



Phytosociological Studies of Tree Species for long-term monitoring and management

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ABSTRACT: Tree species diversity studies help to understand the species composition and determine the information for forest conservation. The current work was conducted in Salumarada Thimmakka Park for the assessment of tree species composition. Random sampling using quadrants was employed for the study. This study assesses the park's biodiversity index to provide a detailed assessment of its ecological health, species richness and distribution. This research used quantitative methodologies, such as Shannon-Weiner and Simpson's Diversity Indices, to assess species abundance and evenness across the ecosystems. The objective is to study composition and diversity of tree species. Tree species and families were identified, a total of 240 species of trees distributed into 8 families were found in all the quadrants and the dominant families were Fabaceae and Santalaceae. This work examined a number of well-known diversity indexes, i.e., Shannon index (H'), Simpson Diversity Index (D), Pielou Evenness Index (J), Margalef's Diversity indicator (R), Berger-Parker Index (d), Menhinick index (D Menhinick), Brillouin's Diversity Index (Hb), McIntosh Diversity Index (DM) and IVI, *Santalum album* has the highest IVI (54.23) and *Mangifera indica* has the lowest IVI (4.6). Quadrant 4 showed highest biodiversity compared to other three quadrants. Variations in species composition demonstrate the significance of conservation efforts to safeguard native species and improve ecosystem stability. This study emphasises the ecological relevance of Salumarada Thimmakka Park and provides baseline data needed for long-term monitoring and management.

KEY WORDS: Biodiversity Indices, Diversity, Quadrants, Species richness, IVI

1. INTRODUCTION

Biodiversity refers to the various forms of life on earth, its structure and functioning is collectively referred to as ecosystem services on which humans rely and are influenced by plants, animals, and microorganisms which is important for ecosystem health and productivity where the flexibility is more with high biodiversity [1]. Global climate change, natural disasters, and anthropogenic activities pose a greater threat to species, with an increase in the threat rate lesser the chances of survival unless the organism has the necessary features and adaptability to survive. Out of different types of diversity, Habitat diversity is one of the most important ecological concepts that reflects the health of ecological systems [2]. Ecologists have proposed a variety of diversity indices for quantifying biodiversity in any location or ecosystem. Shannon-Wiener Index, Simpson's Index, Margalef's Index and the Important Value Index (IVI) are some of the most widely used indices for measuring tree diversity with significant results [3].

Phytosociology is a branch of ecology concerned with the identification, analysis and classification of plant communities and is useful to collect the data, describe the population dynamics of each individual species and how they relate to different kinds of the same community [4]. The species and individual dynamics can reveal that how the community changes over time, disturbance and patterns of response. Biodiversity includes two important features: richness and evenness. Richness is often measured by the number of species in that area, while evenness is the uniformity and distribution among the species [5]. For complete analysis of biodiversity, detailed information (data) regarding the total species, individuals and the ratio of each species in the area or community is required [6]. Biodiversity indices are used to assess threatened species, design protected areas, manage land and forest resources and implement fire management [7].

It has been verified that about 52% of total forests on earth are in tropical regions and regarded as the most important regions as far as biodiversity is concerned [8]. Anthropogenic activities and various natural factors lead to the changes of local and indigenous diversity and include land use change, sea pollution and alien species invasion [9]. The ecosystem and its functioning is negatively affected by the biodiversity loss and it may ultimately lead to ecosystem collapse. To understand the quantification of species



biodiversity there are many illustrations of how different biodiversity indices are utilized in scientific literature and can be used where many examples related to biodiversity indices and changes in it caused by several factors such as climate change, ocean acidification and loss of habitat [10].

In the present scenario, deforestation is a vivid issue worldwide. It is estimated that 420 million hectares of forest have been lost since 1990 through conversion to other land uses. Loss of forest cover due to deforestation was estimated at 10 million per year between 2015 and 2020 [11]. The main causes of the destruction of forests are the fragmentation of natural habitats, urbanization, industrialization, and intensified agricultural practices of human beings [12].

Due to the population explosion, the pressure on forests is rising to meet the demand for food, fuel, and timber. Developmental activities are expanding globally that directly affected the natural environment [13]. The main objective of the current study is to find out structural diversity and the status of tree species in protected vegetation stand by using different biodiversity indices [14]. Due to high anthropogenic activities, there is a risk of losing plant diversity. Studies on diversity are not yet done in this area, so the present work is a benchmark as it provides the status of vegetation that help out to identify the conservation strategy and is requisite to preserve the diversity of this region [15].

This paper highlights the overview of most commonly used indicators for biodiversity analysis. Each index measures richness, diversity and abundance in different ways by considering number of species, types and frequency. By integrating both richness and distribution, these indicators effectively helps in assessing the overall biodiversity in the study area [16].

2. METHODOLOGY

In this current work Salumarada Thimmakka Park of Heggere village, Tumkur Taluk, Tumkur district was selected as our study area. It is an excellent site for biodiversity research due to its focus on native species conservation, restoration ecology, and community engagement. It emphasizes afforestation and environmental awareness, provides a rich habitat for various plant and animal species, making it an ideal location for a biodiversity research. The village has forest coverage ranging upto 100 hectares which is a part of Joint Forest Management (JFM) programme brought into implementation by Forest department, well connected to Arasikere - Tumkur highway (NH 73) and has got good access to transportation [17].

It is the largest and most diverse park in Tumkur, covering an area of approximately 6,671 sq.km. It's located in the Northeast of Tumkur between latitudes 13° 20' 17.7468" N, and between longitudes 77° 6' 5.0760" E as shown in Fig 1. Saalumarada Thimmakka Park is named in honour of great Indian environmentalist from the state of Karnataka noted for her work in planting 385 banyan trees along the highway. Annual rainfall within the park ranges from 669mm in the southern region. The tree species composition and community structure were analyzed by field visits in the park. The study focus on illustrating the status of plant communities and the species diversity.

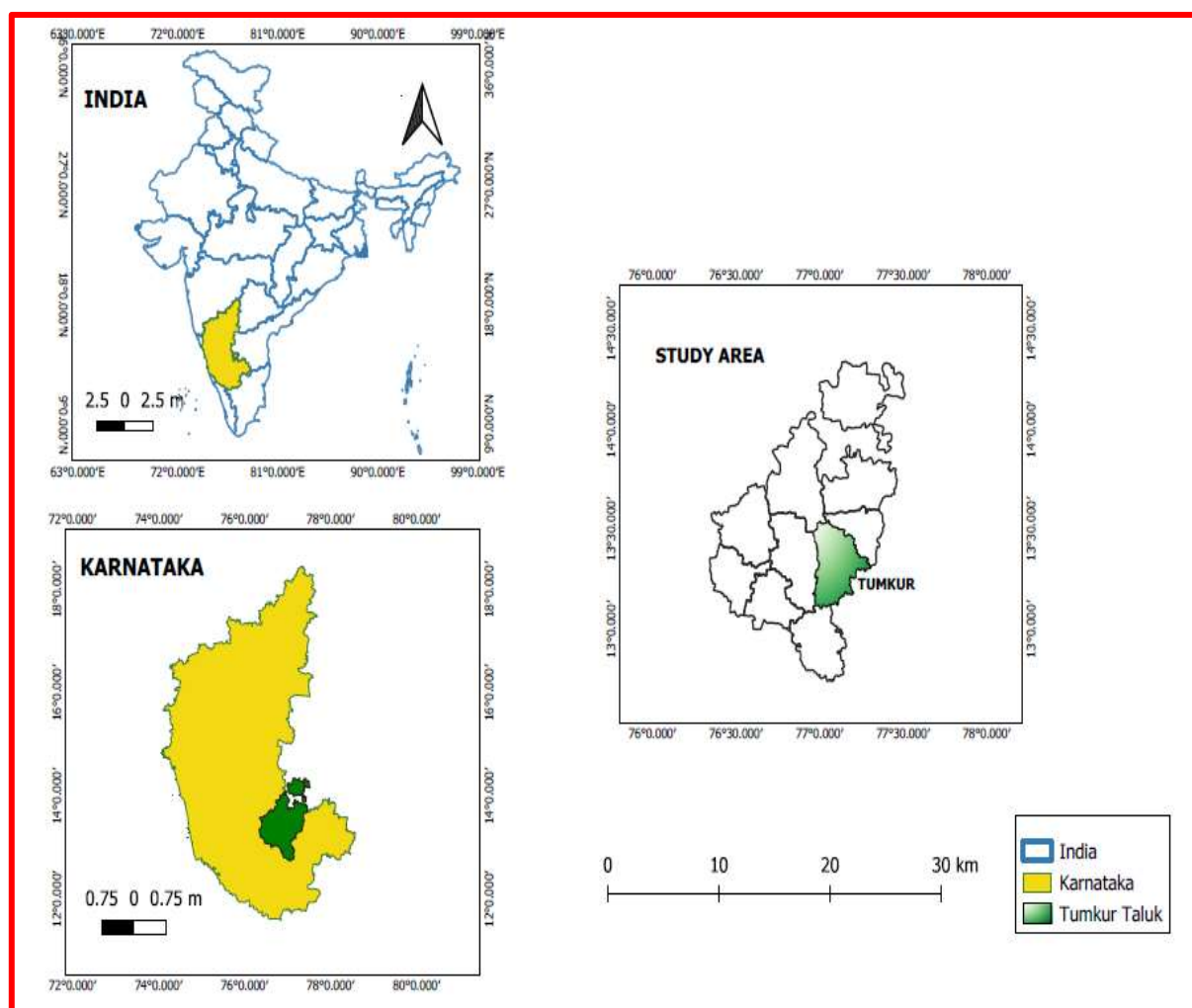


Fig.1 (a) India map, (b) Karnataka map, (c) Tumkur map (Study area map of Heggere)

3. SAMPLING METHOD

Field survey sampling technique is employed using transect and plot measurements. The fundamental aspects of species diversity, specifically species richness and evenness was determined. The research was carried out by dividing the study area into 4 quadrants with 100 x 100 m dimension plots. All the tree species was enumerated by direct counting method and consolidated check list of all the species with their respective family were made in the sample plots [18].

4. DATA COLLECTION AND ANALYSIS

Data collection included identification of species and classification of plant species into families. A botanist with the Park assisted in tree identification. Diameters at breast height and total tree height were measured. Trees identified were listed and classified. DBH was used to calculate the Basal Area, Relative Frequency, Relative Density, Relative Dominance and Importance Value Index (IVI) [19].

5. FORMULAS APPLIED FOR CALCULATIONS:

The data collected from all the quadrants were used to calculate the diversity indices viz; Shannon index (H'), Simpson Diversity Index (D), Margalef's Diversity indicator (R), Pielou Evenness Index (J), Berger-Parker index (d), Menhinick index ($D_{\text{Menhinick}}$), Brillouin's Diversity Index (H_b), McIntosh Diversity Index (D_M) and Important Value index (IVI) [20].

**6. SPECIES RICHNESS**

It refers to the number of species present in habitat. It is exhibited in simplest way as the total number of species and individuals in a given habitat, higher the values, greater the species richness. In order to quantify diversity and to compare species diversities between ecosystems under varying climatic conditions richness is measured [21].

6.1. Shannon index (H')

It combine richness and evenness to provide a measure of species diversity in an area. Higher the Shannon index value, the more diverse or evenly distributed the individuals are in the community [22].

Formula for Shannon diversity index:

$$H' = -\sum_{i=1}^s p_i \ln p_i \quad (1)$$

H': Shannon Diversity Index;

p: Proportion of characters belonging to the type of letter in the string of interest;

n: Number of individuals belonging to i species;

N: Total number of individuals.

The range of the indicator values is 0.0 to 5.0, usually the results may range from 1.5–3.5 with rare instances exceeding 4.5. Indicators of a stable and balanced habitat structure are values greater than 3.0, indicators of a polluted and degraded habitat structure are values less than 1.0.

6.2. Simpson Diversity Index (D)

It acts as an index of dominance within ecological communities. When the ecosystem is dominated by single species the Simpson diversity value attains 1. In contrast, values near to 1 suggests lack of dominance with only few species present. It considers the total number of species and also the relative abundance of each species. Simpson dominance offers an indication of the probability that two randomly chosen samples belong to the same species. A higher Simpson dominance value indicates individual species which is dominant in an area [23].

Simpson Diversity Index is calculated using the formula;

$$D = 1 - \frac{\sum n(n-1)}{N(N-1)} \quad (2)$$

Where:

n = Total number of organisms of a particular species

N = Total number of organisms of all species

6.3. Margalef's Diversity index (R)

It provides species diversity that considers total number of individuals and overall sample size, higher the value indicates greater species diversity by considering the total number of individuals. It also provides a measure of relative species richness in relation to the sample size [24].

It can be calculated using the formula;

$$SR = \frac{S-1}{\ln(N)} \quad (3)$$

Where: R = Margalef's index of species richness

S = Number of species

N = Total number of individual

This parameter does not have threshold values, and its higher values prove higher biodiversity

6.4. Pielou Evenness Index (J)

Species evenness or equitability refers to the distribution of individuals among different species within a community. It measures evenness of a community by taking into account both the number of species present and the relative abundance of each species. The results are based on ratio between the observed value of Shannon index and its maximum value. These values are in the range of 0 to 1. As the value gets close to 1, it means that each individual are distributed equally [25].

Pielou Evenness Index is determined by;

$$J = \frac{H'}{\ln(S)} \quad (4)$$



Where: J = Pielou's measure of species evenness,

H' = Shannon-Wiener index,

S = Total number of species/sample

6.5. Berger-Parker index (d)

It provides a simple quantification of the most abundant species in an area. It ranges from 0 to 1, where 0 refers to complete evenness and 1 indicates complete dominance, with one species accounting for all individuals in the community. It is a simple measure useful for preliminary analyses or comparisons of dominance across different samples. It only considers the dominance of a single species and does not provide information about the overall diversity or richness of the community [26].

Berger-Parker index was calculated using the formula;

$$d = \frac{N(\max)}{N} \quad (5)$$

Here $N_{\max}$ is the number of individuals of the most abundant species. The values range from 0 to 1, with values closer to 0 indicating greater variety and values closer to 1 indicating monoculture.

6.6. Menhinick index ($D_{\text{Menhinick}}$)

It is a simple measure of species richness, allowing for comparisons of diversity between different communities over time. It is used for comparing the diversity of different communities or to assess changes in species richness over time, accounting for the relationship between species richness and sample size. It does not consider species evenness or the relative abundance of different species within the community [27].

Menhinick index is calculated using the formula;

$$D = \frac{R}{\sqrt{N}} \quad (6)$$

R = number of categories, types, species, or classes.

N : number of observations.

6.7. Brillouin's Diversity Index (H_b)

It accounts for both species richness and evenness, providing a measure of diversity that considers how evenly individuals are distributed among species. Higher values indicate greater diversity in a community [28]. It gives more emphasis on species richness and is moderately sensitive to sample size.

Brillouin index is calculated by using the formula.

$$H_b = \frac{\ln N - \ln \sum n_i}{N} \quad (7)$$

Where H_b represents the Brillouin Index,

N is the total number of individuals in the sample,

n_i is the number of individuals in the i th species.

6.8. McIntosh Diversity Index: (DM)

McIntosh index of diversity is derived from the distance measure of similarity within the community. It is represented more naturally by the familiar representation of points in a coordinate system. Base calculations of this McIntosh Diversity Index is [29].

It can be determined using;

$$DM = \frac{N-U}{N-\sqrt{N}} \quad (8)$$

where N is the total number of individuals in the sample

U is given by the expression

$$U = \sqrt{\sum n_i^2} \quad (9)$$

where n_i is the number of individuals in the i th species and the summation is undertaken over all the species. U is the Euclidean distance of the community from the origin when plotted in an S -dimensional hypervolume

where n_i is the abundance of i th species.

6.9. Important Value index

IVI gives the overall ecological importance of each tree species in a community. It is estimated on the basis of relative values of frequency, density, and dominance of the species and it represents establishment and dominance of a species in a community. A high IVI value reflects a well-established and good adaptability of taxa [30] and shows the overall picture of ecological importance of the species in a community and it depicts the phytosociological structure of a species in the community.

IVI can be calculated using the formula

$$IVI = Rd + RF + RD \quad (10)$$

Where IVI = Important value index

Rd = Relative density

Rf = Relative frequency

RD = Relative dominance

$$\text{Relative density} = \frac{\text{Number of individuals of a species}}{\text{Total number of individuals of all species}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Number of occurrences of a species}}{\text{Total number of occurrences of all species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Basal area of species}}{\text{Total basal area of all species}} \times 100$$

Important value index (IVI) = Relative density + Relative frequency + Relative dominance[31]

Table 1: List of Diversity indices and their formulas;

Sl. No	Diversity index	Formula	Meaning
1	Shannon Diversity Index (H')	$H' = -\sum p_i \ln p_i$ p _i : proportional abundance of the i th category.	Larger the H, greater the diversity A high value means the community is more diverse.
2	Simpson Diversity Index (D)	$D = 1 - \frac{\sum n(n-1)}{N(N-1)}$ n: number of observations of the i-th category. N: number of observations.	Closer Dis to 1, greater the diversity. A high value means the community is less diverse and exhibits greater dominance by only one or a few species.
3	Margalef's Diversity indicator (R)	$R = \frac{S-1}{\ln(N)}$	Larger R value, greater the diversity.
4	Pielou Evenness Index (J)	$J = \frac{H'}{\ln(S)}$	As the value gets close to 1, it means that each individual are distributed equally.
5	Berger-Parker Index (d)	$d = \frac{N(\max)}{N}$	Closer BP is to 0, greater the diversity
6	Menhinick index (D _{Menhinick})	$D = \frac{R}{\sqrt{N}}$ R = number of categories, types, species, or classes. N: number of observations.	Larger the D _{Menhinick} , greater the diversity.
7	Brillouin's Diversity Index (H _b)	$H_b = \frac{\ln N - \ln \sum n}{N}$	Larger the H _b , greater the diversity

8	McIntosh Diversity Index (D _M)	$DM = \frac{N - U}{N - \sqrt{N}}$ where N - total number of individuals in the sample U is given by the expression $U = \sqrt{\sum n_i^2}$ Where n_i - number of individuals in the ith species and the summation is undertaken over all the species. Where n_i is the abundance of ith species.	Larger the McIntosh Diversity index the greater the diversity.
9	Important Value Index (IVI)	IVI = RD + RF + Rd	Highest importance value index is the dominant species and species with the lowest importance value is considered least dominant of the given area.

7. RESULTS AND DISCUSSION

The present research was carried out in Salumarada Thimmakka Park of Gubbi, Tumkur. Table 1 represents tree diversity recorded across the four quadrants of the study area. A total of 240 tree species belonging to 8 different families were identified. Out of the 240 species, highest numbers of species were found in Quadrant 1 (77) followed by Quadrant 2 (57), Quadrant 3 (57) and the least number of species (49) were found in Quadrant 4 (Fig. 1). The distribution of trees across the quadrants is recorded in the table 1.

7.1. Tree species in study area

A total of 240 tree species distributed into 8 families were identified in all the four quadrants including dominant families like Fabaceae and Santalaceae followed by Menispermaceae and Bignoniaceae as shown in Table 2. The rest of the families included Meliaceae, Myrtaceae, Moraceae and Anacardiaceae which represented single species. Fabaceae is taxonomically diverse and dominant family which is regarded as one of the most successful families of flowering plants due to its extreme flexibility in the adaptive response to different environments [23]. The total density of trees (stem/ha) studied consists of 99.98 tons/hectare and the total basal area of trees is found to be 700.85 tons/hectare. Higher density and basal area in study area shows less anthropogenic pressure and have optimal conditions for the regeneration of tree species.

Table 2: Tree Species names with their families

Sl. No.	Family	Species	No. of species recorded from each quadrant				Total no. of species observed
			Q 1	Q 2	Q 3	Q 4	
1	Meliaceae	<i>Azadirachta indica</i>	3	5	2	5	15
2	Fabaceae	<i>Tamarindus indica</i>	1	2	6	8	17
		<i>Albizia lebbeck</i>	3	6	10	1	20
		<i>Albizia amara</i>	1	5	1	1	08
3	Myrtaceae	<i>Syzygium cumini</i>	5	5	2	15	27
4	Santalaceae	<i>Santalum album</i>	45	30	9	10	94
5	Moraceae	<i>Ficus gomellira kunth</i>	1	0	3	5	09
6	Menispermaceae	<i>Tinospora cordifolia</i>	8	0	20	2	30
7	Anacardiaceae	<i>Mangifera indica</i>	1	3	0	2	06
8	Bignoniaceae	<i>Tabebuia aurea</i>	9	1	4	0	14

In Quadrant 1, a total of 77 trees were recorded with *S. album* (45) being the most abundant species, followed by, *Tabebuia aurea* (9), *Tinospora cordifolia* (8), *Syzygium cumini* (5) and one each from *Tamarindus indica*, *Albizia amara*, *Ficus gomellira* and *Mangifera indica* species were noticed. In Quadrant 2, a total of 57 trees belonging to 8 different trees species were recorded, among which 30 trees were *Santalum album* and 6 trees belonged to *Albizia lebbeck* while *Tabebuia aurea* had least number. Similarly in Quadrant 3, *Tinospora cordifolia* (20) had the highest numbers followed by *Albizia lebbeck* (10), *Santalum album* (9), *Tamarindus indica* (6) and *Tabebuia aurea* (4). Quadrant 4 had least number of trees compared to all other landscapes, in which the *Syzygium cumini* (15) and *Santalum album* (10) were abundant followed by *Tamarindus indica* (8), *Azadirachta indica* and *Ficus gomellira* (5) and *Tinospora cordifolia* (2) being the least followed by *Mangifera indica* (2), *Albizia lebbeck* (1), *Albizia amara* (1). Among the four quadrants studied, 30 per cent of the tree population was avenue trees, 32 per cent were found in the Quadrant 1, 23 per cent in Quadrant 2, 23 per cent in Quadrant 3 and 20 per cent in Quadrant 4. Tree species composition and density varied across the quadrants. *Santalum album* is found to be most dominant species which constitutes about 39 per cent of the total population from all the four quadrants studied. For assessing the diversity of tree species present in different quadrants of the study area, Shannon alpha diversity index, Simpson's diversity index, *Margalef's index*, Pielou's index, Berger- Parker index, Menhiniks index, Brillouin's Diversity Index, McIntosh Diversity Index and Important value index were used to assess the richness and evenness of the trees.

7.2. Shannon diversity index

Shannon-Weiner index was calculated for all the four quadrants. The Shannon-Weiner index of Q1 is 3.295, Q2 is 4.113, Q3 is 4.769 and Q4 is 4.276 as shown in Table 3. From Table 3 Q3 is having higher Shannon-Weiner index which infers that it is more diverse than other three quadrants, whereas lower values have been recorded in Q1 3.295 which tells that it is having less species diversity compared to other quadrants. Diversity depend on both the number of individuals present as well as the number of species and comparison of H' in all quadrants is seen in Fig 2. Higher the value, more diverse the species in the habitats.

Table 3: Shannon alpha diversity index

Quadrant	Diversity index
Quadrant 1	3.295
Quadrant 2	4.113
Quadrant 3	4.769
Quadrant 4	4.276

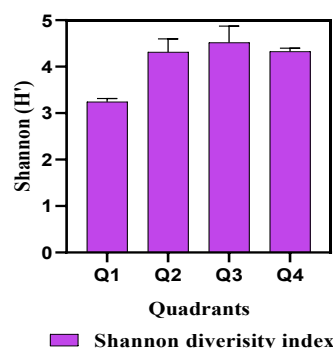


Fig. 2 Comparative analysis of H' in all quadrants

7.3. Simpson's diversity index

The results of Simpson Diversity index are shown in Table 4. It has higher value in Q4 (5.49), lower values were recorded for Q1, these results signifies that Q4 is less diverse but exhibits greater dominance with respect to species abundance of few varieties. The comparative analysis of D in all quadrants is seen in Fig 3. It represents both species richness and evenness for different quadrants.

Table 4: Simpson's diversity index

Quadrant	Diversity index
Quadrant 1	2.70
Quadrant 2	2.93
Quadrant 3	4.44
Quadrant 4	5.49

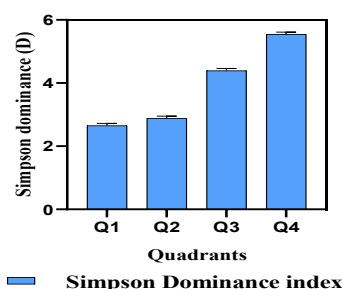


Fig. 3 Comparative analysis of D in all quadrants

7.4. Margalef's index

Margalef's index of species richness for all the quadrants are recorded in Table 5. Highest value were recorded in Q1 showing higher species diversity and even distribution of each species in Q1 and lowest evenness value was recorded in Q2 i.e. 1.73 and its comparison is seen in Fig 4 which means that the quadrant is less diverse compared to all other quadrants.

Table 5: Margalef's index

Quadrant	Diversity index
Quadrant 1	2.07
Quadrant 2	1.73
Quadrant 3	1.97
Quadrant 4	2.05

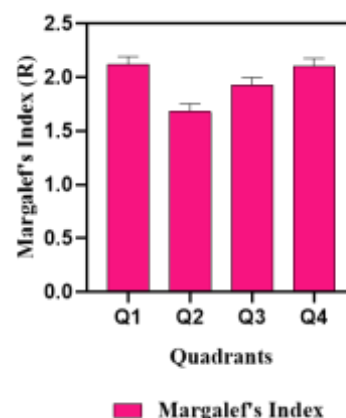


Fig. 4 Comparative analysis of R in all quadrants

7.5. Pielou's index

Pielou's index (J) was recorded for all the quadrants. Quadrant having highest Pielou's index is Q3 i.e. 1.17 as shown in Table 6, which indicates that each individual in Q3 is distributed equally (species evenness) and variation between quadrants is seen in Fig 5. The quadrant having lowest Pielou's evenness value is Q1 i.e. 0.75 that indicates individuals are not distributed equally.

Table 6: Pielou's index

Quadrant	Diversity index
Quadrant 1	0.75
Quadrant 2	1.01
Quadrant 3	1.17
Quadrant 4	1.09

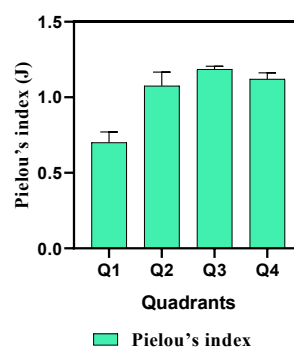


Fig. 5. Comparative analysis J in all quadrants

7.6. Berger-Parker Index (d)

Berger- Parker index for all the quadrants was calculated and expressed in Table 7. Berger- Parker index of Q1 is 0.51, Q2 is 0.48, Q3 is 0.39 and Q4 is 0.31 and their comparison seen in Fig 6. Quadrant having value close to zero indicates highest diversity. According to our results Q4 is having highest biodiversity compared to other quadrants.

Table 7: Berger- Parker index

Quadrant	Diversity index
Quadrant 1	0.58
Quadrant 2	0.52
Quadrant 3	0.35
Quadrant 4	0.26

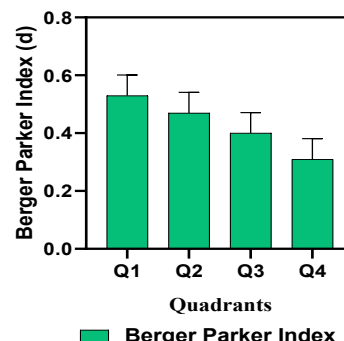


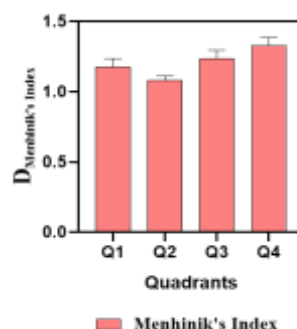
Fig.6 Comparative analysis of d in all quadrants

7.7. Menhiniks index

Menhiniks index for all the quadrants were recorded and is expressed in Table 8. The highest value was recorded in Q4 showing high species diversity and even distribution of each species and lowest value was recorded in Q2 1.06 which means that the quadrant is less diverse compared to all other quadrants.

Table 8: Menhiniks index

Quadrant	Diversity index
Quadrant 1	1.14
Quadrant 2	1.06
Quadrant 3	1.19
Quadrant 4	1.28

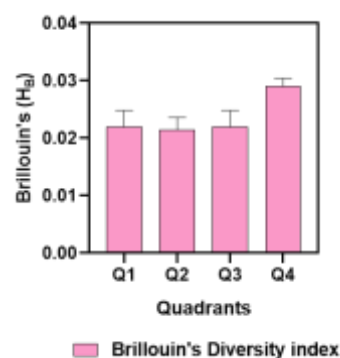

Fig.7 Comparative analysis of $D_{Menhinik}$ in all quadrants

7.8. Brillouin's Diversity Index (H_b)

Brillouin's Diversity Index for all the quadrants were recorded as seen in Table 9. The highest value was recorded in Q4 showing high species diversity and even distribution of each species and all other quadrants were having low biodiversity compared to Q1 as represented in Fig 8, which means that Q1 is less diverse compared to all other quadrants.

Table 9: Brillouin's Diversity Index

Quadrant	Diversity index
Quadrant 1	0.024
Quadrant 2	0.02
Quadrant 3	0.02
Quadrant 4	0.03


Fig.8 Comparative analysis of H_b in all quadrants

7.9. McIntosh Diversity Index (D_M)

McIntosh Diversity Index for all the quadrants was calculated as in Table 10. Q4 is having highest diversity in the study area compared to all three quadrants which can be visualized in Fig 9. The results indicate that highest species diversity and richness was seen in Q4.

Table 10: McIntosh Diversity Index

Quadrant	Diversity index
Quadrant 1	0.43
Quadrant 2	0.50
Quadrant 3	0.63
Quadrant 4	0.66

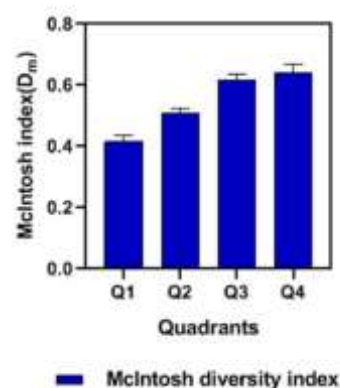


Fig.9 Comparative analysis of D_M in all quadrants

7.10. Important value index (IVI)

In the present study area, species having highest IVI is *Santalum album* (54.23) followed by *Tinospora cordifolia* (18.03), *Syzygium cumini* (16.76), *Albizia lebbbeck* (12.84), *Tamarindus indica* (11.16), *Azadirachta indica* (10.05), *Tabebuia aurea* (9.07), *Ficus gomellira* (6.28), *Albizia amara* (6.13) and *Mangifera indica* (4.6) as indicated in Table 11. The results obtained from the study signifies that *Santalum album* having highest IVI that has been shown in Fig 10 which is dominant species and *Mangifera indica* having lowest IVI is the least dominant species.

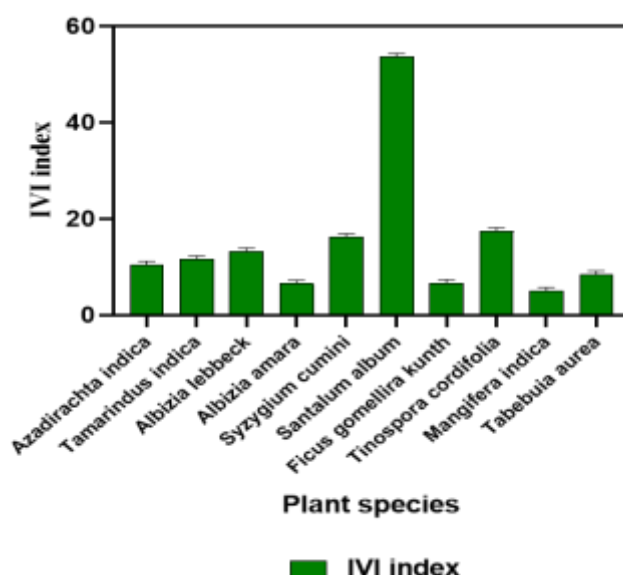


Fig.10 Comparative analysis of IVI among different species

Table 11: IVI of study area tree species

Sl. No.	Name of the species	Relative density (Rd)	Relative frequency (Rf)	Relative dominance (RD)	IVI = Rd+Rf+RD
1	<i>Azadirachta indica</i>	6.25	1.66	2.14	10.05
2	<i>Tamarindus indica</i>	7.08	1.66	2.42	11.16
3	<i>Albizia lebbbeck</i>	8.33	1.66	2.85	12.84
4	<i>Albizia amara</i>	3.33	1.66	1.14	6.13
5	<i>Syzygium cumini</i>	11.25	1.66	3.85	16.76
6	<i>Santalum album</i>	39.16	1.66	13.41	54.23
7	<i>Ficus gomellira kunth</i>	3.75	1.25	1.28	6.28
8	<i>Tinospora cordifolia</i>	12.5	1.25	4.28	18.03
9	<i>Mangifera indica</i>	2.5	1.25	0.85	4.6
10	<i>Tabebuia aurea</i>	5.83	1.25	1.99	9.07

Table 4: Biodiversity indices in all 4 quadrants

Sl. No.	Biodiversity index	Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 4
1	Shannon diversity index	3.29	4.11	4.76	4.27
2	Simpson's diversity index	2.70	2.93	4.44	5.49
3	Pielou's index	0.75	1.01	1.17	1.09
4	Margalef's index	2.07	1.73	1.97	2.05
5	Menhiniks index	1.14	1.06	1.19	1.28
6	Berger-Parker Index	0.58	0.52	0.35	0.26
7	Brillouin's Diversity Index	0.024	0.02	0.02	0.03
8	McIntosh Diversity Index	0.43	0.50	0.63	0.66

Table 5: Biodiversity Evaluation of Salumarada Thimmakka Park, Heggere

Sl No	Forest community species	Q1	Q2	Q3	Q4
1	<i>Azadirachta indica</i> (Neem)	3	5	2	5
2	<i>Tamarindus indica</i> (Tamarind)	1	2	6	8
3	<i>Syzygium cumini</i> (Nerale)	5	5	2	15
4	<i>Santalum album</i> (Sandal wood)	45	30	9	10
5	<i>Albizia lebbbeck</i> (Indian siris)	3	6	10	1
6	<i>Ficus gomellira kunth</i>	1	0	3	5
7	<i>Tinospora cordifolia</i> (Tega)	8	0	20	2
8	<i>Albizia amara</i> (Tuggali)	1	5	1	1
9	<i>Mangifera indica</i>	1	3	0	2
10	<i>Tabebuia aurea</i> (Trumpet tree)	9	1	4	0
	Total number of species in each quadrat (N)	77	57	57	49

8. DISCUSSION

According to Abiem (2018) successful forest conservation depends on species composition and diversity patterns [31]. Additionally, comparing species richness among multiple sites aids in prioritizing areas for conservation (Adeyemi, 2020) [32].

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This study attempted to assess the diversity of tree species across Salumarada Thimmakka Park. Borah *et al.* (2016) recently recorded a total of 222 species (>10 cm cbh) from 152 genera and 65 families from the protected and non-protected areas in the region [33]. In comparison, the current study found fewer species, which may be due to methodological variations and increasing stressors, such as deforestation and encroachment from nearby settlements.

According to Saikia *et al.*, (2017) Fabaceae and Santalaceae dominated the plots followed by Menispermaceae and Bignoniaceae, similar results were obtained in the present study where Fabaceae was the dominant family. Chowdhury (2018) reported similar species of Sterculiaceae and Euphorbiaceae in Old Oyo National Park [34]. These results are comparable to a previous study in Nyando, western Kenya by Makhubele *et al.*, (2025) where farmers integrated trees into their homesteads, grazing land, woodlots, boundaries, cropland, and shrubland. The highest Shannon Weiner index, Simpson diversity index, and species richness were recorded in the quadrant 4. This finding is consistent with Yahya *et al.* (2019) who recorded the highest diversity and species richness in the home gardens in Ethiopia [35]. Pielou's index and Margalef's index was highest in Quadrant 3 and 4 in the study area wherein similar finding was observed in Ethiopia where woodlots had the lowest diversity and evenness because they were dominated by *Eucalyptus globulus* [36]. Menhiniks index and Berger-Parker Index were rich in Quadrant 4 and 2 and requires the collection of data on the total number of individuals and on the densest species [37]. In addition, this study only analyzed the tree species diversity in the forest community as an example, and whether it can be used for analysis of other systems or whether it can be further extended to phylogenetic diversity and functional diversity needs further in-depth study [38]. Therefore, it is advisable to use more than one indices when determining the biodiversity of ecosystem [39]. Habitat diversity research is interested in measuring the structural complexity of the environment or the number of communities present in a specific geographic area.

9. CONCLUSION

Tree diversity assessment is the process of collecting information about the extent and conditions of the vegetation within a specific area. A total of 240 tree species in 8 families were identified in this study and diversity of tree species with different families were distributed heterogeneously with diverse height and sizes forming different storeys in the study area. Tree species composition and structure in this study will serve as management tool in terms of determining appropriate silvicultural treatments and to allow growth of seedlings at forest floor level. Thus, tree diversity assessment in Salumarada Thimmakka Park serves as preferred model that will enable conservationists to quantify tree species composition which are essential for forest management and tree utilization. The presence of rich species diversity indicates the uniqueness and potentiality of the study site for conservation. The phytosociological parameters and diversity indices are the most significant ecological attributes of ecosystems, which show variations in response to environmental as well as anthropogenic variables. The present study imparts extensive information on the diversity that will serve as important reference for the tree diversity assessment, thereby directing propagations and procedures for conservation actions. The study area provides a unique and valuable site for conducting biodiversity research. Its emphasis on native species conservation, coupled with the involvement of the local community, makes it an ideal location to study ecological restoration, species diversity, and ecosystem services. Research here can provide insights not only into the health of local biodiversity but also inform broader conservation strategies for urban and semi-urban green spaces in India.

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Authors' contributions

Poornima D.: Conceptualization, methodology, formal analysis, data curation, visualization, investigation, writing original draft preparation : Supervision, investigation

Samreen Naz G.S.: Supervision, conceptualization, methodology, investigation, writing original draft, reviewing and editing;

Ramya M.V. Supervision, conceptualization, methodology, investigation, writing original draft, reviewing and editing

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Compete of Interest

All authors are agreed that they have no known compete of Interest or personal relationships that could have appeared to influence the work reported in this paper.

Disclosure of potential conflicts of interest

All of the authors declare that they have no actual or potential conflicts of interest, including any financial, personal, or other links with other persons or organizations that may inappropriately impact the current work.

Research involving human participants and animals

Every author declares that humans and animals were not involved in this research study.

Informed consent

This study did not involve any human participants, animals or clinical trials. Therefore ethical approval and informed consent were not required.

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