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Temporal dynamics of plant communities on Thirukudder Hill in Thiruparankundram, Madurai District, Tamil Nadu, India

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Abstract. *Palsamy P, Gayathrippriya S, Krishnan SG, Chinnakaruppan M, Premkumar M, Muthuvel U, Suresh K. 2024. Temporal dynamics of plant communities on Thirukudder Hill in Thiruparankundram, Madurai District, Tamil Nadu, India. Asian J For 8: 115-125.* The present investigation was conducted in Thirukudder Hill, situated in Thiruparankundram, Madurai District, Tamil Nadu, India, aimed to analyze plant community dynamics from December 2019, January, February, and March 2020, total of thirty-six (2×2 m) quadrats were randomly sampled to assess species distribution. The study investigation revealed significant diversity in frequency indices, ranging from 2.778 to 88.889. *Solanum nigrum* displayed the highest frequency (88.88) in December 2019, while 20 species like *Blepharis maderaspatana* and *Corchorus tridens* consistently exhibited lower values (2.778) across all seasons. Density patterns showed ecological dynamics, with *Cardiospermum helicacabum* having maximum density (24.11) in December 2019 and 18 species maintaining consistently low densities (0.028). Abundance fluctuations were observed, with *Chrysopogon orientalis* peaking in February 2020, while species like *Allmania nodiflora, Boerhavia diffusa, Chamaecrista mimosoides, Vachellia leucophloea*, *Corchorus aestuans, Asparagus racemosus* etc., showed minimal abundance (1.00) throughout all study seasons. *Canthium coromandelicum* displayed the highest Importance Value Index (IVI) in February 2020 (48.698), while *V. leucophloea* recorded the lowest (0.002), indicating varied impacts on community structure. In Shannon's Index, *C. orientalis* exhibited a higher value (0.14) in February 2020, contrasting with *C. tridens* and *Vicoa indica*, which showed lower index values (0.001). These findings illustrate the dynamic nature of plant communities in Thirukudder Hill, emphasizing the temporal variability and structural significance of key plant species in shaping the local ecosystem's composition and diversity over the study period. The study highlights how the presence and interactions of specific plant species can lead to substantial changes in the ecosystem's structure, affecting everything from soil composition to the availability of resources for other organisms. By analyzing these temporal changes, the study offers significant insights into the resilience and adaptability of plant communities amid environmental variations. This contributes to a deeper comprehension of ecosystem dynamics and aids in shaping conservation strategies.

Keywords: Plant community, seasonal variations, species distribution, temporal dynamics, Thirukudder Hill

INTRODUCTION

According to the FAO (2020), a forest is characterized as an area of land greater than 0.5 hectares, with trees exceeding 5 meters in height and having a canopy cover of more than 10% or with trees that have the potential to reach these dimensions naturally. Forests are vital ecosystems, serving as essential habitats for various species and offering numerous ecosystem services (Brockerhoff et al. 2017). Vegetation plays a key role in shaping long-term human settlement patterns due to its impact on the environment and resources available for human use. Plant communities change their floristic composition and structure over relatively short periods, responding to both biotic factors, such as interactions with other species, and abiotic factors, including climate, soil conditions, and water availability. These changes in plant assemblages and species diversity significantly influence the nature and absorbance capabilities of forests, affecting everything from local microclimates to the overall health and stability of ecosystems. Thus, understanding vegetation dynamics is crucial for sustainable human development and environmental conservation (Khan et al. 2020). A good knowledge of plant communities is essential for conserving the natural heritage and developing sustainable landscape management strategies (Nuta and Niculescu 2019). Thus, phytosociological surveys provide relevant data on plant communities and verify possible relationships between species (Silva et al. 2002). In addition, these studies define ecological values of varied environments mainly for conserving species diversity considering the different spatial scales (Gomes et al. 2011). To assess the temporal dynamics and predict future trends of plant communities, examining the type of vegetation, their composition and structure, the patterns of species association, and notably, the key factors contributing to their destruction are identified as the fundamental components of community studies (Shimwell 1971; Mueller-Dombios and Ellenberg 1974).

A thorough examination of a community within a specific area can result in a classification system for the different vegetation types. By adhering to fundamental approaches, modern ecologists have resolved numerous issues within their focus areas and have implemented methods responsive to environmental changes and plant adaptations. The evolutionary traits of plants reflect their response to shifting environmental conditions. Stand-level attributes can depict the state of the forest, encapsulating community interactions, prevailing trends, dominance, and diversity. According to a recent study by Hansen et al. (2021), the relentless demand for land and resources driven by global population growth has significantly altered forest ecosystems worldwide. This growing pressure has led to widespread deforestation, disrupting forest growth patterns and contributing to changes in global climatic conditions. The study underscores the rapid pace at which forests are removed for agriculture, urban expansion, and building infrastructure. These actions endanger biodiversity and diminish the essential ecological benefits that forests offer. One critical service is carbon sequestration, where forests absorb carbon dioxide from the air, aiding climate change mitigation. They also regulate water cycles, ensuring the availability of clean water for various ecosystems and human use. The loss of these essential services due to deforestation can have far-reaching impacts on both the environment and human societies. The essential services forests provide, such as carbon sequestration, water regulation, soil conservation, and biodiversity support, are crucial for maintaining ecological balance and supporting human livelihoods. The recognition and detailed examination of plant communities within a specific region are crucial for their comprehensive understanding and management. This involves identifying and analyzing these communities from various ecological, geographical, taxonomic, and dynamic perspectives. Such an approach is invaluable in scientific research and practical applications, providing insights into ecosystem dynamics, species interactions, and environmental health. Therefore, the systematic study and description of plant communities play a pivotal role in ecological research and the sustainable management of natural resources. Such comprehensive studies help understand the intricate relationships within ecosystems, guide conservation efforts, and inform sustainable land-use practices. This holistic approach ensures that ecological integrity and biodiversity are preserved, benefiting future generations. The current study aims to analyze the plant diversity of Thirukudder Hill in Thiruparankundram, located in the Madurai District of Tamil Nadu, India.

MATERIALS AND METHODS:

Study area: Thirukudder Hill

The present investigation focused on Thirukudder Hill, positioned at Latitude 9.88875° and Longitude 78.075294°, within Thiruparankundram of Madurai District, Tamil Nadu, India (Figure 1). The experimental site is situated in the south-eastern part of Thiruparankundram; this study area is distinguished by notable landmarks such as the Arulmigu Kattikulam Soottokkole Mayandi Swamy Temple at the foothill in the north and the Mottaiyarasu Temple located to the north and the study periods revealed a stable temperature regime, with mean monthly minimum and maximum temperatures hovering around 22ºC and 40ºC, respectively. The study region experiences an annual rainfall ranging from 535 to 800 mm, significantly influencing its distinctive ecological profile. These climatic and geographic features underscore the ecological uniqueness of Thirukudder Hill, making it an ideal location for studying local biodiversity and ecosystem dynamics. The temples and natural settings provide a rich backdrop for understanding the interplay between human activities and environmental sustainability.

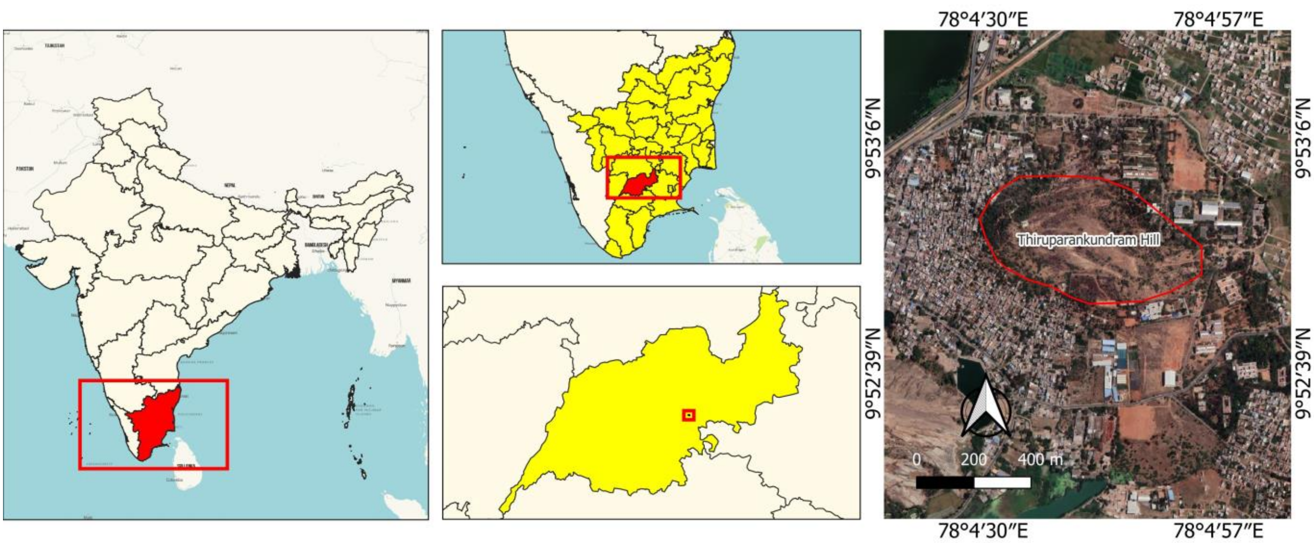

Figure 1. Depicts the geographical details of Thirukudder Hill in Thiruparankundram of Madurai District, Tamil Nadu, India

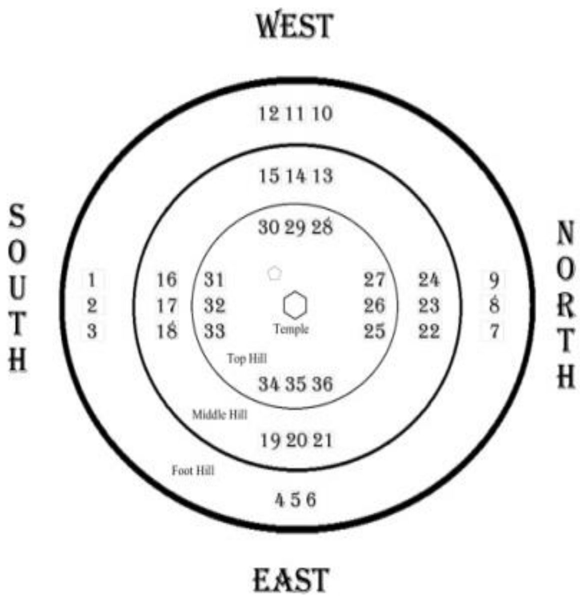

Figure 2. Layout of plant diversity analyzed sites

Field methods

A comprehensive plant community analysis was undertaken during December 2019, January, February, and March 2020. The study utilized the species-area curve method described by Shailaja and Sudha (2001) to accurately determine the appropriate size of the quadrats for the sampling site. In total, 36 quadrats (2×2m) were initially selected randomly; however, their final placement around the temple center may appear systematic due to specific environmental or cultural considerations (Figure 2) within the study area to capture a representative sample of the herbaceous vegetation and tree/shrub seedlings present. The collected data was meticulously analyzed using well-established ecological methods. Frequency, density, and abundance of plant species were calculated according to Magurran (1988), while the basal area of the trees was determined using the formula πr^2. The Importance Value Index (IVI), which provides insight into the ecological significance of each species, was calculated using the Curtis (1959) method. Additionally, the diversity of the plant community was assessed using Shannon's Index, as proposed by Shannon and Weiner (1963). All the formulas are provided below.

Frequency (presence of a species in several samples or plots) (%) = Number of quadrats in which species occur X 100 / Total number of quadrats studied

Density (number of individuals of a species per unit area) = Total number of individuals of a species in all quadrats/ Total number of quadrats studied

Abundance (total number of individuals of a species in a given area) = Total number of individuals of a species in all quadrats/Total number of quadrats in which the species occurred

Basal area (cross-sectional area of a tree trunk or multiple tree trunks at breast height) = $\pi r2$

Where, r = Average diameter ÷ 2, $\pi = 22 / 7$

IVI = Relative Frequency (frequency of a species relative to the total frequency of all species) + Relative density (density of a species relative to the total density of all species) + Relative Basal area (a species' basal area relative to all species' total basal area).

Shannon's Index (H) = $\sum$ pi log pi

Where: pi is the decimal ratio of individuals of a species to the total number of individuals overall.

The collected plant specimens were exactly identified based on their vegetative and reproductive characteristics using authoritative standard regional floras by Gamble and Fischer (1915-1935), Nair and Henry (1983), Henry et al. (1989), and Matthew (1991). These comprehensive references ensured accurate identification. Voucher specimens were then carefully deposited in the Post Graduate and Research Department of Botany at Saraswathi Narayanan College (SN-MH) in Madurai, Tamil Nadu, India, providing a valuable resource for future study and verification.

RESULTS AND DISCUSSION

During the study periods, a significant and comprehensive plant community assessment was conducted in Thirukudder Hill, as detailed in Tables 1 through 4. In December 2019, the diversity analysis recorded 83 plant species. This was followed by 67 species in January 2020, 45 in February 2020, and 50 in March 2020. This extensive assessment involved surveying various plant species, analyzing their distribution patterns, and understanding the ecological dynamics in diverse habitats on the hill studied. The data collected provides valuable insights into the biodiversity and health of the plant community in this region. The result data highlights the seasonal variations in plant species diversity, indicating a significant decrease in species counts from December to February, followed by a slight increase in March. These fluctuations suggest that certain species may be more prevalent during specific times of the year, potentially due to changes in environmental conditions such as temperature, rainfall, and sunlight availability.

The variation in frequency indices, ranging from 2.778 to 88.889, signifies considerable diversity in the distribution of plant species within the study area. In December 2019, *Solanum nigrum* exhibited the highest frequency at 88.888%, indicating its dominance. On the other hand, 20 species, *Blepharis maderaspatana, Corchorus tridens*, and several other species, consistently displayed low-frequency values of 2.778% throughout all study periods, underscoring their less prominent presence. These variations reflect the species' different ecological roles and competitive abilities, further evidenced by their varying density patterns. For instance, *Cardiospermum helicacabum* showed the highest density, reaching 24.111 in December 2019. In contrast, *Cucumis maderaspatanus* and other species maintained low densities of 0.0722 across all study periods. This disparity highlights the complex ecological dynamics and interactions among the species within the habitat, as illustrated in Figures 3 and 4. The data suggests a thriving ecosystem with dominant species and a variety of less abundant ones, each contributing to the biodiversity and ecological balance of the area.

Abundance trends revealed notable fluctuations, with *Chrysopogon orientalis* exhibiting a higher range in January 2020. Conversely, *Allmania nodiflora, Boerhavia diffusa, Chamaecrista mimosoides, Vachellia leucophloea, Corchorus aestuans, Asparagus racemosus* etc., were displayed minimal abundance (1.00), reflecting a limited existence and ecological contribution (Figure 5). The Importance Value Index (IVI) emerged as a valuable parameter for assessing ecological significance; *Canthium coromandelicum* exhibited the highest IVI value (48.698) in December 2019, representing its major contribution to the overall plant community structure. The *V. leucophloea* recorded the lowest IVI value (0.002) during the same month (Figure 6), suggesting a lesser impact on ecological composition.

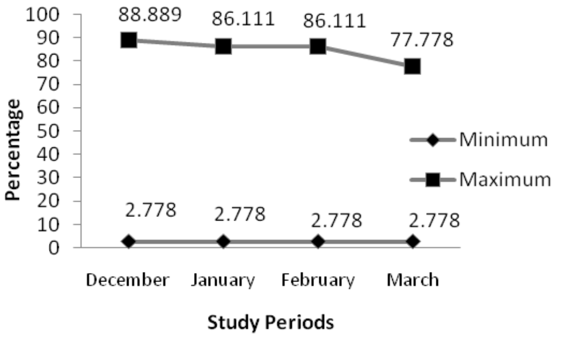

Figure 3. Distribution of species frequencies

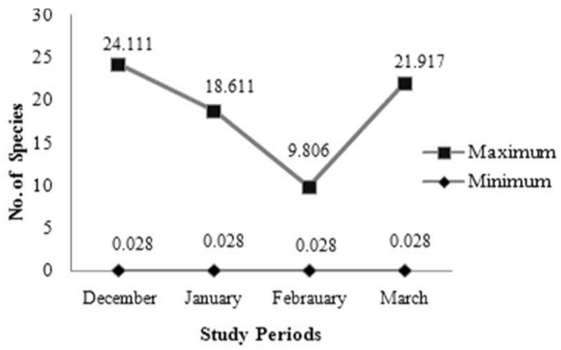

Figure 4. Distribution of species density

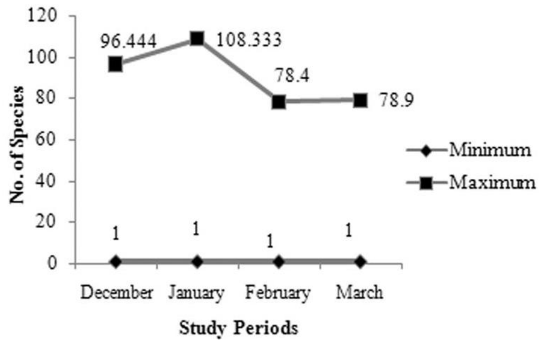

Figure 5. Distribution of species abundance

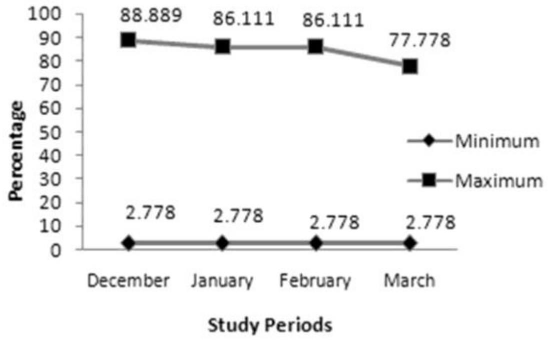

Figure 6. Distribution of species IVI

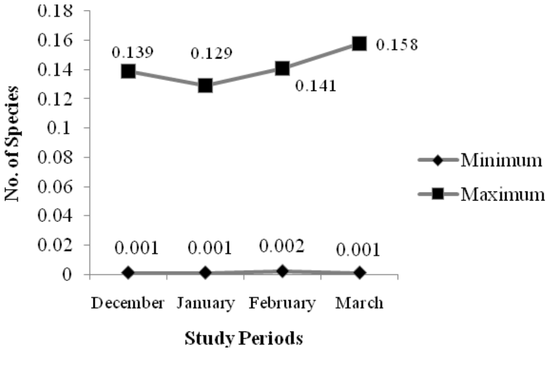

Figure 7. Shannon's Index

Shannon's Index, a comprehensive measure of biodiversity, revealed intriguing patterns in the study. The maximum Shannon's Index value was observed in *C. orientalis* (0.158) during the study period of March 2020, underscoring its significant role in enhancing overall species diversity within the studied ecosystem (Figure 7). This high value suggests a balanced distribution of species and a rich community structure. Conversely, *C. tridens* and *Vicoa indica* exhibited the minimum Shannon's Index value (0.001) across all study seasons, indicating a stark contrast in species evenness and richness and highlighting areas of lower biodiversity and potential ecological stress. These findings underscore the importance of monitoring biodiversity indices for ecosystem health.

Table 1. Plant diversity assessment in Thirukkuder Hill, Madurai District, Tamil Nadu, India (December 2019)

Botanical name	Frequency	Density	Abundance	IVI	Shannon's Index
Abrus precatorius L.	8.333	0.083	1.000	0.663	0.002
Acalypha indica L.	2.778	0.028	1.000	0.344	0.001
Achyranthes aspera L.	66.667	3.056	4.583	7.242	0.040
Albizia lebbeck (L.) Benth.	38.889	0.528	1.357	3.013	0.010
Allmania nodiflora (L.) R. Br. ex Wight	2.778	0.028	1.000	0.264	0.001
Alysicarpus monilifer (L.) DC.	30.556	0.722	2.364	4.686	0.013
Andrographis echioides (L.) Nees	13.889	0.333	2.400	1.265	0.007
Asparagus recemosus Willd.	8.333	0.083	1.000	0.834	0.002
Azima tetracantha Lam.	19.444	2.167	11.143	3.397	0.031
Barleria buxifolia L.	19.444	1.417	7.286	2.647	0.022
B. noctiflora L.f.	8.333	0.083	1.000	0.727	0.002
Blepharis integrifolia (L.f.) E.Mey. & Drège ex Schinz	13.889	0.194	1.400	1.774	0.004
B. maderaspatensis (L.) B. Heyne ex Roth	8.333	0.083	1.000	3.521	0.002
Boerhavia diffusa L.	11.111	0.111	1.000	0.968	0.003
Calotropis gigantea (L.) W.T. Aiton	5.556	0.083	1.500	0.463	0.002
Canthium coromandelicum (Burm.f.) Alston	2.778	0.028	1.000	48.698	0.001
Capparis zeylanica L.	30.556	5.278	17.273	7.223	0.059
Cardiospermum helicacabum L.	25.000	24.111	96.444	26.094	0.139
Catunaregam spinosa (Thunb.) Tirveng.	2.778	0.028	1.000	0.264	0.001
Chamaecrista mimosoides (L.) Greene	11.111	0.111	1.000	0.995	0.003
Chrysopogon orientalis (Desv.) A. Camus	83.333	10.556	12.667	15.809	0.091
Cissus quadrangularis L.	50.000	1.667	3.333	4.782	0.025
Cleome viscosa L.	16.667	0.778	4.667	1.851	0.014
Commelina benghalensis L.	11.111	0.417	3.750	1.116	0.008
C. erecta L.	5.556	0.139	2.500	0.487	0.003
C. longifolia Lam.	30.556	1.750	5.727	3.684	0.026
Corchorus aestuans L.	2.778	0.028	1.000	0.236	0.001
C. tridens L.	2.778	0.028	1.000	0.236	0.001
Crotalaria angulata Mill.	11.111	0.167	1.500	0.897	0.004
Cucumis maderaspatanus L.	2.778	0.028	1.000	0.524	0.001
Cyanthillium cinereum (L.) H. Rob.	72.222	12.278	17.000	16.895	0.100
Cymbopogon caesius (Hook. & Arn.) Stapf	25.000	0.417	1.667	18.211	0.008
Cynodon barberi Rang. & Tadul.	8.333	0.556	6.667	1.254	0.011
Dalbergia coromandeliana Prain.	25.000	0.278	1.111	7.246	0.006
Datura metel L.	2.778	0.028	1.000	0.456	0.001
Dichrostachys cinerea (L.) Wight & Arn.	2.778	0.028	1.000	0.396	0.001
Drimia indica (Roxb.) Jessop	11.111	0.167	1.500	0.885	0.004
Elytraria acaulis (L.fil) Lindau	33.333	0.722	2.167	2.808	0.013
Euphorbia antiquorum L.	8.333	0.194	2.333	0.733	0.004
E. hirta L.	2.778	0.028	1.000	4.833	0.001
Evolvulus alsinoides (L.) L.	2.778	0.028	1.000	0.236	0.001
Hibiscus micranthus L.f.	30.556	0.667	2.182	2.581	0.012
Holoptelea integrifolia (Roxb) Planch.	13.889	0.139	1.000	1.124	0.003
Hypertelis cerviana (L.) Thulin	33.333	0.444	1.333	2.526	0.009
Indigofera aspalathoides Vahl ex DC.	2.778	0.028	1.000	0.396	0.001
Jasminum angustifolium (L.) Willd.	36.111	2.083	5.769	4.388	0.030
Jatropha gossypiifolia L.	2.778	0.111	4.000	10.304	0.003
Leucas aspera (willd.) Link	11.111	0.111	1.000	0.920	0.003
Mesosphaerum suaveolens (L.) Kuntze	19.444	0.194	1.000	1.398	0.004
Microstachys chamaelea (L.) Mull. Arg.	27.778	3.278	11.800	5.029	0.042
Neltuma juliflora (Sw.) Raf.	13.889	0.361	2.600	1.254	0.007
Ocimum americanum L.	2.778	0.028	1.000	0.300	0.001
Oldenlandia umbellata L.	2.778	0.028	1.000	0.264	0.001
Opuntia monacanthos (Willd.) Haw.	11.111	1.167	10.500	1.964	0.019
Ouret lanata (L.) Kuntze	11.111	0.222	2.000	0.941	0.005
Parthenium hysterophorus L.	30.556	0.861	2.818	2.764	0.015
Passiflora foetida L.	5.556	0.056	1.000	0.400	0.002
Pavonia zeylanica (L.) Cav.	44.444	1.917	4.313	4.696	0.028
Pergularia daemia (Forssk.) Chiov.	2.778	0.028	1.000	0.216	0.001
Perotis indica (L.) Kuntze	27.778	0.944	3.400	2.708	0.016
Phyllanthus amarus Schumach. & Thonn.	16.667	0.222	1.333	1.275	0.005
P. maderaspatensis L.	19.444	0.361	1.857	1.621	0.007
Pigea enneasperma (L.) P.I. Forst.	38.889	1.639	4.214	4.128	0.025
Polycarpaea corymbosa (L.) Lam.	5.556	0.056	1.000	0.499	0.002
Polygala arvensis Willd.	27.778	3.500	12.600	5.263	0.044
Rhynchosia minima (L.) DC.	27.778	1.139	4.100	2.877	0.019
Rivea hypocrateriformis (Desr) Choisy	2.778	0.056	2.000	0.232	0.002
Rostellularia mollissima (Nees) Nees	63.889	4.417	6.913	8.414	0.052
R. obtusa Nees	8.333	0.083	1.000	0.686	0.002
Ruellia patula Jacq.	8.333	0.139	1.667	0.709	0.003
R. prostrata Poir.	27.778	1.111	4.000	2.881	0.018
Sida acuta Burm. f.	63.889	9.194	14.391	13.270	0.084
S. cordata (Burm.f.) Borss.Waalk.	13.889	0.306	2.200	1.174	0.006
Solanum nigrum L.	88.889	9.611	10.813	15.245	0.086
Spermacoce articularis L.f	44.444	5.611	12.625	8.415	0.061
Striga densiflora (Benth.) Benth.	2.778	0.028	1.000	4.833	0.001
Tephrosia purpurea (L.) Pers.	13.889	0.250	1.800	1.407	0.005
Trigastrotheca pentaphylla (L.) Thulin	2.778	0.028	1.000	0.300	0.001
Turnera subulata Sm.	2.778	0.028	1.000	0.344	0.001
Vachellia leucophloea (Roxb.) Maslin, Seigler & Ebinger	5.556	0.111	2.000	0.504	0.003
Vicoa indica (L.) DC.	52.778	2.889	5.474	6.186	0.038
Waltheria indica L.	25.00	0.694	2.778	2.255	0.013
Xenostegia tridentata (L.) D.F. Austin & Staples	5.556	0.139	2.500	0.547	0.003

Table 2. Plant diversity assessment in Thirukkuder Hill, Madurai District, Tamil Nadu, India (January 2020)

Botanical name	Frequency	Density	Abundance	IVI	Shannon's Index
Achyranthes aspera L.	5.556	0.056	1.000	0.624	0.002
Ageratum conyzoides L.	2.778	0.389	14.000	0.788	0.009
Allmania nodiflora (L.) R. Br.ex Wight	61.111	4.056	6.636	9.236	0.052
Alysicarpus monilifer (L.) DC.	2.778	0.028	1.000	0.333	0.001
Andrographis echioides (L.) Nees	50.000	1.278	2.556	5.658	0.022
Asparagus racemosus Willd.	8.333	0.083	1.000	0.854	0.002
Atalantia monophylla DC.	2.778	0.028	1.000	1.314	0.001
Azadirachta indica A. Juss.	2.778	0.083	3.000	1.366	0.002
Azima tetracantha Lam.	5.556	0.056	1.000	4.215	0.002
Barleria buxifolia L.	2.778	0.111	4.000	0.934	0.003
B. noctiflora L.f.	8.333	0.194	2.333	1.230	0.005
Benkara malabarica (Lam.) Tirveng.	2.778	0.194	7.000	0.889	0.005
Blepharis integrifolia (L.f.) E.Mey. & Drège ex Schinz	25.000	2.611	10.444	4.653	0.038
B. maderaspatana (L.) B. Heyne ex Roth	8.333	1.361	16.333	2.065	0.023
Boerhavia diffusa L.	5.556	0.056	1.000	1.060	0.002
Capparis zeylanica L.	5.556	0.056	1.000	0.624	0.002
Celosia polygonoides Retz.	5.556	0.139	2.500	0.659	0.004
Chamaecrista mimosoides (L.) Greene	27.778	5.028	18.100	7.143	0.060
Chrysopogon orientalis (Desv.) A. Camus	16.667	18.056	108.333	18.587	0.128
Cissus quadrangularis L.	8.333	0.167	2.000	1.017	0.004
Cleome viscosa L.	5.556	0.194	3.500	0.731	0.005
Commelina benghalensis L.	13.889	0.611	4.400	1.897	0.012
Corchorus aestuans L.	2.778	0.028	1.000	0.333	0.001
Croton bonplandianus Baill.	2.778	0.056	2.000	0.323	0.002
Cucumis maderaspatanus L.	2.778	0.028	1.000	0.333	0.001
Cyanthillium cinereum (L.) H. Rob.	11.111	0.417	3.750	1.488	0.009
Cymbopogon caesius (Hook. & Arn.) Stapf	5.556	0.056	1.000	22.525	0.002
Cynodon barberi Rang. & Tadul.	2.778	0.222	8.000	0.632	0.005
Dalbergia coromandeliana Prain	11.111	0.222	2.000	37.305	0.005
Drimia indica (Roxb.) Jessop	5.556	0.083	1.500	0.868	0.002
Euphorbia antiquorum L.	2.778	0.028	1.000	0.856	0.001
Evolvulus alsinoides (L.) L.	75.000	10.389	13.852	16.268	0.096
Flueggea leucopyrus Willd.	2.778	0.028	1.000	0.529	0.001
Gymnosporia montana (Roth) Benth.	8.333	0.139	1.667	14.928	0.004
Hibiscus micranthus L.f.	16.667	0.556	3.333	2.015	0.011
Holoptelea integrifolia (Roxb) Planch.	2.778	0.028	1.000	0.333	0.001
Indigofera aspalathoides Vahl ex DC.	33.333	1.250	3.750	4.361	0.022
Jasminum angustifolium (L.) Willd.	13.889	0.250	1.800	1.516	0.006
Jatropha glandulifera Roxb.	2.778	0.028	1.000	5.567	0.001
Leucas aspera (Willd.) Link	36.111	2.417	6.692	5.512	0.036
Microstachys chamaelea (L.) Mull. Arg.	38.889	3.111	8.000	6.369	0.043
Neltuma juliflora (Sw.) Raf.	8.333	0.083	1.000	0.854	0.002
Ocimum americanum L.	30.556	0.722	2.364	3.440	0.014
Oldenlandia umbellata L.	25.000	1.722	6.889	3.835	0.028
Ouret lanata (L.) Kuntze	38.889	2.528	6.500	5.822	0.037
Pavonia zeylanica (L.) Cav.	13.889	0.611	4.400	1.855	0.012
Pergularia daemia (Forssk.) Chiov.	2.778	0.028	1.000	0.384	0.001
Perotis indica (L.) Kuntze	2.778	0.194	7.000	0.685	0.005
Phyllanthus maderaspatensis L.	25.000	0.806	3.222	2.968	0.015
Polycarpaea corymbosa (L.) Lam.	8.333	0.306	3.667	1.109	0.007
Rhynchosia minima (L.) DC.	2.778	0.028	1.000	0.384	0.001
Rivea hypocrateriformis (Desr) Choisy	38.889	2.500	6.429	5.742	0.037
Rostellularia mollissima (Nees) Nees	33.333	4.806	14.417	7.478	0.059
R. obtusa Nees	55.556	2.500	4.500	7.268	0.037
Sida acuta Burm. f.	8.333	0.667	8.000	1.389	0.013
S. cordata (Burm.f.) Borss. Waalk.	30.556	1.306	4.273	3.963	0.022
Solanum nigrum L.	2.778	0.028	1.000	0.333	0.001
Spermacoce articularis L.f	27.778	2.833	10.200	5.187	0.040
*Tephrosia purpurea (*L.) Pers.	86.111	11.472	13.323	18.360	0.101
Tridax procumbens L.	2.778	0.028	1.000	0.333	0.001
Trigastrotheca pentaphylla (L.) Thulin	27.778	4.806	17.300	6.927	0.059
Turnera subulata Sm.	2.778	0.028	1.000	8.671	0.001
Vachellia leucophloea (Roxb.) Maslin, Seigler & Ebinger	5.556	0.056	1.000	0.944	0.002
Vicoa indica (L.) DC.	2.778	0.083	3.000	0.349	0.002
Waltheria indica L.	75.000	18.611	24.815	24.060	0.129
Xenostegia tridentata (L.) D.F. Austin & Staples	33.333	1.306	3.917	4.167	0.022
Zornia diphylla (L.) Pers.	2.778	0.028	1.000	0.733	0.001

Table 3. Plant diversity assessment in Thirukkuder Hill, Madurai District, Tamil Nadu, India (February 2020)

Botanical name	Frequency	Density	Abundance	IVI	Shannon's Index
Allmania nodiflora (L.) R. Br. ex Wight	58.333	3.194	5.476	20.478	0.078
Andrographis echioides (L.) Nees	33.333	0.472	1.417	9.005	0.019
Asparagus racemosus Willd.	5.556	0.056	1.000	1.538	0.003
Barleria buxifolia L.	8.333	0.139	1.667	2.417	0.007
B. noctiflora L.f.	8.333	0.139	1.667	2.417	0.007
Boerhavia diffusa L.	5.556	0.056	1.000	1.713	0.003
Calotropis gigantea (L.) W.T. Aiton	5.556	0.222	4.000	1.830	0.011
Canthium coromandelicum (Burm.f.) Alston	2.778	0.028	1.000	0.772	0.002
Capparis zeylanica L.	5.556	0.056	1.000	1.579	0.003
Cardiospermum halicacabum L.	2.778	0.028	1.000	0.937	0.002
Cissus quadrangularis L.	8.333	0.194	2.333	2.516	0.010
Cleome viscosa L.	8.333	0.139	1.667	2.302	0.007
Commelina benghalensis L.	19.444	0.889	4.571	6.526	0.032
Cyanthillium cinereum (L.) H. Rob.	22.222	0.667	3.000	6.703	0.025
Cymbopogon caesius (Hook.f. & Arn.) Stapf	2.778	0.028	1.000	26.821	0.002
Dalbergia coromandeliana Prain	11.111	0.167	1.500	22.770	0.008
Elytraria acaulis (L.f.) Lindau	2.778	0.028	1.000	0.748	0.002
Evolvulus alsinoides (L.) L.	36.111	4.111	11.385	17.014	0.091
Gymnosporia montana (Roth) Benth.	8.333	0.083	1.000	17.631	0.005
Holoptelea integrifolia (Roxb) Planch.	5.556	0.056	1.000	1.713	0.003
Indigofera aspalathoides Vahl ex DC.	2.778	0.056	2.000	9.396	0.003
Jasminum angustifolium (L.) Willd.	8.333	0.111	1.333	2.650	0.006
Jatropha glandulifera Roxb.	2.778	0.028	1.000	8.663	0.002
Leucas aspera (Willd.) Link	16.667	0.944	5.667	5.980	0.033
Microstachys chamaelea (L.) Mull. Arg.	27.778	1.389	5.000	9.499	0.044
Neltuma juliflora (Sw.) Raf.	8.333	0.083	1.000	2.303	0.005
Ocimum americanum L.	22.222	0.889	4.000	7.214	0.032
Oldenlandia umbellata L.	5.556	0.056	1.000	1.464	0.003
Ouret lanata (L.) Kuntze	27.778	0.944	3.400	8.612	0.033
Pavonia zeylanica (L.) Cav.	13.889	0.444	3.200	4.270	0.019
Phyllanthus maderaspatensis L.	5.556	0.056	1.000	1.475	0.003
Rhynchosia minima (L.) DC.	19.444	2.306	11.857	9.349	0.063
Rivea hypocrateriformis (Desr) Choisy	5.556	0.083	1.500	3.084	0.005
Rostellularia mollissima (Nees) Nees	38.889	2.639	6.786	14.691	0.069
R. obtusa Nees	30.556	2.083	6.818	11.613	0.058
Sida acuta Burm. f.	13.889	0.750	5.400	4.881	0.028
S. cordata (Burm.f.) Borss. Waalk.	27.778	0.972	3.500	8.645	0.034
Spermacoce articularis L.f	33.333	3.000	9.000	14.886	0.074
Tephrosia purpurea (L.) Pers.	86.111	8.417	9.774	37.798	0.132
Trigastrotheca pentaphylla (L.) Thulin	16.667	2.139	12.833	8.346	0.060
Turnera subulata Sm.	2.778	0.028	1.000	16.198	0.002
Vachellia leucophloea (Roxb.) Maslin, Seigler & Ebinger	2.778	0.028	1.000	0.937	0.002
Vicoa indica (L.) DC.	2.778	0.028	1.000	0.748	0.002
Waltheria indica L.	75.000	9.806	13.074	37.975	0.140
Xenostegia tridentata (L.) D.F. Austin & Staples	27.778	0.694	2.500	8.081	0.026

Discussion

Diversity analysis in vegetation ecology plays a crucial role in assessing how human activities impact the variety and abundance of plant species. This is an important method for measuring the influence of human actions on the overall diversity and composition of plant communities in ecosystems. Ecological studies not only help us comprehend the interaction between vegetation and the environment but they are also required for monitoring global climate change responses (Davis et al. 2021). It has long been the goal of ecological studies to disentangle the dynamics that underlie the spatiotemporal distribution of biodiversity (Rossi et al. 2021) and further functions of the ecosystem (Jiménez-Alfaro et al. 2018; Peters et al. 2019). Specific drivers of contemporary environments drive both biodiversity and ecosystem functions. The vegetation in any area is shaped over time through complex interactions with biotic and abiotic factors. These factors include topography, changes in land use, soil conditions, climate variations, competition among species, and herbivory. They collectively impact the composition, diversity, and spatial arrangement of plants. Competition for resources and interactions with other organisms are particularly significant biotic factors influencing the distribution of plant communities. Such interactions can directly dictate the presence or absence of specific species within a particular geographical area (Gebrehiwot et al. 2019).

Table 4. Plant diversity assessment in Thirukkuder Hill, Madurai District, Tamil Nadu, India (March 2020)

Botanical name	Frequency	Density	Abundance	IVI	Shannon's Index
Achyranthes aspera L.	2.778	0.056	2.000	0.500	0.002
Allmania nodiflora (L.) R. Br. ex Wight	50.000	2.722	5.444	10.645	0.054
Alysicarpus monilifer (L.) DC.	2.778	0.028	1.000	0.499	0.001
Andrographis echioides (L.) Nees	19.444	0.222	1.143	3.084	0.008
Atalantia monophylla DC.	8.333	0.139	1.667	29.637	0.005
Barleria noctiflora L.f.	2.778	0.056	2.000	3.315	0.002
Blepharis integrifolia (L.f.) E. Mey. & Drège ex Schinz	2.778	0.194	7.000	0.695	0.007
B. maderaspatensis (L.) B. Heyne ex Roth	22.222	1.917	8.625	5.730	0.042
Boerhavia diffusa L.	2.778	0.028	1.000	0.759	0.001
Calotropis gigantea (L.) W.T. Aiton	2.778	0.028	1.000	0.607	0.001
Capparis zeylanica L.	2.778	0.028	1.000	0.461	0.001
Celosia polygonoides Retz.	16.667	1.028	6.167	3.745	0.027
Chamaecrista mimosoides (L.) Greene	8.333	1.111	13.333	2.698	0.028
Chrysopogon orientalis (Desv.) A. Camus	27.778	21.917	78.900	34.793	0.158
Commelina benghalensis L.	13.889	0.806	5.800	3.086	0.022
C. longifolia Lam.	5.556	0.417	7.500	1.527	0.013
Corchorus aestuans L.	2.778	0.083	3.000	0.626	0.003
C. tridens L.	2.778	0.056	2.000	0.500	0.002
Cyanthillium cinereum (L.) H. Rob.	13.889	0.472	3.400	2.608	0.014
Dalbergia coromandeliana Prain.	8.333	0.222	2.667	23.145	0.008
Euphorbia antiquorum L.	2.778	0.028	1.000	7.823	0.001
Evolvulus alsinoides (L.) L.	30.556	2.972	9.727	8.292	0.058
Gymnosporia montana (Roth) Benth.	2.778	0.028	1.000	21.220	0.001
Hibiscus micranthus L.f.	5.556	0.194	3.500	1.069	0.007
Holoptelea integrifolia (Roxb) Planch.	2.778	0.028	1.000	0.607	0.001
Indigofera aspalathoides Vahl ex DC.	13.889	0.361	2.600	2.738	0.012
Jasminum angustifolium (L.) Willd.	5.556	0.056	1.000	14.904	0.002
Leucas aspera (willd.) Link	5.556	0.194	3.500	1.106	0.007
Mesosphaerum suaveolens (L.) Kuntze	2.778	0.028	1.000	0.607	0.001
Microstachys chamaelea (L.) Mull. Arg.	11.111	0.528	4.750	2.284	0.016
Neltuma juliflora (Sw.) Raf.	13.889	0.194	1.400	2.286	0.007
Ocimum americanum L.	11.111	0.389	3.500	2.097	0.012
Oldenlandia umbellata L.	5.556	0.111	2.000	0.969	0.004
Ouret lanata (L.) Kuntze	22.222	1.028	4.625	4.512	0.027
Pavonia zeylanica (L.) Cav.	13.889	0.500	3.600	2.656	0.015
Phyllanthus maderaspatensis L.	5.556	0.083	1.500	0.876	0.003
Rhynchosia minima (L.) DC.	44.444	5.472	12.313	13.674	0.086
Rivea hypocrateriformis (Desr.) Choisy	8.333	0.111	1.333	1.594	0.004
Rostellularia mollissima (Nees) Nees	38.889	5.167	13.286	12.543	0.083
R. obtusa Nees	27.778	3.194	11.500	8.295	0.061
Sida acuta Burm. f.	11.111	1.972	17.750	4.324	0.043
S.cordata (Burm.f.) Borss. Waalk.	22.222	0.722	3.250	4.117	0.020
Spermacoce articularis L.f	16.667	0.750	4.500	3.404	0.021
Tephrosia purpurea (L.) Pers.	77.778	5.278	6.786	17.987	0.084
Trigastrotheca pentaphylla (L.) Thulin	16.667	1.750	10.500	4.708	0.040
Vachellia leucophloea (Roxb.) Maslin, Seigler & Ebinger	5.556	0.056	1.000	0.960	0.002
V. nilotica (L.) P.J.H. Hurter & Mabb.	2.778	0.028	1.000	0.759	0.001
Vicoa indica (L.) DC.	2.778	0.028	1.000	0.434	0.001
Waltheria indica L.	75.000	8.000	10.667	21.427	0.107
Xenostegia tridentata (L.) D.F. Austin & Staples	19.444	0.306	1.571	3.070	0.010

As reported by Kefalew et al. (2022), the study's results indicate that environmental aspects like altitude and slope variations, soil properties such as total nitrogen content and organic matter levels, and disturbances within the ecosystem influence the current makeup and variety of plant species. Tree layer diversity can impact herb layer diversity by influencing resource availability and environmental variables important to herb plants. At the same time, there have been reports of relationships between herb and tree layer diversity. In the last several decades, studies of environmental changes have emerged more rapidly than other studies because to effects of these environmental changes have been intensified by recent anthropogenic activities (Alig et al. 2002). It also revealed that the indicator species of each plant community were linked to a particular set of environmental gradients. A region's forest communities evolve through time, but altitude, slope, latitude, aspect, precipitation, and humidity all have a part in their development and composition (Paudel et al. 2018). Ecosystems respond to simultaneous environmental changes affecting community diversity and distribution (Reich 2009). In each microhabitat type, specialist plant communities thrive and are composed of specific taxa that have adapted to the unique environmental conditions of that particular microhabitat (De Paula et al. 2020). Aboveground and underground communities work together to control whole-ecosystem processes and reactions to environmental changes (Geisen et al. 2022).

Packiaraj et al. (2023) conducted an extensive study on the biodiversity of Thirukudder Hills and discovered a remarkable abundance of plant species. On the other hand, the vegetation within a forest is strongly affected by the local microclimate. Their research highlighted that the significant variation in altitude and the region's diverse soil composition, climate, and microclimates likely contribute to this rich flora. The varying altitudes create unique ecological niches, while the diverse soil types provide different nutrients and conditions favorable for various plant species. Additionally, the climate and microclimates offer a range of temperature and moisture conditions that support a wide array of plant life, leading to a highly diverse and thriving plant community (Jiren et al. 2020). The present study shows that the plant community undergoes fluctuations across different study seasons, showing variations from one season to another. December tends to exhibit consistently the greatest diversity within this community. This research also notes abundant trees and shrubs alongside herbaceous plants. Climate plays a crucial role in determining the makeup of the plant community, while temporal factors also strongly influence its configuration. These periodic changes in vegetation complexity underscore how species respond to evolving environmental conditions, impacting their distribution within the community. As environmental conditions fluctuate, plant species successively replace one another, leading to species composition and distribution variations across ecological gradients. Other studies (Desalegn 2002; Shaheen et al. 2011; Khan et al. 2012) have also found a relationship between plant communities and environmental gradients. The maintaining of biodiversity is critical for environmental conditions to persist. The experimental hill findings illustrate the dynamic nature of plant communities, emphasizing the temporal variability and structural significance of key plant species in shaping the local ecosystem over the study periods. Understanding individual plant species' ecological dynamics is essential because certain species' high frequency, density, and abundance values impact community structure. The landscape is transforming both locally and globally, largely influenced by human activities and the effects of climate change (Sax and Gaines 2003). This study highlighted significant challenges during the observation periods, notably excessive grazing, over-browsing by domestic animals, and deforestation, which have emerged as primary concerns affecting vegetation composition. Furthermore, this study underscores the encroachment of settlement areas into study sites driven by population growth, posing an additional threat to the area under investigation. Uncontrolled grazing in open areas diminishes the diversity and abundance of herbaceous species, accentuating strain on ecosystems; grazing pressure can severely threaten plant biodiversity (Mayer et al. 2009) and species composition. This led to biodiversity loss, drought, ecological imbalance, and environmental degradation (Mewded et al. 2019; Birhanu et al. 2021). Due to increased demand for land, forested areas are converted into agricultural land, industrial belts, and urban areas, leading to loss of habitat as well as habitat fragmentation for both flora and fauna (Van Doorn-Hoekveld et al. 2016). We need to ascertain whatever biodiversity is left in these already stressed habitats for their much-needed preservation to maintain the stability of the ecosystem.

The impacts caused by human activities, such as deforestation and the introduction of alien species, have had major consequences for the local ecosystem in the Thirukudder Hills, leading to a decline in species richness and density from undisturbed to disturbed areas. Despite research documenting these changes, the region faces major challenges in preserving its unique vegetation, leaving Madurai's ecosystem increasingly threatened. Moreover, the varying physical conditions of the study area, specific climatic conditions, and biogeographical position mean that researchers' attention could be more extensive. Therefore, to maintain the diverse and dynamic plant communities of Thirukudder Hills, it is essential to implement informed conservation and management strategies, which can only be developed through extensive research and understanding. These strategies must be tailored to the study area's specific ecological requirements and aim to mitigate ongoing threats while promoting sustainable practices. Future research efforts should focus on comprehensive species mapping, detailing their localized distributions across different zones within the study area. This approach will facilitate a deeper understanding of their ecological roles and structural contributions to the ecosystem. By identifying key areas requiring conservation interventions, such research endeavors will be instrumental in guiding targeted conservation measures. Addressing the current experimental site's conservation challenges demands proactive and scientifically grounded efforts. By investing in robust research and strategic conservation initiatives, we can aspire to preserve this invaluable natural habitat's ecological integrity and biodiversity for generations.

In conclusion, the investigation at Thirukudder Hill in Madurai District revealed an intriguing story of plant community dynamics. The study meticulously recorded fluctuations across various ecological indices and uncovered distinct patterns in species distribution, shedding light on the complex interplay among plant species within this ecosystem. The study habitat's rich species diversity, temporal variability, and key plant species' structural importance emerged as prominent themes. However, the current study also emphasized significant challenges posed by human activities. Deforestation driven by agricultural expansion and urban settlements, along with degradation from selective logging and forest thinning, emerged as major threats to the study area's ecological integrity. As a result, recognizing such an indication might be used to manage species in a range of microhabitats with varying soil types and climatic conditions. Assessing the abiotic and biotic variables that drive the ecosystem dynamics is one of the main goals nowadays, mainly due to the continuous process of climate change and anthropogenic impacts. These findings highlight the dynamic nature of plant communities and underscore the urgency of understanding these dynamics for effective conservation and management strategies. Understanding is crucial for preserving biodiversity and maintaining the ecological balance in this unique habitat. By acknowledging and addressing the impacts of human activities, we can protect these plant communities and uphold their critical roles within the broader ecosystem. These efforts are essential for ensuring the environmental health of Thirukudder Hill, thereby securing its resources and biodiversity for future generations.

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