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Research Article

Inventory and conservation of threatened trees in the Sree Narayanapuram Grama Panchayath, Kerala, India

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Background: This study investigates the occurrence and distribution of six threatened tree species within the Coastal Grama Panchayath of Sree Narayana Puram, spanning an area of 19.4 km². The study underscores the ecological importance of these species, particularly in sacred groves, as well as the threats posed by urbanization, tree removal, and climate change-induced degradation.

Methods: A systematic sampling method was employed for the study. The study area is divided into 42 subunits corresponding to the 21 administrative units, the wards. Surveys were conducted covering 1 km at a time and the completed surveys were in every 21 wards. Data was collected using Google Forms with GPS geotagging in a collaborative effort involving local community members, ward members, the Biodiversity Management Committee, and environmentalists.

Results: Among these species, the White Dammar tree (*Vateria indica*) exhibited a notable frequency of 52.3%, with a density of 1.72 trees per km. Other threatened species, including *Saraca asoca* and *Hydnocarpus pentandrus*, demonstrated densities of 0.50 and 0.45 trees per km, respectively, each showing approximately 25% frequency. *Syzygium caryophyllatum* had a frequency of 21.4% with a density of 0.5 trees per km. The findings highlight the clustered distribution of *Hopea ponga* and *Aporosa cardiosperma*, which, despite their lower density, indicate significant local abundance. The coastal region, excluding saline intrusion areas, is deemed suitable for the preservation of these threatened species.

Conclusion: To enhance conservation efforts, the study advocates for the integration of these findings into the Local Level Biodiversity Strategy and Action Plan (LBSAP), alongside initiatives aimed at safeguarding the identified species and their habitats.

Keywords: *western ghats, kerala, diversity, red list, coastal*

Introduction

The Western Ghats represent one of the most biologically diverse regions globally, encompassing a vast array of flora and fauna, a significant proportion of which is endemic to this locality (Myers et al., 2000). Extending across six Indian states, including Kerala, the Western Ghats serve as a crucial hotspot for botanical diversity, with a considerable number of plant species confronting the imminent threat of extinction (Nayar, 1996; Das et al., 2006). The ecological diversity of Kerala, situated at the southern periphery of the Western Ghats, is particularly distinctive, hosting a multitude of tree species that are either endemic or at risk due to an interplay of natural and human-induced factors (Nayar, 1996; Ramesh et al., 2010). The region encompasses a diverse array of arboreal species, many of which are essential for the preservation of ecological equilibrium (Sukumar et al., 1995). Nonetheless, a significant number of these species have now been designated as threatened. In Kerala, the extensive diversity of tree species is currently faced substantial threats stemming from habitat degradation, overexploitation, and climate change. The primary threats to plant species in Kerala encompass deforestation, encroachment for agricultural and urban expansion, illicit logging, and the repercussions of invasive species (Balakrishnan et al., 2011; Kumar & Mathur, 2005). The fragmentation of forests, in conjunction with escalating human activities, disrupts natural habitats, thereby complicating the processes of regeneration and flourishing for tree species (Menon & Bawa, 1997). Furthermore, climate change represents a threat, with modified precipitation patterns and increasing temperatures adversely impacting the viability of numerous species (Thomas et al., 2004; Sharma et al., 2010). Significant threats encompass extensive deforestation, habitat fragmentation, and alterations in land use instigated by the expansion of agriculture, infrastructure projects, and urban development (Reddy et al., 2016). The unsustainable extraction of forest resources, including timber and medicinal flora, coupled with the increasing prevalence of invasive alien species, further aggravates the decline of biodiversity (Kannan & James, 1999; Sankaran et al., 2001). Moreover, climate change presents a formidable challenge by modifying temperature and precipitation dynamics, thereby influencing species composition and the stability of ecosystems (Joshi & Kotari, 2018). The phenomena of deforestation, habitat fragmentation, climate change, invasive species, and unregulated resource extraction have culminated in the precipitous decline of plant species within the region (Gunawardene et al., 2007; Dasgupta et al., 2012). Furthermore, the expansion of agriculture, the processes of urbanization, and infrastructure development have exacerbated ecological pressures on the delicate ecosystems of the Western Ghats (Jha et al., 2005; Ravindranath et al., 2006). Conservation initiatives have been instituted at both localized and national level to safeguard the diverse flora of the region. The Kerala Forest Department (KFD) along with the Kerala State Biodiversity Board (KSBB) have embarked on a variety of conservation endeavors, including the establishment of protected zones, eco-restoration of degraded landscapes, and the formation of community-involved conservation frameworks (Ravindran et al., 2012; Kumar et al., 2012). Furthermore, the State Government has enacted policies aimed at promoting sustainable forestry methodologies, wildlife conservation and ecorestoration. Notwithstanding these endeavors, the pressing necessity for localized conservation initiatives, such as the compilation of an inventory of threatened species in specific region remains paramount to the overarching objective of safeguarding Kerala's extensive plant biodiversity. Conservation initiatives have concentrated on taxa such as *Madhuca diplostemon*, which was rediscovered after 184 years within a sacred grove (Shailajakumari et al., 2020), and *Dipterocarpus bourdillonii*, a critically endangered arboreal species endemic to the region, with demographic studies underscoring its precarious status (Swarupanandan et al., 2013; Puttaswamy, 2010; Page, 2021). Likewise, *Vateria indica*, a species belonging to the dipterocarp family, has undergone evaluation concerning the determinants influencing its recruitment and viability (Sinu & Shivanna, 2016; Dhyani, 2020). These investigations, in conjunction with conservation efforts spearheaded by the Kerala Forest Research Institute (KFRI), furnish significant insights into the preservation of the state's rare and threatened flora.

The threatened tree species outside the forest region, especially in the plains and coastal areas, are highly threatened due to habitat degradation (Basha et al., 2014). The identification of such species and their habitats at the micro level, especially at the Local Self Government levels, and the incorporation of the data into the People's Biodiversity Register (PBR) or the LSG-level Biodiversity Strategy Action Plans (LBSAP) under the Biodiversity Act of 2002 is very important. This project seeks to document and evaluate the threatened tree species present in Sree Narayanapuram Grama Panchayath, Kodungallur for the first-time, thereby contributing to conservation initiatives, generating benchmark data on threatened species, and enhancing awareness regarding the significance of preserving these plant species within the region.

Materials and methods

Site description

Sree Narayanapuram Grama Panchayath is a local self-governing body located in the Thrissur district of Kerala, India. It operates under the administrative jurisdiction of the Mathilakam Block Panchayath and falls within the Kaipamangalam State Assembly constituency. The Panchayath is situated at coordinates 10°15'31.68"N latitude and 76°10'6.46"E longitude, encompassing a geographical area that contributes to the diverse topography of the Thrissur district (Figure 1). The Sree Narayana Puram Grama Panchayath is situated in the coastal expanse of the Thrissur district within central Kerala, approximately eight kilometers to the north of the Kodungallur township. The delineation of the Kodungallur region of the Thrissur district is characterized by the confluence of the Periyar and Chalakudy rivers, in addition to the Kodungallur backwaters located to the south of the Ernakulam district. The coastal shoreline of Kodungallur is adjacent to the Grama Panchayaths of Eriyadu, Edavilangu, SN Puram, Mathilakam, Perinjanam, and Kaipamangalam, all of which fall under the purview of the Kaipamangalam constituency. The eastern boundary of these Panchayaths, including SN Puram, is demarcated by the Canoly Canal, a backwater channel that extends from the Kodungallur backwaters to Ponnani. The entirety of the SN Puram Panchayath is comprised of sandy deposits and exhibits a richness in freshwater ponds and streams, with notable exceptions on the eastern flank.

The eastern sector of the Panchayath, particularly the portion in proximity to the national highway, is characterized by complete salinity attributable to the brackish water properties of the Canoly Canal. In these sandy ecosystems, freshwater ponds, streams, and wells serve as the principal sources for freshwater provision. The sustainability of water resources is jeopardized due to heightened absorption of surface water, disruption of stream channel connectivity, and the degradation of aquatic bodies resulting from landfilling activities. The Canoly Canal traverses the eastern boundary of the Panchayath, extending over a length of approximately three to four kilometers. This expansive backwater waterway facilitates the connection of the Kodungallur backwaters to the Kochi backwaters in the south, as well as to various other backwaters and estuaries located in the northern districts.

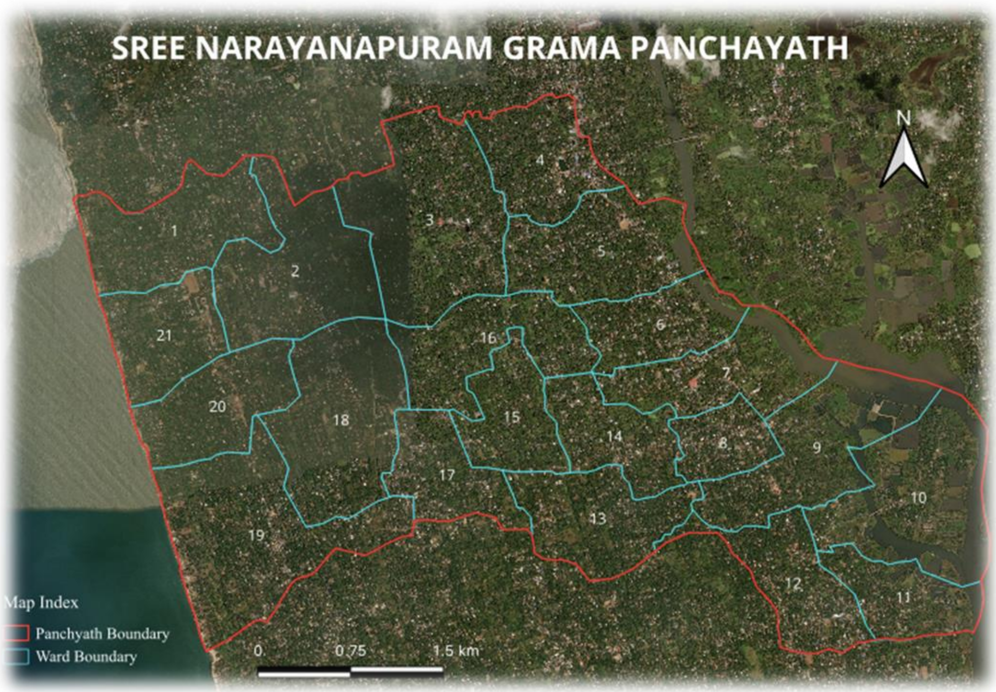

Figure 1. Study area – Sree Narayanapuram Grama Panchayath

Study Design and Data Collection

The study was conducted in Sree Narayanapuram Grama Panchayath, Thrissur district, Kerala, covering all 21 wards. The region consists of diverse ecosystems, including agricultural lands, wetlands, home gardens, sacred groves, and patches of natural forests. A systematic survey was carried out to document the occurrence and distribution of threatened tree species within the Panchayath.

Sampling method

A systematic sampling method was employed for the study. The study area was divided into 42 subunits, corresponding to the 21 administrative units (the wards). Transects of one kilometer in length were conducted in each subunit. Transects were laid covering diverse habitats and avoiding main roads to minimize bias. Surveys were conducted covering 1 km at a time, with completed surveys in every 21 wards. The data sheet was prepared using Google Forms, and the transects were geotagged using GPS. Some points were revisited for data verification, especially for the identification of tree species and their occurrence.

Data collection was conducted in collaboration with local community members, ward members, the Biodiversity Management Committee (BMC), and local environmentalists. Standard taxonomic keys and floras were used for species identification. Local knowledge from residents and traditional healers was also incorporated to validate species identification. The International Plant Names Index (IPNI) was used for validating the scientific names of the species. The taxonomic data were referred to from the India Biodiversity Portal (https://indiabiodiversity.org/) and Eflora Kerala (https://www.eflorakerala.com/) databases. The IUCN Red List status assessment, criteria, and categories were referred to from the IUCN official website (https://www.iucnredlist.org/). Local ecological knowledge from residents, traditional healers, and experienced farmers was also incorporated to improve the accuracy of species identification, following ethnobotanical field survey protocols (Martin, 1995).

Statistical analysis

To quantify the ecological characteristics of the recorded species, three standard phytosociological parameters—Density, Frequency, and Abundance—were calculated (Curtis & McIntosh, 1950):
Density = Total number of individuals / 42 (transects)
Frequency = Number of transects where the species occurred / 42
Abundance = Total number of individuals / Number of transects where the species occurred

These indices are commonly used in vegetation ecology to understand population distribution patterns and to identify species that may require conservation priority due to limited occurrence or low abundance (Misra, 1968; Kent, 2012).

Statistical analysis

Shapiro-Wilk tests for understanding normality of distribution			
Variable	W Statistic	P-value	Is it Normally Distributed?
Frequency	0.87005	0.2264	Yes
Density	0.70296	0.00664	No
Abundance	0.89396	0.3394	Yes

The Shapiro-Wilk tests was conducted in R environment for the three quantitative parameters Density, Frequency and Abundance check the normality of distribution of data. The p-value of frequency (0.2264) and Abundance (0.3394) is greater than the common significance level of 0.05. Therefore, the data for Frequency and Abundance are normally distributed. Whereas the p-value of Density (0.00664) is less than 0.05. This indicates that the data for Density is not normally distributed. Since the data are based on the same data set, a Kruskal-Wallis H test was employed to understand if any significance difference between the species in its phytosociological parameters.

Results

The study encountered the following threatened tree species (Figure 2).

1. ***Aporosa cardiosperma*** **(VU)**

This medium-sized tree, reaching up to 15m in height and commonly known as ‘Vetti’ in forest areas, is rarely found in coastal regions. The present study encountered six mature individuals across three transects, all located within coastal sacred groves. The calculated density (0.14), frequency (7.143), and abundance (2) indicate its rarity and align with its threatened status (Figure 3,4 & 5). The degradation of sacred groves poses a significant threat to this species, especially in coastal regions and outside forest areas (Table 1 & 2).

2. ***Hopea ponga*** **(VU)**

This large tree is endemic to the Western Ghats and the Malabar coast and is considered an important component of tropical low-elevation forests as well as riparian forests (Bachan and Devika, 2021). The present study encountered 11 mature individuals across three transects, specifically located within coastal sacred groves. The density (0.262), frequency (7.143), and abundance (3.6) suggest a clustered distribution of this tree within the coastal sacred groves (Figure 3,4 & 5). The tree forms an important component of the coastal sacred grove ecosystem, contributing to its unique composition (Bachan and Devika, 2021). The degradation of coastal sacred groves due to urbanization and fragmentation presents a significant threat (Table 1 & 2).

3. *Hydnocarpus pentandrus* (VU)

This medium-sized tree is found across low-elevation forest habitats, extending to the coastal regions of Kerala. The species is historically known for its medicinal oil extracted from the seeds, which is still used as a minor forest produce collected by indigenous communities. The study encountered 19 mature individuals across 10 transects, resulting in a density of 0.45 per km, abundance of 1.9, and frequency of 23.8% (Figure 3,4 & 5). The tree is distributed among homesteads and agricultural lands, in addition to sacred groves. The removal of trees due to urbanization is a major threat; a cut-down tree was observed during the survey period. In such situations, sacred groves serve as a refuge for its coastal population (Table 1 & 2).

4. *Saraca asoca* (VU)

This is the popularly known medicinal and sacred “Asoka Tree,” a medium-sized evergreen tree with showy flowers, highly valued for its medicinal properties. In the present study, 21 mature individuals were enumerated from 11 transects within this coastal panchayat. The density (0.5 per km), abundance (1.9), and frequency (26.1%) (Figure 3,4 & 5) indicate a stable population for the species, likely due to its medicinal, ornamental, and worship value. Some religious taboos also discourage people from planting this tree in homesteads (Table 1 & 2).

5. *Syzygium caryophyllatum* (VU)

This large Jamun tree, bearing sour and small fruits and locally known as “Njara” or “Kilinjaval,” is chiefly distributed in plains and also low-elevation forests. It is threatened due to urbanization and the degradation of sacred groves. The study encountered only nine mature individuals across nine transects, with a density of 0.214 per km, abundance of 1.0, and frequency of 21.4% (Figure 3,4 & 5). The species was recently assessed as Vulnerable by IUCN (Devika & Bachan, 2024), with the major threat being the loss of its population in the plains and coastal regions due to urbanization. The present study provides information on its occurrence in the coastal region, where the majority of individuals are found in sacred groves, and one site is protected by a coastal ecorestoration program (Table 1 & 2).

6. *Vateria indica* (VU)

This popularly known large low-elevation rainforest tree is endemic to Southern India, including the Western Ghats and Malabar Coast.

Table 1. IUCN Red list status of located species from the Panchayath

SL. No.	Names of species	IUCN status	
		Category	Criteria
1	*Aporosa cardiosperma*	Vulnerable	A1c
2	*Hopea ponga*	Vulnerable	A1c
3	*Hydnocarpus pentandrus*	Vulnerable	A2cd
4	*Saraca asoca*	Vulnerable	B1+2c
5	*Syzygium caryophyllatum*	Vulnerable	C2a(i)
6	*Vateria indica*	Vulnerable	A2cd

Table 2. Density and Frequency of threatened trees in the Panchayath

Name of Species	Transects of Occurrence	Total Number	Total Transect	Frequency	Density	Abundance
Aporosa cardiosperma	3	6	42	7.143	0.143	2
Hopea ponga	3	11	42	7.143	0.262	3.66
Hydnocarpus pentandrus	10	19	42	23.810	0.452	1.9
Saraca asoca	11	21	42	26.190	0.500	1.90
Syzygium caryophyllatum	9	9	42	21.429	0.214	1
Vateria indica	22	74	42	52.381	1.762	3.36

The tree is known as the “White Dammar Tree” due to the traditional and commercial use of its resins as a fumigant. The study encountered 74 mature individuals across 22 transects, resulting in a density of 1.16 per km, abundance of

3.36, and frequency of 52.38% (Figure 3,4 & 5). The tree is distributed across the coastal wards, except in areas with saline intrusion or suitable for mangroves (Table 1 & 2).

Figure 2. A - *Aporosa cardiosperma* (Gaertn.) Merr., B - *Syzygium caryophyllatum* (L.) Alston., C - *Hopea ponga* (Dennst.) Mabb., D - *Saraca asoca* (Roxb.) W.J.de Wilde, E - *Hydnocarpus pentandrus* (Buch.-Ham.) Oken, F - *Vateria indica* L.

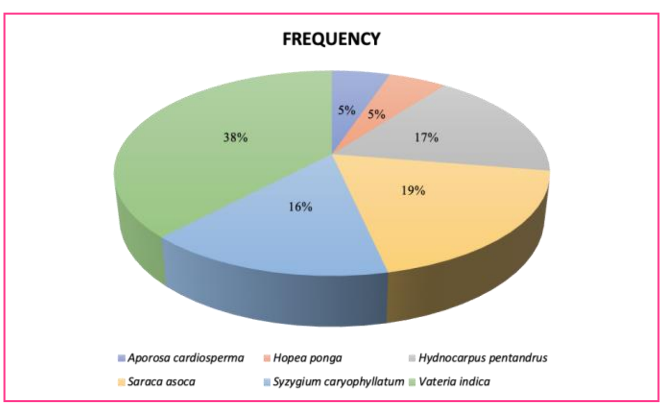

Figure 3. Frequency of threatened species in the study area

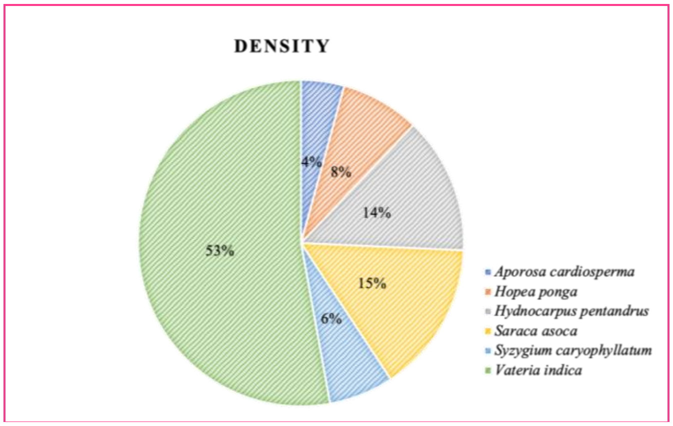

Figure 4. Density of threatened species in the study area

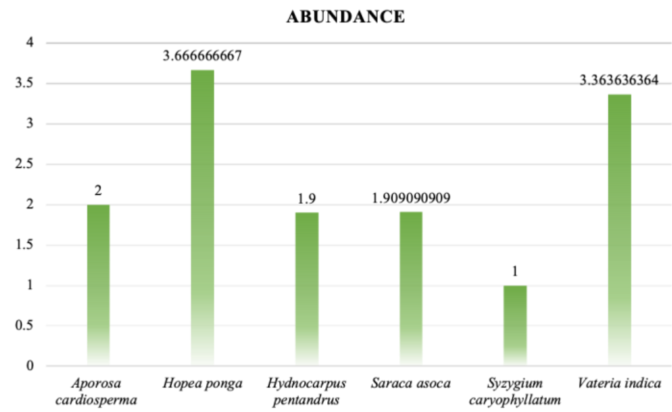

Figure 5. Abundance of threatened trees in the Panchayath

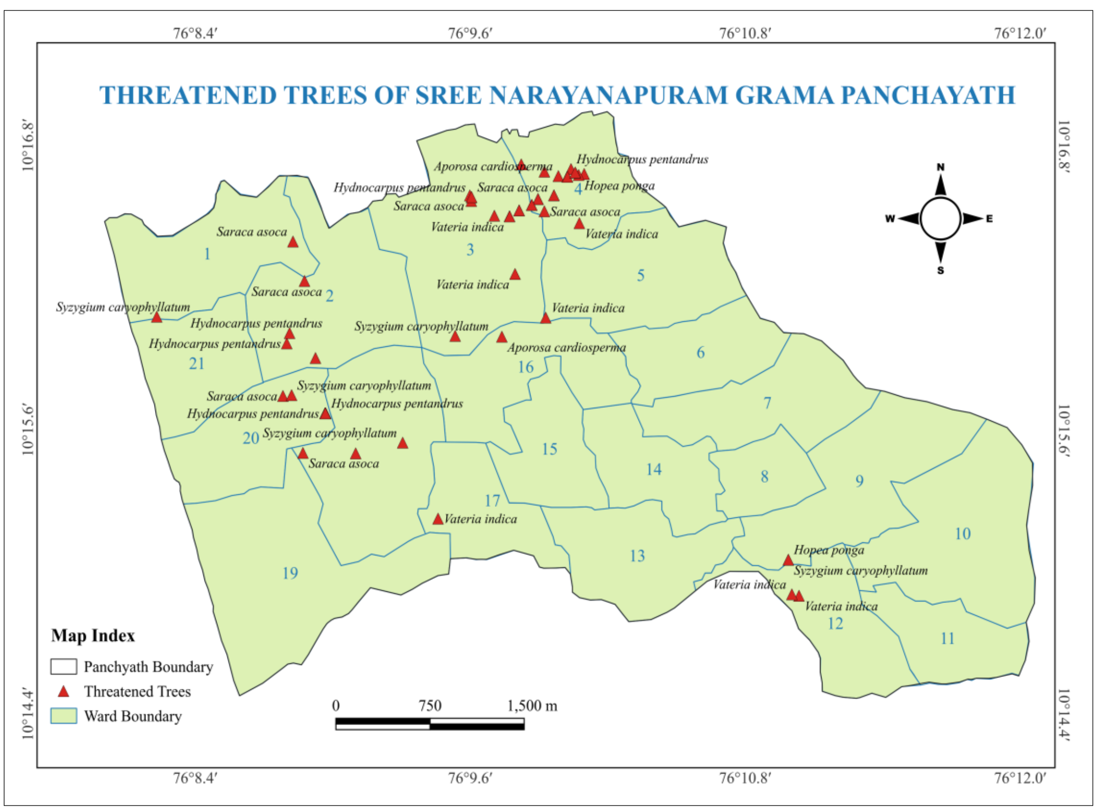

Figure 6. Diversity of threatened trees in the Panchayath (Locations having more than 1 species)

Discussion

This study provides a compelling snapshot of the distribution and abundance of six IUCN-threatened tree species within the coastal Sree Narayanapuram Grama Panchayath in central Kerala (Figure 6), underscoring the significant role even small geographic areas (19.4 km²) can play in harboring threatened biodiversity (Myers et al., 2000). The co-occurrence of *Vateria indica*, *Saraca asoca*, *Hydnocarpus pentandrus*, *Syzygium caryophyllatum*, *Hopea ponga*, and *Aporosa cardiosperma* within this coastal landscape highlights its ecological importance in a region increasingly impacted by anthropogenic activities and climate change (IPCC, 2022).

The normality assessment of data distribution using Shapiro-Wilk test, indicated that a non-parametric approach was suitable for comparing the groups, a Kruskal-Wallis H test was employed to investigate for statistical differences in the median frequency, density, and abundance among the six threatened tree species (Kruskal & Wallis, 1952). The results of the analysis revealed no significant differences in frequency ($H(5) = 5.00$, $p = 0.42$), density ($H(5) = 5.00$, $p = 0.42$), or abundance ($H(5) = 5.00$, $p = 0.42$) across the species. These findings suggest that the frequency, density, and abundance of the six threatened tree species are not statistically different from one another within the surveyed area. This further indicated similar kind of impacts and distribution pattern for the six threatened tree species.

The high frequency and density of *Vateria indica* suggest its relative adaptability to the mosaic of land uses in the panchayat, likely finding refuge in remnant green patches and, notably, sacred groves. This aligns with observations across the Western Ghats, where *V. indica*'s persistence is linked to moist evergreen habitats and relatively stable microclimates, often buffered by traditional conservation practices (Ramesh et al., 2010; Chandran & Hughes, 2020). In contrast, the clustered distribution of *Hopea ponga* and *Aporosa cardiosperma*, despite their lower densities, likely reflects their specific ecological requirements, potentially related to localized microclimatic conditions or soil characteristics, and their susceptibility to habitat fragmentation, a common pattern for threatened taxa in human-modified landscapes (Tilman et al., 1994; Fahrig, 2003). The consistent role of sacred groves as refugia for multiple threatened species in this study strongly supports their recognized importance as in-situ conservation sites within agricultural and residential matrices (Bhagwat & Rutte, 2006; Ormsby & Bhagwat, 2010). This is further supported by conservation work on *Gymnacranthera canarica*, an endangered tree species of Myristica swamps in the Western Ghats, where relic forest patches act as crucial refuges (Jose & Anuraj, 2023).

The moderate density and scattered occurrence of *Saraca asoca* and *Hydnocarpus pentandrus* suggest relatively stable populations in specific areas but also indicate a vulnerability to habitat fragmentation, necessitating consideration for assisted regeneration and habitat connectivity initiatives (Corlett & Primack, 2011). Restoration studies on *Atuna travancorica* show that establishing propagation protocols and planting in suitable forest microhabitats can significantly improve recovery of endemic tree populations (Praveena & Jose, 2024). The comparable frequency and density of *Syzygium caryophyllatum*, with a notable presence in sacred groves and homesteads, further emphasizes the critical role of microhabitats in supporting threatened flora, even within human-dominated landscapes (McIntyre & Hobbs, 1999). The clustered distribution of *Hopea ponga* and *Aporosa cardiosperma* likely reflects a combination of limited seed dispersal and specialized habitat needs, making them particularly susceptible to localized disturbances (Nathan & Muller-Landau, 2000).

The study's affirmation of sacred groves as vital refugia aligns with growing recognition of their conservation value, particularly in densely populated regions like Kerala (Malhotra et al., 2007). However, the observed degradation of these groves due to recent extreme climatic events, such as cyclones and unseasonal rainfall, underscores the synergistic threats posed by climate change and habitat loss, further exacerbated by urban expansion and unsustainable resource extraction (Dobson, 2003; Thomas et al., 2004). These findings strongly advocate for the integration of biodiversity conservation into local land-use planning frameworks.

Conclusion

This study provides critical baseline data on the distribution and abundance of six IUCN-threatened tree species within the 19.4 km² coastal Sree Narayana Puram Grama Panchayath. Notably, Vateria indica exhibited the highest frequency (52.3% across 11 wards) and density (1.72 trees/km²), highlighting its relative success in this landscape. *Saraca asoca* (0.50 trees/km²) and *Hydnocarpus pentandrus* (0.45 trees/km²) also showed moderate density and approximately 25% frequency, indicating stable populations in certain areas. *Syzygium caryophyllatum* (21.4% frequency, 0.5 trees/km²) further underscores the region's ecological significance. In contrast, *Hopea ponga* and *Aporosa cardiosperma* displayed lower frequencies but clustered distributions, suggesting habitat-specific preferences. The widespread occurrence and high abundance of *Vateria indica* likely reflect its adaptability to the coastal environment and its persistence within remnant natural vegetation, particularly sacred groves, which emerged as crucial centers for multiple threatened species. The suitability of most of the coastal region, excluding saline-intruded backwater areas, for these species further emphasizes the conservation potential of this landscape. However, urbanization and direct removal of trees pose significant threats to their persistence. Furthermore, the degradation of sacred groves due to recent extreme climatic events, such as increased tree falls, highlights the growing impact of climate change on these critical refugia. The proactive initiatives of the Sree Narayana Puram Grama Panchayath in implementing coastal ecorestoration programs and establishing species conservatories represent a vital step towards local biodiversity preservation. The study strongly recommends the integration of these identified threatened tree populations, sacred groves, and ecologically important homesteads into the Local Level Biodiversity Strategy and Action Plan (LBSAP) to ensure their long-term conservation within this ecologically significant coastal region. This spatially explicit data provides a crucial foundation for targeted conservation efforts and long-term monitoring in the face of ongoing anthropogenic pressures and increasing climate variability.

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Author contributions

Afra M, Shifamol T.A, Sree Dakshina Dileep: Writing original draft, Data mining and curation
Devika M A: Writing, Data mining and curation, Supervision
Amitha Bachan KH: Conceptualization and methodology, Editing and reviewing

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Conflict of interest

The authors declare no conflict of interest.

Ethics approval

Not applicable.

AI tool usage declaration

The authors did not use any AI and related tools to write this manuscript.

References

Bachan A.K.H. & Devika M. A. 2021. A strategic plan for the conservation, monitoring and ecorestoration of coastal ecosystems and its biodiversity within the SN Puram grama panchayath, Kerala. BMC, SN Puram Grama Panchayath. Pages 35.

Balakrishnan, N., Sivarajan, V. V., & Mathew, M. (2011). Flora of India - Volume 6: Forests of Kerala. University of Calicut.

Basha, S. C., et al. (2014). Biodiversity in Coastal Ecosystems of India. ENVIS.

Bhagwat, S. A., & Rutte, C. (2006). Sacred groves: Potential for biodiversity management. *Frontiers in Ecology and the Environment*, *4*(10), 519–524. https://doi.org/10.1890/1540-9295(2006)4[519:SGPFBM]2.0.CO;2

Chandran, M. D. S., & Hughes, J. D. (2020). Sacred groves and conservation: The comparative history of traditional reserves in the Mediterranean area and South India. *Environment and History*, *26*(3), 289–318. https://doi.org/10.3197/096734019X15463432086996

Corlett, R. T., & Primack, R. B. (2011). Tropical rainforests: An ecological and biogeographical comparison (2nd ed.). Wiley-Blackwell.

Curtis, J. T., & McIntosh, R. P. (1950). The interrelations of certain analytic and synthetic phytosociological characters. *Ecology*, *31*(3), 434–455.

Das, A., Krishnaswamy, J., Bawa, K. S., Kiran, M. C., Srinivas, V., Kumar, N. S., & Karanth, K. U. (2006). Prioritisation of conservation areas in the Western Ghats, India. Current Science, *91*(3), 322–328.

Dasgupta, S., et al. (2012). Climate Change, Biodiversity, and Livelihoods in India. World Bank Policy Research Working Paper.

Devika, M.A. & Amitha Bachan, K.H. 2024. *Syzygium caryophyllatum*. The IUCN Red List of Threatened Species 2024: e.T38036A210023175. https://dx.doi.org/10.2305/IUCN.UK.2024-1.RLTS.T38036A210023175.en. Accessed on 17 May 2025.

Dhyani, A. & Barstow, M. (2020). *Vateria indica*. *The IUCN Red List of Threatened Species 2020*: e.T33029A115932674. https://dx.doi.org/10.2305/IUCN.UK.2020-1.RLTS.T33029A115932674.en. Accessed on 10 March 2025

Dobson, A. (2003). Conservation and biodiversity. Scientific American Library.

Fahrig, L. (2003). Effects of habitat fragmentation on biodiversity. Annual Review of Ecology, *Evolution, and Systematics*, *34*, 487–515. https://doi.org/10.1146/annurev.ecolsys.34.011802.132419.

Gunawardene, N. R., Daniels, D. A. D., Gunatilleke, I. A. U. N., Gunatilleke, C. V. S., Karunakaran, P. V., Nayak, K. G., & Vasanthy, G. (2007). A brief overview of the Western Ghats–Sri Lanka biodiversity hotspot. *Current Science*, *93*(11), 1567–1572.

IPCC. (2022). Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (H.-O. Pörtner, D. C. Roberts, M. Tignor, et al., Eds.). Cambridge University Press. https://doi.org/10.1017/9781009325844

Jha, C., Goparaju, L., Tripathi, A. et al. (2005). Forest fragmentation and its impact on species diversity: an analysis using remote sensing and GIS. *Biodivers Conserv., 14*, 1681–1698. https://doi.org/10.1007/s10531-004-0695-y

Jose, J. K., & Anuraj, K. (2024). Conservation of *Gymnacranthera canarica* (Myristicaceae), a threatened tree species endemic to Myristica swamps of Western Ghats, India. *Biodiversity, 25*(1), 3–6. https://doi.org/10.1080/14888386.2023.2289459

Joshi, P. K., & Kotari, R. (2018). Climate Change and Biodiversity in India: Impacts and Adaptations. Springer.

Kannan, R., & James, D. A. (1999). Effects of Deforestation on South Indian Montane Forest Bird Communities. *Conservation Biology*, *13*(5), 1412-1420.

Kent, M. (2012). Vegetation Description and Analysis: A Practical Approach (2nd ed.). Wiley-Blackwell.

Kumar, R., & Mathur, V. B. (2005). Fragmentation and deforestation: A review of forest loss and degradation. ENVIS Bulletin: Wildlife & Protected Areas.

Kumar, S., et al. (2012). Community Participation in Forest Conservation: A Review. *Journal of Forestry Research, 23*(3), 377–382.

Kruskal, W. H., & Wallis, W. A. (1952). Use of ranks in one-criterion variance analysis. *Journal of the American Statistical Association, 47*(260), 583-621.

Malhotra, K. C., Gokhale, Y., Chatterjee, S., & Srivastava, S. (2007). Sacred groves in India. Aryan Books International.

Martin, G. J. (1995). Ethnobotany: A Methods Manual. Earthscan.

McIntyre, S., & Hobbs, R. J. (1999). A framework for conceptualizing human effects on landscapes and its relevance to management and research models. *Conservation Biology, 13*(6), 1282–1292. https://doi.org/10.1046/j.1523-1739.1999.97509.x

Menon, S., & Bawa, K. S. (1997). Applications of geographic information systems, remote-sensing, and a landscape ecology approach to biodiversity conservation in the Western Ghats. Current Science, 73(2), 134–145.

Misra, R. (1968). Ecological Bulletin No. 5: Ecology Workbook. CSIR, New Delhi.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, *403*(6772), 853-858. https://doi.org/10.1038/35002501

Nathan, R., & Muller-Landau, H. C. (2000). Spatial patterns of seed dispersal, their determinants and consequences for recruitment. *Trends in Ecology & Evolution*, *15*(7), 278–285. https://doi.org/10.1016/S0169-5347(00)01874-7.

Nayar, M. P. (1996). Endemic flora of the Western Ghats. Kerala Forest Research Institute, Kerala.

Ormsby, A. A., & Bhagwat, S. A. (2010). Sacred forests of India: A strong tradition of community-based natural resource management. *Environmental Conservation*, *37*(3), 320–326. https://doi.org/10.1017/S0376892910000561.

Page, N. (2021). A new population record of the critically endangered *Dipterocarpus bourdillonii* Brandis from the Anamalai Tiger Reserve, India. *Journal of Threatened Taxa, 14*(8), 21651-21659.

Praveena, S., & Jose, P. A. (2024). Conservation through restoration: The endangered tree *Atuna travancorica* in the southern Western Ghats, Kerala, India. *Oryx, 58*(4), 419–426. https://doi.org/10.1017/S0030605324000607

Puttaswamy, H. (2010). Distribution and population status of a critically endangered tree species *Dipterocarpus bourdillonii* Brandis in Central Western Ghats. Proceedings of International Forestry and Environment Symposium.

Ramesh, B. R., Swaminath, M. H., Patil, S. V., Dasappa, G., Pandalai, R. C., & Aravajy, S. (2010). Forest tree diversity, composition, and structure across an altitudinal gradient in the central Western Ghats, India. *Journal of the Indian Institute of Science*, *90*(1), 41–52.

Ravindranath, N. H., et al. (2006). Impact of climate change on forests in India. *Current Science, 90*(3), 354–361.

Reddy, C. S., Jha, C. S., & Dadhwal, V. K. (2016). Assessment and Monitoring of Deforestation and Land-Use Changes in Western Ghats of India Using Remote Sensing Data. *Journal of Earth System Science*, *125*(1), 1-12.

Sankaran, K. V., et al. (2001). Invasive Alien Species in Indian Forests: Impact and Control Strategies. Kerala Forest Research Institute.

Shailajakumari, S., Santhosh Kumar, E.S., Sreekala, A.K., Parthipan, B., & Prakashkumar, R. (2020). Rediscovery of *Madhuca diplostemon* (Sapotaceae) – a threatened species of the Western Ghats, India, after a hiatus of 184 years. *Rheedea*, *30*(3), 383-387.

Sharma, J., et al. (2010). Climatic and anthropogenic factors affecting forest biodiversity in India. Biodiversity and Conservation, *19*(3), 641–660.

Sinu, P.A., & Shivanna, K.R. (2016). Factors affecting recruitment of a critically-endangered dipterocarp species, Vateria indica in the Western Ghats, India. Proceedings of the National Academy of Sciences, India Section B: *Biological Sciences*, *86*(4), 865-871.

Sukumar, R., et al. (1995). Climate change and its impact on tropical forest ecosystems. *Current Science, 69*(9), 749–761.

Swarupanandan, K., Indira, E.P., Muralidharan, E.M., Pandalai, R.C., Jose, P.A., & Sanjappa, M. (2013). Species recovery of *Dipterocarpus bourdillonii* and *Humboldtia bourdillonii*, two critically endangered endemic trees of Western Ghats. KFRI Research Report No. 463, Kerala Forest Research Institute, Peechi, Thrissur.

Thomas, C. D., Cameron, A., Green, R. E., Bakkenes, M., Beaumont, L. J., Collingham, Y. C., ... & Williams, S. E. (2004). Extinction risk from climate change. *Nature*, *427*(6970), 145–148. https://doi.org/10.1038/nature02121.

Tilman, D., May, R. M., Lehman, C. L., & Nowak, M. A. (1994). Habitat destruction and the extinction debt. *Nature, 371*(6492), 65–66. https://doi.org/10.1038/371065a0.