock grazing, bridle path usage, and dependence on forest resources by local communities, exert significant pressure on the ecosystem. Religious activities, such as festival gatherings, vehicle parking, and open-fire cooking, further contribute to habitat degradation. Additionally, tree felling and logging accelerate habitat fragmentation, threatening biodiversity conservation efforts. This study provides critical baseline data for future ecological assessments and highlights the importance of conserving herbaceous plant diversity within protected areas.

Keywords: Herb, Plant, Quadrat, Floral, Vegetation, Biodiversity, Habitat

1. INTRODUCTION

Herbaceous plant species are essential components of terrestrial ecosystems worldwide, playing a pivotal role in ecological processes such as primary production, nutrient cycling, and soil stabilization (Henneron et al., 2020; Stefanowicz et al., 2023). In forest ecosystems, understory herbaceous plants represent one of the most species-rich plant forms, accounting for up to 80% of all vascular plant species in temperate forests (Gilliam, 2007). These plants contribute significantly to biodiversity conservation by providing habitats and food resources for various animal species, including pollinators and herbivores (Brockerhoff et al., 2017). Additionally, they influence forest regeneration by interacting with woody plant seedlings, shaping community dynamics and ecological succession (Holeksa, 2003). Unlike woody plants, herbaceous species are smaller in stature and possess less persistent aboveground structures, making them highly sensitive to spatial and temporal environmental changes (Garg et al., 2022). This sensitivity makes them valuable indicators of ecosystem health, especially in regions affected by habitat loss and anthropogenic disturbances (Spicer et al., 2022). Although most studies on forest biodiversity focus on woody plants (Murphy et al., 2016). Herbaceous vegetation forms a foundational layer across diverse ecosystems from grasslands and savannahs to tropical and temperate forests, driving key ecological functions and enhancing ecosystem resilience (Lian et al., 2022; Wang et al., 2021). Despite their ecological significance, comprehensive knowledge of the structure and species diversity of understory herbaceous communities remains limited (Wang et al., 2021), highlighting the need for further research to inform effective conservation strategies.

In biodiversity-rich regions like India, herbaceous species contribute to the structural and functional diversity of forest ecosystems. Indian forests, particularly those in protected areas, harbour diverse herbaceous flora that are integral to maintaining ecological balance and

supporting the broader food web(Radhamoni et al., 2023). However, these species are increasingly threatened by land-use changes, overgrazing, and climate variability. Despite their ecological importance, herbaceous species receive comparatively less research attention than woody plants, resulting in a knowledge gap regarding their diversity, distribution, and ecological significance(Spicer et al., 2022). The Gautala Autramghat Wildlife Sanctuary (GAWLS) Sanctuary, situated in a region of ecological and conservation significance, represents a unique habitat where herbaceous species thrive alongside other vegetation forms. The sanctuary's diverse topography and climatic conditions foster a rich assemblage of herbaceous flora. However, the herbaceous layer is susceptible to various environmental pressures, including habitat fragmentation and human activities such as grazing and resource extraction(Pawar & Mule, 2025b). Understanding the composition and distribution of herbaceous species in this sanctuary is essential for developing effective conservation policies and sustainable management practices.

Anthropogenic disturbances have far-reaching impacts on biodiversity, affecting not only herbaceous vegetation but also the entire wildlife community. Activities such as deforestation, livestock grazing, fuelwood collection, infrastructure development, and agricultural expansion contribute to habitat degradation and fragmentation(Himshikha et al., 2022). These disturbances alter ecosystem dynamics by reducing plant cover, depleting food resources, and disrupting the movement and behaviour of wildlife species(Wilson et al., 2020). Additionally, human-induced pressures such as poaching, pollution, and unregulated tourism further threaten the stability of natural habitats. The cumulative effects of these disturbances can lead to shifts in species composition, declines in population densities, and disruptions in ecological interactions(Battisti et al., 2016). Understanding these challenges is crucial for implementing sustainable conservation strategies that balance human activities with ecosystem protection.

In recent years, floristic studies have become increasingly important as nations, particularly those in developing and underdeveloped regions, strive to assess and understand their plant biodiversity. This research represents the first comprehensive study of herbaceous flora within the GAWLS, systematically evaluating key ecological parameters such as species richness, density, frequency, abundance, and the Importance Value Index (IVI). Additionally, it investigates the diversity and composition of herbaceous species and overall anthropogenic disturbances to wildlife. The findings of this study will provide a crucial baseline for long-term ecological monitoring and contribute to the development of conservation strategies aimed at preserving and sustaining the region's herbaceous biodiversity. The intensity ranking of anthropogenic disturbances will be useful for targeted wildlife management efforts at GAWLS.

2. MATERIALS AND METHODS

2.1 Study Area

The Gautala Autramghat Wildlife Sanctuary (GAWLS) is located in Maharashtra, Western India, covering approximately 260 km² across the Chhatrapati Sambhajnagar (Aurangabad) and Jalgaon districts (Fig. 1). Situated within the Satmala and Ajanta hill ranges of the Western Ghats, the sanctuary features diverse terrain, including rugged hills, plateaus, and plains. It lies at approximately 20.33°N latitude and 75.14°E longitude. The sanctuary's vegetation primarily consists of dry deciduous forests, grasslands, and scrublands, with dominant species including *Tectona grandis* (teak), *Butea monosperma* (Palash), *Diospyros melanoxylon* (Tendu), and *Anogeissus latifolia* (Dhamorda) (Champion & Seth, 1968; Pawar & Mule, 2025b). GAWLS was declared a protected area in 1986 and was designated an eco-sensitive zone in 2016 by the Ministry of Environment, Forest and Climate Change. This status extended the protected area to 483.45 km², incorporating a 1 km peripheral buffer

zone(Ministry of Environment Forest and Climate Change Notification, New Delhi, the 9th December, 2016). The region experiences a dry climate with frequent droughts, resulting in water scarcity, especially during summer. Despite its ecological significance and rich biodiversity(Pawar & Mule, 2025a), the sanctuary faces increasing pressure from human activities such as agricultural encroachment and resource extraction. This study examines the vegetation structure and species composition of GAWLS to support future conservation efforts and promote sustainable resource management.

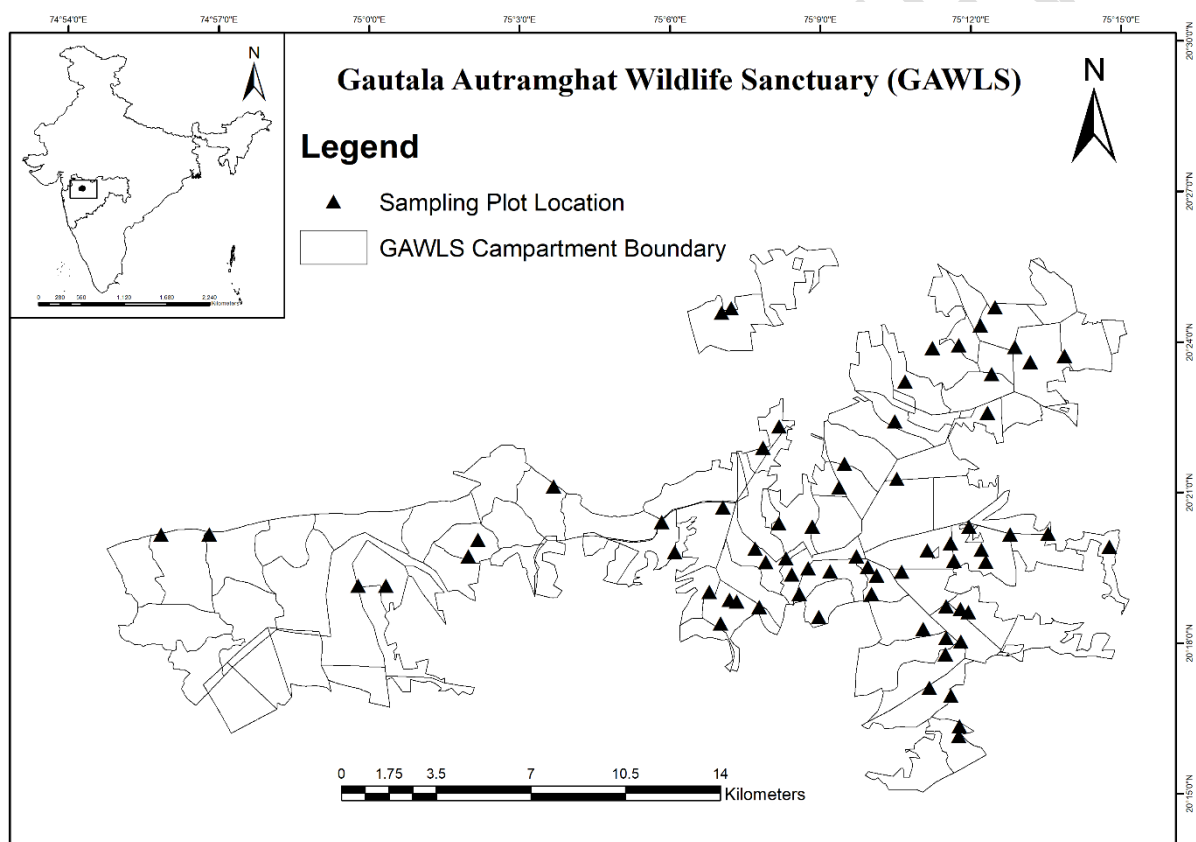


Figure 1: Map depicting the study area and the distribution of sampling plots within Gautala Autramghat Wildlife Sanctuary (GAWLS).

2.2 Field Data Collection

Field data collection was conducted between November 2023 and February 2024. To assess the composition and density of herbaceous species in the GAWLS Sanctuary, 72 randomly

distributed sampling plots were established. Each plot measured 1×1 m (1 m^2), following the systematic random sampling method outlined by (Misra, 1968), ensuring adequate representation of spatial variations across different habitat types. Within each plot, all individual herbaceous plants were identified and counted to determine their frequency and abundance. This approach provided robust quantitative data on species composition and density while minimizing sampling bias, offering a comprehensive assessment of the sanctuary's herbaceous vegetation.

2.3 Data Analysis

2.3.1 Species Richness

Species richness was assessed by counting the number of herb species identified within each sampling plot. This metric represents the variety of herbaceous species across the study area. To ensure consistency, the total species count for each plot was standardized and reported as species per hectare (species/ha). This method enabled a comprehensive evaluation of herb diversity and allowed for direct comparisons across different sampling locations within the GAWLS.

2.3.2 Density

Density was measured by calculating the number of individual herbaceous plants within each quadrat. It is expressed as individuals per hectare (individuals/ha), providing an estimate of species concentration across the study area. This metric reflects the spatial distribution and population density of herb species in the sampled plots. Density and relative density were determined using established phytosociological methods (Yadav et al., 1987), applying the following formula:

$$\text{Relative Density (RD\%)} = \frac{\text{Density of individual species}}{\text{Total density of all species}} \times 100$$

2.3.3 Abundance

Abundance represents the total number of individual herb species recorded across all sampling plots (Kilewa & Rashid, 2014). This measure provides insights into the dominance and relative presence of various herbaceous species within the sanctuary. By analysing both density and abundance, dominant species were identified, and patterns of species distribution across the study area were evaluated.

$$\text{Abundance (A)} = \frac{\text{Total no. of individuals of a species in all quadrats}}{\text{Total no. of quadrats in which the species occurred}}$$

$$\text{Relative Abundance (RA\%)} = \frac{\text{Total no. of individual species}}{\text{Total no. of individuals of all species recorded}} \times 100$$

2.3.4 Frequency

Frequency indicates the proportion of sampling plots where a specific herb species was found, providing insight into its spatial distribution across the study area (Yadav et al., 1987).

It was calculated using the following formula:

$$\text{Frequency (F)(\%)} = \frac{\text{No. of quadrats in which an individual species occurred}}{\text{Total no. of quadrats studied}} \times 100$$

$$\text{Relative Frequency (RF\%)} = \frac{\text{Frequency of individual species}}{\text{Sum of frequencies of all species}} \times 100$$

This metric reflects the consistency of a species' presence across the 72 random sampling plots. Species with higher frequency values are more widely distributed, whereas those with lower frequencies are more localized or rare. Analyzing species frequency provides insights into species dispersion patterns and ecological dominance within the sanctuary.

2.3.5 Importance Value Index (IVI)

The Importance Value Index (IVI) is a comprehensive metric used to assess the ecological dominance of forest species within a specific area. It integrates three key components relative frequency, relative density, and relative abundance to provide a thorough understanding of each species' ecological importance (Cottam & Curtis, 1956). IVI is calculated using the following formula:

$$\text{IVI} = \text{Relative Frequency} + \text{Relative Density} + \text{Relative Abundance}$$

In this study, IVI was calculated for all herb species recorded across the 72 random sampling plots. Species with higher IVI values are considered ecologically dominant, playing a crucial role in the structure and function of the ecosystem. Analysing IVI helps to understand species composition, identify keystone species, and guide effective conservation and management practices.

2.4 Species Diversity

Species diversity represents the variety and relative abundance of species within an ecosystem. It is a vital measure for understanding community structure, ecological balance, and overall biodiversity health. In this study, species diversity was quantified using three key indices: Shannon's diversity index (H), Simpson's diversity index (1 - D), and the Evenness index (e). These indices comprehensively assess species distribution and dominance across the 72 sampling plots.

2.4.1 Shannon's Diversity Index (H)

Shannon's Diversity Index (H) quantifies species richness and evenness, providing an estimate of community diversity (Magurran, 1988; Shannon, 1948). It is calculated using the following formula:

$$\text{Shannon's Diversity Index } (H) = - \sum_{i=1}^n (p_i \times \ln p_i)$$

Where:

H = Shannon's diversity index, p_i = Proportion of individuals of the i^{th} species (number of individuals of a species/total number of individuals), and $\ln p_i$ = Natural logarithm of p_i

Higher values of H indicate greater species diversity, while lower values reflect reduced diversity within the study area. This index provides insights into species distribution and the overall complexity of the herbaceous community.

2.4.2 Simpson's Diversity Index (1 - D)

Simpson's Diversity Index (1 - D) measures the likelihood that two randomly chosen individuals from a sample belong to different species (Simpson, 1949). It is calculated using the following formula:

$$\text{Simpson's Diversity Index } (1 - D) = \sum p_i^2$$

Where, p_i = Proportion of individuals of the i^{th} species

The index ranges from 0 to 1, where values closer to 1 indicate greater species diversity, while values near 0 suggest that a few species dominate the community. This index provides a robust assessment of species distribution and ecological balance within the herbaceous layer.

2.5 Anthropogenic Disturbances

To assess anthropogenic disturbances in the forest, disturbance intensity was ranked at 20 sites of GAWLS using a three-level scale: 1 – rare, 2 – occasional, and 3 – frequent (Mani & Parthasarathy, 2006). Each disturbance type was noted at every site based on field observations and local knowledge. The scores were then summed separately for each site to determine overall disturbance levels and for each disturbance type to assess its relative impact across the study area. This approach provided a comprehensive understanding of spatial and categorical variations in anthropogenic pressures on the forest ecosystem.

3. RESULTS

3.1 Species Richness

The analysis of herb species richness identified 33 individual species across the study area, representing 33 genera and 18 families (Table 1). The genus distribution was relatively uniform, with each genus comprising a single species. Among the families, Asteraceae was the most dominant, with six species recorded. Fabaceae and Acanthaceae followed with four species each, and Amaranthaceae (3 species), Malvaceae Juss., and Lamiaceae (2 species each) also showed significant representation, highlighting their ecological importance within the herbaceous layer (Table 1).

Table 1: List of herb species along with their corresponding families and local names in GAWLS.

Sr. No.	Scientific Names	Family	Local Name
1	<i>Solanum nigrum L.</i> <i>Bhuiringani/Makoi</i>	Solanaceae	Kamuni
2	<i>Achyranthes aspera L.</i>	Amaranthaceae	Aghada
3	<i>Ageratum conyzoides L.</i>	Asteraceae	Osadi
4	<i>Alternanthera tenella Colla</i>	Amaranthaceae	Phuli Gawat

5	<i>Anacyclus pyrethrum (L.) Lag.</i>	Asteraceae	Akkalkara
6	<i>Andrographis paniculata (Burm. fil.) Nees</i>	Acanthaceae	Bhuineem
7	<i>Anisomeles indica (L.) Kuntze</i>	Lamiaceae	Gopali
8	<i>Asparagus racemosus Wild</i>	Asparagaceae	Shatawari
9	<i>Cajanus scarabaeoides (L.) Thouars</i>	Fabaceae	Rantur
10	<i>Canna indica L.</i>	Cannaceae	Ran Kardali
11	<i>Canscora diffusa (Vahl) R.</i>	Gentianaceae	Kilwar
12	<i>Celosia argentea L.</i>	Amaranthaceae	Kurdu/Kombda
13	<i>Corchorus trilocularis Auct.</i>	Malvaceae Juss.	-
14	<i>Oxalis corniculata.</i>	Oxalidaceae	Creeping oxalis
15	<i>Cleome viscosa L.</i>	Brassicaceae	Yellow Spider Flower
16	<i>Cyathocline purpurea (Buch.-Ham. ex D.Don) Kuntze</i>	Asteraceae	Gangotra
17	<i>Dyschoriste vagans (Wight)</i>	Acanthaceae	-
18	<i>Euphorbia thymifolia L.</i>	Euphorbiaceae	Randudhi
19	<i>Evolvulus alsinoides (L.) L</i>	Convolvulaceae	Vishnukant
20	<i>Hemidesmus indicus var. indicus</i>	Apocynaceae	Anantmul
21	<i>Lepidagathis cristata Willd.</i>	Acanthaceae	-
22	<i>Mesosphaerum suaveolens (L.) Kuntze</i>	Lamiaceae	Rantulas
23	<i>Mimosa pudica L.</i>	Fabaceae	Lajalu
24	<i>Pentanema indicum L.</i>	Asteraceae	Sonkandi
25	<i>Peristrophe paniculata (Forssk.) Brummit</i>	Acanthaceae	-
26	<i>Phyllanthus niruri L.</i>	Phyllanthaceae	Bhui Awala
27	<i>Senna tora (L.) Roxb.</i>	Fabaceae	Tarota
28	<i>Sida rhombifolia L.</i>	Malvaceae Juss.	Sahdev
29	<i>Tephrosia purpurea (L.) Pers.</i>	Fabaceae	Sharpunkha
30	<i>Tridax procumbens L.</i>	Asteraceae	Tantani
31	<i>Ceropegia hirsuta Wight & Arn.</i>	Apocynaceae	Hamana
32	<i>Trubulus terrestris, Linn.</i>	Zygoiphyllaceae	Ghokharu
33	<i>Vernonia cinerea (L.)</i>	Asteraceae	-

3.2 Density

The analysis of herb density revealed clear patterns of species dominance within the study area. *Senna tora (L.) Roxb.* exhibited the highest density, with 176.39 individuals per hectare (14.77%), followed by *Mesosphaerum suaveolens (L.) Kuntze* at 141.67 individuals per

hectare (11.86%) and *Hemidesmus indicus var. indicus* at 138.89 individuals per hectare (11.63%). The densities and relative densities of herb species are presented in Table 2.

Table 2. Abundance, frequency, Importance Value Index and Densities of herb species with their relative measures in GAWLS.

Sr . No	Scientific Names	Abundance	Relative abundance	Frequency (F) (%)	Relative Frequency (F) (%)	Importance Value Index (IVI)	Density	Relative Density
1	<i>Senna tora (L.) Roxb.</i>	6.35	14.80	27.78	8.66	38.26	176.39	14.80
2	<i>Mesosphaerum suaveolens (L.) Kuntze</i>	4.86	11.89	29.17	9.09	32.87	141.67	11.89
3	<i>Hemidesmus indicus var. indicus</i>	3.13	11.66	44.44	13.85	37.16	138.89	11.66
4	<i>Euphorbia thymifolia L.</i>	3.50	9.79	33.33	10.39	29.97	116.67	9.79
5	<i>Dyschoriste vagans (Wight)</i>	3.75	8.74	27.78	8.66	26.14	104.17	8.74
6	<i>Tridax procumbens L.</i>	3.26	7.23	26.39	8.23	22.68	86.11	7.23
7	<i>Trubulus terrestris, Linn.</i>	3.47	6.88	23.61	7.36	21.11	81.94	6.88
8	<i>Anisomeles indica (L.) Kuntze</i>	4.00	4.66	13.89	4.33	13.65	55.56	4.66
9	<i>Ageratum conyzoides L.</i>	6.25	2.91	5.56	1.73	7.56	34.72	2.91
10	<i>Corchorus trilocularis Auct.</i>	6.25	2.91	5.56	1.73	7.56	34.72	2.91
11	<i>Mimosa pudica L.</i>	2.78	2.91	12.50	3.90	9.72	34.72	2.91
12	<i>Cyathocline purpurea (Buch.-Ham. ex D. Don) Kuntze</i>	2.86	2.33	9.72	3.03	7.69	27.78	2.33
13	<i>Asparagus racemosus Wild</i>	4.25	1.98	5.56	1.73	5.69	23.61	1.98
14	<i>Evolvulus alsinoides (L.) L</i>	5.33	1.86	4.17	1.30	5.03	22.22	1.86
15	<i>Cleome viscosa L.</i>	1.86	1.52	9.72	3.03	6.06	18.06	1.52
16	<i>Anacyclus pyrethrum (L.) Lag.</i>	3.33	1.17	4.17	1.30	3.63	13.89	1.17
17	<i>Cajanus scarabaeoides (L.) Thouars</i>	2.50	1.17	5.56	1.73	4.06	13.89	1.17
18	<i>Lepidagathis cristata Willd.</i>	3.00	1.05	4.17	1.30	3.40	12.50	1.05
19	<i>Pentanema indicum L.</i>	1.67	0.58	4.17	1.30	2.46	6.94	0.58
20	<i>Vernonia cinerea (L.)</i>	5.00	0.58	1.39	0.43	1.60	6.94	0.58
21	<i>Achyranthes aspera L.</i>	4.00	0.47	1.39	0.43	1.37	5.56	0.47
22	<i>Canscora diffusa (Vahl) R.</i>	2.00	0.47	2.78	0.87	1.80	5.56	0.47
23	<i>Tephrosia purpurea (L.) Pers.</i>	4.00	0.47	1.39	0.43	1.37	5.56	0.47
24	<i>Alternanthera tenella Colla</i>	1.50	0.35	2.78	0.87	1.57	4.17	0.35
25	<i>Celosia argentea L.</i>	3.00	0.35	1.39	0.43	1.13	4.17	0.35
26	<i>Oxalis corniculata</i>	3.00	0.35	1.39	0.43	1.13	4.17	0.35
27	<i>Canna indica L.</i>	1.00	0.23	2.78	0.87	1.33	2.78	0.23
28	<i>Solanum nigrum L. Bhuringani/Makoi.</i>	1.00	0.12	1.39	0.43	0.67	1.39	0.12
29	<i>Andrographis paniculata (Burm. fil.) Nees</i>	1.00	0.12	1.39	0.43	0.67	1.39	0.12
30	<i>Peristrophe paniculata (Forssk.) Brummit</i>	1.00	0.12	1.39	0.43	0.67	1.39	0.12
31	<i>Phyllanthus niruri L.</i>	1.00	0.12	1.39	0.43	0.67	1.39	0.12

32	<i>Sida rhombifolia L.</i>	1.00	0.12	1.39	0.43	0.67	1.39	0.12
33	<i>Ceropegia hirsuta Wight & Arn.</i>	1.00	0.12	1.39	0.43	0.67	1.39	0.12

3.3 Frequency

The frequency analysis of herb species emphasised the most prevalent species in the study area. *Hemidesmus indicus var. indicus* exhibited the highest frequency at 44.44%, accounting for 13.73% of the relative frequency. This was followed by *Euphorbia thymifolia L.*, with a frequency of 33.33% (10.30% relative frequency), and *Mesosphaerum suaveolens (L.) Kuntze* recorded a frequency of 29.17% (9.01% relative frequency). Detailed frequency values for all identified species are provided in Table 2.

3.4 Abundance

The abundance analysis identified the dominant herbaceous species in the study area. *Senna tora (L.) Roxb.* was the most abundant, with 6.35 individuals per plot, followed by *Ageratum conyzoides L.* and *Corchorus trilocularis Auct.*, each having an abundance of 6.25. *Evolvulus alsinoides (L.) L.* showed a moderate abundance of 5.33, while *Vernonia cinerea (L.)* recorded 5 individuals per plot. Detailed abundance values for all identified species are provided in Table 2.

3.5 Importance Value Index (IVI)

The Importance Value Index (IVI) analysis highlighted the dominant herbaceous species in the study area. *Senna tora (L.) Roxb.* had the highest IVI (38.12), followed by *Hemidesmus indicus var. indicus* (36.99) and *Mesosphaerum suaveolens (L.) Kuntze* (32.73). Detailed IVI values for all identified species are provided in Table 2.

3.6 Species Diversity

The herbaceous species diversity in the study area was high, as indicated by the Simpson Diversity Index (0.918) and Shannon Diversity Index (2.76). These values suggest a well-distributed and diverse herbaceous community, with multiple species contributing to overall ecosystem stability. The results highlight a balanced species composition, reflecting minimal dominance by any single species.

UNDER PEER REVIEW

3.7 Anthropogenic Disturbances

The assessment of anthropogenic disturbance scores across different sites highlights significant variations in human impact on the forest as given in Table 3.

Table 3. The site-wise disturbances scores ranked from 1 - rare, 2- occasional and 3 - frequent at 20 sites of GAWLS.

Disturbances	AM	BH	BP	BD	BM	CM	GT	HR	HS	HW	JN	KL	MH	MD	NS	OD	PT	ST	SY	TP	Total	
Bridle path used	3	1	1	3	1	3	2	2	3	2	3	3	1	3	3	3	1	3	3	3	3	47
Temple visitor's impact:																						
1. Vehicle parking (area occupied)	1	2	1	1	1	1	3	1	1	1	1	1	1	1	1	1	3	1	1	1	1	25
2. Cooking inside the forest	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	21
3. Festive occasion	1	3	1	1	1	1	3	1	1	1	2	1	1	1	1	1	3	1	1	2	28	
Approach road to temple (width)	1	2	1	1	1	1	3	1	1	3	3	1	1	1	1	1	3	1	1	1	1	29
Resource Removal:																						
1. Firewood	2	2	3	2	3	3	2	2	1	2	2	2	1	2	2	2	1	2	2	2	2	40
2. Timber	1	1	1	1	3	3	1	2	1	1	1	1	1	1	3	1	1	2	1	2	3	31
3. Grass	1	2	1	1	2	2	1	1	2	1	2	1	1	3	1	3	3	2	2	3	35	
Nearness of habitation and people's dependence on the forest	2	2	3	3	2	3	1	3	2	2	2	2	2	2	2	2	2	1	2	3	3	43
Grazing (cattle/goat)	3	3	2	2	3	3	1	3	1	1	3	3	2	3	3	3	3	3	3	3	3	51
Tree Cutting	1	2	2	1	2	2	1	3	1	2	2	1	2	2	3	1	1	2	2	3	36	
Tree Logging	1	1	1	1	1	2	1	1	1	1	2	1	2	2	2	1	2	2	2	2	2	29
Fire	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
Total	19	23	19	19	22	26	21	22	17	19	25	19	17	23	24	21	25	22	22	28		

Note: The following abbreviations are used for site names in the table:

AM – Ambala, BH – Bchildari, BP – Bhopewadi, BD – Bodhere, BM – Bramhani, CM – Chimnapur, GT – Gautala, HR – Haraswadi, HS – Hasnabad, HW – Hiwarkheda, JN – Junona, KL – Kalanki, MH – Mehun, MD – Mohrda, NS – Nombhora-Sawargaon, OD – Odhare, PT – Patana, ST – Satkund, SY – Saygavhan, TP – Tapowan.

4. DISCUSSION

4.1 Species Richness and Composition

The herbaceous vegetation of the Gautala Autramghat Wildlife Sanctuary (GAWLS) exhibits significant species richness, with 33 species distributed across 33 genera and 16 families (Table 1). This diversity reflects the ecological heterogeneity of the sanctuary, characterized by a mosaic of dry deciduous forests, grasslands, and scrublands. Similar studies conducted in dry deciduous ecosystems have reported comparable species richness, reinforcing the ecological value of GAWLS as a biodiversity hotspot (Champion & Seth, 1968). Among the families, Asteraceae emerged as the most dominant, contributing six species, followed by Fabaceae and Acanthaceae (four species). The dominance of Asteraceae aligns with findings from other dry tropical regions where this family is known for its adaptability to arid conditions, and disturbed environments and has great medicinal uses (Haq et al., 2023; Rolnik & Olas, 2021). The presence of multiple species from Amaranthaceae, Malvaceae Juss., and Lamiaceae further underscores the sanctuary's capacity to support diverse herbaceous flora despite the challenging climatic conditions.

4.2 Species Density Patterns

Senna tora (L.) Roxb. displayed the highest density (176.39 individuals per hectare), making it the most dominant herbaceous species in the study area. This species' widespread occurrence may be attributed to its ecological resilience and ability to thrive in disturbed habitats (Jamago et al., 2018). The high densities of *Mesosphaerum suaveolens* (L.) Kuntze and *Hemidesmus indicus* var. *indicus* further highlight the prevalence of species that are well-adapted to the sanctuary's dry and nutrient-limited soils. These species' dominance suggests a potential role in stabilizing the herbaceous layer and supporting associated fauna.

4.3 Frequency and Abundance Dynamics

The frequency analysis revealed that *Hemidesmus indicus var. indicus* had the highest occurrence (44.44%), indicating a wide spatial distribution across the sanctuary. This high frequency, coupled with a significant relative frequency (13.73%), suggests that the species plays a critical role in the local ecosystem by contributing to ground cover and soil stabilization. The high frequency and abundance of *Euphorbia thymifolia L.* and *Mesosphaerum suaveolens (L.) Kuntze* further emphasizes the dominance of stress-tolerant species in the region. These species' ability to withstand periodic droughts is crucial for maintaining ecosystem functions during the dry season (Pahlevani et al., 2020).

4.4 Ecological Dominance and Importance Value Index (IVI)

The Importance Value Index (IVI) confirms *Senna tora (L.) Roxb.* as the most ecologically significant species (IVI = 38.12), followed by *Hemidesmus indicus var. indicus* (IVI = 36.99) and *Mesosphaerum suaveolens (L.) Kuntze* (IVI = 32.73) (Table 2). The high IVI values of these species suggest their integral roles in shaping the herbaceous community structure and providing ecological services, such as soil protection and supporting herbivorous wildlife. Similar patterns of species dominance have been documented in other dry deciduous regions of India (Kumar & Saikia, 2020). The dominance of a few species suggests that resource availability and environmental stressors, including recurrent droughts and anthropogenic pressures, may be shaping the herbaceous community structure (Onoszko et al., 2024). Species such as *Tridax procumbens L.* and *Ageratum conyzoides L.*, which also exhibited moderate density and frequency, are known to colonize degraded and open areas in tropical and subtropical regions. Their prevalence indicates that parts of the sanctuary are experiencing disturbances, potentially from human activities like grazing and small-scale agriculture (Chibuzo et al., 2023).

4.5 Species Diversity

The high diversity indices such as Simpson Diversity Index (0.918) and Shannon Diversity Index (2.76) indicate a stable and resilient herbaceous plant community, contributing to ecosystem functions such as nutrient cycling and habitat provisioning. The even distribution of species suggests that environmental conditions support diverse herbaceous growth. However, factors such as habitat disturbances and land-use changes could impact species composition over time, necessitating ongoing monitoring and conservation measures.

4.6 Anthropogenic Disturbances

The assessment of anthropogenic disturbances in the forest reveals varying degrees of human impact. Grazing and bridle path usage are the most significant disturbances (Pawar & Mule, 2025b), indicating frequent movement of livestock and human activity that could lead to habitat degradation. The nearness of habitation and people's dependence on the forest also rank high, highlighting the direct reliance of local communities on forest resources. Among resource removal activities, firewood collection, grass extraction, and timber removal pose notable threats to forest integrity, potentially leading to habitat loss and biodiversity decline. Religious activities also contribute to disturbances, with festive occasions, vehicle parking, and cooking inside the forest impacting the ecosystem. Additionally, tree cutting and tree logging further exacerbate habitat fragmentation, while fire remains a concern due to its destructive potential.

4.7 Conservation Implications

The findings of this study have important conservation implications. The identification of dominant and ecologically significant species can inform habitat management strategies aimed at preserving biodiversity and ecosystem resilience. Prioritizing the protection of high-IVI species is essential to maintaining ecological balance (Azevedo de Melo et al., 2021). Additionally, monitoring shifts in species composition and abundance can serve as an early

indicator of environmental changes caused by climate variability or human encroachment (García-Duro et al., 2021). These findings underscore the need for effective conservation measures to regulate resource extraction, control livestock grazing, and manage human activities within forested landscapes.

Future research should focus on long-term monitoring of the herbaceous community to detect temporal changes and their drivers. Further studies on soil properties, microclimatic conditions, and species interactions could provide a more comprehensive understanding of the factors influencing herbaceous diversity and composition in GAWLS. Implementing sustainable management practices, such as controlled grazing and habitat restoration, will be critical for conserving the sanctuary's herbaceous flora and associated wildlife.

5. CONCLUSION

The present study highlights the herbaceous species diversity, composition, and ecological dynamics within the GAWLS. The identification of 33 species across 18 families underscores the ecological richness of the sanctuary, with Asteraceae emerging as the dominant family. The analysis of species density, frequency, abundance, and IVI reveals the dominance of *Senna tora* (L.) Roxb., *Hemidesmus indicus* var. *indicus*, and *Mesosphaerum suaveolens* (L.) Kuntze, indicating their critical role in structuring the herbaceous community. High species diversity, as reflected in the Shannon and Simpson indices, suggests a well-balanced ecosystem, though anthropogenic disturbances such as grazing, firewood collection, and tree logging pose significant threats to habitat stability. These findings emphasize the importance of conservation efforts to mitigate human-induced pressures and ensure the persistence of herbaceous biodiversity. Monitoring species composition over time, coupled with sustainable management practices like controlled grazing and habitat restoration, will be vital in preserving the ecological integrity of the sanctuary. Future research should integrate soil

characteristics, microclimatic factors, and long-term monitoring to deepen our understanding of the drivers influencing herbaceous diversity. By implementing targeted conservation strategies, GAWLS can continue to support its diverse herbaceous flora and contribute to broader biodiversity conservation goals.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of this manuscript.

REFERENCES

- Azevedo de Melo, N., Minuzzi Delevati, D., Ben da Costa, A., & Lobo, E. A. (2021). The use of phytosociology to evaluate the efficiency of headwater preservation areas in the Andreas Stream Hydrographic Basin, RS, Brazil. *Ecological Indicators*, 129, 107904. <https://doi.org/10.1016/J.ECOLIND.2021.107904>
- Battisti, C., Poeta, G., & Fanelli, G. (2016). *An Introduction to Disturbance Ecology* (1st ed.). Springer International Publishing. <https://doi.org/10.1007/978-3-319-32476-0>
- Brockhoff, E. G., Barbaro, L., Castagneyrol, B., Forrester, D. I., Gardiner, B., González-Olabarria, J. R., Lyver, P. O. B., Meurisse, N., Oxbrough, A., Taki, H., Thompson, I. D., van der Plas, F., & Jactel, H. (2017). Forest biodiversity, ecosystem functioning and the provision of ecosystem services. *Biodiversity and Conservation* 2017 26:13, 26(13), 3005–3035. <https://doi.org/10.1007/S10531-017-1453-2>
- Champion, H. G., & Seth, S. K. (1968). A revised survey of the forest types of India. *Government of India Publication*. <https://books.google.com/books?hl=en&lr=&id=hljwAAAAMAAJ&oi=fnd&pg=PA39&dq=A+revised+survey+of+the+forest+types+of+India&ots=IEuY8Dg5v2&sig=gsQAUbKxw4HqfETx1daPTI9RvTY>
- Chibuzo, A. W., Sylvalyn, A. I., Sussan, E. I., Sunday, O. E. C., Nosike, O. T., & Ubaezuonu, S. T. (2023). Ecological Studies of *Tridax procumbens* (Linn) and *Ageratum conyzoides* (Linn) and the comparative Studies of Their Phytochemical. *Asian Journal of Research in Crop Science*, 8(4), 240–254. <https://doi.org/10.9734/AJRCS/2023/V8I4204>

- Cottam, G., & Curtis, J. T. (1956). The Use of Distance Measures in Phytosociological Sampling. *Ecology*, 37(3), 451–460. <https://doi.org/10.2307/1930167>
- García-Duro, J., Ciceu, A., Chivulescu, S., Badea, O., Tanase, M. A., & Aponte, C. (2021). Shifts in forest species composition and abundance under climate change scenarios in southern carpathian romanian temperate forests. *Forests*, 12(11), 1434. <https://doi.org/10.3390/F12111434/S1>
- Garg, S., Joshi, R. K., & Garkoti, S. C. (2022). Effect of tree canopy on herbaceous vegetation and soil characteristics in semi-arid forests of the Aravalli hills. *Arid Land Research and Management*, 36(2), 224–242. <https://doi.org/10.1080/15324982.2021.1953634>
- Gilliam, F. S. (2007). The Ecological Significance of the Herbaceous Layer in Temperate Forest Ecosystems. *BioScience*, 57(10), 845–858. <https://doi.org/10.1641/B571007>
- Haq, S. M., Waheed, M., Bussmann, R. W., & Arshad, F. (2023). Vegetation composition and ecological characteristics of the forest in the Shawilks Mountain Range from Western Himalayas. *Acta Ecologica Sinica*, 43(5), 798–809. <https://doi.org/10.1016/J.CHNAES.2022.10.008>
- Henneron, L., Kardol, P., Wardle, D. A., Cros, C., & Fontaine, S. (2020). Rhizosphere control of soil nitrogen cycling: a key component of plant economic strategies. *New Phytologist*, 228(4), 1269–1282. <https://doi.org/10.1111/NPH.16760>
- Himshikha, Dobhal, S., Ayate, D., & Lal, P. (2022). Influence of Anthropogenic Activities on the Biological Diversity of Forest Ecosystem. *Towards Sustainable Natural Resources: Monitoring and Managing Ecosystem Biodiversity*, 215–233. https://doi.org/10.1007/978-3-031-06443-2_12
- Holeksa, J. (2003). Relationship between field-layer vegetation and canopy openings in a Carpathian subalpine spruce forest. *Plant Ecology*, 168(1), 57–67. <https://doi.org/10.1023/A:1024457303815/METRICS>
- Jamago, J. M., Valleser, J. L., Galleron, G. N., Grace, A., Racines, M., Bactong, B. U., Ata, N. M., & Jamago, J. M. (2018). A highly potential multipurpose species for food, feed, medicine and climate resilience for the Philippines. *CMU Journal of Science*, 22(2). <http://www.fao.org/nr/cgrfa/cthemes/>
- Kilewa, R., & Rashid, A. (2014). Distribution of Invasive Weed Parthenium hysterophorus in Natural and Agro-Ecosystems in Arusha Tanzania. *International Journal of Science and Research*, 3(12), 1723–1727. <https://doi.org/https://www.doi.org/10.21275/SUB14904>
- Kumar, R., & Saikia, P. (2020). Wild edible plants of Jharkhand and their utilitarian perspectives. *Indian Journal of Traditional Knowledge*, 19(2), 237–250. <http://nopr.niscpr.res.in/handle/123456789/54361>

- Lian, Z., Wang, J., Fan, C., & von Gadow, K. (2022). Structure complexity is the primary driver of functional diversity in the temperate forests of northeastern China. *Forest Ecosystems*, 9, 100048. <https://doi.org/10.1016/J.FECS.2022.100048>
- Magurran, A. E. (1988). Ecological Diversity and Its Measurement. In *Ecological Diversity and Its Measurement*. Springer Dordrecht. <https://doi.org/https://doi.org/10.1007/978-94-015-7358-0>
- Mani, S., & Parthasarathy, N. (2006). Tree diversity and stand structure in inland and coastal tropical dry evergreen forests of peninsular India. *Current Science*, 90(9), 1238–1246. <https://www.jstor.org/stable/24092025>
- Ministry of Environment Forest and Climate Change Notification, New Delhi, the 9th December, Pub. L. No. REGD. NO. D. L.-33004/99, The Gazette of India 1 (2016).
- Misra, R. (1968). *Ecology Workbook*. Oxford & IBH Publishing Company. <https://books.google.co.in/books?id=8b6PtgAACAAJ>
- Murphy, S. J., Salpeter, K., & Comita, L. S. (2016). Higher β -diversity observed for herbs over woody plants is driven by stronger habitat filtering in a tropical understory. *Ecology*, 97(8), 2074–2084. <https://doi.org/10.1890/15-1801.1>
- Onoszko, K., Ruiz Gómez, F. J., Lazzaro, L., Lora González, Á., & González-Moreno, P. (2024). Diversity patterns of herbaceous community in environmental gradients of dehesa ecosystems. *Global Ecology and Conservation*, 54, e03162. <https://doi.org/10.1016/J.GECCO.2024.E03162>
- Pahlevani, A. H., Liede-Schumann, S., & Akhiani, H. (2020). Diversity, distribution, endemism and conservation status of Euphorbia (Euphorbiaceae) in SW Asia and adjacent countries. *Plant Systematics and Evolution*, 306(5), 1–26. <https://doi.org/10.1007/S00606-020-01705-4/FIGURES/7>
- Pawar, P., & Mule, M. (2025a). Mammalian Diversity and Prey Population Density of Gautala Autramghat Wildlife Sanctuary, Maharashtra, Western India. *Journal of Biology and Nature*, 17(1), 49–62. <https://doi.org/10.56557/JOBAN/2025/V17I19182>
- Pawar, P., & Mule, M. (2025b). Vegetation Patterns and Anthropogenic Influence in Gautala Autramghat Wildlife Sanctuary (GAWLS): An Analysis of Species Diversity and Ecological Status. *Journal of Global Ecology and Environment*, 21(2), 37–50. <https://doi.org/10.56557/JOGEE/2025/V21I29180>
- Radhamoni, H. V. N., Queenborough, S. A., Arietta, A. Z. A., Suresh, H. S., Dattaraja, H. S., Kumar, S. S., Sukumar, R., & Comita, L. S. (2023). Local- and landscape-scale drivers of terrestrial herbaceous plant diversity along a tropical rainfall gradient in Western Ghats, India. *Journal of Ecology*, 111(5), 1021–1036. <https://doi.org/10.1111/1365-2745.14075>

- Rolnik, A., & Olas, B. (2021). The Plants of the Asteraceae Family as Agents in the Protection of Human Health. *International Journal of Molecular Sciences*, 22(6), 3009. <https://doi.org/10.3390/IJMS22063009>
- Shannon, C. E. (1948). A Mathematical Theory of Communication. *Bell System Technical Journal*, 27(3), 379–423. <https://doi.org/10.1002/J.1538-7305.1948.TB01338.X>
- Simpson, E. H. (1949). Measurement of Diversity. *Nature* 1949 163:4148, 163(4148), 688–688. <https://doi.org/10.1038/163688a0>
- Spicer, M. E., Radhamoni, H. V. N., Duguid, M. C., Queenborough, S. A., & Comita, L. S. (2022). Herbaceous plant diversity in forest ecosystems: patterns, mechanisms, and threats. *Plant Ecology*, 223(2), 117–129. <https://doi.org/10.1007/S11258-021-01202-9/METRICS>
- Stefanowicz, A. M., Kapusta, P., Stanek, M., Rożek, K., Rola, K., & Zubek, S. (2023). Herbaceous plant species and their combinations positively affect soil microorganisms and processes and modify soil physicochemical properties in a mesocosm experiment. *Forest Ecology and Management*, 532, 120826. <https://doi.org/10.1016/J.FORECO.2023.120826>
- Wang, S., Jiménez-Alfaro, B., Pan, S., Yu, J., Sanaei, A., Sayer, E. J., Ye, J., Hao, Z., Fang, S., Lin, F., Yuan, Z., & Wang, X. (2021). Differential responses of forest strata species richness to paleoclimate and forest structure. *Forest Ecology and Management*, 499, 119605. <https://doi.org/10.1016/J.FORECO.2021.119605>
- Wilson, M. W., Ridlon, A. D., Gaynor, K. M., Gaines, S. D., Stier, A. C., & Halpern, B. S. (2020). Ecological impacts of human-induced animal behaviour change. *Ecology Letters*, 23(10), 1522–1536. <https://doi.org/10.1111/ELE.13571>
- Yadav, U. K. R., Zobel, D. B., & Viśvavidyālaya, T. (1987). *A Practical Manual for Ecology*. Ratna Book Distributors. <https://books.google.co.in/books?id=WmpUHQAACAAJ>