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Population Structure, Diversity and Composition of Tree Stand in Nandi Hill Forest Ecosystem

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Abstract

Forests are one of the main components of the terrestrial ecosystems and documenting their diversity is a necessary tool for forest conservation and land-use planning. Hence, this study was conducted to investigate the floristic composition and population structure of the Nandi Hill Forest ecosystem. Vegetation analysis was conducted by laying 0.1-hectare plots randomly. A total of 28 species from 17 families belonging to 16 orders of woody plants were recorded from the study area. A Shannon-Weinner index value of 1.507 was obtained suggesting a moderate diversity of species in the Nandi Hill Forest. Concentration of dominance value of 0.46 and the evenness index value of 0.45 suggests that the study area is dominated by a few species and the distribution of trees is uneven. The density and basal area for the whole forest was 120.71 ± 15 stems ha^{-1} and 62.46 m^2ha^{-1} respectively. *Eucalyptus tereticornis* Sm. was the most frequently occurring with the highest density and the largest contributor to the overall basal area. The DBH class distribution showed an inverse-J pattern with most individuals in the lower DBH classes, suggesting active regeneration and recruitment of new individuals. The height class distribution showed that 32.54 per cent of the individuals had a height between 15-21m. Based on the importance value index the *Eucalyptus tereticornis* Sm. was found to be the most ecologically significant tree species in the Nandi Hill Forest ecosystem.

Keywords : Forest ecosystem, Diversity, Population structure, Regeneration

Forests are one of the main components of the terrestrial biosphere and are critical for mediating the global carbon balance and mitigating global climate change. They are highly productive and intricate terrestrial ecosystems that contain almost 80 per cent above ground carbon. They play a critical role in maintaining the carbon balance and are essential for mitigating climate change (Streck & Scholz, 2006 and Whitehead, 2011). Forests account for more than one-third of the habitable land area, which is around one-quarter of the total land area (both habitable and uninhabitable) (Ritchie and Roser, 2024). According to the United Nations, forests cover 31 per cent of the world's land surface and absorb roughly 15.6 billion tons of carbon dioxide every year. Trees are the dominant vegetation in forest ecosystems and form basic structural components (Haq *et al.,* 2019). Understanding the diversity, distribution and regeneration status of trees offers valuable insights into the health of a forest eco system and the flow of ecosystem services and helps in forecasting forest dynamics (Negi *et al.,* 2019). Therefore, quantitative information on the diversity and distribution of tree species in forest ecosystems

is critical for understanding the community structure and developing actionable conservation strategies.

Documenting vegetation is a necessary tool for forest conservation, landscape mapping and land-use planning (Haq *et al.,* 2017) and is a great method of summarizing our knowledge of vegetation structures and patterns (MacKenzie *et al.,* 2019). Vegetation diversity and distribution data are useful not only for understanding the architecture, species richness and spatial association patterns of an ecosystem but also for providing valuable insights into the habitat requirements of a species for successful restoration and conservation (Wasseige *et al.,* 2014).

According to Saima *et al.* (2018) hill forests exhibit intricate variations in community structure, diversity and distribution that are influenced by factors such as elevation, slope and forest productivity. Nandi Hills is one such hilly forest ecosystem and one of the most eco sensitive areas which is adversely affected by overcrowding and vehicular pollution due to excessive tourism. Therefore, it is clear that the ecosystem in and around the Nandi Hills area should be protected and managed. Monitoring and recording tree diversity and distribution of this valuable forest is essential for understanding the processes related to carbon emissions originating from deforestation and forest degradation. The present study is an attempt to provide baseline data on the diversity and tree population structure of the Nandi Hills for future conservation and better management of forest resources. The objective of this study was to address the questions: *viz* (i) what are the quantitative dissimilarities in tree species diversity and distribution in the Nandi Hill Forest ecosystem and (ii) what is the population structure of tree species in the study site?

Material and Methods

Study Area

Nandi Hill also known as Nandidurga is situated in the Chikkaballapur District, 10 km from Chickballapur Town and approximately 60 km from Bengaluru at an altitudinal range of 1000-1473 MASL (Fig. 1). It covers an area of 2,837 hectares. The Hilly

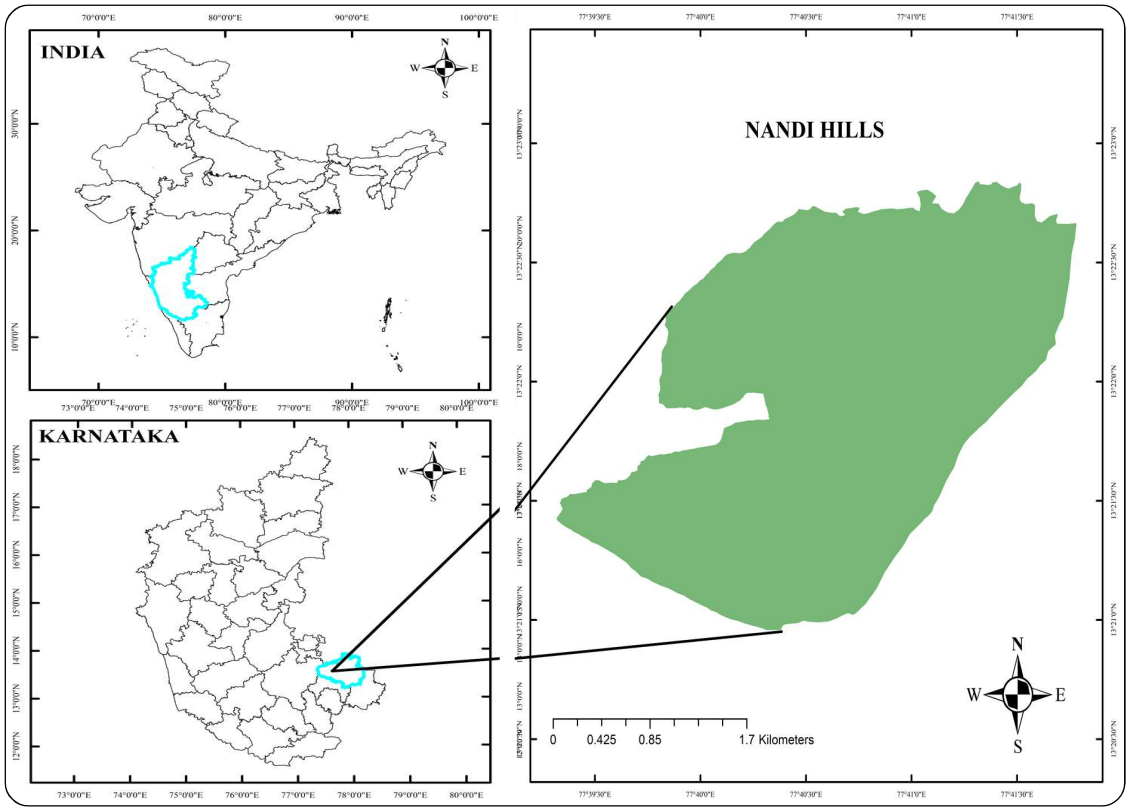

Fig. 1 : Map of the study area

landscape is craggy and rugged. The terrain of Nandi Hills is mostly rocky and consists of slopes covered with scrubs and sparse vegetation. There are six rivers that are monsoon-dependent and are not perennial.

Sampling Design and Collection of Data

Sampling of the tree species was carried out to asses diversity and population structure. Tree species composition was studied by random sampling using the quadrat method, as this method is less biased and most popularly followed (Bhatta *et al.,* 2012). A 0.1-hectare plot (Phillips *et al.,* 2003) was laid at each selected site for tree enumeration. Individuals with a girth of more than 20cm were considered for sampling and their girth and canopy height were measured. All individuals were identified up to the species level using local flora and further authentication was performed at Mahatma Ghandhi Botanical Garden, University of Agricultural Sciences, GKVK, Bangalore. The correct nomenclature, family and order of each identified tree species were assigned using the Plants of the World Online database.

Quantitative Analysis

Vegetation data were compiled and summarized using Microsoft Excel 2021. Shannon diversity index (H') was determined using $H' = -\sum_{i=1}^{N} P_i \ln P_i$, where $p_i = n_i/N$; n_i is the number of individual trees present for species i and N is the total number of individuals (Magurran, 2004) and Concentration of Dominance (Cd) was determined using $Cd = \Sigma(n_i/N)^2$, where n_i = the total number of individuals of particular species and N = the total number of individuals of all species. The indices used in this study assume that individuals are randomly selected from an infinitely large population and the sample includes all species present in the community (Yemata and Haregewoien, 2022). The evenness index (J') was calculated using $J' = H'/ H'_{max,}$ where $H'_{max} = \ln S$ (S=Total number of species). An estimate of the evenness with which the individuals are divided among the species in any sample, we may take the ratio of the observed diversity to the maximum possible for the same number of species (Pielou, 1966).

The Population structure was analyzed by considering key factors such as stem density, frequency, basal area, relative density, relative frequency, relative dominance, diameter class distribution (16 classes, *i.e.* 1:30-60, 2:60-90, 3:90-120, 4:120-150, 5:150-180, 6:180-210, 7:210-240, 8:240-270, 9:270-300, 10:300-330, 11:330-360, 12:360-390, 13:390-420, 14:420-450, 15:450-480, 16:>480 cm), height class distribution (11 classes, *i.e.* 1: <3, 2: 3-6, 3: 6-9, 4: 9-12, 5: 12-15, 6: 15-18, 7: 18-21, 8: 21-24, 9: 24-27, 10:27-30, 11:>30 m) and Importance Value Index (Kent and Coker, 1992).

The importance value index (IVI) is an indicator of the ecological significance of a species. It often reflects the extent of dominance, occurrence and abundance of a given species in relation to other associated species in an area (Kent and Coker, 1992). Relative Frequency, Relative dominance and Relative Density were calculated using the formula,

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of a species}}{\text{Total Frequency of all species}} \times 100$$

$$\text{Relative dominance (RDo)} = \frac{\text{Total basal area of the species in all quadrats}}{\text{Total number basal area of the species in all quadrats}} \times 100$$

$$\text{Relative Density (RD)} = \frac{\text{Number of quadrats in which species is studied}}{\text{Total number of quadrats studied}} \times 100$$

$$IVI = RD + RF + RDo$$

Results and Discussion

Population Structure

Floristic Composition and Tree Species Diversity : A total of 28 tree species, spanning across 17 different families and encompassing 16 orders were documented from the sample plots (Table 1). Half of the total floristic composition was represented by members of five families. Among the families

TABLE 1

Floristic composition in the Nandi Hill Forest ecosystem

Identified Species	List of Families	List of Orders
Acacia auriculiformis A.Cunn. ex Benth.	Myrtaceae	Myrtales
Actinodaphne wightiana (Kuntze) Noltie	Fabaceae	Fabales
Albizia amara (Roxb.) Boivin	Proteaceae	Proteales
Anacardium occidentale L	Moraceae	Rosales
Araucaria bidwillii Hook.	Phyllanthaceae	Malpighiales
Bridelia retusa (L.) A.Juss.	Bignoniaceae	Lamiales
Cordia myxa L.	Lauraceae	Laurales
Delonix regia (Bojer ex Hook.) Raf.	Euphorbiaceae	Malvales
Eucalyptus tereticornis Sm.	Malvaceae	Sapindales
Ficus benghalensis L.	Anacardiaceae	Gentianales
Grevillea robusta A.Cunn. ex R.Br.	Rhamnaceae	Santalales
Grewia tiliifolia Vahl	Rubiaceae	Boraginales
Leucaena leucocephala (Lam.) de Wit	Santalaceae	Proteaceae
Mallotus philippensis (Lam.) Müll.Arg.	Boraginaceae	Solanales
Mangifera indica L.	Solanaceae	Pinales
Mimusops elengi L.	Araucariaceae	Ericales
Pongamia pinnata (L.) Pierre	Sapotaceae	
Santalum album L.		
Senegalia chundra (Roxb. ex Rottler) Maslin		
Senna corymbosa (Lam.) H.S.Irwin & Barneby		
Senna siamea (Lam.) H.S.Irwin & Barneby		
Senna spectabilis (DC.) H.S.Irwin & Barneby		
Solanum chrysotrichum Schltdl.		
Syzygium cumini (L.) Skeels		
Tabebuia aurea (Silva Manso) Benth. & Hook.f. ex S.Moore		
Vachellia nilotica (L.) P.J.H.Hurter & Mabb.		
Wendlandia thyrsoidea (Roth) Steud.		
Ziziphus rugosa Lam.		

surveyed, Fabaceae was the most dominant, with a total of 10 species, accounting for 35.71 per cent of the species diversity, reflecting the family's wide-ranging presence and significance in the ecosystem. Thakur (2015) reported similar observations in the dry deciduous forests of Madhya Pradesh where Fabaceae is the dominant family. Additionally, Myrtaceae and Anacar diaceae demonstrated considerable presence with two unique species each, contributing 7.14 per cent each to the overall diversity (Fig. 2). The diverse representation of these families highlights their richness and variety within the studied ecosystem (Table 1 & Fig. 2). The number of families of tree species found in Nandi Hill was lower than that reported by Gopalakrishna *et al.,* 2015 in the dry forest of Bannerghatta which is nearby. This may be because of the anthropo genic disturbances in the study area due to tourism and plantation activities in contrast to the dry forest of Bannerghatta which is protected by the law, safeguarding it from similar disturbances.

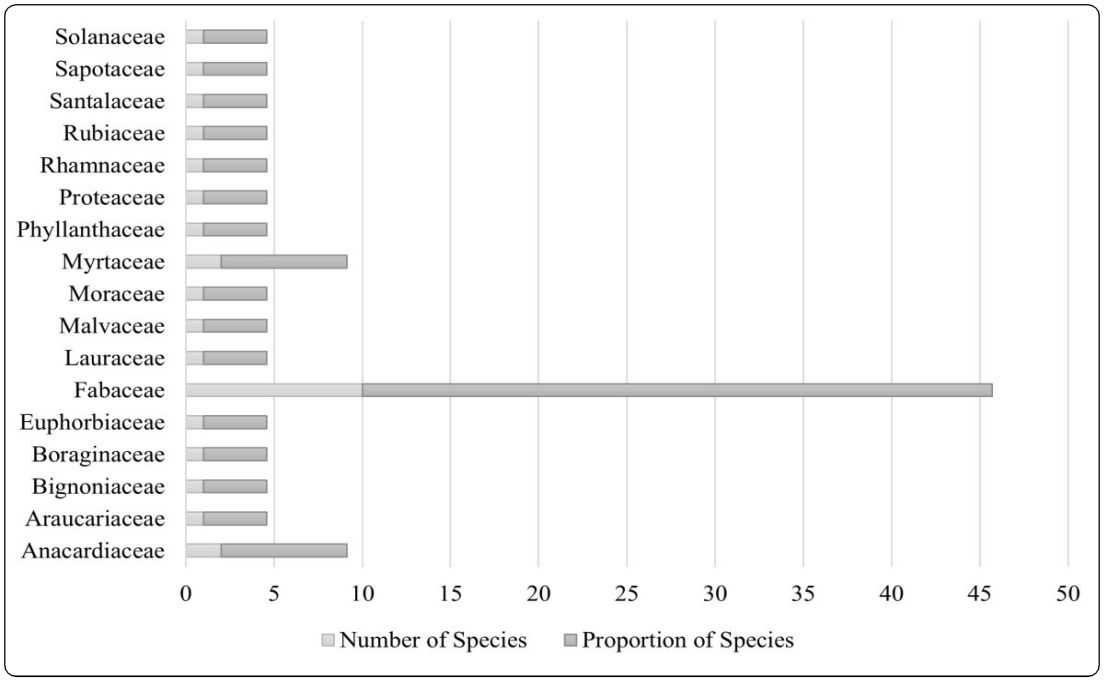

Fig. 2 : Familywise representation of species distribution

TABLE 2

Diversity and Population structure of the study area (S: Number of species; F: Number of Families; O: Number of Orders; *H′*: Shannon Index Cd: Concentration of Dominance; J': Evenness Index; BA: Basal Area (m^2ha^{-1}); d= density (stems ha^{-1}))

S	F	O	*H′*	Cd	J'	BA	d
28	17	16	1.507	0.46	0.45	62.46 ± 4.79	120.71 ± 15

The entire Nandi Hill state forest exhibited a Shannon Diversity index value of 1.507 indicating that the study area is moderately diverse (Table 2). The *H′* value in the current study is within the range (0.83-4.1) reported for forests of the Indian subcontinent (Pandey, 2000 and Pitchairamu *et al.,* 2008). The concentration of dominance (Cd) analysis is presented in Table 2; it shows that the Nandi Hill Forest ecosystem is moderately diverse and is dominated by a few species. The evenness index values indicated that the forest was unevenly distributed and few species dominated the ecosystem (J′ = 0.45) (Table 2). These results were due to the presence of *Eucalyptus tereticornis* Sm. which is an introduced species in the ecosystem and this species dominates the Nandi Hill Forest. The moderate diversity may be due to high levels of anthropogenic disturbance, mainly tourism and the more disturbed dry deciduous forests contain low species diversity when compared to less disturbed forests Murthy *et al.* (2016). The diversity is lower compared to nearby Western ghats (Sundarapandian and Swamy, 2000) and Eastern ghats (Naidu & Kumar, 2016 and Tarakeswara *et al.,* 2018), which may be because the forest receives relatively less rainfall and places that receive less rainfall exhibit lower species diversity.

Stem Density and Frequency

The study area recorded a stem density of 120.71 ± 15 (stems ha^{-1}) (Table 2). *Eucalyptus tereticornis* Sm. Showed the highest density with the 80.36 stems ha^{-1} covering 66.57 per cent of the overall density

TABLE 3

Density of dominant tree species in the study area

Species	Density (stems ha^{-1})	Percentage	Cumulative %
Eucalyptus tereticornis Sm.	80.36	66.57	66.57
Syzygium cumini (L.) Skeels	14.64	12.13	78.70
Leucaena leucocephala (Lam.) de Wit	3.93	3.25	81.95
Ficus benghalensis L.	2.50	2.07	84.02
Grevillea robusta A.Cunn. ex R.Br.	2.50	2.07	86.09
Araucaria bidwillii Hook.	1.79	1.48	87.57
Albizia amara (Roxb.) Boivin	1.43	1.18	88.76
Pongamia pinnata (L.) Pierre	1.43	1.18	89.94
Acacia auriculiformis A.Cunn. ex Benth.	1.07	0.89	90.83
Mallotus philippensis (Lam.) Müll.Arg.	1.07	0.89	91.72

followed by *Syzygium cumini* (L.) Skeels accounted for 12.13 per cent of participants (Table 3). The top ten species with the highest density covered 91.72 per cent of the overall density showing their wider distribution. The stem density in the present investigation is lower than the stem density reported by Panda *et al.* (2013) in northern Eastern Ghats. Pragasan & Parthasarathy (2010) in southern Eastern Ghats, Mohandas & Davidar (2009) in tropical montane evergreen forest (shola) of the Nilgiri Mountains and by Reddy *et al.* (2011) in the Eastern Ghats of northern Andhra Pradesh which indicates that the study area contains a moderate tree diversity and is affected by various anthropogenic factors. The frequency analysis revealed that *Eucalyptus tereticornis* Sm. was the most frequently occurring species which occurred in 82.14 per cent of the quadrats followed by *Syzygium cumini* (L.) Skeels occurred in 42.86 per cent of the quadrats (Table 4). This indicates that these tree species are widespread and are dominant members of the ecosystem.

TABLE 4

Frequency of occurrence of dominant tree species in the Nandi Hill Forest ecosystem

Species	Frequency	Percentage
Eucalyptus tereticornis Sm.	23	82.14
Syzygium cumini (L.) Skeels	12	42.86
Leucaena leucocephala (Lam.) de Wit	7	25.00
Ficus benghalensis L.	5	17.86
Grevillea robusta A.Cunn. ex R.Br.	5	17.86
Senna siamea (Lam.) H.S.Irwin & Barneby	3	10.71
Albizia amara (Roxb.) Boivin	2	7.14
Araucaria bidwillii Hook.	2	7.14
Delonix regia (Bojer ex Hook.) Raf.	2	7.14
Mallotus philippensis (Lam.) Müll.Arg.	2	7.14

Basal Area and DBH Class Distribution

The forest of Nandi Hills recorded an overall basal area of 62.46 m^2/ha (Table 2). *Eucalyptus tereticornis* Sm. Dominated the study area covering 40.21 per cent of the total basal area, followed by *Syzygium cumini* (L.) Skeels which covered 11.21 per cent of the basal area (Table 5). The top 10 dominant species covered 90.76 per cent of the total basal area showing extraordinary representation of these species in the Nandi Hill state forest. This indicates that these tree species are widespread and dominant members of the Nandi Hill Forest ecosystem. The overall basal area recorded in this study was higher than that reported by Naidu and Kumar, 2016 in tropical forests in the Eastern Ghats of Andhra Pradesh. This may be because of the higher contribution of *Eucalyptus tereticornis* Sm. for the total basal area. This species is planted centuries ago

TABLE 5

Basal Area (BA) contribution by the dominant tree species in the Nandi Hill Forest ecosystem

Species	BA (m^2/ha)	Percentage	Cumulative %
Eucalyptus tereticornis Sm.	25.12	40.21	40.21
Syzygium cumini (L.) Skeels	7.00	11.21	51.42
Mangifera indica L.	5.26	8.42	59.85
Tabebuia aurea (Silva Manso) Benth. & Hook.f. ex S.Moore	4.48	7.17	67.01
Araucaria bidwillii Hook.	4.23	6.77	73.78
Delonix regia (Bojer ex Hook.) Raf.	4.03	6.45	80.23
Grevillea robusta A.Cunn. ex R.Br.	1.71	2.73	82.96
Grevillea robusta A.Cunn. ex R.Br.	1.67	2.68	85.64
Acacia auriculiformis A.Cunn. ex Benth.	1.61	2.58	88.22
Pongamia pinnata (L.) Pierre	1.59	2.55	90.76

i.e. in 1790 by Tippu Sultan, the ruler of Mysore (Shyam Sundar, 1984) and exhibits very high DBH which adds to the basal area. The DBH class distribution shows an inverse-J shaped curve (Fig. 3) indicating good forest regeneration status with high seedling recruitment. Similar regeneration status was reported in the biodiversity heritage site of GKVK campus (Sumanth & Prasanna, 2022 and Praveen *et al.,* 2024). The first four DBH classes covered 54.44 per cent of the individuals and only a few individuals were observed in the higher girth classes *i.e.* <1%. Our findings are consistent with those of Sudhakar *et al.* (2008) in the tropical forests of Mudumalai Wildlife Sanctuary. Their study similarly found that a substantial proportion of all tree species in the Mudumalai Wildlife Sanctuary forests were juveniles.

Height Class Distribution

The height class distribution analysis showed that the 21-24m height class recorded the highest number of individuals (18.93%) followed by the 18-21m

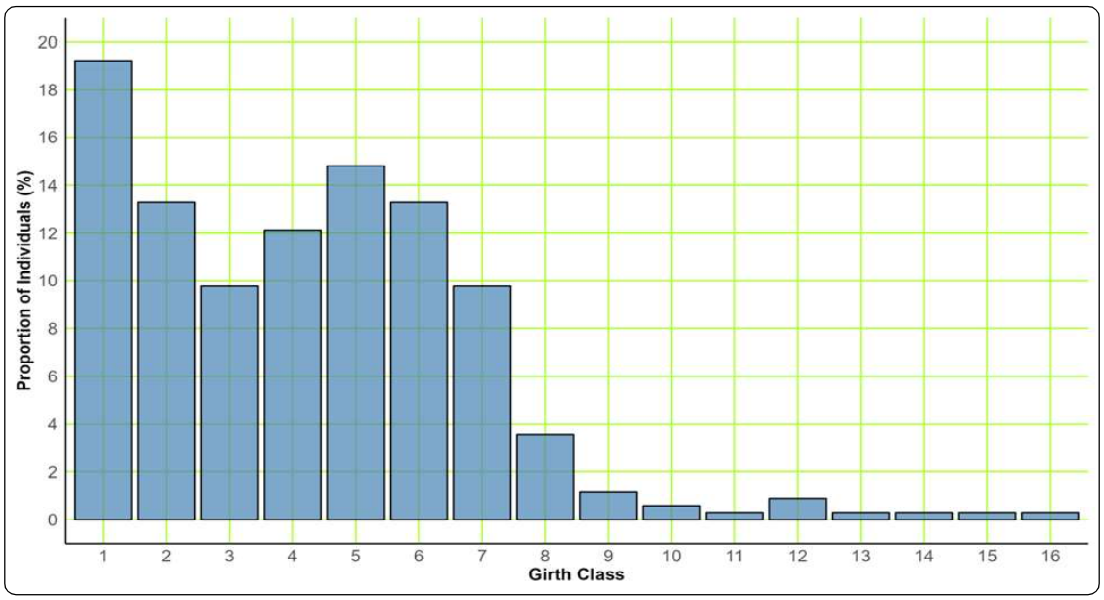

Fig. 3 : Girth class distribution of tree species in the forest of Nandi Hill

(13.61%) class and 1.18 per cent of individuals reached a height of >30m. This indicates that 32.54 per cent of woody plants in the Nandi Hill Forest were dominated by plants up to 24m in height (Table 6) suggesting that the ecosystem was dominated by medium-height trees with a successive decrease in the number of mature individuals in higher height classes.

Importance Value Index

Evaluating IVI offers an effective method for assessing the ecological significance of species within a community. Species with a higher IVI value are considered to have greater ecological importance and play a pivotal role in the overall ecological framework of the community (Lamprecht, 1989). The top ten dominant species in the study site were *Eucalyptus tereticornis* Sm., *Syzygium cumini* (L.) Skeels, *Grevillea robusta* A.Cunn. ex R.Br., *Leucaena leucocephala* (Lam.) de Wit, *Araucaria bidwillii* Hook., *Pongamia pinnata* (L.) Pierre., *Ficus benghalensis* L., *Acacia auriculiformis* A.Cunn. ex Benth., *Mangifera indica* L. and *Albizia amara* (Roxb.) Boivin. (Table 7). The top 10 dominant species covered 85.89 per cent of the IVI showing their ecological significance in the Nandi Hill Forest ecosystem. The remaining 18 species accounted for only 14.11 per cent of the IVI. Based on the IVI results the Nandi Hill Forest ecosystem can be considered as a *Eucalyptus tereticornis* Sm community (Fig. 4).

This study examined 28 species of trees belonging to 17 families and 16 orders. The study area was found to be moderately diverse and was dominated by a few tree species. *Eucalyptus tereticornis* was the most frequently occurring species with the highest density and the largest contributor to the overall basal area. The DBH class distribution showed an inverse-J curve with most individuals in the lower DBH classes

Table 6

Height class distribution of the tree population in the study area

Class Code	Height Class	Frequency	Proportion (%)
1	<3	11	3.25
2	3-6	45	13.31
3	6-9	45	13.31
4	9-12	23	6.80
5	12-15	35	10.36
6	15-18	37	10.95
7	18-21	46	13.61
8	21-24	64	18.93
9	24-27	17	5.03
10	27-30	11	3.25
11	>30	4	1.18

Table 7

Importance Value Index (IVI) of top ten dominant tree species in the Nandi Hill Forest ecosystem (RF: Relative Frequency; RD: Relative Density; RDo: Relative Dominance)

Species	RF	RD	RDo	IVI
Eucalyptus tereticornis Sm.	26.54	66.57	79.35	172.46
Syzygiumcumini (L.) Skeels	8.93	12.13	11.55	32.61
Grevillearobusta A.Cunn. ex R.Br.	4.72	2.37	1.39	8.49
Leucaenaleucocephala (Lam.) de Wit	3.89	3.25	0.95	8.10
Araucariabidwillii Hook.	4.72	1.48	1.16	7.36
Pongamiapinnata (L.) Pierre	5.66	1.18	0.22	7.06
Ficusbenghalensis L.	3.30	2.07	0.58	5.95
Acaciaauriculiformis A.Cunn. ex Benth.	4.25	0.89	0.22	5.36
Mangiferaindica L.	2.83	0.89	1.45	5.16
Albiziaamara (Roxb.) Boivin	3.77	1.18	0.16	5.12

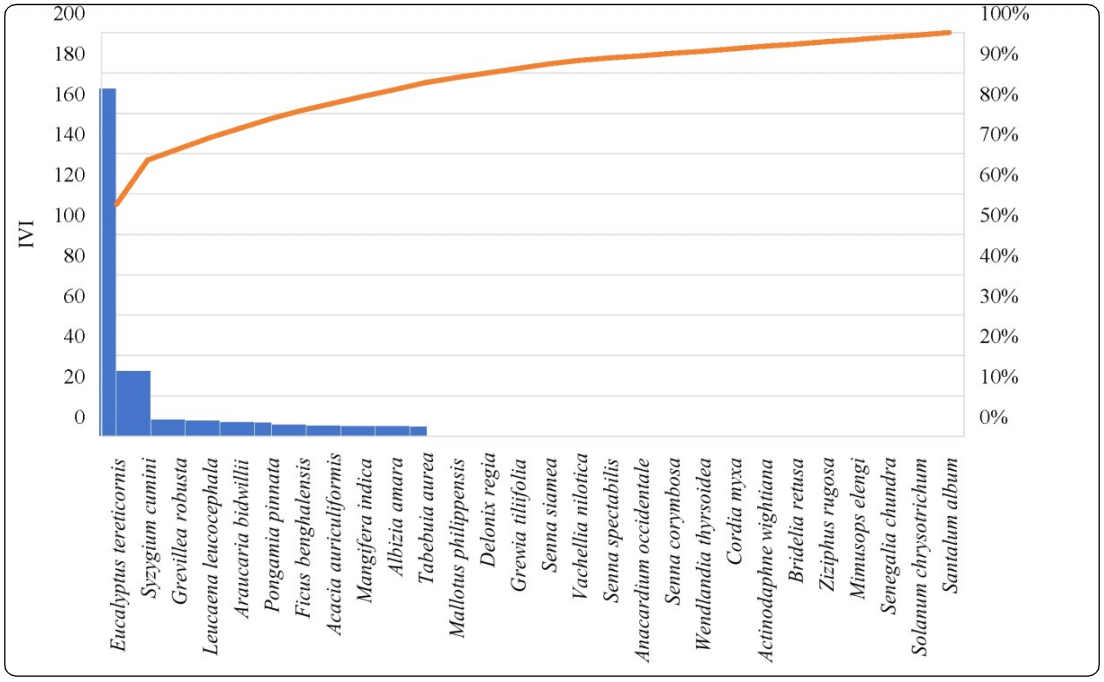

Fig. 4 : Species-wise IVI Distribution

suggesting that it is a healthy forest ecosystem with active regeneration and recruitment of new individuals. We can infer that the Nandi Hill Forest ecosystem is *Eucalyptus tereticornis* Sm. community based on IVI analysis. This study calls for the conservation of this valuable Hilly ecosystem and a proper management strategy to protect it from increasing anthropogenic activities.

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