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Vegetation Patterns and Anthropogenic Influence in Gautala Autramghat Wildlife Sanctuary (GAWLS): An Analysis of Species Diversity and Ecological Status

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Understanding vegetation composition and the impact of human disturbances is critical for effective forest conservation. This study assesses the species diversity, density, and anthropogenic pressures on tree and shrub communities within the Gautala Autramghat Wildlife Sanctuary (GAWLS). Data were collected from 72 sampling plots, recording species richness, abundance, and disturbance indicators. A total of 40 tree genera across 23 families and 46 shrub genera spanning 25 families were identified. Fabaceae emerged as the most diverse family, while Teak (*Tectona grandis* L.f.) was the most dominant species, with a density of 1001.39 individuals/ha (37.51%)

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relative density) among trees and 262.5 individuals/ha (12.41%) among shrubs. Lantana (*Lantana camara* L.) dominated the shrub layer, accounting for 33.81% of shrub density. Diversity indices revealed a Shannon Diversity Index (H) of 2.52, indicating moderate species richness, while the Simpson Diversity Index (0.83) reflected a well-distributed community with low dominance by any single species. Species evenness (0.64) suggested a moderate uniformity of species distribution. Anthropogenic disturbances were prevalent, with grazing observed in 52 out of 72 plots, grass cutting in 31 plots, and tree cutting in 40 plots. Evidence of cattle dung was recorded in 30 plots, while goat dung and tree lopping were present in 5 and 14 plots, respectively. The findings highlight the ecological significance of GAWLS Sanctuary's vegetation while emphasizing the pervasive impact of human activities. This study provides baseline data for future monitoring and suggests that mitigating human disturbances is crucial to maintaining biodiversity and ensuring the long-term ecological health of the sanctuary.

Keywords: Trees; shrub; *Tectona grandis*; biodiversity; Simpson index; Shannon index.

1. INTRODUCTION

Forests serve as critical ecosystems that sustain biodiversity, regulate climate, and provide essential resources for human and wildlife populations (Brockerhoff et al., 2017). Forest composition and structure play a pivotal role in shaping these ecosystems, influencing habitat suitability, resource availability, and ecological interactions (Waheed et al., 2024). Understanding the diversity, density, and distribution of plant species within forested landscapes is fundamental for effective conservation and sustainable management strategies (Waheed et al., 2024). Tropical and subtropical forests, particularly those in India, harbour rich floral diversity, which in turn supports a wide array of faunal species, including large mammals such as leopards (*Panthera pardus fusca*), herbivores, and avian communities (Rajpar & Rajpar, 2018; Sohil & Sharma, 2020). However, anthropogenic disturbances, habitat fragmentation, and invasive species pose significant threats to the stability and resilience of these ecosystems (Banks-Leite et al., 2020; Meyer et al., 2021).

Vegetation dynamics are influenced by multiple ecological factors, including soil composition (Hou et al., 2016), moisture availability, seed dispersal mechanisms, and anthropogenic influences (Banks-Leite et al., 2020; Török et al., 2020; Meyer et al., 2021). The presence and spread of certain forest species may be driven by natural succession processes or external pressures such as habitat modification and the presence of non-native species (Didham et al., 2005; Theoharides & Dukes, n.d.). Invasive forest species, in particular, can significantly alter native plant communities by outcompeting Indigenous flora and changing habitat structures (Pauchard & Shea, 2006). Monitoring and

analyzing these patterns help to understand how forest ecosystems evolve and how best to implement conservation measures.

Quantitative vegetation analysis is a widely used approach to assess forest structure, composition, and ecological dominance of species. Parameters such as density (Yadav et al., 1987), frequency (Yadav et al., 1987), abundance (Khan et al., 2014; Kilewa & Rashid, 2014), and the Importance Value Index (IVI) (Whitford, 1949) provide valuable insights into the dominance and distribution of different plant species within an ecosystem. The IVI, in particular, is an integrated measure that incorporates relative density, relative frequency, and relative dominance to determine the ecological significance of species in a defined area. Identifying dominant species is essential for conservation planning, as these species often define the overall characteristics of the forest and influence the presence of other flora and fauna. Comprehensive vegetation assessments contribute to the broader field of forest ecology by providing baseline data on species distribution and dominance (Wei et al., 2020). These insights are valuable for developing targeted conservation efforts, such as habitat restoration, invasive species management, and afforestation programs. Effective forest management requires an integrative approach that considers both ecological and anthropogenic factors to ensure the long-term sustainability of these ecosystems (Messier et al., 2019). Understanding disturbances is essential for mitigating forest degradation and addressing vegetation loss, which continue to be significant concerns (Sharma et al., 2023). Anthropogenic disturbances affect species diversity and promote the growth of invasive weed species (Gogoi & Sahoo, 2018). Future research should focus on understanding the interactions between dominant plant species and faunal communities

to enhance biodiversity conservation strategies in forested landscapes.

No prior research has examined the ecological status of forest species in GAWLS, including the community structure. This study aims to assess the ecological condition of forests within the sanctuary by analysing their distribution, density, frequency, abundance, anthropogenic disturbances, and diversity (community structure). Understanding the ecological status of forest species in GAWLS is essential for effective forest management and biodiversity conservation. This study provides valuable insights into the distribution, density, frequency, abundance, and diversity of forest species, which can aid in identifying dominant and rare species, assessing ecosystem health, and detecting changes due to environmental or anthropogenic factors. The findings will support conservation planning, habitat restoration efforts, and sustainable resource management within the sanctuary.

2. MATERIALS AND METHODS

2.1 Study Area

The Gautala Autramghat Wildlife Sanctuary (GAWLS) is located in Maharashtra, Western India, spanning approximately 260 km² across the Chhatrapati Sambhajnagar (Aurangabad) and Jalgaon districts (Fig. 1). Positioned within the Satmala and Ajanta hill ranges of the Western Ghats, the sanctuary's topography includes rugged hills, plateaus, and plains. It is geographically situated at approximately 20.33°N latitude and 75.14°E longitude. The sanctuary's primary vegetation consists of dry deciduous forests, grasslands, and scrublands, with prominent forest species such as *Tectona grandis* (teak), *Butea monosperma* (Palash), *Diospyros melanoxylon* (Tendu), and *Anogeissus latifolia* (Dhamorda) (Champion & Seth, 1968). The GAWLS was established as a protected area in 1986 and later declared an eco-sensitive zone in 2016 by the Ministry of Environment, Forest and Climate Change. This designation expanded the sanctuary's protected region to 483.45 km², including a 1km peripheral buffer zone (Ministry of Environment Forest and Climate Change Notification, New Delhi, the 9th December, 2016). The region experiences a dry climate with recurrent drought conditions, leading to water scarcity, particularly during the summer months. Despite its ecological importance and diverse flora and fauna, the sanctuary is under pressure from human activities, including

agricultural encroachment and resource extraction. This study focuses on analyzing the vegetation structure and composition of GAWLS to inform future conservation strategies and sustainable resource management.

2.2 Field Sampling

The data for this study was collected between November 2023 and February 2024. A total of 72 random sampling plots were established across GAWLS to assess forest species composition and density. Each sampling plot was measured 10 × 10 m (100 m²) in area for trees and 5 × 5 m (25 m²) within the same 100 m² plot for shrubs. The systematic random placement of plots (Misra, 1968) aimed to capture the spatial variation in vegetation across different habitat types within the sanctuary. All individual trees (> 6 m height) and shrubs (< 6 m height) (excluding grasses) were identified and counted within each plot to record their frequency and abundance. This method provided quantitative data on forest density and species composition. The random sampling approach reduced bias and comprehensively represented the sanctuary's diverse vegetation.

2.3 Data Analysis

Species richness was determined by counting the number of woody species present. This measure reflects the diversity of forest species across the study area. The total number of species recorded in each plot was standardized and expressed as species/ha to provide a consistent measure of species richness across all sampling units. This approach allowed for the quantification of species diversity and facilitated comparisons between different plots within the Gautala Autramghat Wildlife Sanctuary.

2.3.1 Density and Abundance

Density was calculated as the number of individual forests recorded within each sampling plot. It is expressed as the number of individuals per hectare (individuals/ha), providing an estimate of forest population density across the study area. This measure reflects the concentration of forest species within the sampled plots and helps assess their spatial distribution. The density and relative density (Yadav et al., 1987) were calculated using the following formula:

$$\text{Density (D)(plants/ha)} = \frac{\text{Total no. of individuals of a species in all quadrats}}{\text{Total no. of plots studied} \times \text{Size of the plot (m}^2\text{)}} \times 10,000$$

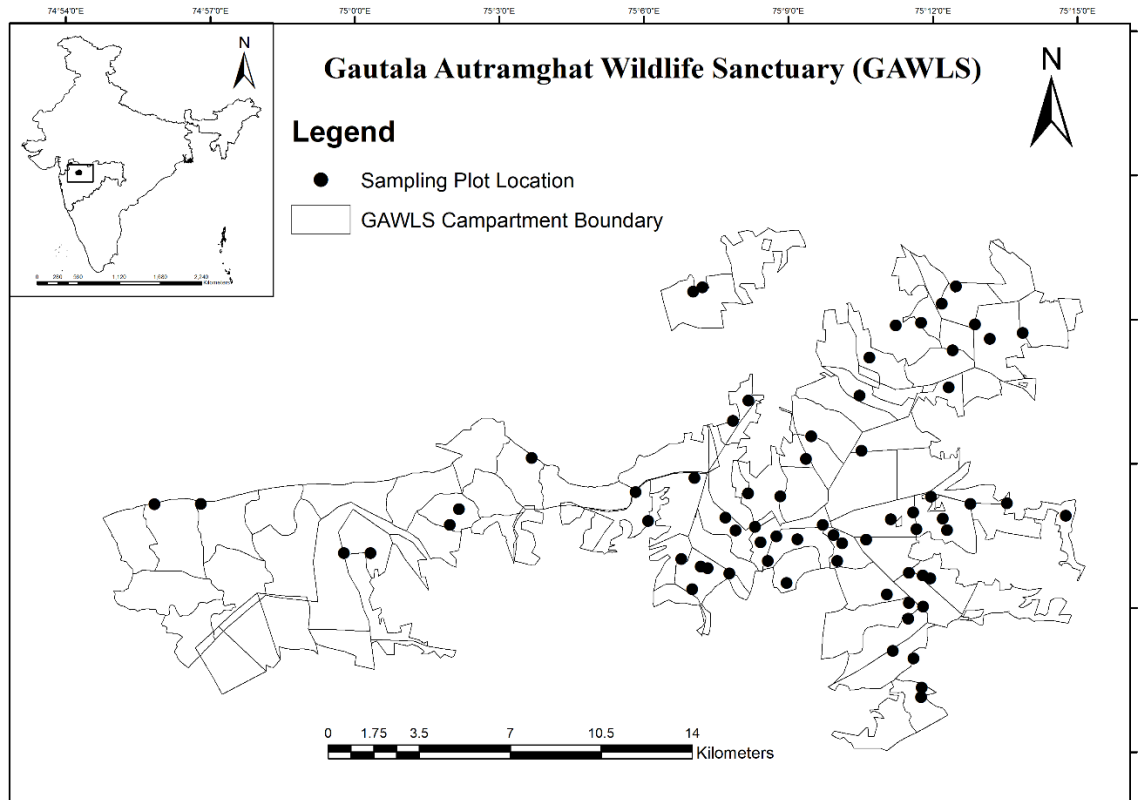


Fig. 1. The study area and the sampling plots at GAWLS

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

Abundance refers to the total number of individuals of each forest species observed across all sampling plots (Kilewa & Rashid, 2014). It provides insights into the dominance and relative presence of different species within the sanctuary. Both density and abundance values were used to identify dominant species and evaluate patterns of species distribution.

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

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

2.3.2 Frequency

Frequency represents the proportion of sampling plots in which a particular forest species occurs, reflecting its 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 indicates how consistently a species is present across the 72 random plots. Species with higher frequency values are more widely distributed, while those with lower frequencies are more localized or rare. Analysing species frequency helps to understand species dispersion patterns and ecological dominance within the sanctuary.

2.3.3 Distribution pattern (A/F ratio)

The distribution pattern of forest species was determined using the Abundance-to-Frequency (A/F) ratio, which helps classify species distribution as regular, random, or clumped. The A/F ratio or Whiteford index (WI) (Singh & Singh, 1987) was calculated using the following formula:

$$\text{Distribution (WI) or } A/F \text{ Ratio} = \frac{\text{Abundance}}{\text{Frequency}}$$

The $A/F < 0.025$ is a Regular distribution, $0.025 \leq A/F \leq 0.05$ - Random distribution, and $A/F > 0.05$ - Clumped distribution (Whitford, 1949).

In this study, the A/F ratio was computed for each species across the 72 random plots. A clumped distribution suggests species aggregation due to favourable microhabitats or specific ecological conditions, while regular distribution indicates even spacing, often influenced by competitive exclusion. Random distribution reflects the absence of strong environmental or biological influences. Analysing the A/F ratio provides insights into forest species' spatial organisation and ecological interactions.

2.3.4 Importance Value Index (IVI)

The Importance Value Index (IVI) is a comprehensive measure used to evaluate the ecological dominance of forest species within a given area. It combines three key parameters, such as relative frequency, relative density, and relative dominance, to provide a holistic understanding of each species' ecological significance (Cottam & Curtis, 1956). IVI is calculated using the following formula by Bhadra and Pattanayak (2016):

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

This study calculated IVI for all forest species recorded within the 72 random plots. Species with higher IVI values are considered ecologically dominant, contributing significantly to the structure and function of the forest ecosystem. Analysing IVI provides insights into species composition, helps identify keystone species, and aids in developing effective conservation and management strategies.

2.4 Species Diversity

Species diversity reflects the variety and relative abundance of species within an ecosystem. It is a crucial indicator for understanding community structure, ecological balance, and biodiversity health. In this study, three key indices, Shannon's diversity index (H), Simpson's diversity index (1 - D), and the Evenness index (e), were used to quantify species diversity across the sampling plots.

2.4.1 Shannon's Diversity Index (H)

Shannon's index measures species richness and evenness, indicating community diversity (Magurran, 1988). It is calculated using the following formula:

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

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 H values indicate greater species diversity, while lower values suggest reduced diversity.

2.4.2 Simpson's Diversity Index (1 - D)

Simpson's index evaluates the probability that two individuals randomly selected from a sample belong to different species (Simpson, 1949). It is calculated as:

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

The diversity index is expressed as 1-D where p_i = Proportion of individuals of the i^{th} species. The Values of 1-D range from 0 to 1, with values closer to 1 indicating higher diversity and values near 0 reflecting dominance by a few species.

2.4.3 Evenness Index (e)

Evenness measures how uniformly individuals are distributed among the species (Pielou, 1966). It is derived from Shannon's index and is calculated using:

$$\text{Evenness Index (e)} = \frac{H}{\ln S}$$

Where H = Shannon's diversity index, S = Total number of species. The evenness ranges from 0 to 1, with values closer to 1 indicating an even distribution of individuals among species.

These indices collectively provide a comprehensive assessment of species diversity, offering insights into the structure and ecological balance of the forest community. By applying these metrics, this study captures the complexity and variability of forest species across the sampled plots, aiding in conservation planning and habitat management.

2.5 Anthropogenic Disturbances

Human disturbances were systematically recorded across 72 sampling plots to assess the extent of anthropogenic pressures within the

GAWLS Sanctuary. Each plot was surveyed for evidence of human activities, including grazing, grass cutting, cattle dung piles, goat dung, tree cutting, and tree lopping. The presence of these indicators was documented through direct observation and quantified by counting occurrences for each plot. This approach provided an understanding of the frequency and spatial distribution of human-induced disturbances affecting vegetation and habitat structure.

3. RESULTS

3.1 Species Richness

The analysis of species richness revealed distinct patterns across forests. A total of 40 genera and 23 families were recorded for tree species, whereas shrubs exhibited slightly higher richness, with 46 genera spanning across 25 families, indicating a diverse composition within this vegetation stratum. Overall, there are 67 individual species of trees and shrubs recorded in GAWLS (Table 1).

The analysis of tree species revealed that *Acacia* and *Ficus* were the most dominant genera, each represented by four species, followed by *Terminalia* with three species. *Bauhinia*, *Dalbergia*, *Ixora*, and *Ziziphus* each contributed two species. Fabaceae exhibited the highest species richness at the family level with 15 species, followed by Rubiaceae (5 species), Anacardiaceae and Moraceae (4 species each), while Combretaceae and Malvaceae Juss. were represented by three species each, and Rhamnaceae by two species.

Among the shrubs, the most dominant genus was *Acacia*, with four species, followed by *Terminalia*, represented by three species. Other genera, including *Bauhinia*, *Ixora*, *Pongamia*, *Senna*, and *Ziziphus*, each contributed two species. Fabaceae is the most dominant family of shrubs, with 18 species, whereas Rubiaceae has 5 species, and Anacardiaceae has 3 species.

3.2 Density

The analysis of vegetation density revealed distinct patterns of species dominance across forests in the study area. *Tectona grandis* L.f. emerged as the most dominant forest species, with a density of 1001.39 individuals per hectare,

contributing 37.51% to the total forest population. *Grewia tiliifolia* Vahl followed with a density of 287.50 individuals per hectare (10.77%), and *Butea monosperma* (Lam.) Taub. ranked third with 218.06 individuals per hectare (8.17%) (Table 2). In the shrub layer, *Lantana camara* L. dominated with 715.28 individuals per hectare, accounting for 33.81% of the total shrub density. *Tectona grandis* L.f. was also prominent as a shrub, with a density of 262.50 individuals per hectare (12.41%), followed by *Butea monosperma* (Lam.) Taub. at 158.33 individuals per hectare (7.49%) (Table 2).

The densities and relative densities of the top 10 dominant tree species across all vegetation strata are provided in Table 2.

3.3 Frequency

The frequency analysis of plant species further highlighted the dominant species across different vegetation strata. Among trees, *Tectona grandis* L.f. exhibited the highest frequency at 84.72%, contributing 13.62% to the total relative frequency. This was followed by *Butea monosperma* (Lam.) Taub., which showed a frequency of 58.33% (9.38% relative frequency), and *Grewia tiliifolia* Vahl with 48.61% frequency (7.81% relative frequency). In the shrub category, *Lantana camara* L. was the most frequently occurring species, appearing in 81.94% of the plots, which constituted 16.08% of the relative frequency. *Tectona grandis* L.f. also had a significant shrub presence with a frequency of 55.56% (10.90% relative frequency), followed by *Butea monosperma* (Lam.) Taub. at 48.61% (9.54% relative frequency) (Table 2). Comprehensive frequency data for other species across all vegetation categories are provided in Table 2. The frequency of other individual species is given in Supplement 1. Supplement.

3.4 Abundance

The abundance analysis revealed key dominant species within each vegetation layer. In the forest stratum, *Dendrocalamus strictus* (Roxb.) exhibited the highest abundance, with an average of 12 individuals per plot, contributing significantly to the overall forest population. This was followed by *Tectona grandis* L.f. with an abundance of 11.82, and *Pongamia pinnata* (L.) Pierre, which recorded 6 individuals per plot (Table 2). Among shrubs, *Lantana camara* L. dominated with an average abundance of 8.73 individuals per plot, reflecting its invasive

Table 1. List of tree and shrub species with their family names at GAWLS

Sr. No	Scientific Names	Family	Local Name
1	<i>Abrus precatorius</i> L.	Fabaceae	Gunj
2	<i>Acacia catechu</i> (L.f.) Willd.	Fabaceae	Khair
3	<i>Acacia leucophloea</i> (Roxb.) Willd.	Fabaceae	Hiwar
4	<i>Acacia nilotica</i> (L.) Delile	Fabaceae	Babhul
5	<i>Acacia torta</i> (Roxb.) Craib	Fabaceae	Chilati
6	<i>Aegle marmelos</i> (L.) Correa	Rutaceae	Bel
7	<i>Alangium salviifolium</i> (L.f.) Wangerin	Cornaceae	Hinkal
8	<i>Anogeissus latifolia</i> (DC.) Wallich ex Guill. et Perr.	Combretaceae	Dhavada
9	<i>Azadirachta indica</i> A. Juss.	Meliaceae	Neem
10	<i>Bauhinia malabarica</i> Roxb.	Fabaceae	Amati
11	<i>Bauhinia racemosa</i> Lam.	Fabaceae	Apta
12	<i>Bombax ceiba</i> L.	Malvaceae Juss.	Kate Sawar
13	<i>Boswellia serrata</i> Roxb. ex Colebr.	Burseraceae	Salai
14	<i>Buchanania cochinchinensis</i> (Lour.) Almeida	Anacardiaceae	Charoli
15	<i>Butea monosperma</i> (Lam.) Taub.	Fabaceae	Palas
16	<i>Carissa carandas</i> L.	Apocynaceae	Karwand
17	<i>Cassia fistula</i> L.	Caesalpinaceae	Amaltash
18	<i>Cordia macleodii</i> Hook. fil.	Boraginaceae	Dahikhada
19	<i>Curculigo orchiodes</i> Gaertn.	Hypoxidaceae	Kali Musal
20	<i>Dalbergia lanceolaria</i> L.f.	Fabaceae	Satpudi
21	<i>Dalbergia pseudo-sissoo</i> Miq.	Fabaceae	Sisam
22	<i>Dendrocalamus strictus</i> (Roxb.) Nees	Poaceae	Bamboo
23	<i>Diospyros melanoxylon</i> Roxb.	Ebenaceae	Tembhurni
24	<i>Dolichandrone falcata</i>	Bignoniaceae	Mersingi
25	<i>Euphorbia neriifolia</i> L.	Euphorbiaceae	Sabar wild
26	<i>Ficus amplissima</i> Sm.	Moraceae	Pimbri
27	<i>Ficus benghalensis</i> L.	Moraceae	Banyan
28	<i>Ficus racemosa</i> L.	Moraceae	Umbar
29	<i>Ficus religiosa</i> L.	Moraceae	Pipal
30	<i>Gliricidia sepium</i> (Jacq.) Walp.	Fabaceae	Gilersidi
31	<i>Grewia tiliifolia</i> Vahl	Malvaceae Juss.	Dhaman
32	<i>Hardwickia binate</i> Roxb.	Fabaceae	Anjan
33	<i>Helicteres isora</i> L.	Malvaceae Juss.	Murud Sheng

Sr. No	Scientific Names	Family	Local Name
34	<i>Ipomoea carnea</i>	Convolvulaceae	Besharam
35	<i>Ixora brachiata</i> Roxb.	Rubiaceae	Lokhandi Black
36	<i>Ixora pavetta</i> Andr.	Rubiaceae	lokhandi white
37	<i>Jatropha curcas</i> L.	Euphorbiaceae	Ran Yerand
38	<i>Lagerstroemia speciosa</i> (L.) Pers.	Lythraceae	Bondara
39	<i>Lannea coromandelica</i> (Houtt.) Merr.	Anacardiaceae	Moi
40	<i>Lantana camara</i> L.	Verbenaceae	lantana
41	<i>Lysiloma latisiliquum</i> (L.) Benth.	Fabaceae	Shevari/subabul
42	<i>Madhuca longifolia</i> (J.Koenig ex L.) J.F.Macbr.	Sapotaceae	Moha
43	<i>Mangifera indica</i> L.	Anacardiaceae	Amba
44	<i>Morinda citrifolia</i> L.	Rubiaceae	Bartondi
45	<i>Murraya paniculata</i> (L.) Jacq.	Rutaceae	Gamoni
46	<i>Neolamarckia cadamba</i> (Roxb.) Bosser	Rubiaceae	Kadamb
47	<i>Opuntia ficus-indica</i> (L.) Mill.	Cactaceae	Sabar
48	<i>Phyllanthus emblica</i> L.	Phyllanthaceae	Awala
49	<i>Pongamia pinnata</i> (L.) Pierre	Fabaceae	Karanj
50	<i>Prosopis juliflora</i> (Sw.) DC.	Fabaceae	Yedi Babhul
51	<i>Pterocarpus marsupium</i> Roxb.	Fabaceae	Bija
52	<i>Santalum album</i> L.	Santalaceae	Chandan
53	<i>Searsia mysorensis</i> (G.Don) Moffett	Anacardiaceae	Yankal
54	<i>Semecarpus anacardium</i> L. f.	Anacardiaceae	Biba
55	<i>Senna auriculata</i> (L.) Roxb.	Fabaceae	Tarwat/Tarwad
56	<i>Senna tora</i> (L.) Roxb.	Fabaceae	Turata
57	<i>Sterculia urens</i> Roxb.	Malvaceae Juss.	Bhutiycase
58	<i>Syzygium jambos</i>	Myrtaceae	Jambhul
59	<i>Tamarindus indica</i> L.	Fabaceae	Chinch
60	<i>Tamilnadia uliginosa</i> (Retz.) Tirveng. & Sastre	Rubiaceae	Kalaphendra
61	<i>Tectona grandis</i> L.f.	Lamiaceae	Teak
62	<i>Terminalia arjuna</i> (Roxb.) Wight & Arn.	Combretaceae	Arjun
63	<i>Terminalia bellirica</i> (Gaertn.) Roxb.	Combretaceae	Behda
64	<i>Terminalia elliptica</i> Willd.	Combretaceae	Ain
65	<i>Wrightia tinctoria</i>	Apocynaceae	Kala Kaduka
66	<i>Ziziphus mauritiana</i> Lam.	Rhamnaceae	Bor
67	<i>Ziziphus xylopyrus</i> (Retz.) Willd.	Rhamnaceae	Ghat Bor

Table 2. Densities, relative density, frequency and Importance Value Index (IVI) of the 10 most dominant tree and shrub species at GAWLS

Tree Species	Density/ha⁻¹	Relative Density (%)	Frequency (%)	Relative Frequency (%)	IVI
<i>Tectona grandis</i> L.f.	1001.38	37.51	84.72	13.62	88.64
<i>Grewia tiliifolia</i> Vahl	287.5	10.77	48.61	7.81	29.35
<i>Butea monosperma</i> (Lam.) Taub.	218.06	8.17	58.33	9.38	25.71
<i>Hardwickia binate</i> Roxb.	162.5	6.09	45.83	7.37	19.54
<i>Diospyros melanoxylon</i> Roxb.	134.72	5.05	31.94	5.13	15.23
<i>Anogeissus latifolia</i> (DC.) Wallich ex Guill. et Perr.	113.89	4.27	38.89	6.25	14.26
<i>Boswellia serrata</i> Roxb. ex Colebr.	106.94	4	22.22	3.57	12.10
<i>Terminalia elliptica</i> Willd.	91.67	3.44	20.83	3.35	10.22
<i>Lannea coromandelica</i> (Houtt.) Merr.	54.17	2.03	27.78	4.46	8.52
<i>Lagerstroemia speciosa</i> (L.) Pers.	48.62	1.83	26.39	4.24	7.88
Shrub Species					
<i>Lantana camara</i> L.	715.28	33.82	81.94	16.08	83.71
<i>Tectona grandis</i> L.f.	262.5	12.41	55.56	10.90	35.72
<i>Butea monosperma</i> (Lam.) Taub.	158.33	7.49	48.61	9.54	24.51
<i>Terminalia arjuna</i> (Roxb.) Wight & Arn.	123.61	5.85	25.00	4.90	16.59
<i>Terminalia elliptica</i> Willd.	115.28	5.45	31.94	6.27	15.20
<i>Yankal</i>	94.45	4.47	19.44	3.81	14.71
<i>Anogeissus latifolia</i> (DC.) Wallich ex Guill. et Perr.	90.28	4.27	23.61	4.63	13.17
<i>Diospyros melanoxylon</i> Roxb.	69.45	3.29	18.06	3.54	10.11
<i>Grewia tiliifolia</i> Vahl	43.06	2.04	18.06	3.54	7.48
<i>Carissa carandas</i> L.	41.67	1.97	12.50	2.45	6.52

potential and widespread distribution. *Alangium salviifolium* (L.f.) Wangerin and *Morinda citrifolia* L. both displayed an abundance of 8, highlighting their notable presence in the understory layer. *Ipomoea* species also showed a moderate abundance of 7 individuals per plot. Further details regarding the abundance of other species across all vegetation types are provided in Table 2. The abundance of other individual species is given in Supplement 1.

3.5 Importance Value Index (IVI)

The Importance Value Index (IVI) analysis revealed the dominant species across different vegetation strata. Among forests, *Tectona grandis* L.f. exhibited the highest IVI (88.64), signifying its strong ecological dominance, followed by *Grewia tiliifolia* Vahl (29.35) and *Butea monosperma* (Lam.) Taub. (25.71) (Table 2). For shrubs, *Lantana camara* L. was the most dominant species with an IVI of 83.71, followed by *Tectona grandis* L.f. (35.72) and *Butea monosperma* (Lam.) Taub. (24.51) (Table 2). The IVI of other individual species is given in Supplement 1.

3.6 Species Diversity

The analysis of species diversity within the study area revealed a Shannon Diversity Index (H) of 2.52, indicating a moderate level of species richness and even distribution of tree species across the sampled plots. This value suggests a relatively diverse tree community, where no single species overwhelmingly dominates the ecosystem. The Simpson Diversity Index was calculated as 0.83, reflecting a high probability that two randomly selected individuals from the sampling plots belong to different species. This high value indicates a well-distributed community with considerable species diversity and minimal dominance by a particular species. The Species Evenness Index (e) was 0.64, suggesting a moderate uniformity in the distribution of individuals across different species. This indicates that while multiple species are present, some species are more abundant than others. The evenness value provides insight into how equally individual trees are distributed among the species present in the sanctuary. The detailed analysis is provided in Supplement 1.

3.7 Anthropogenic Disturbances

The analysis of human disturbances revealed significant anthropogenic pressures across the sampled plots. Grazing was the most prevalent disturbance, observed in 52 out of 72 plots

(72.22%), followed by tree cutting, which occurred in 40 plots (55.56%). Grass cutting was recorded in 31 plots (43.06%), while cattle dung piles were found in 30 plots (41.67%), indicating regular livestock movement. Tree lopping was documented in 14 plots (19.44%), and goat pellets ung was the least frequent, appearing in 5 plots (6.94%). These results indicate varying degrees of human activity, with livestock-related disturbances being particularly widespread.

4. DISCUSSION

The analysis of species richness, density, frequency, abundance, and diversity indices provides a comprehensive understanding of the vegetation structure and ecological dynamics (Husch et al., 2003; Misik et al., 2013) within the GAWLS sanctuary. The findings highlight distinct patterns in species composition across the tree and shrub layers, reflecting the ecological complexity and the potential impacts of both natural processes and anthropogenic influences.

4.1 Species Richness and Composition

The study recorded 67 individual species from 40 genera across 23 families for tree species and 46 genera spanning 25 families for shrubs, indicating a slightly higher richness in the shrub layer. The dominance of genera such as *Acacia*, *Ficus*, and *Terminalia* across both vegetation layers suggests their ecological adaptability and resilience. The family, Fabaceae, exhibited the highest richness in both trees (15 species) and shrubs (18 species), consistent with findings from other tropical and subtropical forests where this family is known to thrive under diverse environmental conditions (Hussein, 2022). This dominance aligns with previous studies highlighting Fabaceae as a key family contributing to forest structure and functioning in semi-arid and tropical ecosystems (Galván-Cisneros et al., 2023).

4.2 Species Density Patterns

Tectona grandis L.f. emerged as the most dominant species in both tree (1001.39 individuals/ha) and shrub (262.50 individuals/ha) layers. Its ecological prominence reflects its adaptive capacity and potential anthropogenic influence through historical afforestation or timber extraction activities (Palanisamy et al., 2009). The dominance of *Grewia tiliifolia* and *Butea monosperma* as the second and third most abundant tree species suggests their ecological

significance in maintaining the forest structure and providing habitat resources. Similarly, *Lantana camara* was the most dominant shrub (715.28 individuals/ha), highlighting its invasive potential and ability to outcompete native species, a phenomenon widely observed in degraded forest areas. The high density of *Lantana camara* could negatively impact native biodiversity by limiting regeneration and altering ecological processes (Lone et al., 2025).

4.3 Frequency and Abundance Dynamics

The frequency analysis reinforced the dominance patterns, with *Tectona grandis* showing the highest frequency (84.72%) among trees and *Lantana camara* (81.94%) among shrubs. Such high frequencies indicate their widespread distribution and potential competitive advantages. Notably, the co-occurrence of *Tectona grandis* in both tree and shrub layers suggests its ability to regenerate under varied canopy conditions. The abundance analysis further emphasizes the ecological importance of these species, with *Dendrocalamus strictus* displaying the highest abundance in the tree layer. The presence of species like *Alangium salviifolium* and *Morinda citrifolia* in the shrub layer reflects their ecological niches and adaptation to the prevailing conditions.

4.4 Ecological Dominance and Importance Value Index (IVI)

The IVI values highlight the ecological dominance of *Tectona grandis* (88.64 for trees) and *Lantana camara* (83.71 for shrubs), underscoring their significant roles in shaping community dynamics. Such dominance may reflect both natural and human-mediated influences, including selective logging, fire regimes, and invasive species proliferation. The relatively high IVI values for *Butea monosperma* and *Grewia tiliifolia* further indicate their substantial contributions to forest structure and ecological interactions. The pronounced IVI of invasive *Lantana camara* raises concerns about its potential to suppress native species and disrupt ecological balance (Sundaram et al., 2012).

4.5 Species Diversity and Evenness

The Shannon Diversity Index ($H = 2.52$) indicates a moderate level of species diversity, consistent with other studies in dry deciduous and tropical forests (Ifo et al., 2016). This suggests that the study area supports a relatively heterogeneous community where multiple species coexist

without extreme dominance by any single taxon. The Simpson Diversity Index (0.83) further reflects high species diversity and low dominance, which are critical for maintaining ecosystem resilience and functional integrity. The Species Evenness Index (0.64) reveals moderate distributional uniformity, suggesting that while the study area harbours diverse species, a few dominant species disproportionately contribute to the total abundance.

4.6 Anthropogenic Disturbances

The observed patterns of human disturbance highlight the substantial anthropogenic influence on the vegetation and habitat structure within the GAWLS Sanctuary. The high incidence of grazing (72.22%) suggests frequent livestock movement, which may contribute to vegetation degradation and alter species composition. Tree cutting (55.56%) and tree lopping (19.44%) indicate ongoing resource extraction, which can reduce tree density and impact forest regeneration. Grass cutting (43.06%) further emphasizes the human reliance on forest resources, potentially affecting ground cover and soil stability. The presence of cattle dung piles (41.67%) and goat dung (6.94%) corroborates the prevalence of livestock grazing, which could exacerbate soil compaction and disrupt plant community dynamics (Souther et al., 2019). These findings underscore the need for effective management strategies to mitigate human disturbances and preserve the ecological integrity of the sanctuary.

4.7 Ecological Implications and Conservation Considerations

The high densities and frequencies of *Tectona grandis* and *Lantana camara* highlight ecological imbalances that may arise from anthropogenic pressures and invasive species encroachment. The presence of dominant invasive species like *Lantana camara* requires targeted management to restore native biodiversity and prevent further ecological degradation (Negi et al., 2019). Furthermore, the dominance of Fabaceae suggests its role in nitrogen fixation and soil enrichment, contributing to ecosystem productivity. However, the relatively low evenness indicates the need for conservation strategies that promote species equilibrium and protect less dominant but ecologically vital taxa.

The findings underscore the importance of maintaining ecological diversity and managing invasive species to ensure long-term ecosystem

stability. Conservation strategies should prioritize the removal or control of invasive species, promote the regeneration of native flora, and monitor species dynamics to mitigate further biodiversity loss. Future research should focus on long-term monitoring and the effects of human disturbance on species composition and ecosystem functions in the GAWLS sanctuary.

5. CONCLUSION

This study provides a comprehensive assessment of the composition and structure of tree and shrub species within the GAWLS Sanctuary. A total of 67 species from 40 genera and 23 families were recorded, highlighting significant species richness and a diverse ecological structure. Fabaceae emerged as the most species-rich family for both trees and shrubs, while genera such as *Acacia*, *Ficus*, and *Terminalia* exhibited notable dominance. The density analysis revealed *Tectona grandis* L.f. as the most dominant tree species, accounting for 37.51% of the total forest population, while *Lantana camara* L. was the most prevalent shrub, constituting 33.81% of the shrub density. Similar patterns were observed in frequency and abundance, with these species maintaining a high relative presence across sampled plots. The Importance Value Index further confirmed the ecological prominence of *Tectona grandis* L.f. and *Lantana camara* L., underscoring their influence on the vegetation structure. Diversity indices indicated a moderately diverse plant community, with a Shannon Diversity Index (H) of 2.52 and a Simpson Diversity Index of 0.83. These values suggest a balanced distribution of species with minimal dominance by any single species. The Species Evenness Index of 0.64 reflects a moderate degree of uniformity across the study area. Anthropogenic disturbances were widespread, with grazing and tree-cutting being the most frequent. These human activities likely impact species composition and distribution, emphasizing the need for conservation efforts to mitigate further ecological degradation while preserving the sanctuary's biodiversity.

SUPPLEMENTARY MATERIALS

Supplementary materials available in this link: <https://ikprress.org/index.php/JOGEE/libraryFiles/downloadPublic/24>

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.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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