

**NICHE SPECIFICITY AND OVERLAP OF THREATENED  
ANGIOSPERMS IN THE WESTERN GHATS AND ITS APPLICABILITY  
IN RED LIST ASSESSMENT, CONSERVATION AND  
ECORESTORATION**

*Thesis submitted to the  
University of Calicut in partial fulfilment of the  
requirements for the award of the degree of*

**DOCTOR OF PHILOSOPHY IN  
BOTANY**

**By**

**DEVIKA M ANILKUMAR**

**Research Guide**

**Dr. AMITHA BACHAN K. H.**



**RESEARCH DEPARTMENT OF BOTANY  
MES ASMABI COLLEGE  
P. VEMBALLUR, THRISSUR, KERALA  
(AFFILIATED TO THE UNIVERSITY OF CALICUT)**

**NOVEMBER 2025**

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## CERTIFICATE

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P. Vemballur

26.11.2025



Principal

Dr. Sanand C Sadananda Kumar  
Principal in charge  
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## DECLARATION

I hereby declare that the work presented in the thesis entitled "NICHE SPECIFICITY AND OVERLAP OF THREATENED ANGIOSPERMS IN THE WESTERN GHATS AND ITS APPLICABILITY IN RED LIST ASSESSMENT, CONSERVATION AND ECORESTORATION" is based on the original work done by me under the guidance of Dr. Amitha Bachan K.H, Assistant Professor and Research Guide, Research Department of Botany, MES Asmabi college, P. Vemballur and it has not been included in any other thesis submitted previously for the award of any degree. The contents of the thesis have undergone a plagiarism check using iThenticate software at C.H.M.K. Library, University of Calicut, and the similarity index was found within the permissible limit. I also declare that the thesis is free from AI generated contents.



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26.11.2025



*Strobilanthes kunthiana*

*Dedicated to*



*My guide and to the wilderness. . .*

*Devika*



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***Devika M Anilkumar***

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## ABSTRACT

Industrialization and accelerated climate change pose severe threats to global biodiversity, demanding highly refined, ecologically precise conservation strategies. This doctoral thesis addresses the critical gap between generalised conservation policies and the micro-scale ecological requirements of threatened endemic flora of the Western Ghats using selected 25 species. These species represent a wide range of Tropical Rainforest types, including low and medium elevation forests, riparian zones, and the Montane Shola-Grassland mosaic. The study's contribution to threat assessment is evidenced by its rigorous application of multiple IUCN criteria, which resulted in 15 published and three in-press Red List entries for the focal species. The primary objective was to define the ecological niche of these species, niche dynamism of the endemic and restricted taxa and functional roles of these species to establish a novel, scientifically grounded framework for ecorestoration planning.

The thesis adopts an integrative, multi-facet approach, combining computational and field-based ecology through Species Distribution Modelling (SDM), integrating both Eltonian and Grinnellian factors to produce highly precise predictions of species' realised and fundamental niche ranges. This was complemented by rigorous field-based phytosociological analysis conducted across 126 standardised plots throughout the Western Ghats. The core methodological advancement was the development of the detailed Niche Profile analysis. This approach empirically quantified the Eltonian niche by measuring Importance Value Index (IVI) across all precise functional height classes, enabling a robust assessment of niche specificity and niche overlap. This assessment, using Schoener's D and Hellinger's I indices, established a strong dual delineation: Grinnellian factors separated the four major vegetation types, a finding corroborated by species dissimilarity indices (90-100% dissimilarity).

The analysis revealed significant fine-scale structural and functional partitioning (beta diversity) and a decisive Niche Dichotomy among the endemic flora. High-elevation species (Montane Shola guild) exhibited consistently high bioclimatic niche overlap (e.g.,  $D \sim 0.72$  between *Strobilanthes kunthiana* and *Elaeocarpus recurvatus*), suggesting they are Niche Conserved Guilds adapted to a broad Grinnellian niche but differ in Eltonian niche, revealed by niche profiling and face high extrinsic, ecosystem-wide risk. Conversely, low-elevation and specialist species (e.g., *Ochna gamblei* in coastal sand)

demonstrated pronounced niche segregation and low overlap ( $D \sim 0.20$  with other low elevation and riparian species), classifying them as Niche Specialists with high intrinsic vulnerability driven by specific edaphic, topographical, and hydrological Eltonian constraints. The data also confirmed the strong functional cohesion of the understorey recruitment pool and the high degree of shared niche space among epiphytes, reinforcing the need for habitat-specific intervention.

The findings of the thesis advocates for a strategic, evidence-based policy shift toward a novel Nature-based Solution (NbS) framework utilising this integrated niche modelling and niche profile methodology for conservation planning and ecorestoration of endemic taxa in the tropical rainforest biome. This standardised functional ecorestoration planning framework, which utilises the Niche Profile metrics and the quantitative overlap indices, provides a robust tool for both refining IUCN threat assessments (particularly for high-risk specialists) and maximising regional Ecosystem-based Adaptation (EbA) outcomes. By operationalizing this niche-specific approach, conservation efforts can maximise regional EbA outcomes, fulfil global Sustainable Development Goals (SDGs), and establish a resilient, scalable management model for threatened tropical rainforest ecosystems.

**Keywords:** Ecological Niche, Nature-based Solutions (NbS), Ecorestoration, Ecosystem-based Adaptation (EbA), Sustainable Development Goals (SDGs), IUCN Red List, Niche Profile, Niche Overlap Indices, Western Ghats

## സംഗ്രഹം

വ്യവസായവൽക്കരണവും ത്വരിതഗതിയിലുള്ള കാലാവസ്ഥാ വ്യതിയാനവും ആഗോള ജൈവവൈവിധ്യത്തിന് ഗുരുതരമായ ഭീഷണി ഉയർത്തുന്ന സാഹചര്യത്തിൽ നൂതനവും പാരിസ്ഥിതികമായി കൃത്യവുമായ ജൈവവൈവിധ്യ സംരക്ഷണ മാർഗ്ഗങ്ങൾ അത്യന്താപേക്ഷിതമാണ്. തിരഞ്ഞെടുത്ത 25 സസ്യ ഇനങ്ങളെ ഉപയോഗിച്ച്, പശ്ചിമഘട്ടത്തിലെ വംശനാശഭീഷണി നേരിടുന്ന സസ്യജാലങ്ങളുടെ സൂക്ഷ്മതല പാരിസ്ഥിതിക ആവശ്യകതകൾക്കും സാമാന്യവൽക്കരിച്ച സംരക്ഷണ നയങ്ങൾക്കും ഇടയിലുള്ള നിർണായക വിടവ് ഈ ഡോക്ടറൽ തീസിസ് അനാവരണം ചെയ്യുന്നു. പശ്ചിമഘട്ടത്തിലെ വിവിധ ഉന്നതിയിലുള്ള മഴക്കാടുകളിലെയും, പുഴയോര വനങ്ങളിലെയും ഉയർന്ന ഉന്നതിയിൽ മാത്രം കാണപ്പെടുന്ന ചോല വനങ്ങൾ പുൽമേടുകൾ എന്നിങ്ങനെ വ്യത്യസ്ത ആവാസവ്യവസ്ഥകളെ ഇവിടെ പതിനിധാനം ചെയ്യുന്നു. ഒന്നിലധികം IUCN മാനദണ്ഡങ്ങൾ കർശനമായി പ്രയോഗിച്ചതിലൂടെ വംശനാശ ഭീഷണി വിലയിരുത്തലിനുള്ള പഠനത്തിന്റെ സംഭാവന ഇതിലൂടെ തെളിയിക്കപ്പെടുന്നു. 15 ഇനങ്ങളുടെ വംശനാശപട്ടിക IUCN ന്റെ ഔദ്യോഗിക റെഡ്‌ലിസ്റ്റിൽ പ്രസിദ്ധീകരിക്കുകയും, 3 എണ്ണം പ്രസിദ്ധീകരണത്തിന്റെ അവസാന ഘട്ടത്തിലെത്തുകയും പ്രസ്തുത പഠനപ്രകാരം സാധ്യമായി. പരിസ്ഥിതി പുനഃസ്ഥാപന ആസൂത്രണത്തിനായി ഒരു നൂതനവും ശാസ്ത്രീയമായി അടിസ്ഥാനപ്പെടുത്തിയതുമായ ചട്ടക്കൂട് സ്ഥാപിക്കുന്നതിന് ഈ സ്പീഷിസുകളുടെ പാരിസ്ഥിതിക സ്ഥാനം, തദ്ദേശീയവും നിയന്ത്രിതവുമായ ടാക്സയുടെ നിഷ് ഡൈനാമിസം, ഈ സ്പീഷിസുകളുടെ പ്രവർത്തനപരമായ പങ്ക് എന്നിവ നിർവ്വചിക്കുക എന്നതായിരുന്നു പ്രാഥമിക ലക്ഷ്യം. സ്പീഷിസ് ഡിസ്ട്രിബ്യൂഷൻ മോഡലിംഗ് (എസ് ഡി എം) വഴി കമ്പ്യൂട്ടേഷണൽ, ഫീൽഡ് അഡിഷ്‌റീത പരിസ്ഥിതിശാസ്ത്രം സംയോജിപ്പിച്ച്, എൽട്ടോണിയൻ, ഗ്രിനെല്ലിയൻ നിഷ് ഘടകങ്ങൾ സംയോജിപ്പിച്ച്, ജീവിവർഗങ്ങളുടെ യാഥാർത്ഥ്യവും അടിസ്ഥാനപരവുമായ ശ്രേണികളുടെ വളരെ കൃത്യമായ പ്രവചനങ്ങൾ സൃഷ്ടിക്കുന്ന ഒരു സംയോജിത, ബഹുമുഖ സമീപനമാണ് ഈ തീസിസ് സ്വീകരിക്കുന്നത്. പശ്ചിമഘട്ടത്തിലുടനീളമുള്ള 126 സ്റ്റാൻഡേർഡ് പ്ലോട്ടുകളിൽ നടത്തിയ കർശനമായ ഫീൽഡ് അഡിഷ്‌റീത ഫൈറ്റോസോഷ്യോളജിക്കൽ വിശകലനം ഇതിന് പൂരകമായി. വിശദമായ നിഷ് പ്രൊഫൈൽ വിശകലനത്തിന്റെ വികസനമായിരുന്നു പ്രധാന രീതിശാസ്ത്രപരമായ പുരോഗതി. എല്ലാ കൃത്യമായ ഫങ്ഷണൽ ഹൈറ്റ് ക്ലാസുകളിലും ഇംപോർട്ടൻസ് വാല്യൂ ഇൻഡക്സ് (IVI) അളന്നുകൊണ്ട് ഈ സമീപനം എൽട്ടോണിയൻ നിഷ് അനുഭവപരമായി കണക്കാക്കി, ഇത് നിഷ് സ്പെസിഫിസിറ്റിയുടെയും നിഷ് ഓവർലാപ്പിന്റെയും ശക്തമായ വിലയിരുത്തൽ സാധ്യമാക്കി. ഷോണറുടെ ഡി, ഹെല്ലിഞ്ചറുടെ ഐ സൂചികകൾ ഉപയോഗിച്ചുള്ള ഈ വിലയിരുത്തൽ ശക്തമായ ഒരു ദ്വിമുഖ നിർവ്വചനം സ്ഥാപിച്ചു: ഗ്രിനെല്ലിയൻ ഘടകങ്ങൾ നാല് പ്രധാന സസ്യ തരങ്ങളെ വേർതിരിക്കുന്നു.

ഇത് സ്പീഷീസ് അസമത്വ സൂചികകളാൽ (90-100% അസമത്വം) സ്ഥിരീകരിക്കുന്നു. വിശകലനം, തദ്ദേശീയ സസ്യജാലങ്ങളിൽ ഗണ്യമായ സൂക്ഷ്മ-സ്കെയിൽ ഘടനാപരവും പ്രവർത്തനപരവുമായ വിഭജനവും (ബീറ്റ വൈവിധ്യം) നിർണായകമായ ഒരു നിഷ് ഡിക്കോട്ടമിയും വെളിപ്പെടുത്തി. ഉയർന്ന ഉന്നതിയിലുള്ള സ്പീഷീസുകൾ (മൊണ്ടെയ്ൻ ഷോല ഗിൽഡ്) സ്ഥിരമായി ഉയർന്ന ജൈവകാലാവസ്ഥാ നിഷ് ഓവർലാപ്പ് (ഉദാ. നീലകുറിഞ്ഞിക്കും നായ്ക്കോട്ടെ മരത്തിനും ഇടയിൽ  $D \sim 0.72$ ) കണ്ടെത്തി, അവ വിശാലമായ ഗ്രിനെല്ലിയൻ നീചുമായി പൊരുത്തപ്പെടുന്ന നിഷ് കൺസർവഡ് ഗിൽഡുകളാണെന്നും എന്നാൽ എൽട്ടോണിയൻ നിചിൽ വ്യത്യാസമുണ്ടെന്നും ഇത് നിഷ് പ്രൊഫൈലിംഗ് വഴി വെളിപ്പെടുത്തുകയും ഉയർന്ന ബാഹ്യ, ആവാസവ്യവസ്ഥാ അപകടസാധ്യത നേരിടുകയും ചെയ്യുന്നുവെന്നും സൂചിപ്പിക്കുന്നു. നേരെമറിച്ച്, താഴ്ന്ന ഉന്നതിയിലുള്ള സ്പെഷ്യലിസ്റ്റ് സ്പീഷീസുകളും (ഉദാ. തീരദേശ മണലിലെ ഒക്ന ഗാംബി) വ്യക്തമായ നിഷ് സെഗ്രിഗേഷനും കുറഞ്ഞ ഓവർലാപ്പും പ്രകടമാക്കി (മറ്റ് താഴ്ന്ന ഉന്നതിയിലുള്ളതും തീരദേശ ജീവിവർഗങ്ങളുമായി  $D \sim 0.20$ ), നിർദ്ദിഷ്ട മണ്ണിന, ഭൗമോപരിതലതര, ജലശാസ്ത്ര എൽട്ടോണിയൻ നിയന്ത്രണങ്ങളാൽ നയിക്കപ്പെടുന്ന ഉയർന്ന ആന്തരിക ദുർബലതയുള്ള നിഷ് സ്പെഷ്യലിസ്റ്റുകളായി അവയെ തരംതിരിക്കുന്നു. അടിത്തട്ടിലെ റിക്രൂട്ട്മെന്റ് പൂളിന്റെ ശക്തമായ പ്രവർത്തനപരമായ ഐക്യവും എപ്പിഫൈറ്റുകൾക്കിടയിൽ ഉയർന്ന തോതിലുള്ള പങ്കിട്ട ഇടവും ഗവേഷണ ഫലം സ്ഥിരീകരിച്ചു, ഇത് ആവാസ വ്യവസ്ഥയ്ക്ക് പ്രത്യേക ഇടപെടലിന്റെ ആവശ്യകതയെ ശക്തിപ്പെടുത്തുന്നു.

ഉഷ്ണമേഖലാ മഴക്കാടുകളിലെ തദ്ദേശീയ സസ്യ ഇനങ്ങളുടെ സംരക്ഷണ ആസൂത്രണത്തിനും പരിസ്ഥിതി പുനഃസ്ഥാപനത്തിനുമായി ഈ സംയോജിത നിഷ് മോഡലിംഗും നിഷ് പ്രൊഫൈൽ രീതിശാസ്ത്രവും ഉപയോഗിച്ച്, നേച്ചർ അഡിഷ്വിത പരിഹാര (എൻബിഎസ്) ചട്ടക്കൂടിലേക്കുള്ള തന്ത്രപരവും തെളിവുകൾ അടിസ്ഥാനമാക്കിയുള്ളതുമായ നയമാറ്റത്തിനായി തീസിസിന്റെ കണ്ടെത്തലുകൾ വാദിക്കുന്നു. നിഷ് പ്രൊഫൈൽ മെട്രിക്സും ക്വാണ്ടിറ്റേറ്റീവ് ഓവർലാപ്പ് സൂചികകളും ഉപയോഗിക്കുന്ന ഈ സ്റ്റാൻഡേർഡൈസ്ഡ് ഫങ്ഷണൽ ഇക്കോറൊസ്റ്ററേഷൻ പ്ലാനിംഗ് ചട്ടക്കൂട്, ഐയുസിഎൻ ഭീഷണി വിലയിരുത്തലുകൾ (പ്രത്യേകിച്ച് ഉയർന്ന അപകടസാധ്യതയുള്ള സ്പെഷ്യലിസ്റ്റ് ഇനങ്ങൾക്ക്) പരിഷ്കരിക്കുന്നതിനും പ്രാദേശിക ഇക്കോസിസ്റ്റം അഡിഷ്വിത അഡാപ്റ്റേഷൻ (ഇബിഎ) ഫലങ്ങൾ പരമാവധിയാക്കുന്നതിനും ശക്തമായ ഒരു ഉപകരണം നൽകുന്നു. ഈ പ്രത്യേക സമീപനം നടപ്പിലാക്കുന്നതിലൂടെ, സംരക്ഷണ ശ്രമങ്ങൾക്ക് പ്രാദേശിക ഇബിഎ ഫലങ്ങൾ പരമാവധിയാക്കാനും ആഗോള സുസ്ഥിര വികസന ലക്ഷ്യങ്ങൾ (എസ്ഡിജികൾ) നിറവേറ്റാനും ഭീഷണി നേരിടുന്ന ഉഷ്ണമേഖലാ മഴക്കാടുകളുടെ ആവാസവ്യവസ്ഥയ്ക്കായി ഒരു പ്രതിരോധശേഷിയുള്ളതും അളക്കാവുന്നതുമായ മാനേജ്മെന്റ് മോഡൽ സ്ഥാപിക്കാനും കഴിയും.

കീവേഡുകൾ: നിഷ്, പ്രകൃതിയെ അടിസ്ഥാനമാക്കിയുള്ള പരിഹാരങ്ങൾ (NbS), പരിസ്ഥിതി പുനഃസ്ഥാപനം, ആവാസ വ്യവസ്ഥയെ അടിസ്ഥാനമാക്കിയുള്ള പൊരുത്തപ്പെടുത്തൽ (EbA), സുസ്ഥിര വികസന ലക്ഷ്യങ്ങൾ (SDGs), IUCN റെഡ് ലിസ്റ്റ്, നിഷ് പ്രൊഫൈൽ, നിഷ് ഓവർലാപ്പ്, പശ്ചിമഘട്ടം.

A stylized illustration featuring a range of teal mountains on the left and a thin black stem with three small, heart-shaped flowers on the right. Below the mountains and the base of the plant are three overlapping circles in brown, orange, and green. A horizontal line spans the width of the illustration and text.

# Chapter 1

General Introduction



# **Chapter 1**

## **General Introduction**

### **1.1. The Background and the Rationale**

Industrialisation and other anthropogenic drivers have accelerated species extinctions, a trend further exacerbated by the recent paradigm of climate change (Ceballos et al., 2015). This has raised serious concerns regarding the conservation of endemic and threatened species in globally significant biodiversity hotspots, such as the Western Ghats (Warrier et al., 2020). Contemporary ecological understanding, when combined with advances in computational science, offers significant opportunities for developing refined conservation strategies for threatened species and their habitats (Kerr et al., 2011). Concerns about species with restricted distributions first gained formal recognition in the Russian Red Data Book (1978). Identifying the ecological niche of a species, its fundamental and realised distribution range and habitat, requires long-term, collaborative fieldwork and in-depth ecological understanding.

Digital bioinformatics platforms have since revolutionised the field by providing global access and enabling the pooling of data within relatively short timeframes. The assessment of threatened species has now evolved into the global IUCN Red List, which currently includes more than 1,72,620 species, of which ~ 48,600 are categorised as threatened (IUCN, 2025). Modern conservation assessments increasingly integrate species distribution data with population metrics, necessitating rigorous taxonomic review and reliable population baselines. Multi-criteria assessments that combine distribution, population, and conservation data have become essential not only for evaluating the current conservation status of species but also for establishing benchmark datasets that allow long-term monitoring of population recovery and habitat resilience.

For India, global assessments of threatened species require further strengthening in this direction. In this doctoral thesis, integrated population data with taxonomic and distributional records into a multi-criteria assessment framework of IUCN aiming at standardised benchmarks to monitor species status and population dynamics over time and forms the preliminary conceptual objective of this doctoral research.

The concept of niche was originated from the thoughts of Grinnell (1917) where the environmental factors was considered as the basic distributional unit of a species. Conceptually, the niche is the physical and functional space occupied by an organism within the ecosystem. The species thrive, compete, segregate and coexist in their niche for their

survival and sometimes construct. Elton (1927) disclosed the complex functionality of a species in their dynamic ecosystem and its occurrence with respect to the environment and species interactions. Hutchinson (1957) emphasised his notion through the fundamental and realised niche. Earlier, the Grinnellian niche conveyed environmental factors especially climatic factors alone (Grinnell, 1917). Later, influence of species interactions for building up the niche of a species defined as the Eltonian niche (Elton, 1927).

Bioclimate, defined by the interplay of temperature, light, and precipitation (Fosberg 1967; Mueller-Dombois & Ellenberg, 1974; Meher-Homji, 2001), provides a framework for vegetation classification. Unregulated species propagation can disrupt habitats and damage ecosystems, a problem exacerbated by widespread monoculture practices. Maxent-based niche modelling offers a simple, effective tool for predicting species distribution, protected areas, and invasion risks (Miller, 2010). While bioclimate envelope models highlight climate impacts (Pearson & Dawson, 2003), they often overlook biotic interactions, evolution, and dispersal. Combining GIS-based environmental layers with niche modelling and profiling addresses these limitations (Rotenberry et al., 2006; Bachan & Devika, 2021) and has been successfully applied to endangered species like *Cryptocarya anamalayana* to guide niche-specific conservation and ecorestoration (Devika & Bachan, 2021; Bachan & Devika, 2022). Standard SDMs use variables like elevation and mean rainfall, which are too coarse to capture the true limitations on endemic species. If the Grinnellian niche alone were the driver, high-overlap species should be ecologically interchangeable and common in suitable areas. The fact that they are not common suggests that an unmodeled for the Eltonian filters at play.

In a hyper-diverse region like the Western Ghats, high endemic plant diversity must be maintained by specialised biotic interactions (e.g., host-epiphyte dependence) or intense resource partitioning. The integrated framework posits that these specialised community structures (Ecological Guilds) are the ultimate mechanism driving species partitioning and allowing high diversity to coexist within broadly similar climatic zones (e.g., the Montane Shola core). Effective species conservation and habitat restoration require a clear understanding of species' niches, including their specificity and spatial or interaction-level overlap, which forms the foundation of this thesis. Niche modelling-based habitat predictions are rare in the context of India and the Western Ghats (Priti et al., 2016; Pramanik et al., 2017; Jalal & Singh, 2017; Malik et al., 2022; Karpakal et al., 2022; Namitha et al., 2022; Bhavya et al., 2025; Maya & Suresh, 2025). We piloted standardised bioclimatic niche prediction protocols for the Western Ghats (Bachan & Devika, 2021), applying them to threatened species

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(Bachan & Devika, 2022) and ecosystems (Bachan et al., 2022). Niche profiling has been used to define Eltonian niches and address limitations of Maxent-based models (Devika & Bachan, 2025). Understanding niche specificity and overlap across species with diverse distribution patterns, habits, and habitats provides insights into resource sharing, as defined by Abrams (1980) and Carothers & Jaksic (1984). Theoretical models (MacArthur, 1971, 1972; Colwell & Futuyma, 1971; Hespeneide, 1973) show that limits of niche overlap depend on environmental variability and competition.

The conceptualization and definition of a species' niche is inherently complex, owing to its multiple factors and dimensions. The concepts of the Grinnellian and Eltonian niches provide a useful framework for distinguishing between environmental determinants and species interaction factors. In the present study, 25 threatened angiosperms of the Western Ghats, representing diverse habits, habitats, and distribution patterns, were selected to examine niche specificity and niche overlap within both the Grinnellian and Eltonian regimes. The study hypothesises that analysing niche overlap and specificity across taxa with contrasting ecological attributes within a common geographical unit can provide insights into the functioning of ecological niches.

Bioclimatic parameters are employed as the primary environmental factors to characterise the Grinnellian niche through niche modelling, while a modified framework incorporates additional environmental variables in a standardised manner. Niche profiling is further extended to capture species interaction factors, thereby elucidating Eltonian niche dimensions. The study also hypothesises that the integration of classified vegetation layers can refine bioclimatic predictions derived from niche modelling, effectively linking Grinnellian and Eltonian perspectives. Furthermore, species occupying similar bioclimatic niches may exhibit unique or inclusive niches defined by species composition within distinct vegetation types.

The selection of 25 species from five well-defined vegetation types of the Western Ghats namely, Montane Grasslands, Montane Shola, Medium-elevation Wet Evergreen Forests, Low-elevation Evergreen Forests, and Low-elevation Riparian Forests—serves as a standardised framework. This framework enables the evaluation of these methodologies within the context of established ecological groupings of the Western Ghats ecosystems, which are represented by endemic indicator plant species.

This doctoral research ultimately seeks to quantify niche overlap across habitats represented by the selected species. In addition, it identifies niche-specific areas for

conservation and ecological restoration at both landscape and ecosystem levels. The resulting niche profiles and community composition datasets are intended to serve as practical guidelines for ecological restoration, supporting the selection of suitable species for potential restoration sites without disrupting existing niche relationships. This integrative framework contributes to Nature-based Solutions (NbS) for conservation and restoration planning in the Western Ghats.

### **Hypothesis (H1)**

The integrated framework combining Grinnellian and Eltonian niche concepts provides a more comprehensive and accurate understanding of species partitioning than either model used in isolation. We hypothesise that while threatened and endemic species may exhibit a high degree of overlap within their Grinnellian (bioclimatic) niches, this apparent overlap is effectively partitioned by distinct Eltonian (species interaction and community composition) niches. Specifically, species with similar bioclimatic envelopes will demonstrate significant compositional dissimilarity when analysed within distinct vegetation types, providing a more precise explanation for their distribution and habitat selection.

## **1.2. Objectives**

1. Taxonomic scrutiny and IUCN status assessment of the selected species
2. Niche modelling for bioclimatic prediction of potential areas and elucidation of the Grinnellian niche
3. Analyse species composition and develop niche profile to elucidate the factors of Eltonian niche
4. Understanding the niche specificity and niche overlap for conservation planning and ecorestoration

## **1.3. Significance of the study**

This research makes a comprehensive and multi-faceted contribution to the conservation of threatened species in the Western Ghats by integrating ecological theory with practical, data-driven applications. It moves beyond traditional correlative models to provide a holistic framework for conservation planning. The study's significance is centred on four key areas.

***Establishing Population Baselines and Taxonomic Clarity:*** The research provides a systematic update on the selected species, creating a crucial benchmark of population data.

This is vital for the long-term monitoring of population dynamics and for conducting rigorous and effective conservation status assessments. The detailed taxonomic scrutiny based on herbarium records contributes to a more accurate understanding of these species.

***Refining Niche Understanding:*** By combining Grinnellian (bioclimatic) niche modelling and terrain suitability analysis with Eltonian (community-based) niche profiling, the study provides a more nuanced understanding of species habitats. This approach moves beyond theoretical predictions by incorporating empirical data on species composition and species-environment relationships gathered from field studies. This integrated framework effectively links where a species could live with the ecological community it actually exists within.

***Guiding Practical Restoration Efforts:*** The research provides tangible guidelines for ecorestoration by quantifying niche specificity and overlap. This is critical for selecting appropriate species for restoration sites without risking negative inter-species interactions, competitive exclusion, or the introduction of invasive elements. The resulting niche profiles and community composition datasets will serve as a practical, evidence-based tool for selecting species and habitats that support long-term population persistence.

***Informing Policy and Conservation Strategy:*** By quantifying niche overlap and identifying niche-specific areas for conservation, the study offers a robust, data-driven foundation for developing Nature-based Solutions (NbS). The integrated framework and its findings are intended to be a practical guide for conservation and restoration planning at both landscape and ecosystem levels in the Western Ghats, directly contributing to the strategic management of this vital biodiversity hotspot.

#### **1.4. Study area: The Western Ghats**

The geographical area selected for the study is the Western Ghats (Fig. 1.1). The study focusses on selected 25 threatened angiosperms of the Western Ghats region (Table 1.1). The Western Ghats, also known as the Sahyadri Hills, form a 1,600 km long mountain chain that runs parallel to the western coast of India, spanning six states: Gujarat, Maharashtra, Goa, Karnataka, Kerala, and Tamil Nadu (Pascal, 1988; Gunawardene et al., 2007). Geographically, the Ghats extend from the Tapti River in the north to the southern tip of the Indian peninsula, with an altitudinal gradient ranging from sea level to over 2,695 m at Anamudi, the highest peak in peninsular India. Recognised as one of the world's eight "hottest hotspots" of biodiversity (Myers et al., 2000), the Western Ghats are a globally significant conservation priority due to their high levels of endemism, species richness, and habitat heterogeneity. In 2012, UNESCO

designated 39 serial sites within the Western Ghats as World Heritage Sites in recognition of their exceptional ecological and evolutionary significance (UNESCO, 2012).

#### **1.4.a. Biogeography and Climate**

The region represents a unique biogeographic zone (Rodgers & Panwar, 1988), straddling tropical and subtropical latitudes and hosting a diversity of ecosystems including evergreen, semi-evergreen, moist deciduous, montane shola, grasslands, and lateritic scrublands (Pascal, 1982; Ramesh & Gurukkal, 2007). Rainfall patterns are heavily influenced by the southwest monsoon, with annual precipitation exceeding 6,000 mm in some areas, especially in the windward zones of the southern Western Ghats (Joseph et al., 2012). The steep climatic and elevational gradients result in sharp ecological zonation and niche specialization.

#### **1.4.b. Floral Diversity and Endemism**

The Western Ghats harbor approximately 7,402 species of flowering plants, of which nearly 2,600 species are endemic to the region (Nayar et al., 2014; Page & Shanker, 2020). This floristic richness includes numerous narrow-range and critically endangered taxa, many of which are restricted to specific microhabitats or elevation zones (Ramesh & Pascal, 1991; Gadgil et al., 2011). The family-level diversity is also striking, with major representation from Rubiaceae, Lauraceae, Euphorbiaceae, and Myrtaceae in the wetter zones, and Fabaceae, Malvaceae, and Poaceae in the drier eastern slopes.

#### **1.4.c. Conservation Challenges**

Despite its significant biological value, the Western Ghats face severe conservation threats from land-use change, forest fragmentation, hydroelectric initiatives, mining activities, monoculture plantations, and climate change (Jha et al., 2000; Reddy, 2016). Habitat degradation has led to population declines and range contractions in numerous endemic and threatened angiosperms (Sasidharan & Sujanalpal, 2005; Bawa et al., 2007). The recent global attention for prioritization of different regions of the Western Ghats primarily based on its biodiversity significance, species endemism and habitat fragility (Gadgil, 2011). Many species are poorly represented in protected areas and lack targeted management strategies due to data deficiency. Furthermore, restoration efforts in degraded zones are often hampered by a lack of ecological understanding of the niche requirements of target species. This emphasises the necessity for research initiatives that amalgamate species distribution modelling, field-based habitat profiling, and niche theory into conservation and restoration planning.

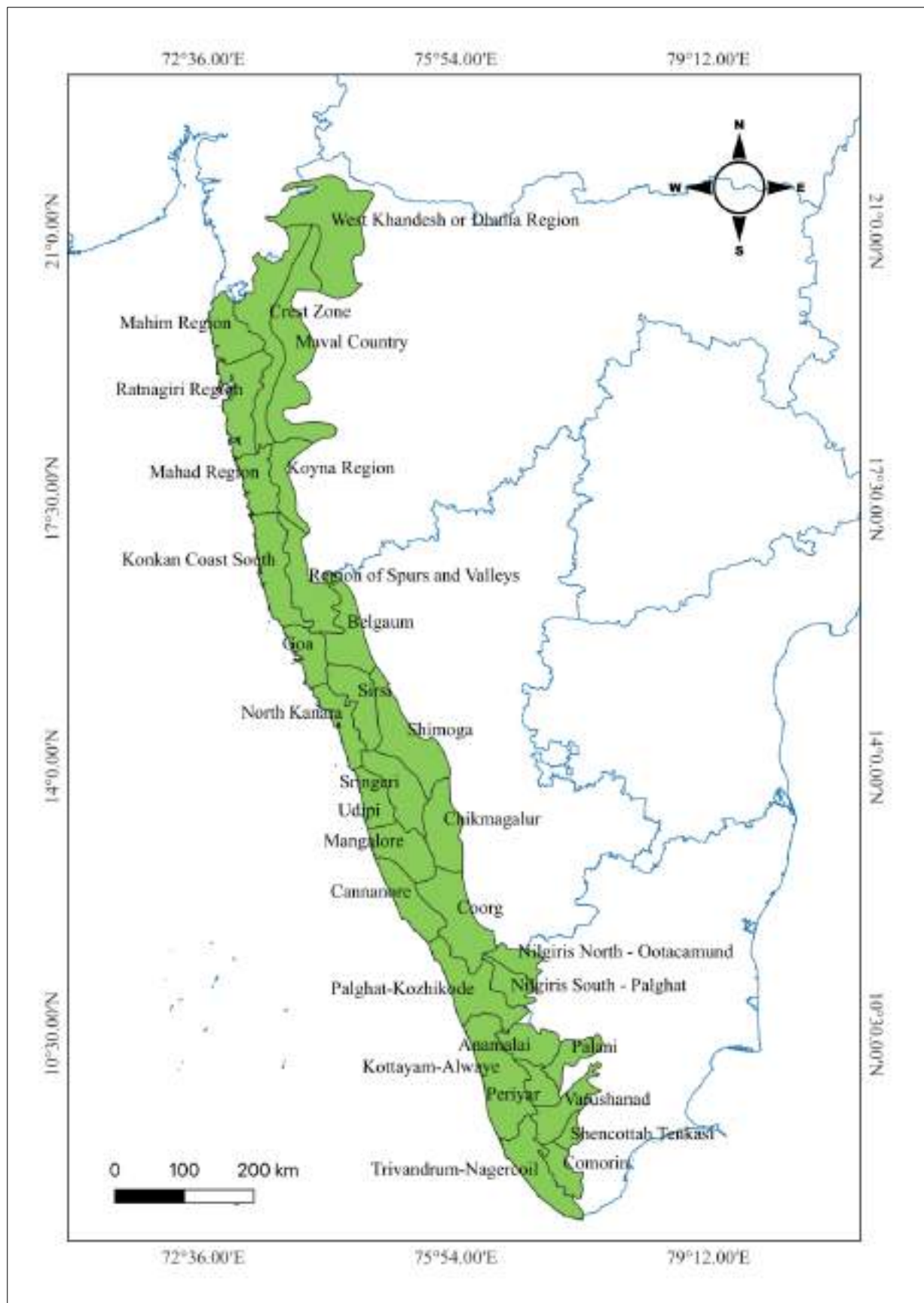


Fig. 1.1. Ecoregions of the Western Ghats

### 1.5. Methodology

A combined methodology of Niche modelling standardised for the Western Ghats region has been used here (Bachan & Devika, 2021; Devika & Bachan, 2023, 2025; Bachan & Devika, 2025). This includes a critical review of the taxonomic records, assessment of threatened status of the species using various IUCN criteria, Maxent based Niche modelling, incorporation of terrain, edaphic and topographic features, phytosociological sampling and Niche profiling (Bachan & Devika, 2021). This will be analysed using various statistical tools using R package and QGIS spatial platform to understand niche specificity, overlap (Schoener's D and Hellinger's I) and the factors of the Grinnellian and Eltonian niche. Threatened angiosperm species covering different habit, habitat and differential distribution patterns of the Western Ghats were selected for the study. The following are the selected 25 threatened plant species.

Table 1.1. List of selected 25 threatened angiosperms in the Western Ghats

| SL. No. | Species                                         | Family           |
|---------|-------------------------------------------------|------------------|
| 1       | <i>Aglaia malabarica</i> Sasidh.                | Meliaceae        |
| 2       | <i>Aporosa bourdillonii</i> Stapf               | Phyllanthaceae   |
| 3       | <i>Cryptocarya anamalayana</i> Gamble           | Lauraceae        |
| 4       | <i>Cryptocarya lawsonii</i> Gamble              | Lauraceae        |
| 5       | <i>Diospyros crumenata</i> Thwaites             | Ebenaceae        |
| 6       | <i>Dipterocarpus indicus</i> Bedd.              | Dipterocarpaceae |
| 7       | <i>Elaeocarpus munroi</i> (Wight) Mast.         | Elaeocarpaceae   |
| 8       | <i>Elaeocarpus recurvatus</i> Corner            | Elaeocarpaceae   |
| 9       | <i>Ficus beddomei</i> King                      | Moraceae         |
| 10      | <i>Garcinia wightii</i> T.Anderson              | Clusiaceae       |
| 11      | <i>Goniothalamus wightii</i> Hook.f. & Thomson  | Annonaceae       |
| 12      | <i>Humboldtia vahliana</i> Wight                | Fabaceae         |
| 13      | <i>Hydnocarpus pentandrus</i> (Buch.-Ham.) Oken | Achariaceae      |
| 14      | <i>Impatiens parasitica</i> Bedd.               | Balsaminaceae    |
| 15      | <i>Litsea oleoides</i> (Meisn.) Hook.f.         | Lauraceae        |



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|    |                                                            |                 |
|----|------------------------------------------------------------|-----------------|
| 16 | <i>Medinilla anamalaiana</i> Sasidh. & Sujanapal           | Melastomataceae |
| 17 | <i>Meiogyne pannosa</i> (Dalzell) J.Sinclair               | Annonaceae      |
| 18 | <i>Ochna gamblei</i> King ex Brandis                       | Ochnaceae       |
| 19 | <i>Prioria pinnata</i> (Roxb. ex DC.) Breteler             | Fabaceae        |
| 20 | <i>Strobilanthes kunthiana</i> (Nees) T.Anderson ex Benth. | Acanthaceae     |
| 21 | <i>Syzygium densiflorum</i> Wall. ex Wight & Arn.          | Myrtaceae       |
| 22 | <i>Syzygium occidentale</i> (Bourd.) Gandhi                | Myrtaceae       |
| 23 | <i>Syzygium palghatense</i> Gamble                         | Myrtaceae       |
| 24 | <i>Syzygium parameswaranii</i> M.Mohanan & A.N.Henry       | Myrtaceae       |
| 25 | <i>Syzygium sahyadricum</i> Sujanapal, Robi & Sasidh.      | Myrtaceae       |

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### 1.5.1. Taxonomic scrutiny and IUCN status assessment of the selected species

The taxonomic scrutiny and conservation assessment of 25 selected threatened species, employed a multi-pronged approach combining extensive literature review, herbarium scrutiny, systematic fieldwork, and application of IUCN Red List standards. The initial phase involved taxonomic scrutiny and literature survey. This entailed meticulous examination of floristic literature, validating accepted nomenclature and synonyms against resources like the Kew Virtual Herbarium, International Plant Name Index (IPNI), (India Biodiversity Portal (IBP). Protologues were examined, and original publications were retrieved from sources like Biodiversity Heritage Library (BHL). Critical analysis of specimens in herbaria (CALI, KFRI, TBGT, MH, BSI, and several international virtual herbaria) was conducted to confirm taxonomic identity, distribution, and phenology. Nomenclatural conventions adhered to the Shenzhen Code, referencing databases like Plants of the World Online (POWO) and World Flora Online (WFO). The field research involved relocating the species and specimen collection. Systematic field surveys were conducted in the Western Ghats, targeting previously documented localities traced through literature and herbarium records. GPS coordinates were recorded, and multiple accessions were collected, primarily during fruiting seasons, to gather detailed population and phenological data. Collected materials were processed into herbarium specimens following standard methodologies (Bridson & Forman, 1992) and deposited at

MESAH and CALI. Finally, the IUCN Red List Status Assessment was performed. The threat level for each species was evaluated against the IUCN guidelines version 16 and the five quantitative criteria (A–E) of version 3.1 second edition (IUCN, 2012). This assessment used the compiled field data, distribution records, including Global Biodiversity Information Facility (GBIF), and population estimations to determine if the species qualify for a threatened category (CR, EN, VU).

### **1.5.2. Niche modelling for bioclimatic prediction of potential areas and elucidation of the Grinnellian niche**

The process began with species occurrence data collection, compiling precise Global Positioning System (GPS) geocoordinates from primary field surveys and secondary sources (herbarium records, research articles, digital databases like IBP, E-flora Kerala). Data was transformed into decimal degrees and filtered for quality.

#### **(A) Modelling Setup and Analysis**

**Environmental Variables:** The model utilised 19 bioclimatic variables for the current climate scenario (1970–2000) sourced from WorldClim 2.1 (2.5m resolution) (Soberón & Peterson, 2005; Guisan et al., 2007; Peterson et al., 2011), along with non-bioclimatic variables like elevation, slope, and aspect.

**Addressing Multicollinearity:** The bioclimatic variables were filtered using Pearson's correlation coefficient ( $r^2 > 0.75$ ) (Dormann et al., 2013; R Core Team, 2024; ) in R to eliminate highly correlated layers, enhancing model stability and interpretability.

**Ecological Niche Modelling (ENM):** The Maximum Entropy (MaxEnt) model (Version 3.4.4) (Phillips et al., 2006) was employed, a presence-only algorithm chosen for its robust performance, particularly with limited occurrence data. MaxEnt was used to estimate the probability of species presence based on environmental constraints.

**Model Calibration and Evaluation:** Models were calibrated using cross-validation or bootstrap replication based on sample size. Area Under the Curve (AUC) was the primary metric for model evaluation (Phillips et al., 2006), with all species models achieving an AUC between "Very Good" (0.8–0.9) and "Excellent" (0.9–1.0) (Swets, 1988). The Jackknife test was used to determine variable importance.

#### **(B) Niche Refinement and Statistical Analysis**

**Overlaying with Classified Vegetation Layer:** MaxEnt's 'fundamental niche' output was refined into a more accurate 'realised niche' by superimposing it onto a classified vegetation

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layer (Bachan & Devika, 2025; Devika & Bachan, 2025) in QGIS. This process integrated Eltonian niche factors (species interactions/land use) to delineate areas for conservation, restoration, and irreversible habitat loss.

**Statistical Analysis:** Principal Component Analysis (PCA) was used to identify key bioclimatic variables influencing species distribution and to evaluate the conservation importance of different ecoregions (Breiman et al., 1984; Das, 2015). Multivariate Analysis of Variance (MANOVA) and subsequent univariate ANOVAs were performed to test for differences in bioclimatic parameters among species subgroups (Vernes et al., 2016; Abapihi et al., 2021).

### **1.5.3. Species composition and Niche profile to elucidate the Eltonian niche factors**

The methodology overview for elucidating the Eltonian Niche factors influencing the distribution of the 25 target species is through phytosociological sampling and community analysis.

#### **(A) Sampling and Data Collection**

Sampling sites were identified based on herbarium records, field reconnaissance, and the habitat suitability maps generated in Chapter 4. A species-focused systematic sampling design was adopted, laying a minimum of three 0.1 hectare (31.62 x 31.62 m) square plots (MoEFCC, 2014) for each species within suitable evergreen forest habitats (with minor size adjustments for specific growth forms like shrubs or epiphytes). Within each of the 126 sampled plots, data collected includes total individual species count, Girth at Breast Height (GBH) and height class for all mature trees (>30 cm GBH), GPS coordinates and altitude for mapping.

#### **(B) Community Structure Analysis and Niche Profiling**

**Bray-Curtis Dissimilarity Analysis:** Phytosociological data were analysed using the Bray-Curtis dissimilarity index (Bray & Curtis, 1957; Legendre & Legendre, 2012) and hierarchical clustering to objectively classify the 126 plots into distinct, floristically homogenous community types.

**Phytosociological Metrics:** Plot-level data for each cluster were used to calculate standard community metrics, including tree density, frequency, basal area, and the Importance Value Index (IVI) (Misra, 1968; Weaver & Clements, 1983; Romesburg, 1984; Jongman et al., 1995; Bachan, 2010), which indicates the dominance of species within the community.

**Eltonian Niche Profiling:** This core analysis involved segregating species data into five tree height layers: Emergent Tree (ET), Large Tree (LT), Medium Tree (MT), Small Tree (ST), and Very Small Tree (VST), to capture physical and vertical distribution (Whitmore, 1975; Devika

& Bachan, 2021). The spatial distribution of the focal species, along with their associated metrics (density, basal area, IVI), was modeled in a two-dimensional spatial plan using R software (RStudio Version 2024.04.2+764). This approach detailed habitat associations and inter-species interactions, which were interpreted as the key parameters defining the realised or Eltonian Niche.

#### **1.5.4. Niche Specificity and Niche Overlap of Selected Threatened Angiosperms**

*Indices and Software:* Pairwise niche overlap analyses were executed for all 300 unique species combinations (n=25) using the R programming environment (specifically the ENMTools and ecospat packages).

*Overlap Quantification:* Two complementary indices were calculated:

**Schoener's D:** Highly sensitive to the spatial overlap of high-suitability areas.

**Hellinger's I:** Measures proportional similarity across the entire suitability distribution.

Both indices range from 0 (no overlap) to 1 (complete overlap).

The resulting overlap matrices were visualised using heatmaps and clustered dendrograms to easily identify patterns of high niche similarity ( $D > 0.6$  or  $I > 0.7$ ) or segregation (Hellinger, 1909; Schoener, 1968; Warren et al., 2008).

#### **Statistical Rigor**

*Hypothesis Testing:* To test the ecological significance of the observed overlap values, a statistical significance test (Null Model) was performed.

#### **Null Hypothesis (H0)**

Threatened and endemic species that exhibit a high degree of overlap within their Grinnellian (bioclimatic) niches will not demonstrate significant compositional dissimilarity across distinct vegetation types. Consequently, the apparent overlap in abiotic niches is not effectively partitioned by distinct Eltonian (biotic) niches, and community composition is primarily dictated by broad environmental suitability.

#### **1.6. Plan of the Thesis**

The thesis is organised into eight chapters, including an introduction, literature review, study results and discussion, a concise summary and recommendations. This addresses the specific aspects of the ecological and conservation biology of threatened angiosperms in the Western Ghats, with a focus on niche specificity, overlap, and restoration relevance. The research

progresses from foundational context-setting and taxonomic validation to advanced ecological modelling and synthesis, offering a comprehensive framework for conservation planning.

The chapter 1 provides the overall background and significance of the study, emphasizing the ecological uniqueness and conservation importance of the Western Ghats. The objectives, research questions, and methodological overview are also presented here. The chapter 2 offers a critical review of existing literature relevant to the study.

Chapter 3 presents a detailed taxonomic analysis of the 25 selected threatened tree species, based on herbarium records and field surveys as per the first objective. This chapter also reassesses the conservation status of each species following the IUCN Red List criteria, incorporating updated field observations, distribution data, and population assessments. In chapter 4, species distribution models are developed using presence-only occurrence data and bioclimatic variables to predict suitable habitats and define the Grinnellian niche and integration of Eltonian factors using classified vegetation layers. Modelling outputs highlight both current and potential habitats and an ecoregion level conservation, ecorestoration areas for each species, thereby aiding in the identification of conservation gaps and restoration sites.

The chapter 5 explores the Eltonian niche of selected species by integrating field-based ecological data on community composition and habitat characteristics. It also reflects the niche profiles to understand how each species functions within its ecological community. The 6<sup>th</sup> chapter synthesises the findings and analyses to evaluate the niche specificity and overlap among the selected threatened species.

Each chapter opens with an introduction, followed by a detailed account of the methods used, presentation of results, interpretation through discussion, and concludes with a concise summary. The chapter 7 summarises the key findings of the study and their implications for Red List assessments, conservation prioritization, and ecoregion level ecological restoration area. This is followed by recommendations derived from the study. The thesis concludes with a comprehensive list of references and supporting appendices. Appendix I contains the distribution data of selected species which is used for the analysis of Chapter 3 and Chapter 4. Appendix II contains the percentage contribution of each bioclimatic variables. Appendix III present the data related to phytosociological sampling and analysis corresponding to Chapter 5. Appendix IV contains the data used for the analysis of niche specificity and overlap of selected species.



# Chapter 2

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Review of Literature

## Chapter 2

### Review of Literature

#### 2.1. IUCN Red List Assessment

##### 2.1.1. Historical Context: Foundations of Floristics and the Emergence of Conservation Tools

The Indian subcontinent, especially the highly rainfed Western Ghats mountains, has been a major focus of botanical explorations, particularly the scientific documentation originating from the colonial era. The first such documentation dates back to the pre-Linnaean period, culminating in the publication of the monumental work, *Hortus Malabaricus*, by Hendrik van Rheede (1678–1693), which transcribed the traditional Ayurvedic knowledge of the plants of the Malabar Coast. Due to their highly endemic nature and restriction to the forest landscape, none of the 25 species selected in this study are among the 742 species documented in *Hortus Malabaricus*. Only a few common species belonging to the genera *Ficus*, *Garcinia*, and *Syzygium* are mentioned in that work. Post-Linnaean works, beginning as early as Burman (1768), were followed by the significant publications of the 19th century, which included the *Prodromus Florae Peninsulae Indiae* by Wight and Walker-Arnott (1834), *Flora Indica* by Hooker & Thompson (1855), extensive regional delineations and illustrations presented by Beddome (1868–1874, 1869–1874), the *Forest Flora of North-West and Central India* by Brandis (1874), Volume 2 of *The Flora of British India* by Hooker (1882), and the enumeration of forest trees in Mysore and Coorg by Cameron (1894). The systematic floristic explorations continued into the 20th century with Bourdillon's (1908) research on Travancore forest trees, Brandis's (1921) revision of Indian trees, and Fischer's (1921) exploration of the Anamalai hills. Fischer (1928), augmenting Gamble's *Flora of the Presidency of Madras*, further solidified the foundational knowledge on the flora of the Western Ghats. Aiyar's (1932) ecological and silvicultural investigation of the sholas in Palghat could be one of the earliest synthesis of ecological principles along with floristic studies.

The global conservation assessment began with the IUCN Red Data Book (1964), followed by the seminal USSR Red Data Book (1978), which influenced national red-listing frameworks globally. This was followed by detailed regional floristic documentation across the globe, here it marked with pivotal works such as the revised *Flora of Ceylon* by

Dassanayake and Fosberg (1980) and the Synoptic Flora of Mysore by Rao and Razi (1981). Other systematic regional documentations comprised Ansari's (1985) flora of Kasaragod, revision of the genus *Humboldtia* by Sanjappa (1986), and the publication of a novel *Syzygium* species by Mohanan and Henry (1987). The Red Data Book of Indian Plants (Nayar & Sastry, 1987–1990) was the first to establish framework for assessing India's threatened flora. In conjunction with species-level evaluations, Rodgers and Panwar (1988) introduced a biogeographical classification that triggered conservation planning throughout India along with Regional investigations in Kerala by Antony (1989) and Balasubramanyan et al. (1989). The onset of the 1990s marked the more focus towards endemic and threatened species of the Western Ghats. Ramesh and Pascal (1991) documented the distribution patterns of endemic evergreen species, elucidating the spatial heterogeneity of biodiversity and emphasising conservation needs within the southern Western Ghats landscapes. The emphasis on conservation intensified throughout the 20<sup>th</sup> Century, with Ashton (1990) supplying annotations pertinent to the conservation of Dipterocarpaceae, Babu (1990) flora of the Malappuram district, and Sanjappa (1991) endemic legumes. The increased botanical enumerations worldwide requisite standardised systematic treatments, which was supported by Bridson & Forman (1992) and Brummitt & Powell (1992) manuals for herbarium methodologies and nomenclature. Chakrabarty and Gangopadhyay (1993) did the revision of the genus *Aporosa*, Euphorbiaceae, conservation revision by Balakrishna (1993) and review of the biodiversity hotspot encompassing the Western Ghats–Sri Lanka region (Gunawardene et al. 2007) comprehended endemism and threats arising from habitat conversion. The Critical Ecosystem Partnership Fund (CEPF 2007; Bawa et al., 2007) generated ecosystem profiles that identified conservation priorities and proffered strategic interventions across this global biodiversity hotspot. This was supported again by the southern Western Ghats' forest landscapes by Ramesh & Gurukkal (2007), highlighting the complex relationships between biodiversity, human ecology, and management issues.

### **2.1.2. Adoption of IUCN Criteria, Geospatial Tools, and Red List Index**

The comprehensive framework for species assessment and evaluation was established with the publication of the IUCN Red List Categories (IUCN, 1994). This was followed by Collar (1996) who scrutinised the rationale behind Red Data Books, Elouard et al. (1997) and Ramesh et al. (1997), initiated the monitoring of the structural characteristics and dynamics of evergreen forests, Atlas of endemics of the Western Ghats by Ramesh and

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Pascal (1997, coinciding with the release of the and also the Flora of Madhya Pradesh by Mudgal et al. (1997). The first Conservation Assessment and Management Plan (CAMP) workshop for South Indian medicinal plants was held by Molur and Walker (1997), The new IUCN criteria were immediately applied to species like *Dipterocarpus indicus* (Ashton, 1998) and *Aporosa bourdillonii* (WCMC, 1998), *Elaeocarpus munroi* (WCMC, 1998). Keith (1998) evaluated and modified the criteria for vascular plants. Other important studies include, population and diversity studies of Varagalaia (Ayyappan & Parthasarathy, 1999), the Agasthyamalai Region (Varghese & Balasubramanyan, 1999), Varghese and Menon (1999) niches of rare trees in Peppara, and Dipterocarp composition Ayyappan and Parthasarathy (2001).

The early 2000s saw a strong emphasis on methodological refinement. Clark and May (2002) discussed taxonomic bias in conservation research, while Mohanan & Sivadasan (2002) released the Flora of Agasthyamala. The incorporation of geospatial methodologies commenced, as exemplified by Amarnath et al. (2003) in their analysis of conservation zones. Willis et al. (2003) elucidated the significance of herbarium data, an essential taxonomic asset, in the context of Red List evaluations, a critical endeavour in light of the implications of land utilization (Daniels, 2003). The floristic work by Biju (2004) on Eravikulam National Park and the revision of the genus *Strobilanthes* by Carine et al. (2004) are important ones in the context of the study. The floristic enumeration of Pathanamthitta district were conducted by Anilkumar et al. (2005).

During this epoch, the development of tools for monitoring global biodiversity was realised (Rodrigues et al., 2006; Baillie et al., 2008), which included enhancements to the Red List Index (Butchart et al., 2007). Regionally, Vasudeva Rao (2007) provided critical notes on *Diospyros*, while Rodriguez (2008) highlighted the importance of national Red Lists. The application of the Red List as a global barometer for plant diversity was assessed by Brummitt et al. (2008), and regional floras continued to be documented (Chetty et al., 2008; Ratheesh, 2009). The importance of herbaria as a frontier for species discovery was emphasised by Bebbier et al. (2010), while Aravind et al. (2010) analysed patterns of endemism in the Western Ghats. Other focused studies included riparian flora (Bachan, 2010) where the first time comprehensive enumeration of the flora, vegetation ecology and classification of the riparian forests from the Western Ghats addressed. This was followed by revision of the genus *Litsea* (Bhuinya et al., 2010), and variations in tree growth (Deviprasad & Al-Sagheer, 2010), alongside nomenclature standardization (Brummitt,

2010). The Geospatial Conservation Assessment Tool (GeoCAT) an important mapping tool for the IUCN assessments was introduced by Bachman et al. (2011), a major step in practical assessment, concurrent with the use of IUCN criteria for fungal species (Dahlberg & Mueller, 2011) and the global Index Herbariorum (Thiers, 2011). Taxonomic monographs for endemic genera like *Impatiens* (Bhaskar, 2012) and synopses of widespread genera like *Ficus* (Chaudhary et al., 2012) were published. Preliminary floristic studies (Jomy, 2012), threat status reports (Rasingam, 2012), and ecological reviews (Robin & Nandini, 2012) further contextualised the threat. The application of species distribution models (Syfert et al., 2014), the regional research on medicinal plants (Joshi & Harijan, 2014; Kottaimuthu et al., 2014), the introduction of new floras (Nayar et al., 2014), and the publication of new species, which is used in this study, *Syzygium sahyadricum* (Sujanapal et al., 2014), the evaluation of endangered tree species Warriar et al. (2020), enumeration of threatened coastal species (Bachan & Nair, 2020) and multicriteria based IUCN assessments and niche modelling of four species (Devika & Bachan, 2021, 2022) has been significant.

### **2.1.3. Advancements in Fine-Scale IUCN Assessment using an integrated approach**

The initial decades of the 21<sup>st</sup> century was characterised by an emphasis on the enhancement and expansion of the application of IUCN evaluative instruments. The comprehensive assessment of green plants was disseminated (Brummitt et al., 2015), in conjunction with deliberations on temporal associations in population dynamics (Keith et al., 2015) and a comprehensive manual for the implementation of the IUCN Red List of Ecosystems criteria (Rodríguez et al., 2015). The conservation evaluations of the Western Ghats Region-specific concentrated more on decapod crustaceans (Raghavan et al., 2015), particular medicinal flora (Tali et al., 2015), red list assessments of *Humboldtia vahliana* (Ved et al., 2015) and *Hydnocarpus pentandrus* (Ved et al., 2015) were important during the period. Joppa et al. (2016) provided alternative metrics on estimates of extent of occurrence and canopy gaps and, species dynamics was investigated by Devagiri et al. (2016), conservation status assessment of the endemic tree species (Murugan & Sivakumar, 2016; Ramasubbu et al., 2016) and protected areas (Raghavan et al., 2016; Tamil Selvan et al., 2016).

This signified with the publication of revised Red List guidelines (IUCN Standards and Petitions Committee, 2017) reflected in regional surveillance (Athira et al., 2017; Dantas

& Sasidharan, 2017). Works of Jose et al. (2017) on restoration, floral biology of endemic species *Humboldtia vahliana* (Kumary et al., 2017) and *Syzygium occidentale* (Varghese & Sreekala, 2017) were also important.

Research works gradually concentrated towards species-specific threat prioritisation, as illustrated in works of Aravind and Krishnaswamy (2018), threat status evaluations for the Kerala region (Nayar & Sasidharan, 2018), lectotypification of *Cryptocarya anamalayana* (Bachan et al., 2018), status reports for other important genera such as *Strobilanthes* (Augustine, 2018) and distribution records by Veach and Hegde (2018). The accuracy of assessments supported by systematic reviews of the Ebenaceae (Samuel et al., 2019) and regional floristic surveys (Board, 2019; Britto, 2019). The new decade was commenced with ecological and geospatial integration, studies on the ecology and molecular characterisation of *Cryptocarya anamalayana* (Bachan & Abidha, 2019), comprehensive ecological monitoring in Vazhachal (Bachan et al., 2019), impact of climate change induced flooding (Bachan et al., 2019), the transition to the Area of Habitat metric (Brooks et al., 2019) and were supported with worldwide resources like PlantSearch (BGCI, 2019).

The next decade (2020s), research concentrated more on anthropogenic influences and predictive modelling. The impact of dams on riparian vegetation by Bachan and Devika (2020), documentation of the endemic floristic wealth within coastal ecosystems (Bachan & Nair, 2020), multi-criteria based conservation prioritisation analysis (Das et al., 2020), role of the Red List in facilitating conservation initiatives (Betts et al., 2020), conservation assessments *Garcinia wightii* (Deepu & Geethakumary, 2020) and publication of pharmacology and conservation of *Strobilanthes kunthiana* (Bera et al., 2020) were important.

The Broader ecological discourses pertaining to the Western Ghats (D'Souza, 2020) and the international databases such as IPNI (2021) and IBP (2021) were important in providing occurrence records. Novel species have been elucidated (Arya et al., 2021), and incorporation of ecological niche profile for conservation prioritisation has been undertaken (Devika & Bachan, 2021).

The significance of comprehensive data has culminated in new IUCN assessments for taxa such as *Cryptocarya anamalayana* (de Kok & Bachan, 2021) and *Dipterocarpus indicus* (Deepu et al., 2021), as well as *Meiogyne pannosa* (Vespagan et al., 2022). The prevailing literature prominently features Niche profiling and Niche modelling as instrumental

frameworks for restoration guidance (Bachan & Devika, 2022; Devika & Bachan, 2023), evolved from the inputs of this study, in conjunction with evaluations of endangered ecosystems such as Riparian Forests (Bachan et al., 2022). Global initiatives such as the Kunming-Montreal Global Biodiversity Framework (CBD, 2022) and the revised IUCN Guidelines (IUCN Standards and Petitions Committee, 2022) has furnished the policy framework for the present study and equal initiatives.

The recent global IUCN Red list assessments from this region, Chifley form inputs form this study reflected red list assessments of different species including *Goniothalamus wightii* (Vespagan et al., 2022), multiple *Syzygium* species, *S. occidentale*, (Bachan & Devika, 2023), *S. palghatense*, (Bachan & Devika, 2023), *S. parameswaranii*, (Bachan & Devika, 2023), *Diospyros crumenata* (Bachan & Devika, 2023), *Cryptocarya lawsonii* (Bachan & Devika, 2023), *Aporosa bourdillonii* (Deepu et al., 2023), *Aglaia malabarica* (Deepu et al., 2023), *Litsea oleoides* (de Kok, 2023), *Ficus beddomei* (Bachan & Devika, 2023), *Medinilla anamalaiana* (Devika & Bachan, 2023), *Ochna gamblei* (Bachan & Devika, 2023), *Prioria pinnata* (Devika & Bachan, 2023) *Syzygium occidentale* (Bachan & Devika, 2023), *Syzygium parameswaranii* (Bachan & Devika, 2023) and *Syzygium palghatense* (Devika & Bachan, 2023). The suitable habitat prediction for *Impatiens parasitica* were done (Ashok et al., 2023) and also an endangered orchid (Decruse, 2023). Other works covered ecosystem valuation (Balasubramanian & Sangha, 2023), an overview of Western Ghats conservation (Deepu et al., 2023), and the need for rigorous prioritization (Trivedi & Bharucha, 2023).

Some of the most recent work includes 2024 IUCN updates for *Elaeocarpus recurvatus* and *Strobilanthes kunthiana* (Bachan & Devika, 2024), and *Impatiens parasitica* (Devika & Bachan, 2024). Studies on quantifying extinction risk (Bates et al., 2024), species ecology (Thomas & Jameson, 2024), and cultural practices in conservation (Rathoure, 2024) continue, with new research on *Diospyros crumenata* edibility (Jose et al., 2024), and broader conservation needs (Durmaz et al., 2024). These efforts are governed by the newest IUCN guidelines (IUCN Standards and Petitions Committee, 2024) and the overall IUCN Red List (IUCN, 2024). Some of the latest IUCN assessments published with outputs from the present study *Syzygium densiflorum* (Devika & Bachan, 2025) The expected future research includes advanced niche modelling for ecorestoration (Bachan & Devika, 2025) and integrating policy and science for conservation (Acharya et al., 2025), highlighting the trajectory of this field towards predictive, fine-scale conservation action.

## 2.2. Ecological Niche Modelling

The earliest theoretical contribution established the ecological niche concept, initially defined by Grinnell (1917) in terms of the habitat requirements that restrict a species' geographic distribution. This concept was soon complemented by Elton (1927), who focused on the functional role of a species within its biotic community. The two perspectives were famously synthesised by Hutchinson (1957) into the quantitative notion of the n-dimensional hypervolume, defining the fundamental niche. In parallel, regional biogeographic studies began to provide essential spatial context. Singh (1977) published a comprehensive regional geography of India, laying the groundwork for spatial ecology in the region. The works of Meher-Homji (1982) established a basic classification of India's phytogeographic zones. The introduction of Classification and Regression Trees by Breiman et al. (1984) formed the basis for many machine learning techniques used in Species Distribution Modelling (SDM). The tools for measuring accuracy of SDMs using strong performance metric developed by Swets (1988) and initial phase ended with Gallopín (1989) pursuing a unified concept of the ecological niche, bringing together its different spatial and functional aspects. The escalating urgency in biodiversity conservation especially of the moist topics has pushed for more precise and field based ecological methods, that was contributed for the region by Ramesh et al. (1997) globally as by Myers et al. (2000). The predictive habitat distribution models were critically reviewed by Guisan and Zimmermann (2000). Meher-Homji's (2001) publication on the bioclimatology and plant geography of India has been a significant foundation on ecological understanding of complex tropical terrains such as Western Ghats. A significant innovation during this time was the introduction of Ecological Niche Factor Analysis (ENFA) by Hirzel et al. (2002). This analysis provided a method to create habitat-suitability maps without relying on true absence data. Instead, it focused on the environmental specialization and marginality of species. Peterson (2001) defined the principles of predicting species geographic distributions using Ecological Niche Modelling. Elith (2002) evaluated the performance of different quantitative methods for habitat modelling of species. The ecological impacts of landscape changes have remained a crucial topic, with Fahrig (2003) reviewing the widespread effects of habitat fragmentation on biodiversity. Concerns have also emerged about climate change effects. Pearson and Dawson (2003) assessed the reliability of bioclimate envelope models. Later, Seoane et al. (2003) studied how landscape, vegetation, topography, and climate compete

in influencing avian distribution models. Kerr et al. (2011) emphasised the need to integrate ecological theory with predictive models for effective conservation planning.

### **2.2.1. The MaxEnt Era and Data Standardization**

The early 2000 and the decade saw new methods and the standardization of global environmental data, which triggered faster and wide scale its global use. Graham et al. (2004) discussed recent developments in using museum collection data, which serves as the main input for occurrence-based species distribution models (SDMs). Guisan and Thuiller (2005) advocated for moving beyond basic habitat models to more predictive species distribution methods. The foundation for global SDMs improved significantly when Hijmans et al. (2005) released high-resolution interpolated climate surfaces (WorldClim). Hoekstra et al. (2005) highlighted global inequalities in habitat loss and protection. Soberón and Peterson (2005) developed an important framework that distinguishes between models of the fundamental ecological niche and the species' actual distribution areas. Thuiller et al. (2005) examined how niche properties can predict a species' sensitivity to climate change. The year 2006 marked a significant change. Das et al. (2006) used spatial analysis to prioritise conservation areas in the Western Ghats. Elith et al. (2006) demonstrated that new methods could greatly improve predictions from occurrence data. Most importantly, Phillips et al. (2006) introduced Maximum Entropy (MaxEnt) modelling, which quickly became the standard. Hijmans and Graham (2006) tackled the perennial problem of sampling bias. Rotenberry et al. (2006) showed how GIS-based niche modelling could be used for mapping species habitat. Following this, Araújo & Luoto (2007) highlighted the importance of biotic interactions in modelling future species distributions. Guisan et al. (2007) provided guidance on the key considerations for predicting climate change effects on species. Irfan-Ullah et al. (2007) published an early application, mapping the endemic *Aglaia bourdillonii* in the Western Ghats. Further conceptual clarity on the theory guiding these models emerged as Hirzel and Lay (2008) provided a synthesis of habitat suitability modelling and niche theory. In 2008, Jarvis et al. (2008) released the widely used hole-filled seamless SRTM elevation data. Giriraj et al. (2008) applied ENM to another Western Ghats endemic, *Rhododendron arboreum*. Loiselle et al. (2008) conducted SDM in the Andes, and Phillips and Dudík (2008) offered new MaxEnt extensions and a comprehensive performance evaluation. Miller (2010) examined statistical concerns, especially spatial autocorrelation, which is essential for enhancing the reliability of SDM models. Pramanik et al. (2017) employed Ecological

Niche Modelling (ENM) methodologies to forecast climate-induced shifts in the geographical range of *Garcinia indica*, while Karpakal et al. (2022) assessed the potential habitats for *Madhuca insignis* using SDM.

### **2.2.2. MaxEnt Refinement, and Biotic Challenges**

The MaxEnt approach was quickly adopted for managing biological invasions, such as Kumar and Stohlgren (2009). Holt (2009) provided a significant theoretical update through bringing the Hutchinsonian niche into the 21st century technology and machine learning algorithms and integrated both ecological and evolutionary views. Costa (2009) provided a broad perspective, combining niche modelling patterns of species richness, factors influencing range limits and conservation planning. Franklin (2010) published an important text on mapping species distributions. Renard et al. (2010) offered essential high-resolution vegetation cover data for the Southern Western Ghats. Benham et al. (2011) used satellite imagery to identify new critical habitat in the Andes. Methodological clarity improved when Elith et al. (2011) presented a statistical explanation of MaxEnt aimed at 21<sup>st</sup> century ecologists. Peterson et al. (2011) published a volume that integrated ecological niches and geographic distribution. Regional climate research increased, with Ravindranath et al. (2011) studying climate change impacts on Indian forests, and Rodríguez et al. (2011) setting IUCN Red List criteria for threatened ecosystems.

The refinement of predictive modelling occurred with works of Peterson and Soberón (2012) and complementary gradient analytic view Halvorsen (2012). In the following years, targeted conservation efforts emerged: Adhikari et al. (2012) modeled habitat for reintroducing the critically endangered *Ilex khasiana* of the Himalayan landscape. Babar et al. (2012) did it for endemic *Pterocarpus santalinus* in the Western Ghats, Dormann et al. (2013) reviewed a methodological challenge collinearity among predictors and Franklin (2013) provided a analysis of SDMs in conservation biogeography, outlining ongoing developments and challenges. SDMs application emerged for invasive species like *Sapium sebiferum* (Jaryan et al., 2013). The publication of a practical guide to MaxEnt that detailed the effect of inputs and settings by Merow et al. (2013) helped to spread the use of the SDM. Nagaraju et al. (2013) tested ENM predictions for the adaptive landscape of *Myristica malabarica*. Kalle et al. (2013) predicted the distribution of small carnivores in the Western Ghats, whereas Qiao et al. (2013) discussed the theoretical foundations, future directions, and challenges for SDMs. Wisz et al. (2013) delivered a critical review

on the role of biotic interactions in shaping species distributions pointing out a limitation in correlative SDMs and Yang et al. (2013) published the distribution of the medicinal plant *Justicia adhatoda*.

The discussion on biotic interactions continued when de Araújo et al. (2014) tested the Eltonian noise hypothesis, initiated discourses and experiments which helped to refine SDM models and predictions, that formed foundations for this present study. Varela et al. (2014) measured the impact of geographical sampling bias on SDM reliability. Qiao et al. (2015) tested multiple algorithms for niche estimation and concluded that there are "no silver bullets" in correlative ecological niche modelling, highlighting the need for strong model selection. Vaz et al. (2015) conducted a bibliometric analysis, highlighting trends and biases in the global scientific literature concerning ENMs. Thesis research by Das (2015) analysed the influence of environmental factors and landcover change on upper montane (shola) forests in the Western Ghats. The long-term effects of fragmentation were forcefully argued by Haddad et al. (2015). Remya et al. (2015) applied MaxEnt to predict the habitat of *Myristica dactyloides* in the Eastern Ghats. Priti et al. (2016) modeled the future climate impacts on Myristicaceae species in the Western Ghats. Vernes et al. (2016) conducted fine-scale habitat preference modelling for mycophagous mammals. Reddy et al. (2016) provided assessment and monitoring of long-term forest cover changes (1920-2013) in Western Ghats region and Dutta et al. (2016) on quantification and monitoring of forest cover changes in Agasthyamalai Biosphere Reserve, Western Ghats.

In 2017, the foundational data was updated with Fick and Hijmans (2017) releasing WorldClim 2. Jalal and Singh (2017) provided an ENM case study for the endangered orchid *Habenaria suaveolens*. Methodological scrutiny intensified with Morales et al. (2017) conducting a systematic review on MaxEnt's parameter configuration and its use with small sample sizes. Robinson et al. (2017) provided a systematic review of marine-based SDMs, offering recommendations for best practices. Karasiewicz et al. (2017) proposed an innovative refinement of the Outlying Mean Index (OMI) analysis, called Within Outlying Mean Indexes, for a clearer decomposition of the realised niche. The increasing dependence on global occurrence data was acknowledged by Meyer and Kreft (2017) on the Global Biodiversity Information Facility (GBIF). Suárez-Seoane et al. (2017) presented a multi-scale SDM approach for vertebrates in the Iberian Peninsula, Ma and Sun (2018) predicted the distribution of *Stipa purpurea* on the Tibetan Plateau. Sony et al. (2018) studied how climate change affects the endangered Nilgiri Tahr in the Western



Ghats using SDMs. Suwal et al. (2018) examined climatic niche differences among *Macaca assamensis* subspecies. A review that explained the evolution of niche concepts and methods was published by Brown and Carnaval (2019) and Baruah et al. (2019) emphasised habitat modelling and support for the threatened *Elaeocarpus serratus*. Senay et al. (2019) elaborated the creation of multi-scenario SDMs for risk assessment which was followed by significant insights into global invasion dynamics. Gong et al. (2020) highlighted the "double-edged effects" of climate change on alien plant invasions, Page and Shanker (2020) linked climatic stability to latitudinal trends in the range size of woody plants in of the Western Ghats, Palkar et al. (2020) predicted the potential distribution of 'Kokkam' *Garcinia indica* using ENM and Yang et al. (2020) explored the influence of slope and aspect on vegetation attributes through SDM.

The methodological toolkit continued to grow. Abapihi et al. (2021) proposed ANOVA on principal components. The global prediction of invasive species proceeded with Changjun et al. (2021) modelling *Ageratina adenophora*. Localised thesis work by Devika and Bachan (2021) provided niche profiling and reassessment for endemic tree species. Lissovsky and Dudov (2021) published a review on the pros and cons of MaxEnt. Singh et al. (2021) modeled potential hotspots of the invasive *Prosopis juliflora* in India. Srinivasulu et al. (2021) modeled endemic threatened squamates in the Western Ghats. Sun et al. (2021) employed a multi-scale MaxEnt approach for giant pandas. In 2022, Tourinho (2022) provided a crucial synthesis for model selection, discussing how to choose among correlative, mechanistic, and hybrid models of species' niche and distribution. This marked a shift towards integrated approaches. Predicting the habitat suitability of *Dipterocarpus indicus* (Malik et al., 2022), Bachan and Devika (2022) published niche modelling work on the endangered *Cryptocarya anamalayana*. Bachan et al. (2022) characterised the riparian forest of the Western Ghats as an endangered ecosystem. Devika and Bachan (2022) addressed the methodological limitations of niche modelling with specific reference to the Western Ghats. Dorji et al. (2022) predicted the distribution of invasive *Parthenium hysterophorus*. Namitha et al. (2022) modeled the potential habitats for *Gluta travancorica*. Roy et al. (2022) provided a comprehensive retrospective on SDM use in the Indian subcontinent. Sahana et al. (2022) used SDMs to prioritise mangrove restoration. Tesfamariam et al. (2022) modeled habitat suitability for *Podocarpus* forest rehabilitation. In recent years, the emphasis has been on predictive niche modelling for immediate reintroduction and ecorestoration planning. Methodological challenges, such as dealing

with sampling bias, remain highly relevant, as shown by Pires-Oliveira et al. (2023), who demonstrated that sampling bias worsens the predictive ability of niche models. The evolution of SDM from simple bioclimatic envelopes to machine learning algorithms to deal multiple parameters was reviewed by Rupesh (2023) and Pshegusov (2023) explored the theoretical modelling issues related to the correlation approach, shifting focus from spatial distribution to the ecological niche. Cuervo et al. (2023) identified specific challenges and applications of ENM in modelling vector-borne diseases. Devika and Bachan (2023) predicted habitat suitability at the ecoregion level for *Syzygium caryophyllatum*. The growing reliance on global occurrence data was backed by the GBIF (2023) occurrence data download. Applied studies included Jianhui et al. (2023) modelling the suitable habitats of the snow leopard in the Tianshan Mountains, followed by Konwar et al. (2023) identifying conservation priority areas for *Nepenthes khasiana* under climate change. Mathur et al. (2023) modeled the critically endangered *Commiphora wightii*. Lawrence et al. (2023) conducted a systematic review on using ENM to predict emerging infectious diseases. The importance of these regional applications is underscored by the repeated citation of Jianhui et al. (2023), Konwar et al. (2023), and Mathur et al. (2023) in this body of literature. Mirhashemi et al. (2023) investigated the effect of the spatial database on predicting climate change impacts on *Quercus brantii*. Finally, the work by Yibin et al. (2023) further contributed to the snow leopard habitat modelling literature. Babanezhad and Alireza (2024) reviewed SDMs in plant conservation science. Belfiore et al. (2024) studied adding fossil data to current species observations to evaluate climate vulnerability. Javeed et al. (2024) provided a global bibliometric assessment of ecological niche modelling, confirming its growing prominence. Moreno-Arzate and Martínez-Meyer (2024) introduced a retrospective approach for evaluating ENM transferability over time using Mexican endemic rodents. Rojas-Soto et al. (2024) provided a critical review of the concepts and approaches used for defining calibration areas in ENM. Kharouba and Williams (2024) explored the use of the space-for-time substitution approach for forecasting species' responses to climate change. Soley-Guardia et al. (2024) provided a highly didactic guide for practitioners, outlining the "top ten hazards to avoid" when modelling species distributions, covering assumptions and common problems. Pasanisi et al. (2024) provided a global systematic review of SDM approaches for cetaceans and sea turtles. Vasconcelos et al. (2024) offered a mixed review on the current advances and challenges in species ecological niche modelling. Athamanakath et al. (2024) analysed

niche overlap between the endemic *Albizia lathamii* and the invasive *Prosopis juliflora*. Devika and Bachan (2024) predicted conservation and ecorestoration areas for the threatened *Prioria pinnata*. Conceptually, Feng et al. (2024) proposed rethinking ecological niches in the Anthropocene to account for pervasive human influence. Gebrewahid et al. (2024) modeled *Rhamnus prinoides* under climate change. Hosseini et al. (2024) modeled the habitat potential and climate change effect on three *Thymus* species. The role of microclimate was explored by John et al. (2024) in coastal California. Kishore et al. (2024) used ENM to understand the invasion potential of *Chromolaena odorata* and *Lantana camara* in the Western Ghats. Addressing inherent model limitations, Passos et al. (2024) analysed uncertainties in plant species niche modelling under climate change scenarios.

Projected research in 2025 suggests a move toward more data-informed and integrated modelling. Abdelwahed et al. (2025) introduced a model conditioned on incomplete species observations. Koldasbayeva and Zaytsev (2025) focused on the fundamental issue of unbiased cross-validation in spatio-temporal SDMs. Klaassen et al. (2025) provided a review of methodological advances and future challenges specifically for marine species distribution models. The current and future habitat suitability of *Cullenia exarillata* were predicted (Bhavya et al., 2025) and the impact of climate change on *Elaeocarpus munroi* in the Western Ghats were forecasted (Maya & Suresh, 2025). Bachan and Devika (2025) argued for integrating vegetation inputs to address both Grinnellian and Eltonian niche factors in niche specific conservation and ecorestoration planning. Devika and Bachan (2025) presented work on integrating niche modelling and species assemblage to predict present and future habitats of *Diospyros crumenata* under climate change. Kim et al. (2025) proposed objective parameterization of the InVEST model using PCA and SEM. Recently, Rivadeneira et al. (2025) focused on applying ENM to microendemic montane frogs.

### **2.3. Niche Specificity and Overlap**

The concepts of niche specificity and niche overlap are fundamental to ecological theory, providing the framework for understanding species coexistence, resource partitioning, and community structure.

### **2.3.1. The Theoretical Foundations of Species Coexistence**

The theoretical bedrock for niche concepts was laid early in the 20th century. While primarily mathematical, the work of Hellinger (1909) on quadratic forms of infinitely many variables foreshadowed the multi-dimensional complexity later inherent in niche modelling. Early ecological applications were often taxonomic, such as the classification of Coccidae presented by MacGillivray (1921). The modern ecological niche was formally introduced by Hutchinson (1957), who established the duality between the fundamental niche (the total environmental conditions a species can utilise) and the realised niche (the portion used in the presence of competitors). This framework was quickly contested and improved upon by Hardin's (1960) competitive exclusion principle, which stated that two species cannot permanently inhabit the same niche.

### **2.3.2. The Era of Limiting Similarity and Empirical Testing**

The mid-1960s saw the development of basic mathematical models for ecological coexistence. MacArthur and Levins (1967) introduced the idea of limiting similarity. This concept defined the maximum overlap two species could have while living together. Following this theoretical work, research focused on how resources are divided. Schoener (1968) studied on *Anolis* lizards and described how different species shared resources in both space and diet. He further indicated that various patterns of spatial overlap could allow coexistence in uneven habitats (Schoener, 1970). The methodologies to measure niche breadth and overlap were provided by Colwell and Futuyma (1971). MacArthur (1971, 1972) made significant contributions demonstrating how ecological patterns arise from interactions between species and their environment as well as in resource partitioning applying niche theory to specific communities. Pianka (1973) studied the makeup of lizard communities and the studies led to the idea of diffuse competition and how competitive effects of several species could limit a species' realised niche (Pianka, 1974). Gaffney (1975) discussed the origins of the niche concept and the works of Edmunds and Alstad (1978) explored the coevolutionary context of resource use while examining insect herbivores and conifers.

### **2.3.3. Methodological Scrutiny and Theoretical Refinement**

The 1980s brought a focus on methodological advancements for measuring niche overlap. Abrams (1980) discussed the challenges, Rappoldt and Hogeweg (1980) looked into the link between niche packing and the number of species and this was followed by research

on competition, Jackson (1981) provided an overview of interspecific competition and species distributions, Abramsky and Sella (1982) validated competition and niche concepts through experiments using removal experiments to clarify the role of habitat selection in two *Gerbillus* species and Maurer (1982) strengthened the statistical basis through developing statistical inference techniques for MacArthur-Levins niche overlap.

The early 1980s saw significant developments in ecological theory, particularly on species coexistence and the niche concept. Aarssen (1983) developed a general evolutionary framework for coexistence, which was complemented by Abrams' (1983) comprehensive review of the limiting similarity theory. The following year, the focus shifted to empirical methods, with Zaret and Smith (1984) analysing how to quantify niches and debating the necessity of such measurement and James et al. (1984) explored these measurement issues by applying the Grinnellian niche concept.

The conceptual limits of the niche was also in discourse. Silvertown and Law (1987) questioned whether the niche concept was required in plant community ecology studies, whereas Gallopín (1989) addressed this debate while seeking a unified concept. The multidimensionality of the Ncihes were addressed by Litvak and Hansell (1990) and Chesson (1991) and Shorrocks (1991) confirmed the importance of the niche concept through developing dedicated tools for measuring niche breadth and overlap, similar to that introduced by Ganis (1991). Specificity in different systems was measured including the role of intraguild predation in size-structured populations (Wissinger, 1992) and niche width in Himalayan forests (Bisht & Kusumlata, 1993). A critical revision of the niche concept was done by Leibold (1995) promoting the mechanistic models. The studies in the decade wrapped up by empirical studies on alpine niche width (Pandey et al., 1999) and niche conservatism over evolutionary time Peterson et al (1999), setting the stage for Species Distribution Models (SDMs).

#### **2.3.4. The SDM Revolution and Modern Synthesis**

The practical application of the niche theories advanced in the 21st century through merging of niche theory with biodiversity and predictive modelling. Chesson (2000) explained how species diversity is maintained complimenting Looijen's (2000) adaptation of the Lotka-Volterra model to modern niche theory. The idea connected to conservation by identifying biodiversity hotspots (Myers et al., 2000) and Pulliam (2000) examined the links between the niche and species distribution. Studies on niche separation in primates

(Singh et al., 2000) and warblers (Zhou & Fang, 2000) continued the empirical methods. The early 2000s brought a wave of studies linking niche to speciation. Schlieuwen et al. (2001) and Via (2001) looked at genetic divergence and sympatric speciation. Statzner et al. (2001) reviewed the influence of species traits. Niche conservatism emerged as a key theme. Graham et al. (2004) and Wiens (2004) explored this in relation to speciation. Silvertown (2004) revisited plant coexistence. Young (2004) studied competition and habitat selection in juvenile salmonids. The focus on methods grew. Guisan and Thuiller (2005) advocated for predictive models. Phillips et al. (2006) introduced the MaxEnt algorithm, and climate data became widely used (Hijmans et al., 2005). Mouillot et al. (2005) suggested new non-parametric indices for niche overlap based on functional traits. Thuiller et al. (2005, 2006) used niche properties to predict species sensitivity to climate change and evaluate functional diversity. Miller and Davidson (2005) and Provencher et al. (2005) published works on scale insect biology.

Soberón (2007) through distinguishing Grinnellian and Eltonian niches continued the conceptual discourse, meanwhile Colwell and Rangel (2009) revisited Hutchinson's duality. Holt (2009) argued for updating the Hutchinsonian niche for the 21st century. Raxworthy et al. (2007) and Rissler and Apodaca (2007) reviewed the use of SDMs for defining species boundaries. They applied their research to geckos (Pearson et al., 2007) and cryptic species (Pfenninger & Schwenk, 2007; Oliver et al., 2009; Anderson et al., 2010; Gwiazdowski et al., 2011; Vea et al., 2012). This period was marked with elevating the standards for methodological frame works in niche based studies. Warren et al. (2008) provided methods for testing niche equivalency and conservatism and later released the ENMTools package (Warren et al., 2010). Detailed guides and explanations for SDMs provided by Elith et al. (2009, 2011) and Lobo et al. (2008), Peterson et al. (2008), Radosavljevic and Anderson (2014) addressed model evaluation issues and complexity (Merow et al., 2013; Muscarella et al., 2014). Meanwhile researchers detailed the link between niche and evolution in jays (McCormack et al., 2010), kingsnakes (Pyron & Burbrink, 2009), and salamanders (Kozak & Wiens, 2006; Rissler & Apodaca, 2007; Waltari & Hickerson, 2012).

Many advances in methods aimed at assessing niche overlap emerged, exemplified by Rödder and Engler (2011) review of quantitative metrics for overlap in Grinnellian niches, Broennimann et al. (2012) framework for measuring niche overlap in environmental space using occurrence data, Cáceres et al. (2011) framework for niche metrics based on

qualitative resources and later Blonder et al. (2014) introduced the hypervolume approach, and Blonder (2018) reviewed it thoroughly. Studies emerged linking ecological dynamics to niche metrics indicated by studies such as competition in grassland communities (Mason et al., 2011; Zepeda & Martorell, 2019), species packing (Scriven et al., 2016), and the impact of generalist exotic species resulting from niche overlap (Uricchio et al., 2018). Research in the Western Ghats mountains focused on vulnerability (Sharma et al., 2017), plant diversity (Nayar et al., 2014), and local endemism (Shigwan et al., 2020) during these periods.

### **2.3.5. Current Frontiers: Integration, Intraspecific Variation, and Climate Change**

The present ecological research paradigm builds on foundational and methodological advancements to tackle complex multi-species interactions and the impacts of global change. Sobéron and Peterson (2020) revisited the essential Grinnellian niche shape, Li et al. (2018) highlighted advances in trait-based ecology on habitat filtering and Schellenberger Costa et al. (2018) on niche breadth. All these continued to refine our understanding of how traits relate to environmental space. Godoy et al. (2018) emphasised the need to integrate niche and network theories. Climate change adaptation remains a major theme. Studies explored rapid range shifts (Chen et al., 2011), the invasive niche of *Phragmites* (Guo et al., 2013), the impact on functional diversity (Thuiller et al., 2014), and modelling future distributions of endangered species (Qin et al., 2017; Zhang et al., 2022) and pests (Ning et al., 2017; Dale & Frank, 2017). The niche studies in Western Ghats in the context of invasives and endemics under climate change during this time (Trivedi & Bharchula, 2023; Athamanakath et al., 2024; Manna et al., 2024; Sakkamuthu et al., 2024). These also included intraspecific variation (Ingram et al., 2018; Zhang & Kubota, 2021), behavioral trophic differences (Kumar et al., 2020; Probert et al., 2021; Yang et al., 2023; Petalas et al., 2024) and approaches for nonparametric statistical inference of overlap among multiple species (Langthaler et al., 2024). Studies also explored coexistence geometry (Blumenthal & Mehta, 2023; Spaak et al., 2022), link between niche overlap and productivity (Higgins et al., 2024), and community stability (Evans et al., 2024). The work of Caron et al. (2025), examined the evolution of Hutchinsonian climatic niche hypervolumes in gymnosperms and that of Wang et al. (2025) looked at how niche overlap affects the diversity-productivity relationship.

## **2.4. Vegetation Ecology and Conservation**

The studies on plant communities emerged in the late 19th and early 20th centuries after the initial plant exploration and early systematics era. The ecological foundations and community ecology sought systematic methods to analyse the composition and dynamics of natural vegetation in all the terrestrial ecosystems especially of the tropical far east

### **2.4.1. Forest Typology, Sampling, and the Continuum Concept**

The foundation for quantitative methods in vegetation ecology was provided by Pound and Clements (1898) and proposed a way to determine the population of , which set the stage for phytosociological assessments that dominated the ecological studies for decades and relevant still today. The initial work was elaborated by Clements (1905) “Research Methods in Ecology,” as basic toll for understanding structure of ecosystems though phytosociological analysis of the plant communities or the vegetation. The concept of the plant community and its analytical frameworks became a central topic of the ecological discourse in early 20th century. The Clementsian view, depicted in Clements’s (1916) work, “Plant Succession: An analysis of the development of vegetation,” and his later studies introduced the idea of the successional stages defined by *communitas* and especially the culminating climax community. This visualised the vegetation as a super assemblage community that develops through predictable stages of seral communities to a stable, determined endpoint, the climax community shaped chiefly by the prevailing climate. The period was early emerging stages of vegetation classifications across the globe and which necessitated detailed understanding of the community structure, tis dynamics, succession and culmination. Discourses aroused on structural definitions of vegetation based on the standing crops and understanding of the climax. Gleason (1917) proposed a different perspective in his monumental work “The structure and development of the plant association,” questioning the deterministic nature of the climax. His subsequent work in 1920, “Some applications of the quadrat method,” showcased practical guidelines for sampling vegetation and *communitas*. This empirical methods supported the early 20th forest studies through comprehensive resource surveys and classification efforts across the globe especially in the tropical world. Stebbing (1922, 1926) published The forests of India (Vol. 1 and Vol. 3) providing the early classifications of the subcontinent’s forests. The thoughts of Gleason’s (1926) published in the “The individualistic concept of the plant association” provided more clarity on plant species distribution and .he argued that plant



communities are just temporary groups formed by the independent migration. The publication of the book “Aims and Methods in the Study of Vegetation,” by Tansley and Chip (1926) became an essential field for ecologists.

At the same periods, the European ecologists progressed through descriptive and classification traditions. The works of the plant distributions in alpine zones Jaccard (1912) resulted in the methodological framework for comparing communities guilds through species similarity and species richness. The Braun-Blanquet (1932) studies formalised the quantities phytosociological method in phytosociology. His approach that defined and classified distinct vegetation units became globally influential classification system. Raunkiaer (1934) publication “The life forms of plants and statistical geography,” added another dimension to understand plant communities. The first comprehensive classification of the Indian forests was provided by Champion (1936) and Champion and Seth (1968). Cain (1938) worked on field techniques and introduced the species-area curve as an essential method to determine the minimum size of the sample to be taken in an ecosystem for ecological samplings.

This kind of understanding and launch of the ecological studies gained pace with the mid-20th century supported by mathematical development of systematic sampling. Madow and Madow (1944) began the rigorous mathematical treatment in ecology in the work “On the Theory of Systematic Sampling”. Madow (1946) published two volumes “Systematic Sampling and Its Relation to Other Sampling Designs,” supporting studies on systematic methods in forestry and resource assessment. At the same time global research progressed aiming at vegetation observable traits focusing on the structure and form of plant communities exemplified by the studies such as Kuchler (1949) physiognomic classification of vegetation and Wyatt-Smith (1949) A note on the tropical lowland evergreen forest in Malaya. The mid-century also marked a conceptual shift in ecology, seeing vegetation as a continuum and individualistic concepts, driven by Whittaker (1951) and Curtis and McIntosh (1951). They criticised the Clementian climatic climax concepts. The 1950s advanced with theoretical and practical studies sampling. The publication by Cochran (1953) on Sampling Techniques, became a definitive guide for statistical sampling in ecology and Hansen et al. (1953) provided an encyclopedic overview of Sample Survey Methods and Theory (Vols I & II). The Whittaker’s (1953) publication “A consideration of climax theory: The climax as a population and pattern,” further strengthened continuum concept recasting the climax as a steady-state pattern of

populations. Bray and Curtis (1957) made this technique more popular and the individualistic theory gained more momentum when Hutchinson (1957) introduced the concept of the n-dimensional hypervolume niche. This fundamentally shifted the focus from community structure to the individual species' environmental needs and roles and the niche concepts.

This shift to individualist niche definitions demanded for methodological tools to quantify individualistic species patterns. The major contributions were Daubenmire (1959) - canopy coverage method of vegetation analysis, Phillips (1959) comprehensive guide in Methods of vegetation study, Webb (1959) A physiognomic classification of Australian rain forests and Curtis (1959) - The vegetation of Wisconsin. The studies in this aspect in the Western Ghats region marked with Chandrasekharan's (1962) study on the "Forest types of Kerala state." Ellenberg and Mueller-Dombois (1967) provided a highly comprehensive work - Tentative physiognomic-ecological classification of plant formations of the earth. This followed by Fosberg (1967) gave a new dimension on vegetation ecology and forest classification of the globe. The studies on tropical rainforests (Whittaker, 1967) became another testament of tropical ecology. The works of Misra (1968) introduced practical methods for ecological fieldwork, enabling systematic vegetation sampling and species documentation in India. The Champion and Seth's (1968) A revised survey of the forest types of India became an essential reference for Indian forestry and forest ecology in India used still today. This has classified all the Indian vegetation based on descriptive community species compositions and brought under six major and 16 minor forests types in India. Other studies include Pajmans (1970), analysis of four tropical rain forest sites in New Guinea, Hespenheide (1973), Mueller-Dombois and Ellenberg (1974) - Aims and methods of vegetation ecology, Whittaker (1975) Communities and Ecosystems. Westhoff and van der Maarel's (1978) on The Braun-Blanquet approach in the Classification of Plant Communities in Whittaker (1978).

#### **2.4.2. Tropical Diversity and the Dawn of Conservation Ecology**

The intensified explorations and comprehensive understanding of the ecology, especially of the tropical forests accelerated by quantitative methods and classifications paved way for the rise of the conservation ecology. Works of Parsons and Cameron (1974) on the concept of maximum plant species diversity in terrestrial communities, Connell (1978) diversity in tropical rain forests and coral reefs, Whitmore (1975) Tropical rainforests of

the Far East, and its second edition (Whitmore, 1984), Mueller-Dombois (1984) Classification and mapping of plant communities and Magurran's (1988) Ecological Diversity and its measurement were significant works of ecology.

The ecological studies on vegetation of the Western Ghats of India provided by Pascal (1988) Wet evergreen forests of the Western Ghats, Pascal et al. (1988) structure and composition of the "Kan forests" on the Karnataka Plateau, Pascal (1990) floristic composition and distribution of evergreen forests in the Western Ghats and the era was wrapped up with Nayar and Sastry's (1990) monumental Red Data Book of Indian Plants (Vols. I–III).

#### **2.4.3. Conservation Crisis, Fragmentation, and Landscape Ecology**

The historical forest conversion of the tropical world, started from the colonial period in India, especially at the Western Ghats was intensive in the industrial post independent period and resulted in degradation of 80% of the natural forests. This has triggered a shift towards the applied conservation to address the issues of tropical deforestation, fragmentation and biodiversity loss. The pioneering studies helped in creating foundational ecological datasets, studies such as Joshi and Gadgil (1991), tree species diversity in the shola forests of the Western Ghats, Bhat (1992), who detailed the flora of tropical moist forests of Uttara Kannada District, Hartshorn (1995) ecological basis for sustainable development in tropical forests, Jongman et al. (1995), multivariate analysis of ecological datasets, Pascal and Pelissier (1996) structure and floristic composition of a tropical evergreen forest in southwest India, and Ganesh et al. (1996), plant biodiversity at a mid-elevation evergreen forest in the Kalakad-Mundanthurai Tiger Reserve.

The late 1990s showed studies on conservation threats and conservation mechanisms. Studies by Khan et al. (1997) effectiveness of the protected area network in Meghalaya, Menon and Bawa (1997), landscape ecology approach to boost biodiversity conservation in the Western Ghats, Bawa and Dayanandan (1998) causes of tropical deforestation and institutional barriers to conservation, Chandrashekara and Sankar (1998) and Tiwari et al. (1998) ecology and management of sacred groves in Kerala and Meghalaya, respectively and the methodological input by Haullier and Carpentier (1998) review of sampling for biodiversity were important.

The trend continued at the end of the century with studies by Ayyappan and Parthasarathy (1999) biodiversity inventory of trees in a large permanent plot at Varagalaiair,

Ganesh and Davidar (1999) fruit biomass and the relative abundance of frugivores in a rainforest, Bonnefille et al. (1999) altitudinal distribution of modern pollen spectra from tropical South India and Sri Lanka, Naskar and Mandal (1999), ecology and biodiversity of Indian mangroves, Parthasarathy (1999) tree species diversity in human-affected tropical evergreen forests in the southern Western Ghats, Chittibabu and Parthasarathy (2000) in Varagalaia and Sundarapandian and Swamy (2000) reviewed forest ecosystem structure and composition along an altitudinal gradient.

The 21<sup>st</sup> century begun with studies on landscape-level analysis and restoration. Studies of Jha et al. (2000) forest loss throughout the Western Ghats, Bhat et al. (2001) overview of the formation and recovery of secondary forests in India, and Nagendra (2001) on forest transformation. Ganesan (2002) studied evergreen forest swamps and their plant species diversity in the Kalakad-Mundanthurai Tiger Reserve. Sundaram and Parthasarathy (2002) published work on tree growth, mortality, and recruitment in the Eastern Ghats. The studies on tropical rainforest birds of the Western Ghats by Raman and Sukumar (2002) and Roy and Behera (2002) advocated for landscape-level biodiversity assessments using GIS.

Amarnath et al. (2003) did a diagnostic analysis of conservation zones using GIS, Ganesan and Davidar (2003) impact of logging on the structure and regrowth of key fruit-bearing trees, Devy and Davidar (2003) analysed tree pollination systems, Gimaret-Carpentier et al. (2003) mapped the broad-scale biodiversity pattern of endemic tree flora in the Western Ghats, and Puyravaud et al. (2003) conducted an analysis of threatened endemic trees. In the social context, Boraiah et al. (2003) compared the richness of medicinal plants in informally managed sacred groves against that in reserve forests, illustrating the conservation role of local traditions. Nagendra and Utkarsh (2003) further demonstrated Landscape ecological planning through a multi-scale characterization of pattern. Finally, a strong emphasis was placed on restoration and community engagement: Ramesh (2003) reviewed Biodiversity conservation and management, and Stewart and Balear (2003) and Shankar and Mudappa (2003) explored Restoration of southern Indian shola forests and Bridging the gap: Sharing responsibility for ecological restoration and wildlife conservation on private lands, respectively. The urgency of the conservation crisis was summarised by Umapathy and Kumar (2003), who assessed the Impacts of Forest Fragmentation on Lion-Tailed Macaque and Nilgiri Langur. The Western Ghats Ecology Expert Panel Report (Gadgil, 2011) reshaped environmental policy by advocating

decentralised governance and ecosystem-sensitive development. Joseph et al. (2012) integrated climatic and ecological evidence to show increasing extreme rainfall events in the region. Global perspectives such as Ceballos et al. (2015) on accelerated species losses situate Western Ghats biodiversity within the broader context of the sixth mass extinction. The long-term monitoring gained importance in the context of climate change and biodiversity monitoring. Studies by Reddy et al. (2016) and Dutta et al. (2016) indicated ongoing declines in forest cover, and Srivathsa et al. (2023), connected biodiversity conservation with ecosystem services and human well-being.

#### **2.4.4. Modern Synthesis: Niches, Landscape, and Contemporary Methods**

The niche theories, quantitative methods, assessments of anthropogenic threats in biodiversity hotspots and conservation planning marked present period. Iachan (1983) provided statistical insights on asymptotic theory of systematic sampling, Pulliam (2000) clarified the connections between niche and species distributions, Myers et al. (2000) officially listed the Western Ghats as a global biodiversity hotspot, Parker (2000) emphasised the importance of canopy stratification for understanding vertical forest structure and profiles and Faith (2002) introduced phylogenetic measures of biodiversity. These studies were complemented by Webb et al. (2002), exploring the evolutionary basis of community assembly, Wright (2002), mechanisms of species coexistence and Chase and Leibold (2003) linking classical and modern niche theory.

Concurrently, ecological studies documented ongoing environmental change, including rain forest expansion through successional processes (Puyravaud et al., 2003) and increasing fire frequencies as a significant conservation threat (Kodandapani et al., 2004). Pontius and Pacheco (2004) provided a Calibration and validation of a model of forest disturbance in the region. Rai and Uhl (2004) linked local use patterns to conservation in their study of 'Uppage' fruit harvest. Wihermanto (2004) and Ylhäisi (2004) provided comparative examples of dispersion patterns of threatened plants in Indonesia and the significance of ethnic forests in Tanzania, respectively, broadening the global context. Magurran (2004) in *Measuring biological diversity*, providing current statistical standards. Soberón and Peterson (2005) provided the fundamental Interpretation of models of fundamental ecological niches and species' distributional areas, formalizing the link between niche theory and spatial modelling. Krishnan and Ramesh (2005) provided an evolutionary context by studying Endemism and sexual systems in the evergreen tree flora.

Bhagwat et al. (2005a, 2005b) used a landscape approach to biodiversity conservation of sacred groves and detailed the role of informal protected areas, respectively. Roleček et al. (2007) cautioned researchers to avoid sacrificing ecological thinking to statistical purism! in large-scale studies. Gunawardene et al. (2007) provided a brief overview of the Western Ghats–Sri Lanka biodiversity hotspot. Bascompte and Jordano (2007) explored Plant–animal mutualistic networks. Hao et al. (2007) provided an international example of measuring Vertical structure and spatial associations of dominant tree species in an old-growth forest, a level of detail necessary for understanding tropical systems. Reddy et al. (2007) applied Phytosociological analysis to the Similipal Biosphere Reserve. Thomas and Palmer (2007) focused on the community ecology of the montane grasslands (sholas). Soberón (2007) further clarified the distinction between Grinnellian and Eltonian niches. Giriraj et al. (2008) investigated vegetation composition, structure and patterns of diversity in the Western Ghats. Giriraj et al. (2009) proposed A method for assessing evergreen habitats using phytodiversity and geospatial techniques. Valentine et al. (2009) addressed the Systematic sampling of discrete and continuous populations, focusing on sample selection and estimator choice. Bachan (2010) studied the Riparian flora of the Chalakudy river basin. Mohandass and Davidar (2010) examined the relationship between area and vegetation structure and diversity in shola patches. Aravind et al. (2010) explored the Impact of human-caused disturbances on plant–pollinator interactions. Devictor et al. (2010) defined and measured ecological specialization. Blüthgen and Klein (2011) detailed the Functional complementarity and specialization in these interactions. Bhat et al. (2011) presented detailed structure and composition of tropical rain forests in Uttara Kannada District. The works of Kent (2012), vegetation description and data analysis, and Legendre and Legendre (2012), numerical ecology, have become foundational references for contemporary data analysis methodologies. Brilliant et al. (2012) conducted vegetation analysis of montane forest with emphasis on RET species. This period also saw the integration of climatic and ecological perspectives, with studies demonstrating the rising frequency of extreme rainfall events, such as the work by Joseph et al. (2012). Sathish et al. (2013) provided a comparative assessment of floristic structure, diversity and regeneration status. Ashton (2014) provided a contemporary reflection on the forests of tropical Asia. Bregman et al. (2015) studied the collapse of biodiversity in forest fragments. Das et al. (2015) provided a regional example of an ecological report on vegetation dynamics in Gorumara National Park. Sreejith et al. (2015) conducted phytosociological

studies on major forest ecosystems of Kerala through permanent sample plots, a type of long-term monitoring. Rao et al. (2015) conducted plant biodiversity and phytosociological studies in Telangana State. Joshi et al. (2015) examined tree diversity and community composition in the Western Ghats. Sarkar (2015) performed Phytosociological studies of tree vegetation in Moraghat forest range. Global ecological principles, such as those related to species range and changes (Stewart et al., 2015), were being applied to fragmentation studies. Bawa, et al. (2016) examined biogeography and vegetation turnover in the Western Ghats. Devagiri et al. (2016) assessed Species diversity, regeneration and dominance as influenced by canopy gaps. Shin and Kim (2016) proposed a practical balancing for a random sample from a finite population by systematic selection. Vikas and Desai (2016) conducted a similar phytosociological study in South Gujarat. Bhadra and Pattanayak (2017) later argued that dominance is more justified than abundance to calculate Importance Value Index (IVI). Manikandan and Balasubramanian (2018) analysed woody vegetation in a riparian forest. Arasumani et al. (2018) revisited the conservation threat of increasing fire frequencies. Davidar et al. (2018) studied patterns of plant diversity along elevation. Mostafa and Ahmad (2018) provided a contemporary review of recent developments in systematic sampling. Roby et al. (2018) assessing the *Myristica* swamp forests. Sreejith et al. (2019) formalised long-term monitoring in their reinvestigating the permanent plots established by KFRI. Chandran et al. (2020) focused on the comparative phytosociological assessment of ecosystems in Wayanad Wildlife Sanctuary. Harrison et al. (2020) provided a contemporary synthesis of the link between biodiversity and ecosystem function in tropical forests. Page and Shanker (2020) demonstrated how climatic stability influences species richness and range size patterns of woody plants across the Western Ghats. Bachan and Devika (2021) proposed niche specific conservation using integrated niche modelling to harmonise our understandings to healthy ecosystems. Devika and Bachan (2021) applied Niche profiling and niche modelling to endangered endemic tree species (*Cryptocarya anamalayana*) for conservation and restoration. Keddy (2021) offered an updated perspective on Competition and the assembly of ecological communities, underscoring the persistence of foundational ecological questions. Bachan and Devika (2022) conducted further research on this topic. Bachan et al. (2022) highlighted the critical status of the Riparian forest of Western Ghats as an endangered ecosystem.

The utility of the integrated niche framework developed in this study has been broadly confirmed by recent research in the Western Ghats and surrounding regions. Methodologies stemming from this work have been successfully applied to predict ecoregion-level, niche-specific conservation and restoration areas for endemics such as *Syzygium caryophyllatum* (Devika & Bachan, 2023). Several subsequent IUCN Red List assessments, derived from this study, have been published for specialised riparian and Myristica swamp species, including *Atuna travancorica* (Bachan & Devika, 2024), *Myristica magnifica* (Bachan & Devika, 2024), and *Myristica malabarica* (Bachan & Devika, 2024). The publication of the first IUCN Red List assessment for the flagship montane species *Strobilanthes kunthiana*, also informed by this research, catalysed conservation action, notably leading the National Green Tribunal (NGT) to call for urgent habitat conservation intervention. These niche models have also been used to predict conservation and ecorestoration areas by linking the IUCN status and conservation implications of the threatened tree *Prioria pinnata* (Devika & Bachan, 2024).

These efforts are situated within a larger regional context of conservation prioritization. Landscape-level studies have helped to identify high-importance conservation areas usually omitted from global-scale assessments, proposing management zoning through participatory and state-driven approaches (Srivathsa et al., 2023). Supporting regional findings, studies in Sri Lanka demonstrated that the percentage of endemic species is greater in lowland rainforests than in high-altitude montane forests (Sanjeevani et al., 2024). Recent analyses confirm a significant decline in evergreen forest cover (indicated at 10.98% since 1990), establishing that 54.41% of the region is highly sensitive (Ramachandra et al., 2025). These studies now shifted towards more predictive power through advanced modelling and integrating various niche factors. The spatial prioritization tools (Satish et al., 2024), monitoring algorithms (Anjitha et al., 2025) and the use of integrated methodologies developed from the inferences of the present study with classified vegetation layer inputs for Grinnellian and Eltonian niche factors (Bachan & Devika, 2025) and future climate change vulnerability assessments for species like *Diospyros crumenata* (Devika & Bachan, 2025), indicate that the integrated niche framework evolved through this study is highly effective guiding conservation and restoration (Bachan et al., 2025) and its further empirical evidences forms the basis of this doctoral work.





## Chapter 3

Taxonomic Scrutiny and IUCN Status Assessment of the  
Selected Species

## **Chapter 3**

### **Taxonomic Scrutiny and IUCN Status Assessment of the Selected Species**

#### **3.1. Introduction**

Accurate species identification and conservation status assessment are central to global efforts in biodiversity conservation and ecological restoration. The International Union for Conservation of Nature (IUCN), established in 1948, arose in response to the increasing awareness and realization of biodiversity loss and the need for coordinated international action to conserve nature (Holdgate, 1999). One of its most influential contributions has been the development of the Red Data Book, first published in the 1960s, which provided the earliest systematic attempt to catalogue species at risk of extinction using standardised categories of threat (Collar, 1996; Fitter & Fitter, 1987; IUCN, 1964). Over time, this initiative evolved into the IUCN Red List of Threatened Species, now widely regarded as the most comprehensive global information source on the conservation status of plant and animal species (Brummitt et al., 2008; Rodrigues et al., 2015; IUCN, 2024). The IUCN Red List assessments form the global standard for the listing and prioritization of species for conservation planning, using a robust and transparent set of categories and criteria that reflect each species' proximity to extinction (Miller, 2013; Mace et al., 2008; IUCN Standards and Petitions Committee, 2022). These criteria incorporate a combination of factors such as population size, rate of decline, geographic range, and degree of fragmentation. Earlier assessments, particularly those conducted around the 1990s and published by 1998, relied heavily on geographic parameters especially the Extent of Occurrence (EOO) and Area of Occupancy (AOO) under Criterion B (IUCN, 1994). These parameters were primarily estimated from known occurrence records and often lacked integration of ecological, demographic, or threat-based data (Willis et al., 2003). While this framework offered an objective starting point for assessing extinction risk, it also underscored the need for taxonomically and ecologically nuanced assessments to improve conservation prioritization.

However, comprehensive Red List assessments require the application of multiple criteria, particularly incorporating data on population dynamics, habitat characteristics, and ongoing conservation actions. The current conservation paradigm in the Anthropocene, coupled with the urgency of climate change and ambitious targets such as the Kunming-

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Montreal Global Biodiversity Framework's 2030 goals, necessitates such comprehensive assessments. These assessments can serve as benchmark information, crucial not only for effective conservation and species recovery planning but also for understanding the current status of species and evaluating the future implications of our conservation efforts. This level of insight can only be achieved through multi-criteria Red List assessments conducted using global standards across every biodiversity region. Fortunately, online open collaborative platforms dedicated to biodiversity information, such as virtual herbaria, GBIF, the India Biodiversity Portal, and iNaturalist, offer significant opportunities to understand species distribution based on occurrence records. These robust occurrence or collection records form the foundation for global species distribution data, which can then be utilised for rigorous IUCN assessments and advanced species distribution modeling

### **3.1.1. Limitations of Previous Red List Assessments**

Large-scale Red List assessments of plants from the Western Ghats region were primarily conducted as CAMP (Conservation Assessment and Management Plan) workshops in 1988. Data from the IUCN database indicate that the majority of assessments during that period were restricted to Criterion B, utilizing only the Extent of Occurrence (EOO) and Area of Occupancy (AOO). Population data, if available, were limited to basic counts of mature individuals, and information on habitat quality decline was often merely a broad-scale indication. Consequently, to achieve comprehensive, multi-criteria Red List assessments of plant species, the following aspects are crucial (Bachan & Devika, 2025):

- i. **Rigorous Taxonomic Scrutiny:** A careful taxonomic review of each occurrence record (e.g., herbarium specimens and photograph-based human observations) is essential to ensure accurate species identification.
- ii. **Systematic Population Data Collection:** Population data should be based on systematic sampling, at least within one subpopulation.
- iii. **Detailed Habitat Degradation Assessment:** Habitat degradation data should be derived from vegetation or land-use maps for the relevant population or a geographical region encompassing at least one subpopulation.
- iv. **Comprehensive Conservation Information:** All conservation actions, species recovery information, and available ecological data must be meticulously recorded in the conservation section.

A recent analysis of IUCN assessments for the angiosperm flora of the Kerala part of the Western Ghats reveals significant gaps. Out of a potential 782 threatened angiosperm taxa, only 100 were assessed in 1998. While 164 taxa have been assessed since 2011, with the majority occurring between 2021 and 2025, it is critical to note that the 1998 assessments and those conducted prior to 2021 largely lack multi-criteria evaluation. Our team was assigned with multi-criteria IUCN Red List assessments through IUCN Species Specialist Groups in 2021, commencing with the assessment of the Endangered *Cryptocarya anamalayana* (de Kok & Bachan, 2022). Of the 164 plant taxa assessed from our region since 2011, have been assessed by our laboratory to date (Bachan & Devika, 2022, 2025).

### **3.1.2. Need of Taxonomic scrutiny, review and Integration of population data**

A careful taxonomic scrutiny and review of each occurrence records (herbarium records and photograph based human observations) of each species to ensure that the species identity is correct as per the record. ii. Have population data based on systematic sampling at least in one sub population. The need for rigorous taxonomic scrutiny and periodic review of species identities is critical in the context of biodiversity conservation, particularly for threatened taxa. Inaccuracies in taxonomy such as unresolved synonymies, misidentifications, can lead to flawed conservation assessments, ineffective policy decisions, and even the neglect of truly imperiled species (Wheeler et al., 2004; Bebbier et al., 2010). In biodiversity hotspots like the Western Ghats, where many species are narrow endemics with limited morphological variation and cryptic diversity, traditional morphological approaches must be revisited through integrative taxonomic methods that combine herbarium studies, field-based assessments, and updated literature reviews (Puyravaud et al., 2003). Alongside taxonomic clarity, the integration of accurate population data including population size, structure, spatial distribution, and trends is essential for meaningful conservation assessments under the IUCN framework. Fragmentary or outdated population estimates can underestimate extinction risk or misrepresent species' recovery trends (Keith et al., 2015). Therefore, this chapter emphasises the combined importance of taxonomic validation and updated population data to inform robust IUCN Red List assessments, prioritise conservation action, and guide restoration strategies for the selected threatened angiosperms.

For this study, we have carefully selected 25 significant angiosperm taxa, representing various IUCN threat categories, to gain a comprehensive understanding of the current

conservation scenario. This selection encompasses species ranging from the Critically Endangered tree *Syzygium palaghatense*, characterised by its highly restricted distribution, to the previously unassessed, yet popular, flagship species *Strobilanthes kunthiana*, which boasts a high number of mature individuals in higher elevations. The inclusion of low-elevation evergreen species further broadens this understanding; examples include *Diospyros crumenata*, a species with restricted distribution, and *Hydnocarpus pentandrus* and *Dipterocarpus indicus*, both known for their wider distributions. Riparian tree species, such as *Syzygium occidentale* and *Aporosa bourdillonii*, which exhibit patchy, linear distributions along river stretches, offer insights into the impact of climate-change-induced floods on conservation status. Additionally, epiphytic species from montane and sub montane Shola ecosystems, like *Impatiens parasitica* and *Medinilla anamalaiana*, provide unique dimensions for IUCN Red List assessments, particularly concerning climate change and habitat loss. The inclusion of well-known and conserved species, such as *Prioria pinnata*, which benefits from ongoing conservation and species recovery plans, exemplifies the potential for 'Reversal of the Red' status.

This study aims to visualise the prospects of using a gradient of examples in IUCN Red List assessments through the careful inclusion of these 25 diverse threatened species. Ultimately, this research visualises developing modalities and extracting learnings that can serve as models for future multi-criteria assessments from the Western Ghats region. Beyond filling existing data gaps and establishing a benchmark for future reassessments, this study seeks to understand the chances of reversing the 'Red' status for these selected, highly important species of the Western Ghats.

## **3.2. Methodology**

### **3.2.1. Taxonomic Scrutiny and Literature Survey**

Literatures pertinent to the selected 25 species were meticulously examined through a thorough exploration of floristic literatures. Publications encompassing the type specimen, accepted nomenclature, and synonyms of the selected threatened species was validated by referring the Kew Virtual Herbarium and the International Plant Names Index (IPNI). To ensure nomenclatural clarity and accurate identification of the herbarium records under review, the protologues of the original publications for each selected taxon were thoroughly examined. Access to type specimens was secured from Kew Virtual

Herbarium, while original publications were retrieved from various open-access resources, notably the Biodiversity Heritage Library (BHL). The herbarium specimens preserved in various herbaria were referenced and critically analysed to ascertain taxonomic identity, as well as to comprehend the distribution patterns, and phenological characteristics of the taxa. The herbaria that were visited include CALI, KFRI, TBGT, MH and BSI (Fig. 3.1). Information retrieval systems such as the Biodiversity Heritage Library (BHL) (<http://www.biodiversityheritagelibrary.org>), digital libraries such as JSTOR (<https://www.jstor.org>), and online flora databases including E-Flora Kerala (<https://www.eflorakerala.com/>) alongside other virtual herbarium were also referred. The acronyms for the herbaria adhered to the standards set forth in the Index Herbarium (Thiers, 2011). Occurrence data sourced from the Global Biodiversity Information Facility (GBIF) (<https://www.gbif.org/>) were employed to elucidate the actual distribution of the species.

### **3.2.2. Nomenclature and Citations**

Plant citations were followed with the guidelines established by the International Plant Names Index (IPNI). Author names were determined according to the protocols delineated by Brummitt and Powell (1992). Nomenclatural conventions were adhered to as per the Shenzhen Code (Turland et al., 2018). Digital databases such as Plants of the World Online (<http://powo.science.kew.org/>) and The World Flora Online were also referenced (<https://www.worldfloraonline.org/>).

### **3.2.3. Relocating the Species and Specimen Collection**

The selected species were identified through comprehensive and systematic field surveys conducted in suitable habitats within the Western Ghats, from where the species is located. Previously documented localities of the species were traced through diverse literature sources and herbarium specimens archived in both national and international herbaria (Appendix I). Extensive fieldwork was undertaken to gather data on species collection and population estimation. Field visits were primarily conducted during fruiting seasons to acquire both vegetative and floral material. All targeted species were collected in their living state and The GPS (Garmin) coordinates of their locations were noted. Multiple accessions of each species were obtained for study, and various populations of each species were examined to comprehend population related data both within and between species.

Flowering, fruiting phenological characteristics and other notable traits of the collected specimens were recorded in the field book during the fieldwork.

#### **3.2.4. Herbarium Preparation**

Specimens collected from the field, of proper size, were used to prepare herbarium specimens following established conventional methodologies (Bridson & Forman, 1992). The specimens underwent a drying process and were properly affixed to herbarium sheets measuring 28 x 42 cm. Each sheet was accurately labeled with comprehensive information pertaining to the plant. The herbarium specimens were deposited at the herbarium of University of Calicut (CALI).

#### **3.2.5. IUCN Red List Status Assessment using Multiple criteria**

The International Union for Conservation of Nature (IUCN) Red List offers a comprehensive framework for assessing the extinction risk of species globally. The process of assessment encompasses the analysis of the conservation status of species according to established standardised criteria. The IUCN Species Information Service (SIS) serves as the principal database utilised by IUCN to archive and oversee species accounts and assessments intended for dissemination via the IUCN Red List. The evaluation of the threat level for the species has been conducted in accordance with the most recent IUCN guidelines version 16 (IUCN, 2024) and through the application of various IUCN categories and criteria as delineated in version 3.1 second edition (IUCN, 2012). Five quantitative criteria are employed to assess whether a taxon is classified as threatened, and if so, to determine the specific category of threat to which it corresponds Critically Endangered (CR), Endangered (EN), or Vulnerable (VU) (Fig. 3.2). To classify a particular taxon within any of the threat categories, it is sufficient for only one of the criteria A, B, C, D, or E has to be satisfied (Table 3.1).



**Fig. 3.1.** Herbarium Visit: A. Fischer Herbarium, Coimbatore, IFGTB; B. & C. Specimen of *Elaeocarpus recurvatus* - Fischer's herbarium; D & E. Botanical Survey of India, Coimbatore; F. Herbarium of the University of Calicut (CALI); G. Herbarium, Kerala Forest Research Institute.



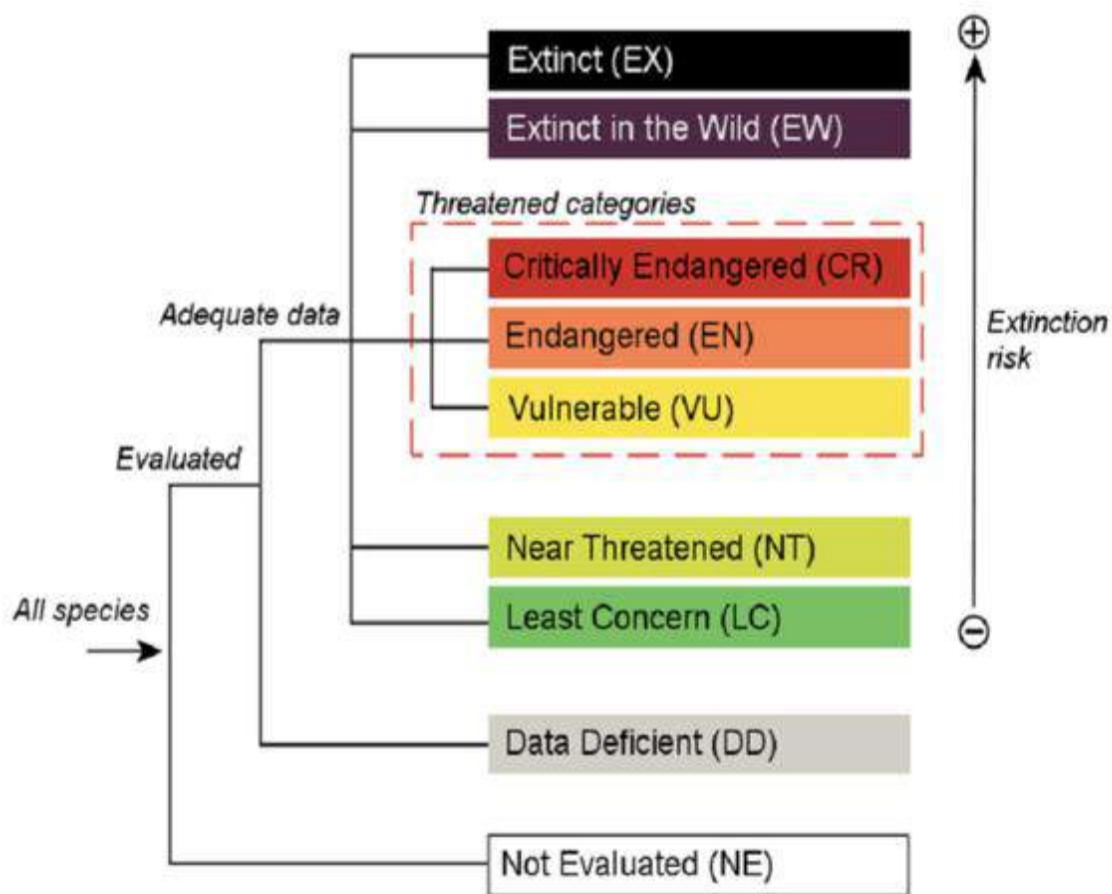


**Fig. 3.2. IUCN Red List Categories (IUCN, 2024)**

The IUCN Red List framework classifies species' extinction risk using five primary criteria (A–E), which are based on quantitative thresholds for specific demographic and geographic parameters (IUCN, 2001; IUCN, 2017). Meeting the threshold of any single criterion is sufficient for a species to be placed into a threatened category. Criterion A assesses the rate of population reduction, both observed and projected, over a specified time period. This can be based on direct observation, indices of abundance, or a decrease in Area of Occupancy (AOO), Extent of Occurrence (EOO), and habitat quality. Criterion B evaluates the species' geographic range and is applied to taxa with a restricted EOO or AOO. This criterion requires a sub-assessment for factors such as severe fragmentation of the population, a small number of locations, or a continuing decline in various ecological metrics. Criterion C focuses on species with small and declining populations, defining thresholds based on the number of mature individuals in conjunction with a projected continuing decline. It also incorporates sub-criteria related to extreme fluctuations and

population structure. Criterion D is reserved for species with very small or restricted populations, setting thresholds for the number of mature individuals or an extremely limited AOO, especially when faced with plausible, imminent threats. Finally, Criterion E provides a pathway for classification through quantitative analysis, such as a Population Viability Analysis (PVA), which estimates the probability of extinction within a specific time frame. This multi-criteria approach ensures that species are assessed comprehensively, moving beyond simple distribution data to include crucial demographic and ecological viability factors.

### **3.2.6. Estimation of AOO and EOO**

The Extent of Occurrence (EOO) constitutes a metric that quantifies the geographical distribution of regions or an imaginary boundary presently inhabited by the taxon. EOO is not designed to serve as an approximation of the quantity of occupied or potential habitat, nor does it function as a comprehensive indicator of the taxon's distribution. The Area of Occupancy (AOO) is a standardised metric that delineates the expanse of suitable habitat that is currently occupied by the taxon. In most instances, 4 km<sup>2</sup> (2 × 2 km) grid cells are advocated as the standard scale for the calculation of AOO (IUCN, 2024). The values pertaining to Area of Occupancy (AOO) and Extent of Occurrence (EOO) were calculated using the online GeoCAT software accessible at <https://geocat.iucnredlist.org>, facilitating the evaluation of the species' spatial distribution. The occurrence points based on preserved specimens and geocodes collected during field work were imported to calculate the EOO and AOO in GeoCAT. The species occurrence data containing geographical locations (latitude and longitude) with CSV data format were prepared for each species based on the field work, herbarium reviews, and other literatures.

SUMMARY OF THE FIVE CRITERIA (A-E) USED TO EVALUATE IF A TAXON BELONGS IN AN IUCN RED LIST THREATENED CATEGORY (CRITICALLY ENDANGERED, ENDANGERED OR VULNERABLE).<sup>1</sup>

| A. Population size reduction. Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4                                                                                                                                                              |                                                                          |                                                                                                 |                                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
|                                                                                                                                                                                                                                                                                                  | Critically Endangered                                                    | Endangered                                                                                      | Vulnerable                                                               |
| A1                                                                                                                                                                                                                                                                                               | ≥ 90%                                                                    | ≥ 70%                                                                                           | ≥ 50%                                                                    |
| A2, A3 & A4                                                                                                                                                                                                                                                                                      | ≥ 80%                                                                    | ≥ 50%                                                                                           | ≥ 30%                                                                    |
| A1 Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible AND understood AND have ceased.                                                                                                                         | based on any of the following:                                           | (a) direct observation [except A3]                                                              |                                                                          |
| A2 Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.                                                                                                             |                                                                          | (b) an index of abundance appropriate to the taxon                                              |                                                                          |
| A3 Population reduction projected, inferred or suspected to be met in the future (up to a maximum of 100 years) [(a) cannot be used for A3].                                                                                                                                                     |                                                                          | (c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality     |                                                                          |
| A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible. |                                                                          | (d) actual or potential levels of exploitation                                                  |                                                                          |
|                                                                                                                                                                                                                                                                                                  |                                                                          | (e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites. |                                                                          |
| B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)                                                                                                                                                                                                |                                                                          |                                                                                                 |                                                                          |
|                                                                                                                                                                                                                                                                                                  | Critically Endangered                                                    | Endangered                                                                                      | Vulnerable                                                               |
| B1. Extent of occurrence (EOO)                                                                                                                                                                                                                                                                   | < 100 km <sup>2</sup>                                                    | < 5,000 km <sup>2</sup>                                                                         | < 20,000 km <sup>2</sup>                                                 |
| B2. Area of occupancy (AOO)                                                                                                                                                                                                                                                                      | < 10 km <sup>2</sup>                                                     | < 500 km <sup>2</sup>                                                                           | < 2,000 km <sup>2</sup>                                                  |
| AND at least 2 of the following 3 conditions:                                                                                                                                                                                                                                                    |                                                                          |                                                                                                 |                                                                          |
| (a) Severely fragmented OR Number of locations                                                                                                                                                                                                                                                   | = 1                                                                      | ≤ 5                                                                                             | ≤ 10                                                                     |
| (b) Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals                                        |                                                                          |                                                                                                 |                                                                          |
| (c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals                                                                                                                             |                                                                          |                                                                                                 |                                                                          |
| C. Small population size and decline                                                                                                                                                                                                                                                             |                                                                          |                                                                                                 |                                                                          |
|                                                                                                                                                                                                                                                                                                  | Critically Endangered                                                    | Endangered                                                                                      | Vulnerable                                                               |
| Number of mature individuals                                                                                                                                                                                                                                                                     | < 250                                                                    | < 2,500                                                                                         | < 10,000                                                                 |
| AND at least one of C1 or C2                                                                                                                                                                                                                                                                     |                                                                          |                                                                                                 |                                                                          |
| C1. An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future):                                                                                                                                                                                    | 25% in 3 years or 1 generation (whichever is longer)                     | 20% in 5 years or 2 generations (whichever is longer)                                           | 10% in 10 years or 3 generations (whichever is longer)                   |
| C2. An observed, estimated, projected or inferred continuing decline AND at least 1 of the following 3 conditions:                                                                                                                                                                               |                                                                          |                                                                                                 |                                                                          |
| (a) (i) Number of mature individuals in each subpopulation                                                                                                                                                                                                                                       | ≤ 50                                                                     | ≤ 250                                                                                           | ≤ 1,000                                                                  |
| (ii) % of mature individuals in one subpopulation =                                                                                                                                                                                                                                              | 90–100%                                                                  | 95–100%                                                                                         | 100%                                                                     |
| (b) Extreme fluctuations in the number of mature individuals                                                                                                                                                                                                                                     |                                                                          |                                                                                                 |                                                                          |
| D. Very small or restricted population                                                                                                                                                                                                                                                           |                                                                          |                                                                                                 |                                                                          |
|                                                                                                                                                                                                                                                                                                  | Critically Endangered                                                    | Endangered                                                                                      | Vulnerable                                                               |
| D. Number of mature individuals                                                                                                                                                                                                                                                                  | < 50                                                                     | < 250                                                                                           | D1. < 1,000                                                              |
| D2. Only applies to the VU category<br>Restricted area of occupancy or number of locations with a plausible future threat that could drive the taxon to CR or EX in a very short time.                                                                                                           | -                                                                        | -                                                                                               | D2. typically:<br>AOO < 20 km <sup>2</sup> or<br>number of locations ≤ 5 |
| E. Quantitative Analysis                                                                                                                                                                                                                                                                         |                                                                          |                                                                                                 |                                                                          |
|                                                                                                                                                                                                                                                                                                  | Critically Endangered                                                    | Endangered                                                                                      | Vulnerable                                                               |
| Indicating the probability of extinction in the wild to be:                                                                                                                                                                                                                                      | ≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.) | ≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)                        | ≥ 10% in 100 years                                                       |

Table 3.1. Summary sheet of IUCN Red List Criteria (IUCN, 2024)

The data concerning species occurrences was systematically uploaded into the GeoCAT platform. GeoCAT employed advanced computational geometry algorithms, including Quick Hull and Graham's Scan, to determine the convex hull. These algorithms proficiently identified the most minimal boundary that encapsulated all occurrence points, thereby ensuring a reduced risk of overestimating the species' geographic range (Bachman et al., 2011; Joppa et al., 2016). GeoCAT superimposed a grid of predetermined dimensions onto the area of species occurrence. The cumulative number of occupied grid cells was multiplied by the area of each individual grid cell (4 km<sup>2</sup> for a 2x2 km grid) in order to derive the Area of Occupancy (AOO). The findings were generally expressed in square kilometers (km<sup>2</sup>). The AOO was represented as the aggregate area encompassed by the occupied grid cells. GeoCAT offered tools to facilitate the visualization of the grid overlay along with the occupied cells, thereby enabling users to assess the precision of the calculation (Bachman et al., 2011). Grid cells that exhibited no species presence or were located outside the species' designated suitable habitat were omitted from the final count.

### **3.2.7. The Population Data**

The number of mature individuals or number of mature individuals estimated based on phytosociological sampling of entire population or at least one sub population or the largest sub population is basic requirement for inclusion of population data in the IUCN Red list Assessments. These data were derived from field level phytosociological sampling and enumeration (0.1 ha plots) conducted for each species during relocation of the species and habitat assessment for its associated species, structure and composition to understand the Eltonian niche factors and which is explained in details in the Chapter V. Population data from previous our own studies and of the others if suitable for standardization into the total population data or any single sub population were also used in the IUCN Red list assessments.

The available historical and current data regarding the species population were used to understand population decline along with studies on habitat degradation. The information regarding population decline was derived either from direct observations made during the field investigation or extracted from previously published documentation found in scholarly literature and herbarium collections, with the goal of assessing the rate of population decline over a specified temporal interval. Data concerning the total number of mature individuals documented at each locality, as well as the cumulative localities of

occurrence, were gathered during field surveys, which served as the foundation for calculating the total number of existing mature individuals.

### **3.2.7. Habitat and Ecology, Threats, Use and Trade Information and Conservation Actions**

Information concerning habitat degradation, fragmentation, and destruction was collected during field excursions to various localities. This information was subsequently employed to establish the threat status based on the characteristics of the habitat. Understanding of a species' habitat and ecology, its threat environment, patterns of use and trade, and existing or required conservation actions is essential for informed biodiversity management and effective Red List assessments. In the complex and topographically diverse landscapes of the Western Ghats face major threats like habitat loss due to deforestation, infrastructure development, agricultural expansion, fire regimes, invasive species, and climate change (Nair et al., 2015; Das et al., 2020).

## **3.3. Results**

### **3.3.1. *Aglaia malabarica* Sasidh.** In Kew Bull., Addit. Ser. 16: 369 (1992)

**Synonyms:** No Synonyms

**Vernacular Name:** Chuvanna Cheeralam, Chuvannakil (Malayalam)

**Family:** Meliaceae

**Identifying Features:** A polygamo dioecious tree reaching up to 25 m height, characterised by smooth, brown bark and imparipinnate leaves with 10-19 pairs of lateral nerves. Its flowers are yellow, and its fruit is an obovoid or subglobose capsule (3.5-4.5 x 2.7-4 cm) featuring numerous irregular longitudinal ridges, dense peltate scales, and a granular pericarp. The capsule contains 1-3 seeds, each 1.7-2.5 x 1-1.5 cm, which are entirely encased in a thin, pale pink, translucent aril (Fig. 3.4).

**Flowering and Fruiting:** December – July

### **IUCN Status Assessment**

The first IUCN Red list assessment was done for the species during 1998 and it was considered Critically Endangered based on Criteria D showing the number of mature individuals less than 50 (Pannell, 1998). This was recently assessed and updated as Endangered (Deepu et al., 2023) based on three number of locations under criteria B1ab

(ii,iii) + 2ab (ii,iii). The present study identified five locations for the species based on 10 collection records.

### Distribution

According to the present study, *Aglaia malabarica* found to occur in five locations of Kerala part of the Western Ghats, enumerated from 10 preserved specimen records. The estimated AOO of the species is 40 km<sup>2</sup>, EOO is 6524 km<sup>2</sup> (Fig. 3.3).

### Population

The species was reported first time with few individuals from Vellkettupara, Peechi, Kerala India (Sasidharan, 1992). According to the recent IUCN assessment (Deepu et al., 2023), the estimated number of mature individuals within the population is between 300 and 1,000 in their natural habitat. A diminution in population size has been observed, attributed to a decrease in both the area of occupancy and the quality of habitat over time, a trend that is anticipated to persist. The species exhibits a comparatively low rate of regeneration.

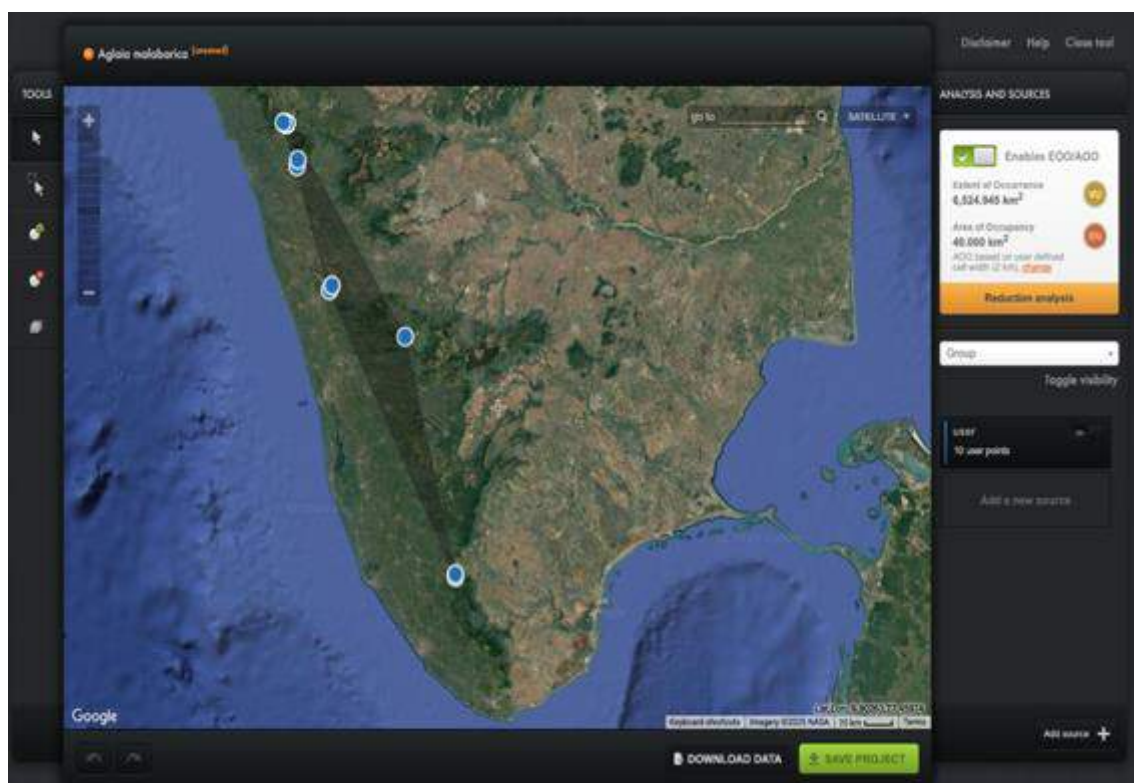


**Fig. 3.3. Calculated AOO and EOO using GeoCAT for *Aglaia malabarica***

The present study estimated the species density at 0.13 individuals per hectare within the area of occupancy, based on sampling from three subpopulations. While the current IUCN

assessment (Deepu et al., 2023) indicates the species is known from three subpopulations, this study expands its known distribution to five subpopulations. Based on the calculated density and an updated Area of Occupancy (AOO) of 40 km<sup>2</sup> the total mature population for the species is estimated to be between 520 and 700 individuals. The largest single subpopulation is estimated to be at Kakkadampoyil, containing approximately 100 mature individuals. Other important subpopulations are located in Wayanad, Shendurney, Peechi, and Shekklumudi.

### **Habitat and Ecology**

This is a tree species about 25 m high occurs in evergreen forests. The phenological events of flowering and fruiting for this species have been documented from November - July (Deepu et al., 2023). According to the present study *Aglaia malabarica* is a medium elevation evergreen tree species seen associated with *Cryptocarya lawsonii*, *Calophyllum polyanthum*, *Cullenia exarillata*, *Litsea floribunda*, *Mesua ferea* etc.

### **Threats**

The species is subjected to various threats including habitat loss, recalcitrant seed characteristics, seed infestation, and inadequate regeneration. Additionally, timber extraction activities conducted by local people also poses a threat to this species (Deepu et al., 2023). The present study points out factors contributing to its vulnerability include dams and reservoirs, monoculture plantations, habitat loss and fragmentation due to human activities. Its narrow geographic range and specific habitat requirements make it particularly susceptible to environmental changes.

### **Use and Trade**

Other than timber extraction, no other applications or uses have been documented.

### **Conservation Actions**

This species is found within protected regions of the Western Ghats and is represented in multiple ex situ conservation collections. A comprehensive investigation is required to gain insights into the population trends of this species (Deepu et al., 2023). The present study confirms that Three of the five subpopulations are found in Protected Areas such as the Peechi Wildlife Sanctuary, Shendurney Wildlife Sanctuary and Parambikulam Tiger Reserve in Kerala. Conversely, the largest subpopulations at Kakkadampoyil and Wayanad need to be given more conservation effort.



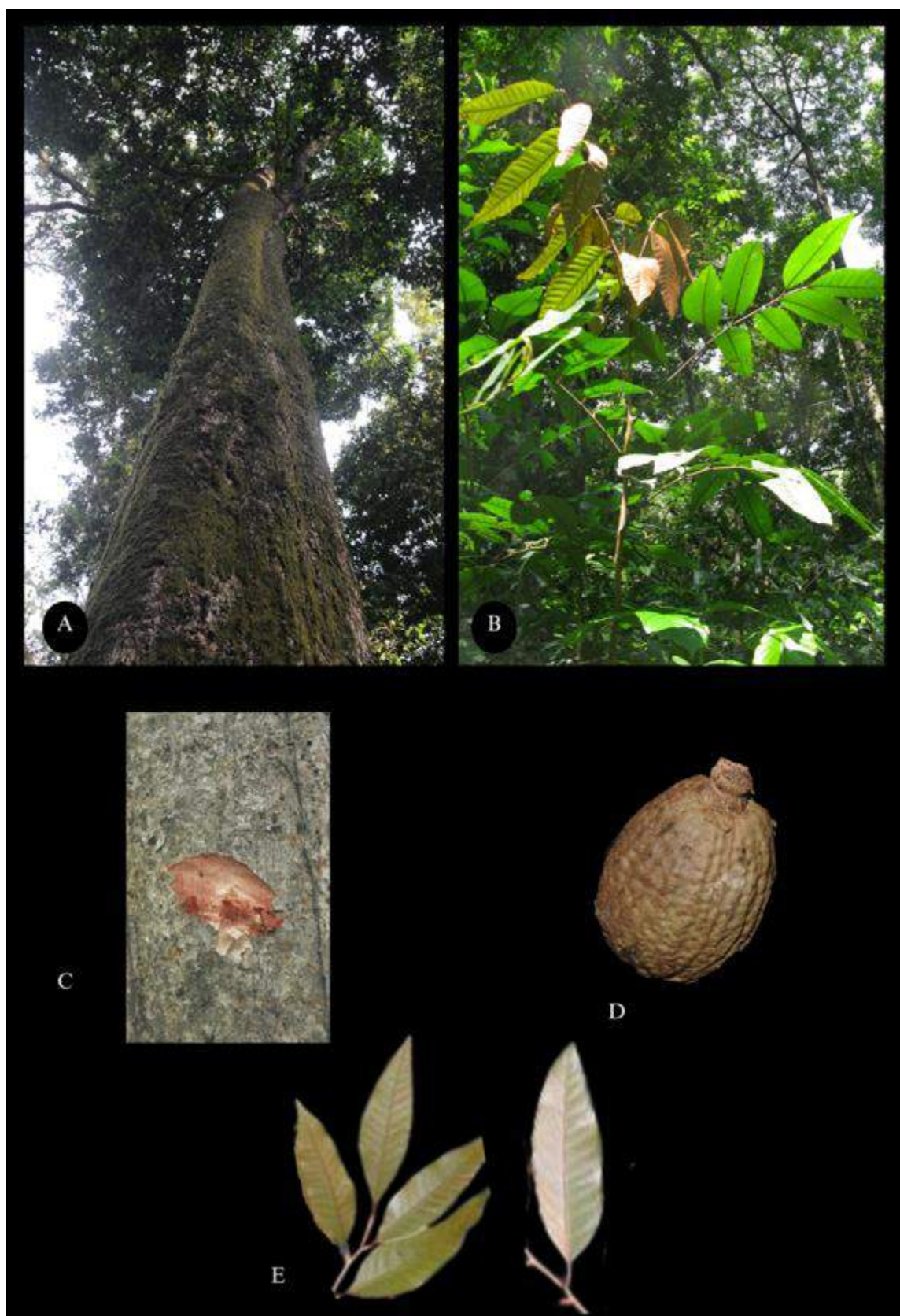


**Fig. 3.4.** *Aglaia malabarica* Sasidh.: A. Habit; B. Sapling; C. Bark; D. Fruit; E. Leaf abaxial side.



**Assessment Rationale in IUCN Red List**

“*Aglaiia malabarica* is endemic to the Western Ghats in India, confined to the state of Kerala. This is a tree species about 25 m high, found to be growing in medium elevation evergreen forests with a dense growth of upper stratum trees. The species is known from three locations. The species is expected to have less than 1,000 mature individuals. The species is expected to have undergone habitat fragmentation over the past. This species has an Extent of Occurrence (EOO) of 2,239.172 km<sup>2</sup> and a relatively small Area of Occupancy (AOO of 24 km<sup>2</sup>). The AOO is based on collections only, and this species is likely to be under collected. However, given our present knowledge about this species, the AOO is unlikely to exceed 500 km<sup>2</sup>. Given that the species has a continuing decline in the population size due to its habitat specificity, threats to the habitats and poor regeneration, the species is assessed as Endangered” (Deepu et al., 2023).

**Discussion - Proposed Amendment to the IUCN Assessment Rationale**

*Aglaiia malabarica* is a medium elevation evergreen tree grows up to 25 m height. The species is reported only from five locations and is restricted to the Kerala part of Western Ghats, South-West India. The estimated EOO is 6524 km<sup>2</sup> and AOO is 40 km<sup>2</sup>. The estimated number of mature individuals of the species 520-700 based on systematic sampling of three populations and the largest population is the Kakkadumpoyil and Wayanad. The habitat of species has been subjected to habitat fragmentation, selection felling of the old growth trees, habitat conversion for monoculture forest plantations, tea plantations, dams and reservoirs. The associated species include *Cryptocarya lawsonii*, *Cullenia excerillta*, *Palaquium ellipticum*, *Calophyllum polyanthum* etc. Three of the five subpopulations are seen in PAs. The regeneration of the species is very low and hence the species is assessed here as Endangered.

**3.3.2. *Aporosa bourdillonii* Stapf** in Hooker's Icon. Pl. 23: t. 2204 (1892).

**Synonyms:** No Synonyms

**Vernacular Name:** Malamvetti (Malayalam)

**Family:** Phyllanthaceae

**Identifying Features:** This species is a shrub or a small tree with pubescent branchlets. The leaves are oblong in shape and can grow up to 18 cm long and 6 cm wide. The leaf

tips are caudate acuminate, meaning they taper to a long, tail-like point, while the base is rounded or obtuse. The upper surface of the leaves is glabrous and the lower surface is tomentose along the midrib. Male inflorescence 1.5 cm long with densely tomentose bract. Female flowers in axillary catkins, bracteate similar as in male flowers. Stamens 3. The fruit is a tomentose capsule, which is ovoid in shape and can grow up to 2 cm long. It is beaked and ridged, with a persistent, 6-lobed stigma at the top. The species can be identified from its allies with the oblong acuminate leaf and the tomentose beaked capsule (Fig. 3.6).

**Flowering and Fruiting:** March – April

#### **IUCN Status Assessment**

The first IUCN Red List assessment for the species was conducted in 1998, categorizing it as Endangered (EN) based on Criteria B1+2c (World Conservation Monitoring Centre, 1998). A later assessment, published in 2018, was an amended version of the 1998 finding, resulting in no change in category or criteria. More recently, in 2021, *Aporosa bourdillonii* was reassessed as Endangered (EN) under the criteria B1ab(iii,v)+2ab(iii,v); C2a(i); and D. This assessment estimated the Area of Occupancy (AOO) at 32 km<sup>2</sup>, the Extent of Occurrence (EOO) at 3,573 km<sup>2</sup>, and identified five locations (Deepu et al., 2023). The present study, based on 25 collection records, identified 12 locations for the species, with a corresponding change in AOO to 76 km<sup>2</sup> and EOO to 9,364 km<sup>2</sup>. The present study propose amendment to the IUCN assessment rationale based on it increase in AOO, EOO and detailed population estimation.

#### **Distribution**

The species is endemic to Kerala part of the Western Ghats. *Aporosa bourdillonii* found to occur in 12 locations enumerated from 25 occurrence records. The estimated AOO of the species is 76 km<sup>2</sup>, EOO is 9,364 km<sup>2</sup> (Fig. 3.5).

#### **Population**

The recent IUCN Assessment for the species (Deepu et al., 2023) indicated that the species was reported from five locations, with a total of 500 mature individuals and each subpopulation comprising fewer than 50 mature individuals. The present study, based on a detailed review of collections and extensive fieldwork, indicates there are 25 collection records from 12 subpopulations of *Aporosa bourdillonii* since the collection of the Holotype by Bourdillon in 1925.

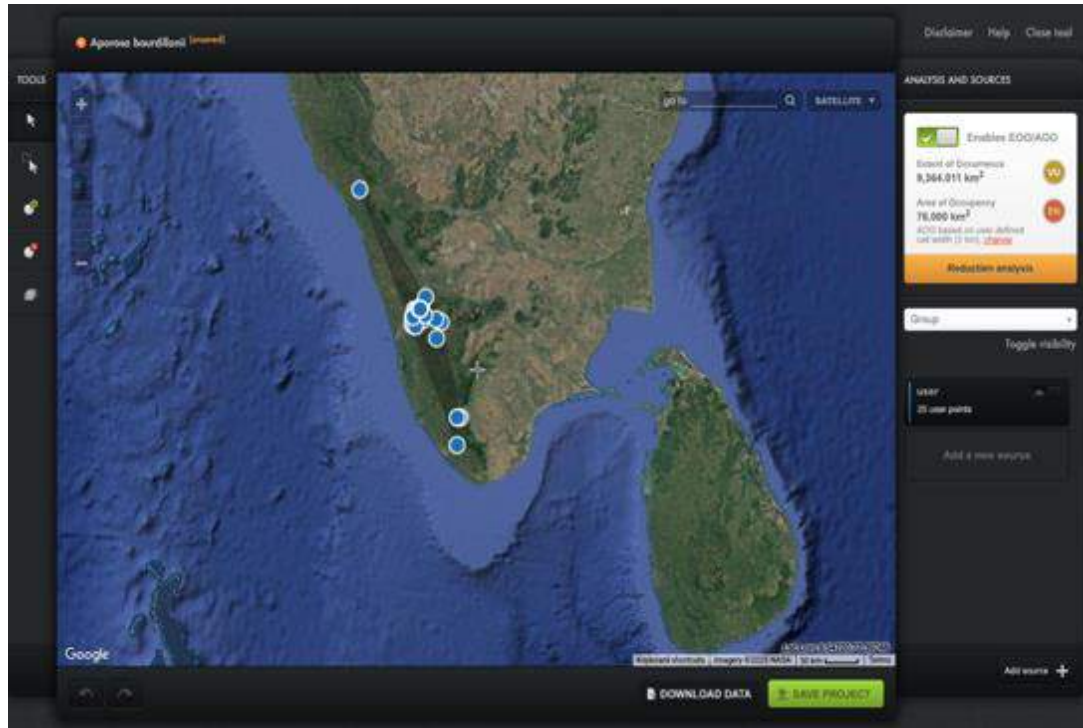


**Fig. 3.5. Calculated AOO and EOO using GeoCAT for *Aporosa bourdillonii***

The current authors' collections since 2010 contribute seven herbarium records from different locations. The majority of these records are from riparian forests or streamsides, confirming the species' identification as an important component of low-elevation riparian forests (Bachan, 2020; Bachan et al., 2022). The study enumerated a density of 0.35 individuals per hectare, and while the average number of mature individuals in one subpopulation is less than 100, the population in the largest subpopulation the riparian forest of Vazhachal is approximately 160 (Bachan, 2010; Bachan et al., 2022). The Area of Occupancy (AOO) estimated for the species is 76 km<sup>2</sup>, which leads to an estimated total population size of 1,260 mature individuals.

### **Habitat and Ecology**

This species manifests as an understorey tree, reaching heights of approximately 8 m. It predominantly inhabits evergreen and semi-evergreen forest ecosystems, primarily located in proximity to watercourses (Deepu et al., 2023). Detailed research on the species and its riparian habitat indicated that it is an important component of the streamside vegetation in low- to medium-elevation tropical riparian evergreen forests (Bachan, 2010; Bachan et al., 2022).

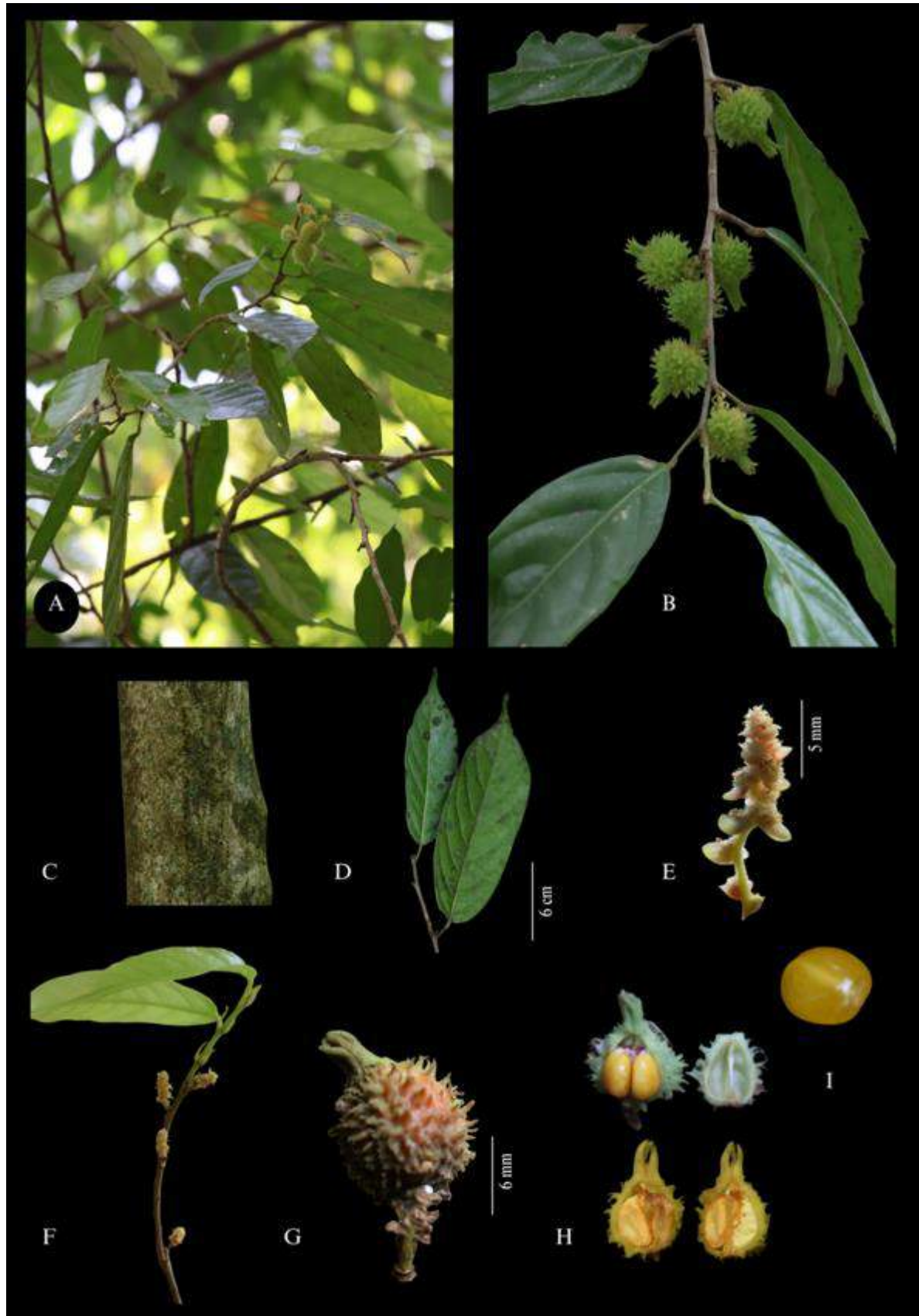


**Fig. 3.6.** *Aporosa bourdillonii* Stapf.: A. Habit; B. Fruiting twig; C. Bark; D. Leaf abaxial side; E. Inflorescence; F. Flowering twig; G. Fruit; H. Fruit LS; I. Seed with the pulp.

### Threats

The habitat extent of this species has been adversely affected by historical alterations in land-use patterns. Additionally, the species has been observed to exhibit diminished reproductive success in its natural habitat (Rakesh et al., 2018). There has been a significant reduction in the population in the past, chiefly due to alterations in riparian habitats. Furthermore, 84% degradation of the low-elevation riparian forests and a significant decline in its largest subpopulation are reported (Bachan et al., 2022). Compounding these issues, climate change-induced floods in 2018 and 2019 caused serious damage to the existing population (Bachan et al., 2019).

### Use and Trade

There is an absence of documented use and trade information pertaining to this species. However, the fruits of related species are deemed edible and are utilised in the production of black dye (Deepu et al., 2023).

### Conservation Actions

The present study's confirmation of the species' dependence on riparian habitats, combined with the documented 84% degradation of low-elevation riparian forests and the recurrent threat from climate change-induced floods (Bachan et al., 2022; Bachan et al., 2019), necessitates a dual-strategy conservation approach. It is recommended that the 12 confirmed subpopulations of *Aporosa bourdillonii*, which vastly expands upon previous estimates (Deepu et al., 2023), be formally designated and protected as Key Biodiversity Areas (KBAs) to mitigate the ongoing threat from land-use change. Furthermore, given the observed diminished reproductive success in its natural environment (Rakesh et al., 2018), urgent ex situ conservation programs focused on large-scale seed collection and propagation, must be implemented to safeguard the species' genetic viability against future catastrophic loss, particularly at the largest known population site in Vazhachal (Bachan et al., 2022).

### Assessment Rationale in the Present IUCN Red List

“*Aporosa bourdillonii* is endemic to the Western Ghats in India. This is an understorey tree species about 8 m high. It grows in the evergreen forests, and is mainly confined to the river courses, and is known from five locations. Considering the present distribution of the species and the magnitude of land conversion that has happened over the past, it is expected to have undergone habitat fragmentation. This species has an extent of occurrence

(EOO) of 3,573.524 km<sup>2</sup> and a relatively small area of occupancy (AOO of 32 km<sup>2</sup>). The AOO is based on collections only, and this species is likely to be under collected. However, given our present knowledge about this species, the AOO is unlikely to exceed 500 km<sup>2</sup>. The species is currently known from limited locations and has a continuing decline in the population size due to a reduction in the quality of habitat. It is expected to have less than 500 mature individuals with less than 50 mature individuals per subpopulation; it is assessed as Endangered” (Deepu et al., 2023).

### **Discussion - Proposed Amendment to the IUCN Assessment Rationale**

The species *Aporosa bourdillonii* is an understorey tree endemic to the Kerala part of the Western Ghats, ecologically confined to riparian and streamside zones of low-to-medium elevation evergreen forests (Bachan, 2010; Bachan et al., 2022). The present study necessitates a revision of its IUCN status from Endangered (EN) to Vulnerable (VU). This is because the confirmed distribution has been significantly expanded to 12 subpopulations based on 25 collection records, resulting in a revised Area of Occupancy (AOO) of 76 km<sup>2</sup> and a resulting estimated total mature population of 1,260 individuals. However, it qualifies as Vulnerable (VU) under multiple criteria due to its narrow habitat range and extreme vulnerability to threats. The species meets criteria B2ab(iii, v) because the AOO is restricted, and there is a continuing decline in habitat quality and mature individuals, evidenced by the 84% degradation of its riparian habitat (Bachan et al., 2022). Crucially, the species meets criteria A2c, d because it has undergone a past population reduction due to habitat alteration, including submergence due to dams (Bachan & Devika, 2020), and faces recurrent, severe damage from climate change-induced floods (Bachan et al., 2019). This ongoing vulnerability is compounded by observed diminished reproductive success in the wild (Rakesh et al., 2018), further supporting its categorization as Vulnerable (VU) under criterion C2a(i).

### **3.3.3. *Cryptocarya anamalayana* Gamble Bull. Misc. Inform. Kew 1925: 126 (1925)**

**Synonyms:** No Synonyms

**Vernacular Name:** Vatilavinayali chevukodi (Malayalam)

**Family:** Lauraceae

**Identifying Features:** A bisexual evergreen tree, up to 8 m tall, with tomentose young shoots and leaves. The leaves have 6-10 pairs of lateral nerves and fulvous tomentose nerves and nervules on the underside. The fruit is a sparsely pubescent berry, oblongoid to slightly oblong-obovoid (2.5-4.0 x 0.8-1.3 cm), with 10-12 longitudinal ribs. The berries are light to bright green when young and ripen to a glossy black, and are borne on 2-4 mm long velutinous-tomentose fruiting pedicels. The tree produces a solitary, oblanceoloid seed (Fig. 3.8).

**Flowering and Fruiting:** April – August

#### **IUCN Status Assessment**

The first IUCN Red List assessment for the species, conducted in 1998, categorised it as Endangered (EN) based on Criteria B1+2c. More recently, the status was re-assessed and published in 2021 by (de Kok, & Bachan, 2021), retaining the Endangered (EN) category based on five locations under Criteria B1ab(iii)+2ab(iii). The present study, utilizing 13 occurrence records, within the identified five locations for the species. However, the calculation of the spatial metrics resulted in a change: the Area of Occupancy (AOO) was determined to be 48 km<sup>2</sup>, and the Extent of Occurrence (EOO) was 5,324 km<sup>2</sup>.

#### **Distribution**

The species is distributed in Kerala and Tamil Nadu part of South India, with an estimated AOO 48 km<sup>2</sup> and EOO 5324 km<sup>2</sup> (Fig. 3.7).

#### **Population**

Research has demonstrated that this species exists at extremely low population densities. An investigation into population metrics carried out at two distinct sites indicated an average mature tree density of 0.012 individuals per hectare (Bachan & Devika, 2021). Furthermore, the density of saplings was found to be merely 0.001 individuals per hectare (Bachan & Devika, 2021), suggesting poor regeneration. The density estimated through systematic sampling across the entire forest area was even lower, recorded as 0.00001 individuals per hectare (Bachan et al., 2019). Considering this extremely low density and the Area of Occupancy (AOO), the present study estimates the number of mature individuals of the species to be less than 200 individuals.



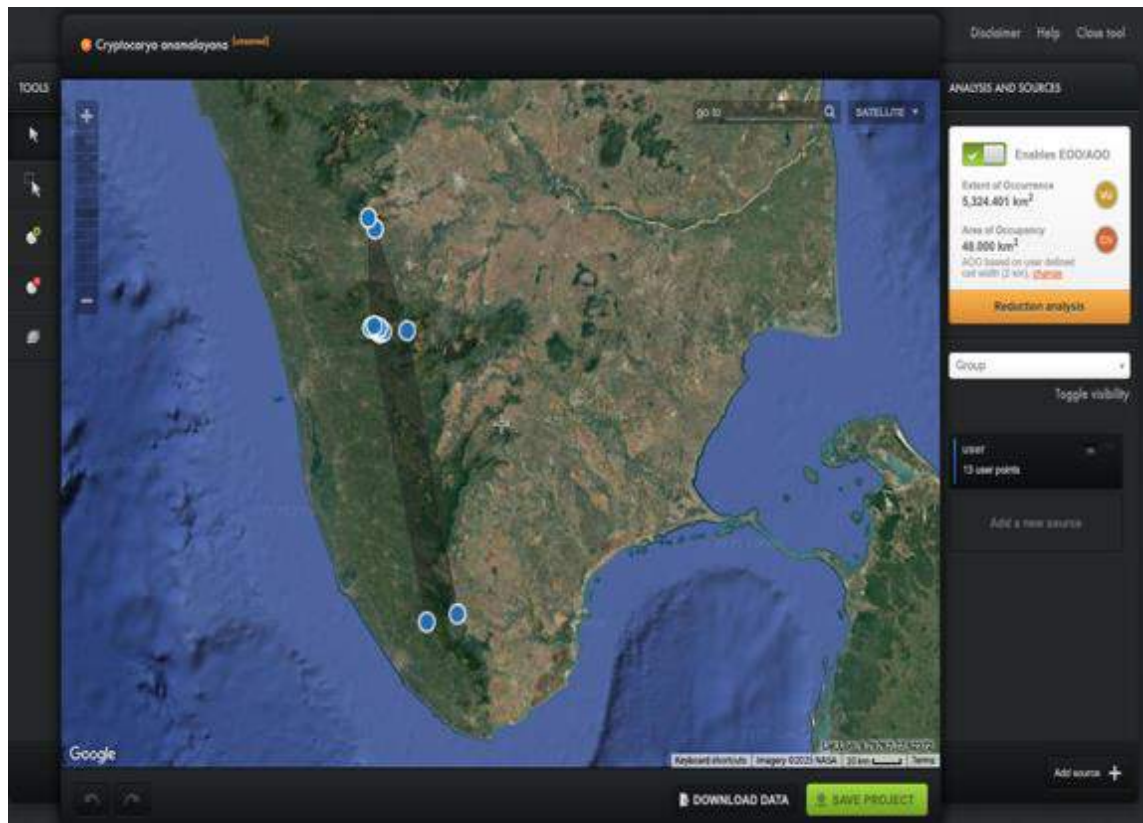


**Fig. 3.7.** Calculated AOO and EOO using GeoCAT for *Cryptocarya anamalayana*

### Habitat and Ecology

*Cryptocarya anamalayana* is a tree species that ranges in height from 3 to 16 m. It is confined to evergreen and montane wet forests, typically found on hill slopes at altitudes varying between 600 m and 1,200 m. Its flowering and fruiting period extends from April to August. The species exists at extremely low population densities, and research highlights its poor natural regeneration (Bachan & Devika, 2021). The precise ecological requirements and low recruitment rate make the species highly vulnerable to habitat degradation. Important associated species are *Cullenia exarillata*, *Elaeocarpus tuberculatus*, *Palaguium ellipticum*, *Vateria indica*, *Litsea floribunda*, *Antidesma montana*, *Turpina malabarica*.





**Fig. 3.8.** *Cryptocarya anamalayana* Gamble: A. Habit; B. Twig; C. Bark; D. Leaf abaxial side; E. Flowering twig; F. Young leaves; G. Flower; H. Fruit.

### **Threats**

The primary threats confronting *Cryptocarya anamalayana* are driven by habitat loss and degradation, which directly contribute to its extremely low population density and poor regeneration success. Deforestation and habitat fragmentation resulting from agricultural conversion and the establishment of monoculture plantations are the main historical and ongoing drivers of decline. Crucially, the presence of reservoirs for hydroelectric projects (Sholayar and Kallada Reservoir) at two of its five known localities is causing ongoing reduction and inundation of habitat, leading to a continuous decline in the Area of Occupancy (AOO) and habitat quality. Furthermore, the species' naturally low population density and severely poor sapling recruitment (Bachan & Devika, 2021) mean that even minor habitat disturbance can lead to localised extirpation and impede natural recovery.

### **Use and Trade**

Currently, there exists a lack of information regarding the utilization or trade of this species.

### **Conservation Actions**

Conservation efforts for the Endangered (EN) *Cryptocarya anamalayana*, which is confirmed to exist in only five severely threatened locations with fewer than 200 mature individuals, must focus on three simultaneous actions. Strict protection and the establishment of regulatory buffer zones are immediately required for all five known occurrence sites, particularly to mitigate the continuous habitat degradation caused by agricultural expansion, deforestation, and the ongoing inundation effects from nearby hydroelectric reservoirs like Sholayar and Kallada. Given the species' extremely low mature tree density and severely diminished reproductive success (Bachan & Devika, 2021). The conservation plan for the species is incorporated in the Working Plan of the Vazhachal Forest Division, in its largest sub population (Bachan et al., 2019; Rajesh et al., 2018). the highest priority should be placed on establishing a genetic safeguard ex situ program through urgent seed collection, as the species is currently unrepresented in any ex-situ collections (BGCI, 2019); these collected seeds must then support targeted in situ habitat restoration trials to actively supplement the critically low natural recruitment rates.

### **Assessment Rationale**

“This tree species is only known from five scattered localities in Kerala & Tamil Nadu in southern India. It grows in evergreen and montane wet forest on hill slopes between 600–

1,200 m altitude. These forests are under threat of deforestation and habitat destruction. This species has a relatively small extent of occurrence (EOO of 4,026 km<sup>2</sup>) and a small area of occupancy (AOO of 24 km<sup>2</sup>). The AOO is based on collections only and this species is likely to be under collected. However, given our present knowledge about this species, the AOO is unlikely to exceed 500 km<sup>2</sup>. Given that it is only known from five locations (two in a protected area), that it has a small AOO, and the threats to its habitat, it is considered as Endangered” (de Kok & Bachan, 2021).

### **Discussion – Assessment Rationale**

The species *Cryptocarya anamalayana* is an evergreen tree (3–16 m tall) endemic to the evergreen and montane wet forests on hill slopes (600 m to 1,200 m) in the Kerala and Tamil Nadu parts of the Western Ghats. The current assessment retains the Endangered (EN) status, justified under criteria B2ab(iii, v) + C2a(i), despite the AOO of 48 km<sup>2</sup> matching the previous assessment and its occurrence being confirmed across five locations (13 collection records). The EN classification is driven by the combined evidence of a restricted range and a critically small, declining population: the AOO is below the 500 km<sup>2</sup> threshold and is experiencing a continuing decline in habitat quality (iii) due to deforestation and, critically, a continuing decline in the area and extent of habitat (v) caused by the ongoing inundation effects of hydroelectric reservoirs (Sholayar and Kallada). This habitat loss directly impacts its critically small mature population, estimated at fewer than 200 individuals (VU D1 threshold is <1,000), which meets the EN C2a(i) criterion. The decline is further compounded by the species' extremely poor natural regeneration (sapling density is 0.001 individuals/ha) and diminished reproductive success (Bachan & Devika, 2021), confirming the population's high vulnerability to extinction.

**3.3.4. *Cryptocarya lawsonii*** Gamble Bull. Misc. Inform. Kew 1925(3): 127 (1925).

**Synonyms:** *Cryptocarya sheikelmudiyana* A.K.H.Bachan & P.K.Fasila in Taiwania 65: 266 (2020)

**Vernacular Name:** Chembalamaram (Malayalam)

**Family:** Lauraceae

**Identifying Features:** Evergreen tree with lenticellate branchlets and oblong-lanceolate leaves that are 7-16 cm long and 2.5-6 cm wide. The leaves have an acute or acuminate

apex, a rounded or acute base, and are glabrous and shiny on the upper side, while being white-glaucous underneath with obliquely curved lateral nerves. Fulvous-pubescent panicle up to 9 cm long, and its flowers have stamens of the first row with produced connectives. The fruit is an oblong, furrowed, and often lenticellate berry measuring 1-3.5 cm long and 0.5-2 cm wide (Fig. 3.9).

**Flowering and Fruiting:** April – June

### **IUCN Status Assessment**

The present study identified 13 locations for the species based on 42 occurrence records. The Vulnerable (VU) C2a(i) status is the first-ever IUCN assessment for the species (Bachan & Devika, 2023), made possible entirely by the 42 occurrence records from 13 locations contributed by the present study (Fig. 3.10).

### **Distribution**

The species' distribution spans the southern Western Ghats, being confirmed across the states of Kerala, Tamil Nadu, Karnataka, and Maharashtra, based on the 13 identified locations. The calculated AOO (128 km<sup>2</sup>) and EOO (70,181 km<sup>2</sup>) highlight that while the species is geographically widespread, its actual occupied area is highly restricted (Fig. 3.10).

### **Population**

The species is found across 13 distinct, fragmented subpopulations throughout the four states, based on 43 collection records (Tamil Nadu 20, Kerala 15, Maharashtra 5 and Karnataka 2). The density estimated for the species is 0.50 per ha in its habitat and the total population estimated based on the present AOO 6500-10000, hence the total population is estimated at fewer than 10,000 mature individuals, with no single subpopulation exceeding 1,000 mature individuals, a critical condition for the Vulnerable (VU) C2a(i) classification. This population size is further subject to a persistent, documented decline caused by habitat conversion for agro-industrial plantations and infrastructure advancement.

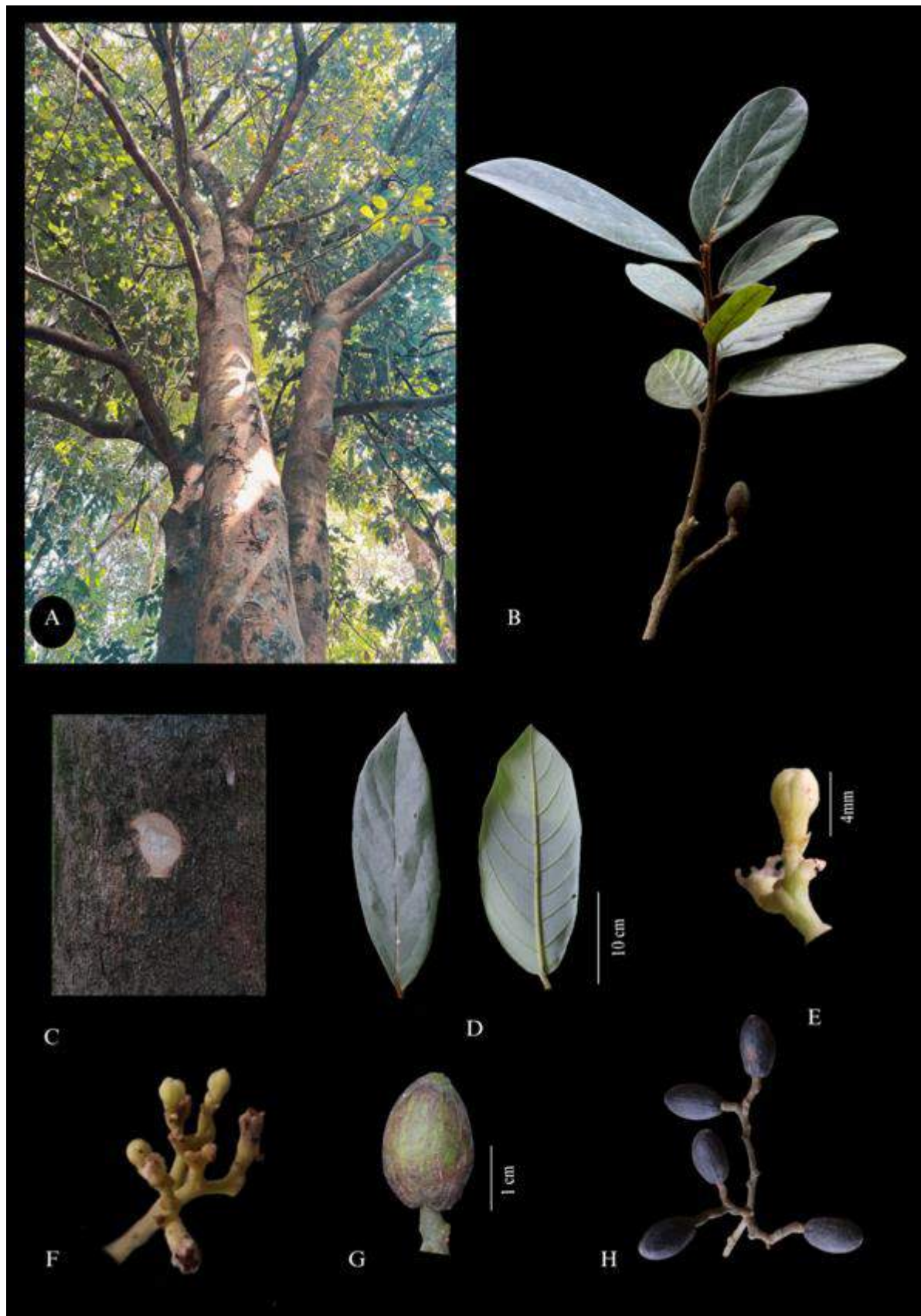


**Fig. 3.9.** *Cryptocarya lawsonii* Gamble: A. Habit; B. Fruiting twig; C. Bark; D. Leaf; E. Flower; F. Flower bud; G. Immature fruit; H. Mature fruit.



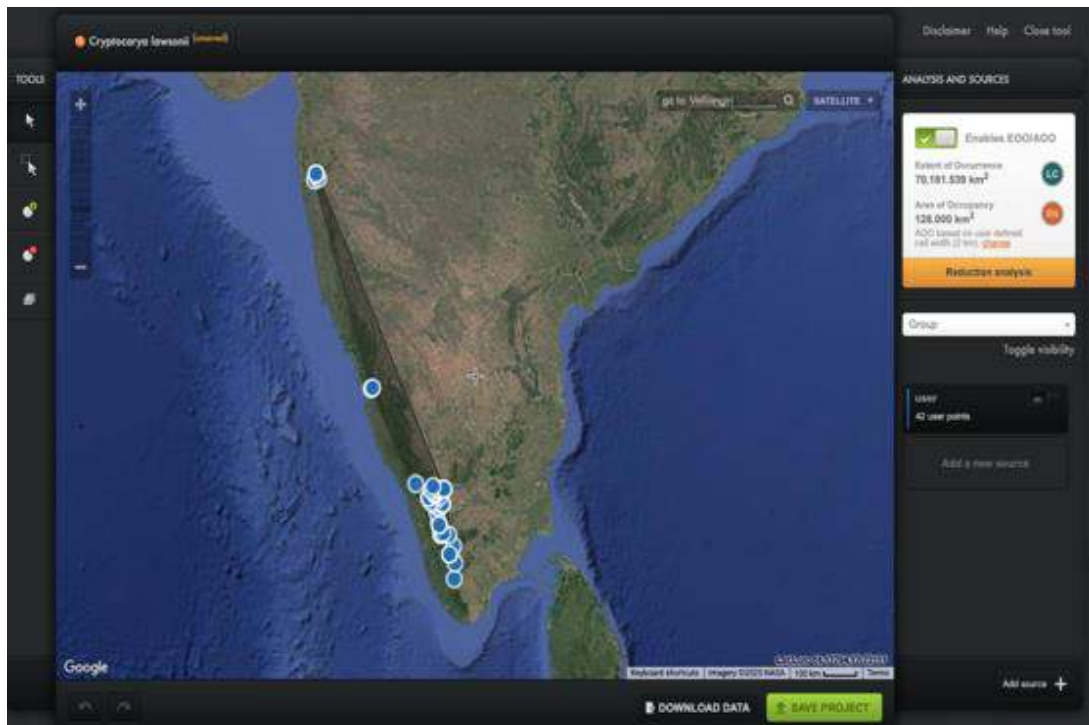


Fig. 3.10. Calculated AOO and EOO using GeoCAT for *Cryptocarya lawsonii*

### Habitat and Ecology

This medium-to-tall tree (15 to 20 m) is characteristic of medium to high-elevation sub montane ecosystems, thriving within evergreen and sub montane shola forests between 1,000 m and 2,100 m. The remaining habitat is severely fragmented across its range. The habitat is fragmented, and the associated flora includes *Heritiera papilio*, *Mesua ferrea*, *Cullinea exarillata*, *Calophyllum polyanthum*, *Litsea species* and *Aglaia spp.*

### Threats

The predominant threats are deforestation and severe habitat degradation, primarily driven by the conversion of montane evergreen forests for agro-industrial plantations (e.g., tea and coffee), alongside infrastructure advancement. This conversion directly impacts the remaining subpopulations, causing the documented, persistent decline in the number and quality of mature individuals.

### Use and Trade

Currently, there exists a lack of information regarding the utilization or commercial trade of this species.

### Conservation Actions

While three of the 13 locations are situated within Protected Areas (PAs), the effectiveness of this protection is severely compromised by historical habitat conversion for tea and coffee cultivation within those boundaries. Therefore, the species requires immediate in situ monitoring and habitat restoration within the PAs. Furthermore, the species is not represented in any ex situ conservation collections (BGCI, 2019), necessitating urgent seed collection to safeguard its genetic viability.

### Assessment Rationale

“*Cryptocarya lawsonii* is characterized as a medium-sized tree found in mid-elevation to montane evergreen forests (1,000–2,100 m) across 13 locations within the southern Western Ghats of India. The extent of occurrence (EOO) for this species is recorded at 70181 km<sup>2</sup>, with the area of occupancy (AOO) at 128 km<sup>2</sup>. Among the 13 locations, three are situated within protected areas, although the habitat has been converted for tea and coffee cultivation. There has been a significant decline in both the area and quality of the habitat, with ongoing threats present. The population of mature individuals is presumed to be decreasing. The total population size is estimated at fewer than 10,000 mature individuals, with less than 1,000 mature individuals per subpopulation. Consequently, the species is classified as Vulnerable (VU)”.

### Discussion

The Vulnerable (VU) status for *Cryptocarya lawsonii* is robustly justified under criteria C2a(i), based on the 42 occurrence records across 13 locations contributed by this study. While the Area of Occupancy (AOO) is restricted to 128 km<sup>2</sup>, the classification stems from the critical population structure: the total mature population is estimated to be between 6,500 and maximum of 10,000 individuals, with no single subpopulation exceeding 1,000 mature individuals. This population, which exhibits a density of 0.50 individuals per hectare, based on the study is further subject to a persistent, documented decline caused by extensive habitat fragmentation and degradation in its montane forests due to conversion for agro-industrial plantations and infrastructure advancement.

**3.3.5. *Diospyros crumenata* Thwaites** Enum. Pl. Zeyl. 179 (1860).**Synonyms:** No Synonyms**Vernacular Name:** Karimbudan (Malayalam); Kanthumari, Karithumari (Kannada)**Family:** Ebenaceae

**Identifying Features:** A dioecious, medium-sized to large arboreal species of the evergreen canopy with a black bark and a fruit with a distinctive enlarged and woody persistent calyx and a fruit with a distinctive enlarged and woody persistent calyx. It features simple, alternate leaves. It features simple, alternate leaves (7-15 cm) and produces unisexual flowers. The fruit is a smooth, subglobose berry, 3-5 cm across, with an enlarged and woody persistent calyx. The berry contains 1-8 glossy black, oblong, and compressed seeds, which are up to 2.2 x 1 cm (Fig. 3.11).

**Flowering and Fruiting:** April – February**IUCN Status Assessment**

The first IUCN Red List assessment for the species, conducted in 1998, categorised it as Endangered (EN) under Criteria B1+2c (World Conservation Monitoring Centre, 1998). This assessment was based solely on two historical collection records, with all other data noted as requiring updating. More recently, the species was assessed as Critically Endangered (CR) under Criteria C2a(i) (Bachan & Devika, 2023), based on 24 occurrence records used for ecological niche modeling. However, the present study's 28 collection records, incorporating new locations from Karnataka and historical records from Sri Lanka, expanded the known range to 12 subpopulations. This increase resulted in revised spatial metrics: AOO is now calculated as 96 km<sup>2</sup> and EOO as 152,781 km<sup>2</sup>, leading to a proposed status revision to Endangered (EN).

**Distribution**

*Diospyros crumenata* is distributed across the southern Western Ghats of India (Kerala, Tamil Nadu, and Karnataka) and Sri Lanka, with a confirmed 12 subpopulations identified from the study's 28 collection records. Despite a large EOO of 152,781 km<sup>2</sup>, the AOO of 96 km<sup>2</sup> confirms that the species is geographically widespread but occupies an extremely restricted and fragmented habitat. (Fig. 3.12).





**Fig. 3.11.** *Diospyros crumenata* Thwaites.: A. Habit; B. Twig; C. Bark; D. Leaf abaxial side; E. Calyx; F. Flower; G. Corolla; H. Immature fruit; I. Mature fruit; J. Seeds.

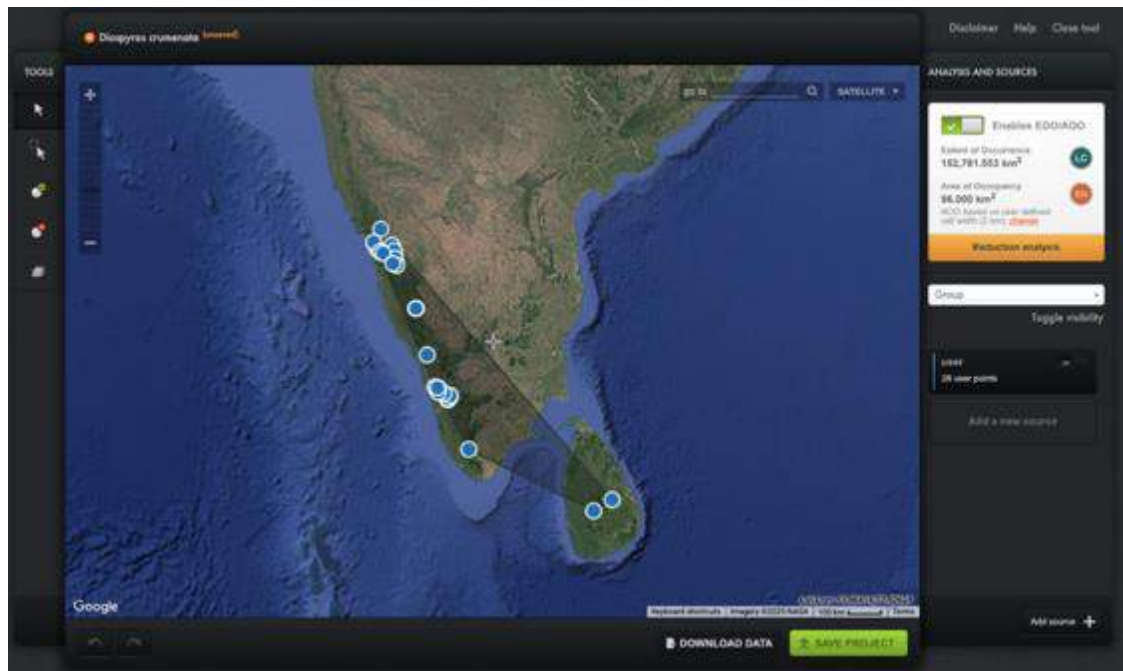


**Fig. 3.12.** Calculated AOO and EOO using GeoCAT for *Diospyros crumenata*

### Population

The total estimated population of the species now stands at 400–500 mature individuals, distributed across 12 highly fragmented locations, expanded from six by this study and recent reports from Karnataka (Shashwathi & Krishnamurthy, 2024; Kumar, 2023). This population exhibits a low density (previously 0.1 individuals/ha) and is characterised by a critical lack of large aggregations; the largest subpopulation accounts for fewer than 50 mature individuals. This extremely small population size and fragmentation contribute directly to the species' high threat classification.

### Habitat and Ecology

*Diospyros crumenata* is a significant arboreal species found within low-elevation evergreen forest ecosystems (100 m to 600 m). The species exists at an extremely low abundance across its locations, with the largest known subpopulation comprising fewer than 50 individuals. Its survival is tied to complex Eltonian niche factors, including mutualisms with specialised seed dispersal agents (e.g., Great Hornbills, Civets, Lion-Tailed Macaque), and specific climatic requirements (suitable intermittent rainfall for fruit setting, and fungal interaction coupled with early mid-summer rain for germination). This

high dependence makes the species highly susceptible to disruption from habitat fragmentation and predicted climate change (Devika & Bachan, 2025).

### **Threats**

The primary threats confronting this species involve drastic habitat loss and fragmentation. Evidence indicates 60–84% of its low-elevation habitat is degraded (Devika & Bachan, 2021; Bachan et al., 2022) due to the transformation of land into agricultural areas, forest plantations, and the construction of dams. The most critical impact is that this degradation disrupts the complex Eltonian niche factors required for successful fruit setting, seed dispersal, and germination (Devika & Bachan, 2025), severely impeding natural population recovery.

### **Use and Trade**

The species holds ethnobotanical significance for the indigenous Kadar community residing in the Vazhachal region, who utilise its fruits (Bachan, 2010). The unique vernacular name, ‘Karimbudan’, used by the Kadar tribe, highlights its cultural recognition and was specifically provided for inclusion in the IUCN database (Devika & Bachan, 2023; Bachan et al., 2025).

### **Conservation Actions**

The species was first identified as a unique species with an extremely low population by Bachan (2010) along the low-elevation riparian forests. This finding was later confirmed by Devika and Bachan (2021), which led to the IUCN assessment by Bachan and Devika (2023) that indicated less than 200 mature individuals in the wild and a very low germination and survival rate. Subsequently, more than 400 individuals have been successfully germinated by incorporating the Eltonian and Grinnellian niche factors at the seed germination center of the Research Department of Botany and the Western Ghats Hornbill Foundation, supported by the Rufford Nature Conservation Grant and Prakriti Fellowship (Devika & Bachan, 2023; Devika & Bachan, 2025). Furthermore, a niche-profiled and reference ecosystem-based ecorestoration initiative has been implemented for the species' degraded habitat for the first time, utilizing a convergence model involving the local Kadar community, Local Self Government, the Kerala State Biodiversity Board, and the Kerala Forest Department.

### **IUCN Assessment Rationale**

The species was recently assessed by (Bachan & Devika, 2023).

“*Diospyros crumenata* is a 25 m high, large evergreen tree species endemic to low elevation evergreen forest of southern Western Ghats in India and Sri Lanka (six locations). The species has a narrow range of bioclimatic and habitat suitability (125 m to 600 m in elevation). Studies indicate drastic land-use change in its potential habitats with a decline in the population (Devika & Bachan, 2021). The estimated extent of occurrence (EOO) of the species is 98,446 km<sup>2</sup>. The area of occupancy (AOO) is 28 km<sup>2</sup>. The estimated population size is 200 individuals, with 40 mature individuals in the largest subpopulation. The locations are severely fragmented and the species require seed dispersal agents such as smaller mammals and larger frugivore birds like the great hornbill for seed germination (Devika & Bachan, 2021). Most of the locations occur in areas that have been subjected to habitat loss from monoculture forest plantations, dams, agriculture expansion and the species is facing decline in population. Hence, it is assessed Critically Endangered (EN) with criteria C2a(i)”.

Recent studies in the Karnataka region brought out new locations and subpopulations of the species, as did fieldwork in the Vazhachal Forests with the present study. Now, the present number of subpopulations becomes 12, and the estimated population comes to around 300–400 mature individuals. Hence, the species is classified as Endangered.

### **Discussion – Amendment to the Assessment**

The species *Diospyros crumenata* is a medium-sized, dioecious evergreen tree of low-elevation forest ecosystems (100 m to 600 m) across the southern Western Ghats and Sri Lanka. The status is proposed to be amended from Critically Endangered (CR) to Endangered (EN), justified under criteria B2ab(iii, v) + C2a(i), due to new data from 28 collection records that expanded the known distribution to 12 highly fragmented subpopulations. This resulted in a revised Area of Occupancy (AOO) of 96 km<sup>2</sup> and a total mature population estimated at 400–500 individuals, which is above the CR threshold. However, the species remains EN because the AOO is severely restricted, and the population is subject to a continuing decline: 60–84% of its low-elevation habitat is degraded (Devika & Bachan, 2021) due to agricultural expansion, forest plantations, and dams (B2b(iii, v)). The population meets the C2a(i) threshold, as the total number of mature individuals is below 2,500, and the largest subpopulation accounts for fewer than

50 mature individuals. The high threat level is further justified by the finding that despite ecological niche modeling predicting an increase in bioclimatic suitability (Grinnellian Niche) of 29% per decade under future climate scenarios, the species' recovery is critically constrained by the severe disruption of Eltonian niche factors, the loss of specialised seed dispersal mutualisms (e.g., Great Hornbills) and fungal interactions required for germination (Devika & Bachan, 2025).

### **3.3.6. *Dipterocarpus indicus* Bedd. in Conserv. For. Rep. (1864-65) 17.**

**Synonyms:** No Synonyms

**Vernacular Name:** Guga, Dhuna (Kannada); Arayangili, Kalpayin, Kakka, Karanjili, Vavangu, Vella-ayani (Malayalam)

**Family:** Dipterocarpaceae

**Identifying Features:** A characteristic large evergreen tree of the low-medium elevation evergreen forests of the Western Ghats. It reaches 30–45 m in height, featuring a straight, cylindrical bole that is buttressed at the base. The whitish-grey bark is densely lenticellate and exudes an aromatic white resin. The branchlets bear tubercular dots and subulate scales. Leaves are large, simple and alternate with prominent veins. The flowers are bisexual, large, fragrant, and either pink or white. The large, nut-like fruit is enclosed in the calyx tube, which develops two accrescent (enlarging), wing-like lobes measuring up to 18 cm long, which aids in dispersal (Fig. 3.14).

**Flowering and Fruiting:** February-July

#### **IUCN Status Assessment**

The first IUCN Red List assessment for the species, conducted in 1998 (Ashton, 1998), categorised it as Endangered (EN) under Criteria A1cd+2cd and B1+2c. This initial assessment did not report data for Area of Occupancy (AOO) or Extent of Occurrence (EOO). The status was more recently reassessed and updated in 2023 (Deepu et al., 2023), retaining the Endangered (EN) category based on C2a(i). This assessment was based on 33 locations, estimating the AOO at 156 km<sup>2</sup> and the EOO at 80,151.108 km<sup>2</sup>. The present study, utilizing 90 occurrence records, identified 56 locations for the species. This significant increase in known occurrences resulted in a calculated AOO of 320 km<sup>2</sup> (nearly double the previous estimate) and an EOO of 61,772 km<sup>2</sup>. Hence, based on these new



spatial metrics and the increased number of locations (which invalidates the EN C2a(i) criteria of <250 mature individuals per subpopulation), the present study recommends categorizing the species as Vulnerable (VU).

### Distribution

The species is distributed in the Kerala, Tamil Nadu and Karnataka part of the Western Ghats. According to the present study, *Dipterocarpus indicus* found to occur in 56 locations from 90 collection records, the highest is Kerala (51 records), Karnataka (26) and Tamil Nadu (13). The estimated AOO 320 km<sup>2</sup> and EOO is 61772 km<sup>2</sup> reflects the species restricted but expanded distribution (Fig. 3.13).

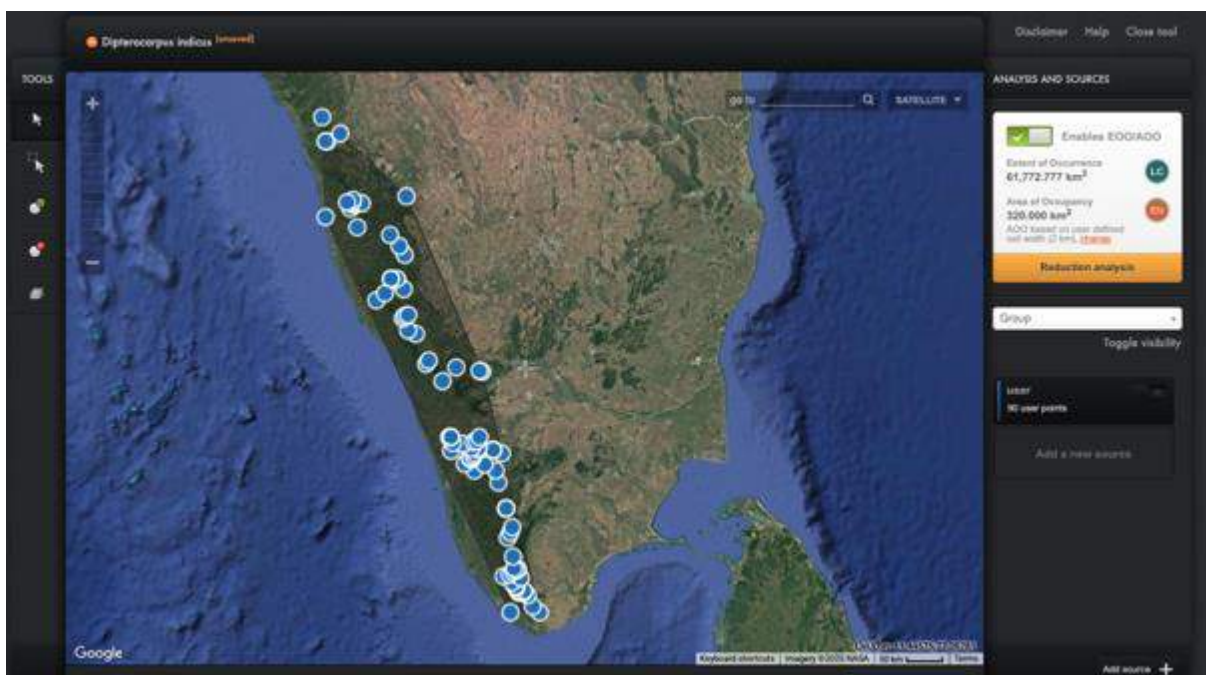


Fig. 3.13. Calculated AOO and EOO using GeoCAT for *Dipterocarpus indicus*

### Population

While earlier surveys suggested the total number of mature individuals was below the 2,500 threshold and that there were fewer than 100 mature individuals per subpopulation (Deepu et al., 2021), the present study offers a revised, more optimistic estimate. Based on current field study data, the species density is estimated at 0.17 individuals per hectare, which translates to a total estimated population ranging between 5,700 and 10,000 mature individuals when extrapolated across the revised AOO and EOO. This population size exceeds the thresholds for the Endangered (EN) category.

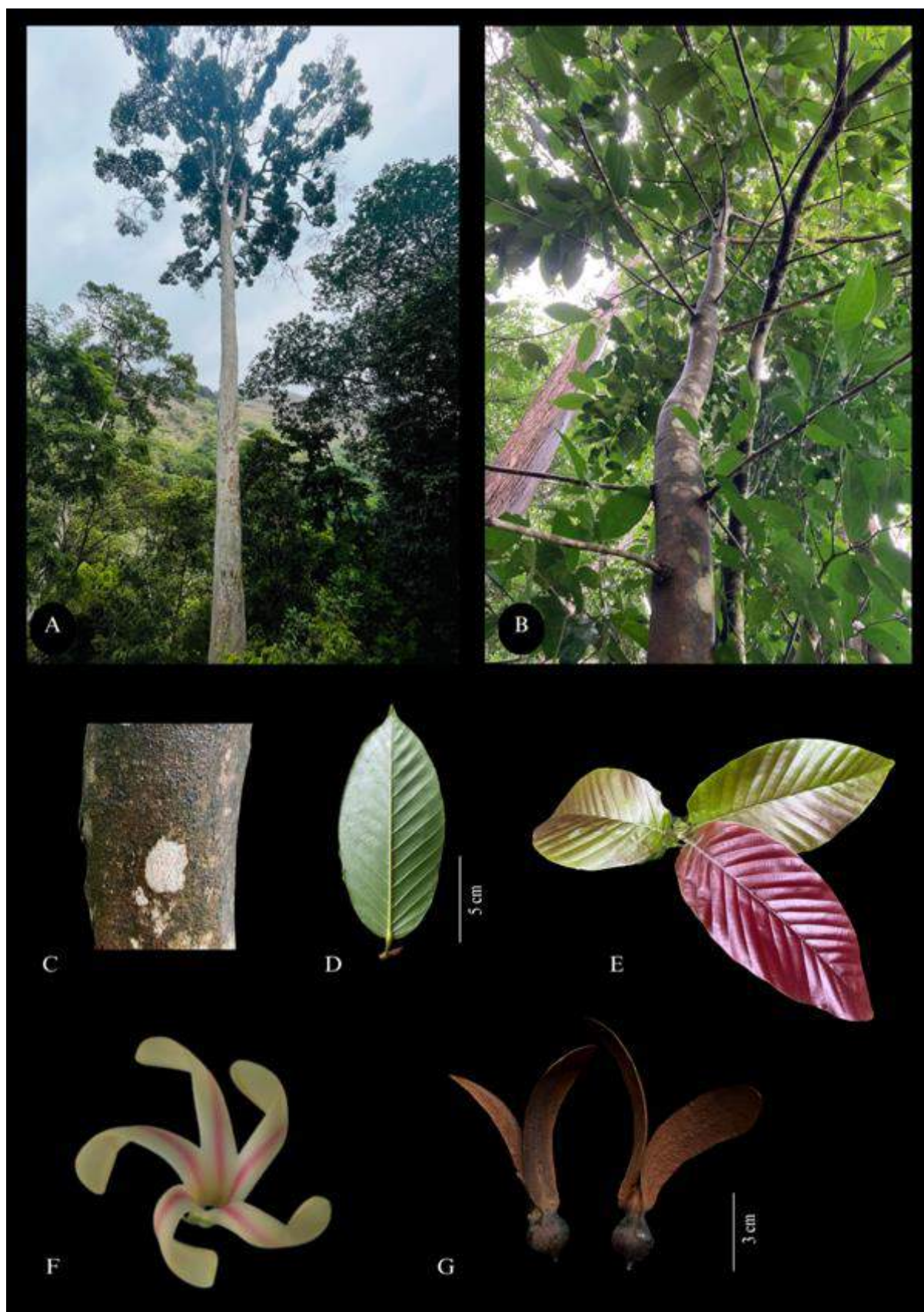


**Fig. 3.14.** *Dipterocarpus indicus* Bedd.: A. Habit; B. Twig; C. Bark; D. Leaf abaxial side; E. Young leaves; F. Flower; G. Fruit.

**Habitat and Ecology**

The species is a flagship species found in evergreen and semi-evergreen forests. It is a major component contributing to the composition and architecture of the low-elevation forest type, notably defining the *Dipterocarpus bourdillonii* – *D. indicus* – *Anacolosa densiflora* community structure within the tropical moist forests (Champion & Seth, 1968).

**Threats**

The species faces significant historical and ongoing threats, including deforestation and habitat destruction driven by land conversion for teak and other timber forest plantations, construction of dams and reservoirs, agricultural lands, and infrastructure development. In the past, this activity has resulted in an estimated 40–70% habitat loss. Furthermore, specific locations in Kerala have experienced population loss due to floods and landslides resulting from torrential rains in 2018 (Bachan et al., 2019). The current study utilised species distribution modeling to precisely map the area of irreversibly converted habitat (888.42 km<sup>2</sup>), degraded area (1113.67 km<sup>2</sup>), and the present potential conservation area (3207.89 km<sup>2</sup>) for this species, providing a quantitative basis for conservation management.

**Use and Trade**

The species had been extracted in large scale for its timber during colonial periods and also for the plywood industry in the post independent period. It is also considered a source of resin, oil and medicine.

**Conservation Actions**

This species occurs in several protected areas in the Western Ghats. This species is also kept in ex situ collections.

**Assessment Rationale**

The recent assessment of the species was done by Deepu et al. (2023).

“*Dipterocarpus indicus* is endemic to the Western Ghats in India. This is a tree species of about 35 m high. It grows in the evergreen and semi-evergreen forests and known from thirty-three localities. Considering the present distribution of the species, and the magnitude of land conversion that has happened, it is expected to have undergone habitat fragmentation over the past. This species has an extent of occurrence (EOO) of 80,151.108 km<sup>2</sup> and a relatively small area of occupancy (AOO of 156 km<sup>2</sup>). The AOO is based on



collections only, and this species is likely to be under collected. However, given our present knowledge about this species, the AOO is unlikely to exceed 500 km<sup>2</sup>. Given that the species have an estimated continuing decline in the population size due to threats to the habitats and it is expected to be having fewer than 2,500 mature individuals with fewer than 250 mature individuals per subpopulation, the species is assessed as Endangered (Deepu et al., 2021).”

#### **Discussion – Amendment to the Assessment**

The status of *Dipterocarpus indicus* is proposed to be downgraded from Endangered (EN) to Vulnerable (VU). The 90 occurrence records across 56 locations resulted in a substantially increased AOO of 320 km<sup>2</sup>, and an estimated total mature population of 5,700 to 10,000 individuals. While this population size exceeds the numerical thresholds for the Endangered and Vulnerable C and D criteria, the species qualifies as Vulnerable under the criterion A3c. This classification is based on a suspected future population reduction of  $\geq 30\%$  within the next three generations, inferred from the continuing severity of documented threats. These threats include 40–70% habitat loss from land conversion to plantations and dams, ongoing habitat fragmentation, and the recent acute threat of floods and landslides (Bachan et al., 2019). The population, while currently large, is facing a continuing, predicted decline inferred from this persistent and unmitigated habitat degradation.

**3.3.7. *Elaeocarpus munroi* (Wight) Mast.** Fl. Brit. India [J. D. Hooker] 1(2): 407 (1874).

**Synonyms:** *Monocera munroi* Wight in Ill. Ind. Bot. 1: 84 (1838)

**Vernacular Name:** Narebikki (Tamil); Kalrudraksham, Pungari, Shirukodala (Malayalam); Kalbikki (Karnataka)

**Family:** Elaeocarpaceae

**Identifying Features:** A characteristic large tree of high-elevation montane shola forests, this plant has slender branchlets and glabrous leaves. The leaves, measuring 4-9 x 3-4 cm, are ovate-lanceolate with an acuminate apex, a rounded base, and a crenate margin, and are five-nerved with a petiole 2-3 cm long. The flowers are distinguished by thinly tomentose sepals and white petals with reddish lines at the base, which are also densely

tomentose. The fruit is a terete, glabrous, and glaucous drupe measuring 1.5-2 cm long, containing tubercled seeds (Fig. 3.15).

**Flowering and Fruiting:** September – April

#### **IUCN Status Assessment**

The first IUCN Red List assessment for the species, conducted in 1998 (World Conservation Monitoring Centre, 1998), categorised it as Near Threatened (NT). The specific criteria used for this classification were not explicitly stated, and the assessment itself was noted as requiring updating. According to the present study, utilizing 128 collection records, identified 42 subpopulations, the first record of the species is 200 years back recorded by Beddome in 1804, from the Palani hills and Anmalais in the same year. Now there are 128 collection records, identified 42 subpopulations within the species' distribution range in the state of Kerala, Tamil Nadu and Karnataka. Based on these data, the Area of Occupancy (AOO) was estimated at 424 km<sup>2</sup>, and the Extent of Occurrence (EOO) was 59,410 km<sup>2</sup>. This is significantly higher than the thresholds for Critically Endangered (CR) and Endangered (EN) classification under criteria B. Hence, based on these new spatial and demographic metrics, the present study recommends categorizing the species as Vulnerable (VU), revising the outdated 1998 NT status.

#### **Distribution**

The *Elaeocarpus munroi* is endemic to the Western Ghats, India, particularly in Kerala, Tamil Nadu and Karnataka. The species occur in an AOO of 424 km<sup>2</sup> and EOO of 59,410 km<sup>2</sup> (Fig. 3.16).

#### **Population**

*Elaeocarpus munroi* represents a medium-sized evergreen arboreal species endemic to the Western Ghats Mountain range in Southwestern India, typically occurring at altitudinal gradients ranging from 700 - 2,100 m. The earliest collection records date back to 1804 by Beddome from Anamalai and Palani hills. The present study, based on a careful review of 128 collection records, confirmed 42 subpopulations. The species density is estimated at 0.37 individuals per hectare, yielding a total estimated population of 13,000–18,000 mature individuals when extrapolated across the AOO and EOO. Substantial subpopulations are concentrated in the Munnar, Nilgiris, and Anamalai regions. Crucially, historical data indicate a 26% population decline over the preceding three generations (90 years), primarily attributable to habitat degradation.

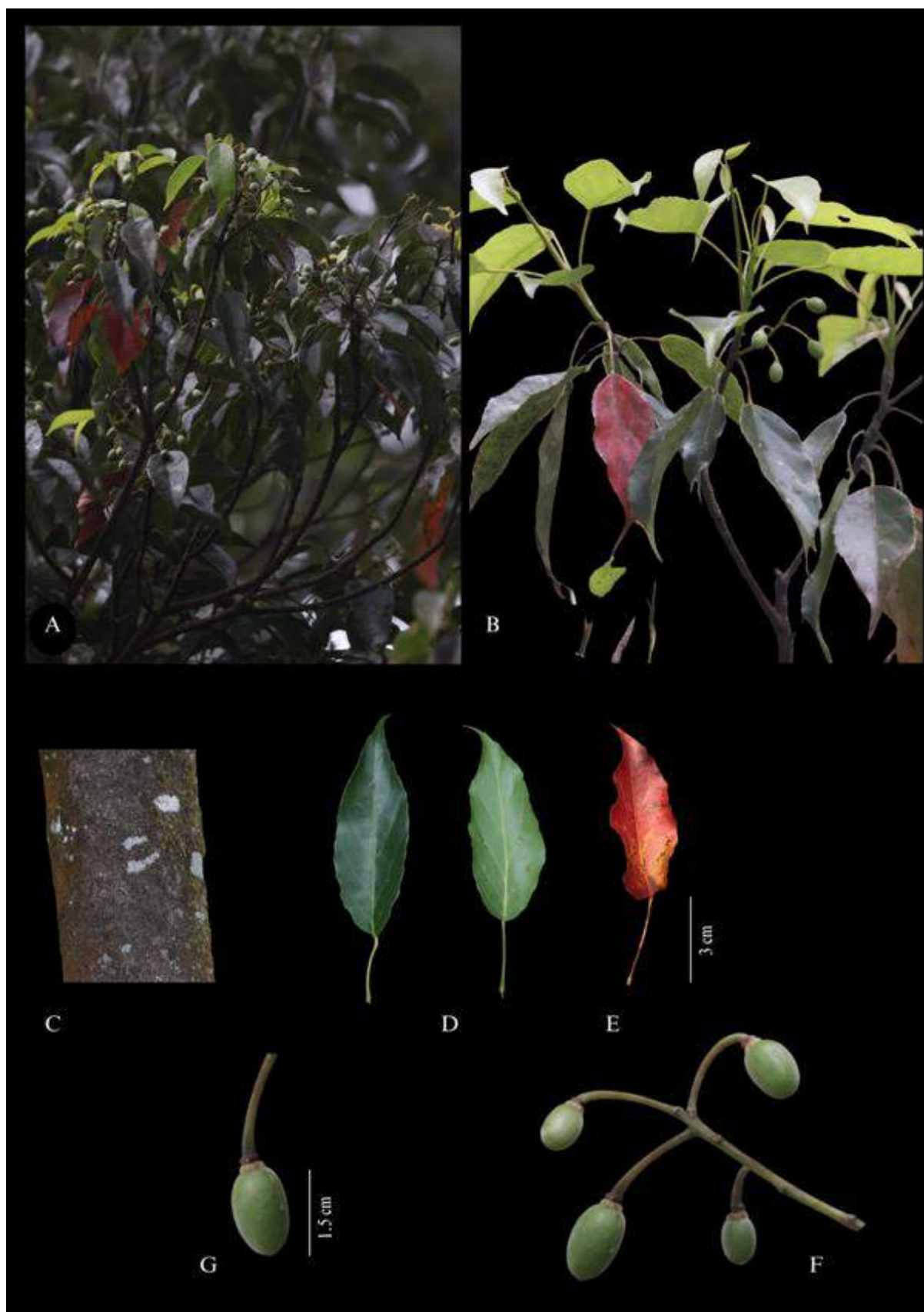


**Fig. 3.15.** *Elaeocarpus munroi* (Wight) Mast.: A. Habit; B. Twig; C. Bark; D. Leaf; E. Leaf at senescence; F. Infructescence; G. Fruit.

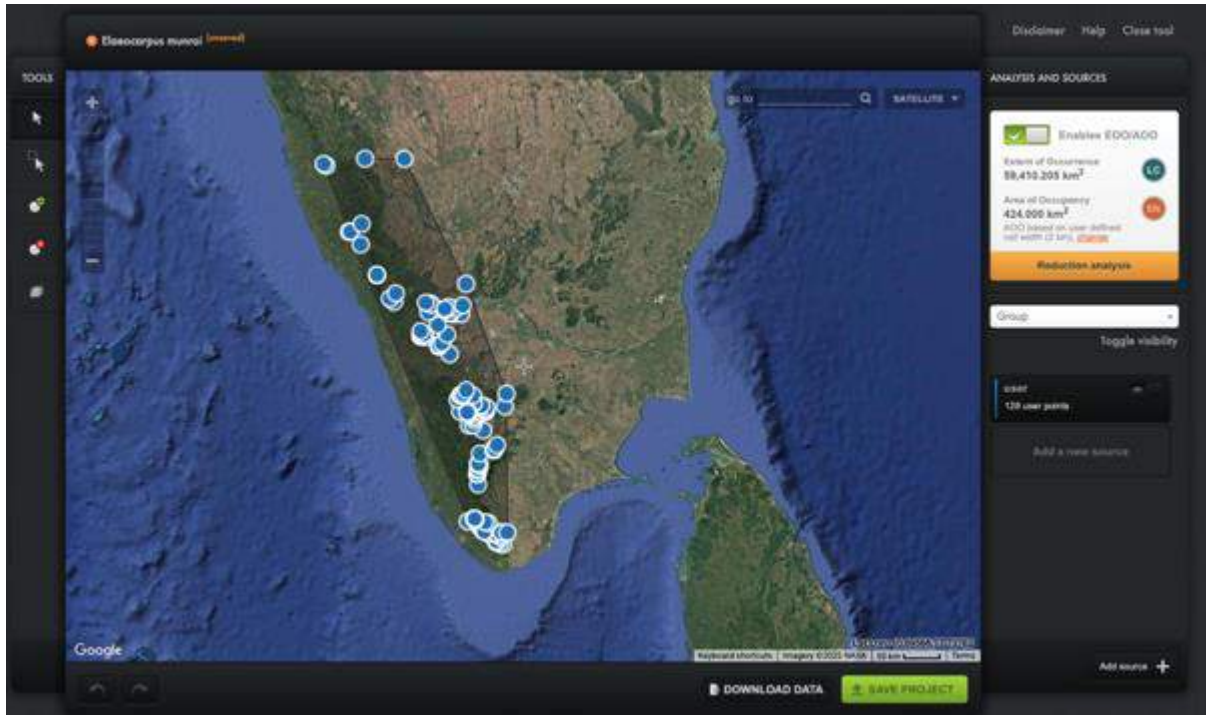


**Fig. 3.16. Calculated AOO and EOO using GeoCAT for *Elaeocarpus munroi***

### Habitat and Ecology

*Elaeocarpus munroi* is characterised as a medium-sized evergreen tree, achieving heights of up to 20 m, and is distributed across the tropical rainforests of the Western Ghats at elevations between 700 and 2,100 m especially the sub montane and montane shola forests and its transitional guilds to the medium elevation evergreen forests. The species is documented to have 42 subpopulations located in the elevated regions of the Western Ghats, substantiated by 58 collection records. Ecologically, this species is typically associated with a variety of flora including *Canarium strictum*, *Syzygium sahyadricum*, *Elaeocarpus variabilis*, *Palaequium ellipticum*, *Cullenia exarillata*, *Litsea oleoides*, and *Glochidion indicum* among others.

### Threats

The habitats of *Elaeocarpus munroi* are predominantly subjected to clearance for the establishment of forestry and agricultural monoculture plantations, especially of tea and coffee, construction of dams and reservoirs, as well as infrastructural development initiatives.

### Use and Trade

There exists a paucity of information regarding the use and trade of this species.

### Conservation Actions

While this species is known to occur in several Protected Areas across the Western Ghats (given its distribution in Munnar, Nilgiris, and Anamalai), there are currently no dedicated, species-specific in situ management or ex situ conservation strategies tailored to address the documented 26% population decline.

### Assessment Rationale

The recent IUCN assessment for the species based on the present study has been submitted to IUCN and is completed review and under publication at the IUCN official red list (Devika & Bachan, 2026 *in press*). The assessment rationale is:

“*Elaeocarpus munroi* is a medium-sized evergreen tree endemic to the Western Ghats mountains of Southwestern India, thriving at elevations between 700 and 2,100 m. The area of occupancy (AOO) is quantified at 424 km<sup>2</sup>, while the extent of occurrence (EOO) spans 59410 km<sup>2</sup>. The species comprises approximately 18,000 mature individuals distributed across 42 subpopulations within its geographical range. It is commonly found in association with species such as *Canarium strictum*, *Syzygium sahyadricum*, *Elaeocarpus variabilis*, *Palaquium ellipticum*, *Cullenia exarillata*, *Litsea oleoides*, and *Glochidion indicum*. The habitats are continually being cleared for forest and agricultural monoculture plantations and infrastructural projects, resulting in ongoing threats to the species. A noted reduction of 26% in the population has occurred over the preceding three generations (90 years) due to habitat degradation. Consequently, the species is classified as Near Threatened (NT) in this assessment”.

### Discussion on the IUCN Assessment for the Species

The IUCN status for *Elaeocarpus munroi* is proposed to be revised from the outdated 1998 Near Threatened (NT) classification to Vulnerable (VU). This upgrade in threat status is primarily driven by the documentation of a significant, quantifiable decline in population, rather than restrictions in geographic range. Although the species exhibits a relatively large distribution, with an AOO of 424 km<sup>2</sup> and an estimated mature population of 13,000–18,000 individuals across 42 subpopulations, it qualifies for the Vulnerable category under criteria A2c. This classification is based on an observed and inferred population reduction of 26% over the preceding three generations (90 years). This reduction is directly attributable to the continuing decline in habitat quality and area, fuelled by clearance for forest and agricultural monoculture plantations (tea and coffee),

construction of dams and reservoirs, and infrastructural projects. The evidence of a sustained, high-magnitude threat leading to an inferred population decline of  $\geq 20\%$  means that despite the large current population size, the species remains highly susceptible to extinction in the medium term, thereby warranting the VU A2c classification.

**3.3.8. *Elaeocarpus recurvatus* Corner** Gard. Bull. Straits Settlem. 10: 325 (1939).

**Synonyms:** *Elaeocarpus ferrugineus* Bedd. in Fl. Sylv. S. India: 112 (1871), nom. illeg.; *Monocera ferruginea* Wight in Icon. Pl. Ind. Orient. 1: t. 205 (1839), nom. illeg.

**Vernacular Name:** Cholarudraksham, Naikotta (Malayalam)

**Family:** Elaeocarpaceae

**Identifying Features:** Characteristic canopy tree of the montane shola forest up to 13 m tall, distinguished by a buttressed bole and young branches and leaves covered in rusty, velvety. Its simple, alternate leaves are clustered at the branchlet tips, with free, lateral, deciduous stipules. The stout, woolly leaf-stalks are 1.5-5 cm long, and the leaf blade is 7.5–15 x 4–8 cm, ovate or ovate-oblong with a boat-shaped appearance. The leaves have a pointed or wedge-shaped base, a pointed or caudate tip, a rounded-toothed margin, and are leathery. The upper surface is hairless except for a downy midrib, while the underside is softly velvet-hairy, with 6-10 prominent pinnate lateral nerve pairs and veins that divide dichotomously towards the margin. The bisexual flowers are white, velvety, lance-shaped sepals and 5 broadly ovate petals, each 1.2 cm long. The numerous stamens are inserted between glands on the disc, and the anthers end in a straight bristle. The fruit is a single-seeded, ovoid drupe (Fig. 3.18).

**Flowering and Fruiting:** October – April

**IUCN Status Assessment**

The first IUCN Red List assessment for the species, conducted in 1998 (World Conservation Monitoring Centre, 1998), categorised it as Vulnerable (VU) under Criteria B1+2c. This assessment was noted as being based on limited data and requiring updating. The recent assessment (Bachan & Devika, 2024) found the species to be more threatened, resulting in an Endangered (EN) categorization under Criteria A2c. This was based on an estimated Area of Occupancy (AOO) of 104 km<sup>2</sup> and an Extent of Occurrence (EOO) of 7,211 km<sup>2</sup>. The present study, utilizing 50 collection records, identified 15 subpopulations

for the species. The re-calculation of spatial metrics resulted in an AOO of 156 km<sup>2</sup> and an EOO of 10,196 km<sup>2</sup>. Although these spatial metrics slightly exceed the thresholds for the previous assessment, the EN categorization under A2c remains valid due to the documented severe population decline (Fig. 3.17).

### **Distribution**

The *Elaeocarpus recurvatus* is endemic to the Western Ghats, India, particularly in Kerala and Tamil Nadu. The species occur in an AOO of 156 km<sup>2</sup> and EOO of 10196 km<sup>2</sup> (Fig. 3.17).

### **Population**

The distribution of *Elaeocarpus recurvatus* is confined to 15 distinct subpopulations, represented with 50 collection records, 34 from Kerala and 16 from Tamil Nadu located within the high altitude montane shola forests of the Munnar and Nilgiri regions. The estimated mature population size is fewer than 4,000 individuals, with the largest subpopulation comprising 500 individuals, yielding a density of approximately 5 specimens per hectare. The habitat has experienced significant fragmentation, with 66% of the area converted for the establishment of tea and wattle plantations. It is posited that the population has experienced a similar decline, estimated at 50–70%. A stable demographic is anticipated within the confines of the Anamudi Shola National Park, while the burning of grasslands poses adverse effects on the shola ecosystem and the population of the species in other designated protected areas (Devika & Bachan, 2023).

### **Habitat and Ecology**

*Elaeocarpus recurvatus* is classified as an evergreen arboreal species, attaining heights of up to 15 m within the montane shola ecosystems situated at elevations ranging from 1,700 - 2,550 m. The species functions as a canopy tree in the stunted montane evergreen shola forest ecosystem, cohabitating with flora such as *Rhododendron arboreum*, *Syzygium sahyadricum*, *Syzygium densiflorum*, and *Litsea spp.* The reproductive phases of flowering and fruiting are observed predominantly from February to May.

### **Threats**

The habitat of *Elaeocarpus recurvatus* has been substantially transformed for the establishment of commercial tea and wattle plantations, resulting in a 66% reduction in its habitat and a concomitant 50–70% decrease in population numbers. Out of the 15 identified



subpopulations, five are situated within protected areas. A stable population is likely to exist in the Anamudi Shola National Park; however, habitat fragmentation and fire incidents continue to pose significant threats to the species' survival in other protected regions. Ongoing activities associated with the cultivation of commercial tea, wattle, and eucalyptus plantations are prevalent in the majority of the species' habitat.

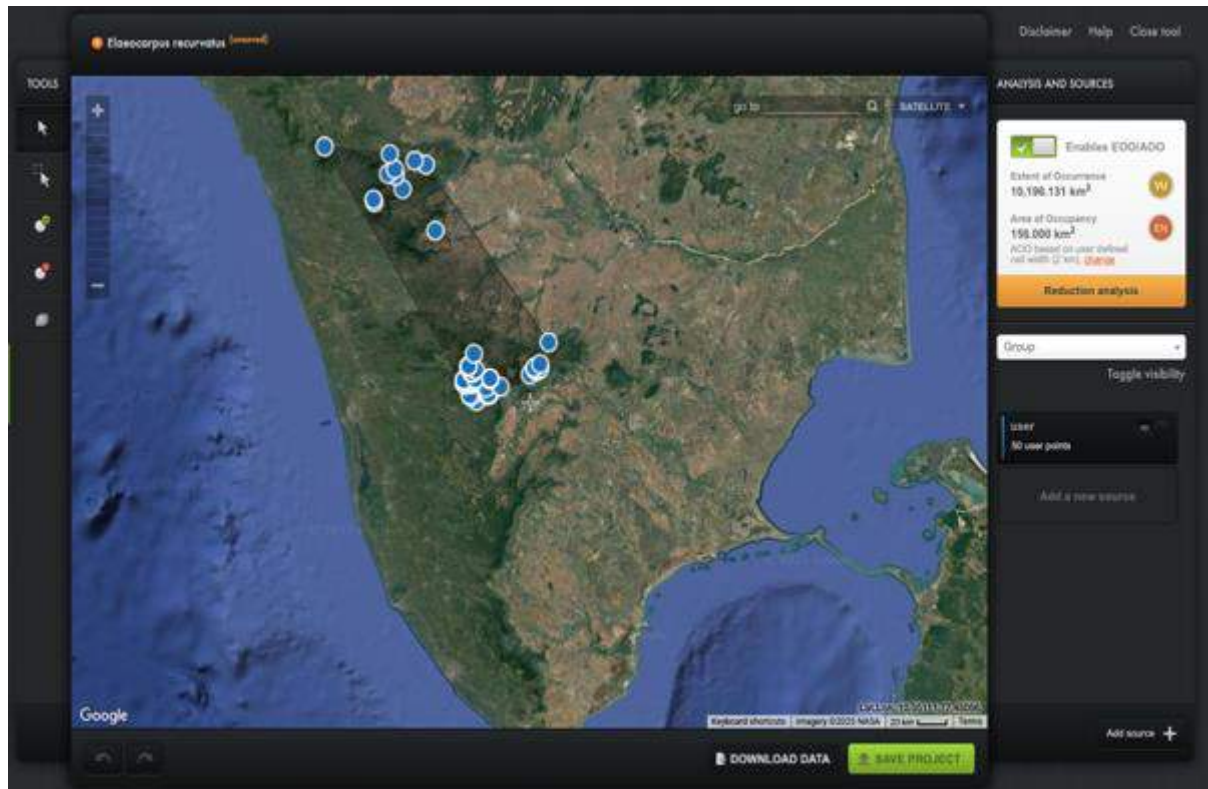


**Fig. 3.17.** Calculated AOO and EOO using GeoCAT for *Elaeocarpus recurvatus*

### Use and Trade

There exists a lack of documented information regarding the use and trade of this species.

### Conservation Actions

Five of the 15 identified subpopulations are located within protected areas including a stable population observed in the Anamudi Shola National Park. Although a specialised conservation and restoration strategy has been formally formulated (Devika & Bachan, 2023), there are currently no specific, site-directed actions or restoration initiatives implemented in the field.



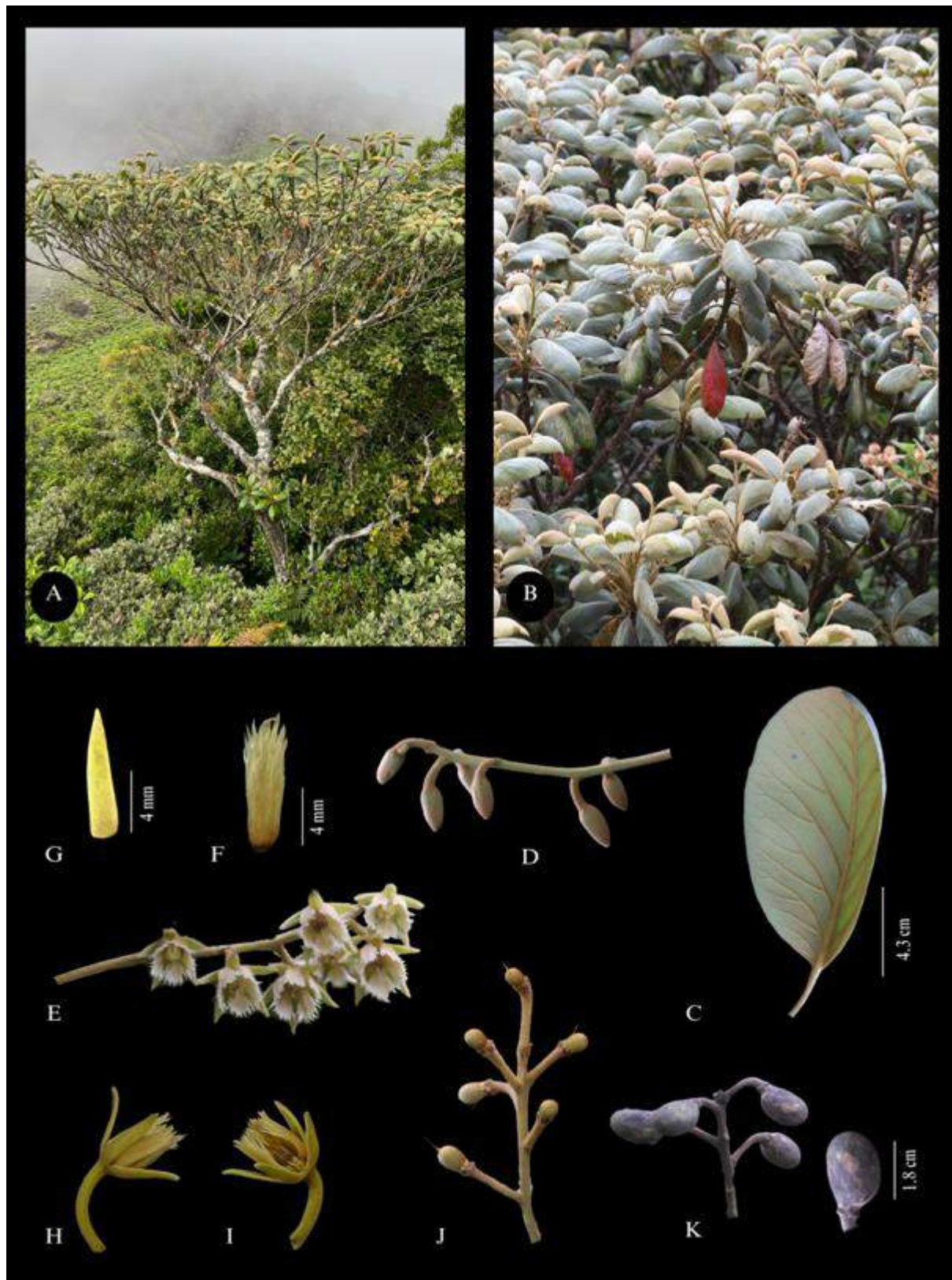


**Fig. 3.18.** *Elaeocarpus recurvatus* Corner: A. Habit; B. Twig; C. Leaf abaxial side; D. Buds; E. Inflorescence; F. Petal; G. Sepal; H. Flower; I. Flower LS; J. Young fruit; K. Mature Fruit.

**Assessment Rationale**

The species was recently assessed by Bachan and Devika (2024) and the assessment rationale is as follows:

“This species represents a medium-sized canopy tree endemic to the high-elevation shola forests of the southern Western Ghats, primarily confined to the Munnar and Nilgiri landscapes. The overall population is estimated to be fewer than 4,000 individuals distributed across 15 subpopulations, with five of these subpopulations residing within protected areas. The area of occupancy is quantified at 156 km<sup>2</sup>, while the extent of occurrence measures 10196 km<sup>2</sup>. It is estimated that 66% of the habitat has been converted for tea and wattle plantations. The population is suspected to have declined by a comparable extent over the past three generations (50–70%). The ongoing threats include habitat fragmentation, incidences of fire, and commercial plantation activities. Consequently, the species is assessed as Endangered (EN)”.

**Discussion**

The species is assessed as Endangered (EN). It meets the criteria A2c, based on a suspected population reduction of 50–70% over the past three generations, where the reduction cause (habitat conversion) has not ceased. This reduction is directly correlated with the estimated 66% habitat conversion for commercial tea and wattle plantations. Additionally, the species meets criteria B2ab(i, ii, iii, v), as the AOO (156 km<sup>2</sup>) is below the 500 km<sup>2</sup> threshold, the population is known from only 15 locations, and there is a continuing decline observed in AOO, EOO, area/extent/quality of habitat, and number of mature individuals.

**3.3.9. *Ficus beddomei* King** Ann. Roy. Bot. Gard. (Calcutta) 1: 26, t. 24 (1888).

**Synonyms:** *Ficus rama-varmae* Bourd. in J. Bombay Nat. Hist. Soc. 13: 155 (1900).

**Vernacular Name:** Chela, Thavittaal (Malayalam)

**Family:** Moraceae

**Identifying Features:** A large, characteristic fig tree of the canopy layer in tropical low-elevation forests, initially establishing as an epiphyte/strangler, featuring branchlets with prominent stipular scars. It's simple, alternate leaves are broadly ovate, measuring 25-33 x 9-11 cm, with an abruptly acuminate apex and a rounded base. The leaves are 3-ribbed,

have 13-15 pairs of primary nerves, and possess a sinuate or entire margin. They are supported by a petiole 5-6 cm long (Fig. 3.20).

**Flowering and Fruiting:** July-February

### IUCN Status Assessment

The first IUCN Red list assessment for *Ficus beddomei* (Bachan & Devika, 2023) utilised multiple criteria resulting in an Endangered (EN) categorization under Criteria A2c. This present assessment was based on 56 collection records which informed the spatial estimates of EOO 102,897 km<sup>2</sup> and AOO 232 km<sup>2</sup>.

### Distribution

This species is scattered in forest hills of Peninsular India, particularly in Kerala, Tamil Nadu, Karnataka, Maharashtra and Andhra Pradesh. The estimated EOO is 102,897 km<sup>2</sup> and AOO is 232 km<sup>2</sup> (Fig. 3.19).

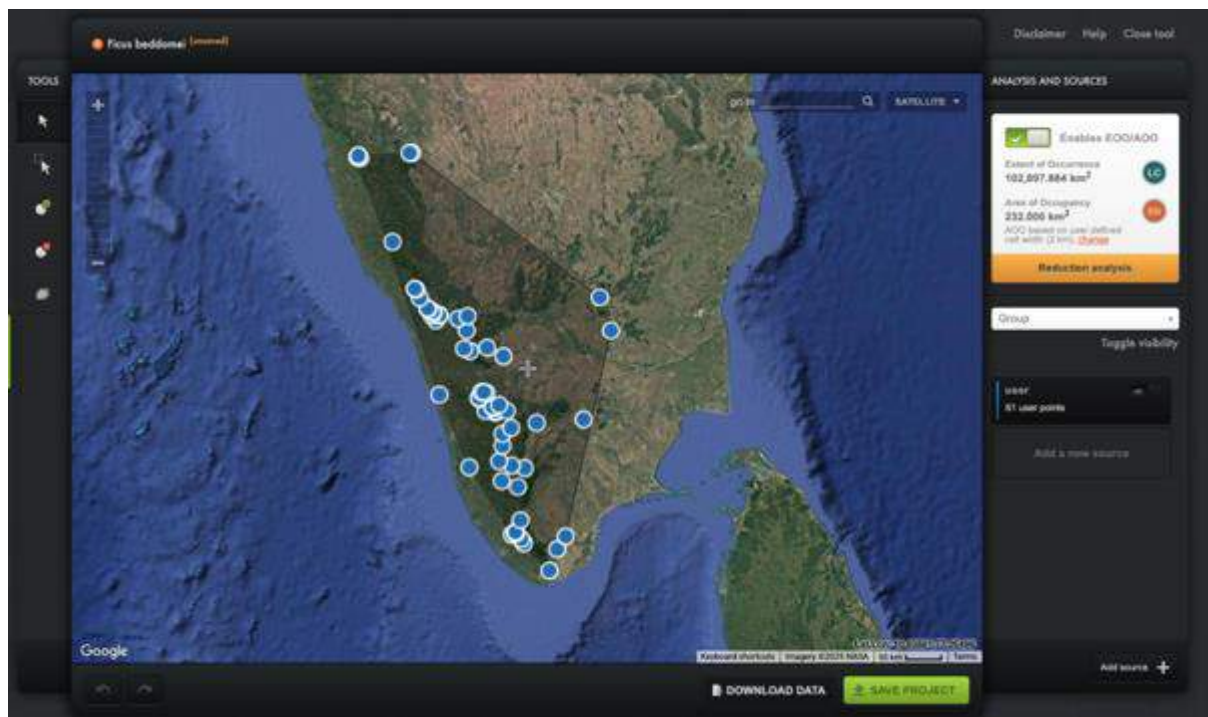


**Fig. 3.19.** Calculated AOO and EOO using GeoCAT for *Ficus beddomei*

### Population

The species' distribution is defined by 15 dispersed locations within Peninsular India, of which 13 locations are situated within eight distinct ecoregions of the Western Ghats (with two locations outside: one in Kolli Hills, Tamil Nadu, and one in Chittoor, Andhra

Pradesh). The records are heavily skewed towards Kerala (38 records), Tamil Nadu (13), and Karnataka (5). The population estimate is 9,000–15,000 mature individuals, with a density of 0.37 individuals per hectare. A 40–60% decline in population is inferred over the three-generation period, directly correlating with the degradation of its potential habitat.

### **Habitat and Ecology**

*Ficus beddomei* is characterised as an evergreen tree that can attain heights of up to 30 m. It is an obligate strangler fig that initially establishes itself as an epiphyte on host trees or rocky surfaces before ascending to dominate the low to medium elevation forest canopies.

### **Threats**

The primary threats to *Ficus beddomei* include the extensive conversion of wet evergreen forests prior to the 1980s in South India, land clearing for developmental initiatives, selective logging of mature old-growth trees for the plywood industry, and the consequential fragmentation of its habitat.

### **Use and Trade**

During the colonial and post-colonial periods of natural forest conversion in Anamalai, *Ficus beddomei* was extensively harvested to provision captive elephants, along with other sizable fig species.

### **Conservation Actions**

The species appears to be distributed across a limited number of wet evergreen forest locations. Given its function as a large canopy tree and vital nutrient source/canopy gap contributor (Bachan et al., 2019), its ecological contribution is significant. Therefore, species-specific conservation strategies focusing on protection within Protected Areas and ex-situ propagation are urgently recommended.

### **Assessment Rationale**

The recent IUCN Assessment for the species was done by Bachan and Devika (2023).

“*Ficus beddomei* is classified as a large evergreen tree that inhabits the canopy of moist forests, found sporadically across the Western Ghats and other hilly terrains of Peninsular India, with an extent of occurrence (EOO) measuring 102,897 km<sup>2</sup> and an area of occupancy (AOO) of 232 km<sup>2</sup>. Current records denote merely 15 locations within eight ecoregions, with an estimated mature individual count falling below 2,500. Systematic

sampling of one ecoregion has provided an estimated density of 0.009 and an abundance of 1 for the species (Bachan et al., 2019). There has been a habitat loss ranging from 40–60% over three generations, with a corresponding population decline inferred. Significant threats have arisen from habitat conversion for plantations, agriculture, dams, reservoirs, and various developmental projects. Additionally, the selective harvesting of canopy trees, particularly targeting large fig trees for the sustenance of captive elephants during timber operations in the Western Ghats, poses an essential threat to this species. Consequently, the species has been assessed as Endangered under criterion A2c. The ecological significance of the species in maintaining canopy gaps within moist forests is critical, further serving as a vital nutrient source for avian and mammalian fauna. It is recommended that efforts be made to raise awareness, conduct studies focusing on the species, implement recovery strategies, and engage in ecorestoration actions.

### **Discussion on the IUCN Assessment of the Species**

The status of *Ficus beddomei* is assessed as Endangered (EN) under criterion A2c. While the present study, utilizing 56 collection records, yielded substantially higher spatial and demographic metrics, an Area of Occupancy (AOO) of 232 km<sup>2</sup> and an estimated population of 9,000–15,000 mature individuals, the species remains highly threatened. The classification is retained as Endangered based on a suspected population reduction of 40–60% over three generations, directly inferred from the severe and continuing threats to its habitat. These threats include the extensive conversion of moist forest for plantations, agriculture, dams, and developmental projects, which has resulted in a 40–60% loss of habitat. Furthermore, the selective harvesting of this large canopy fig for the sustenance of captive elephants during historical timber operations remains an important contributing factor to the decline. Given its critical ecological role in maintaining canopy gaps and acting as a vital nutrient supplier for avian and mammalian fauna, the observed decline rate warrants the EN A2c listing, emphasizing the urgent need for awareness, dedicated studies, and targeted ecorestoration actions.



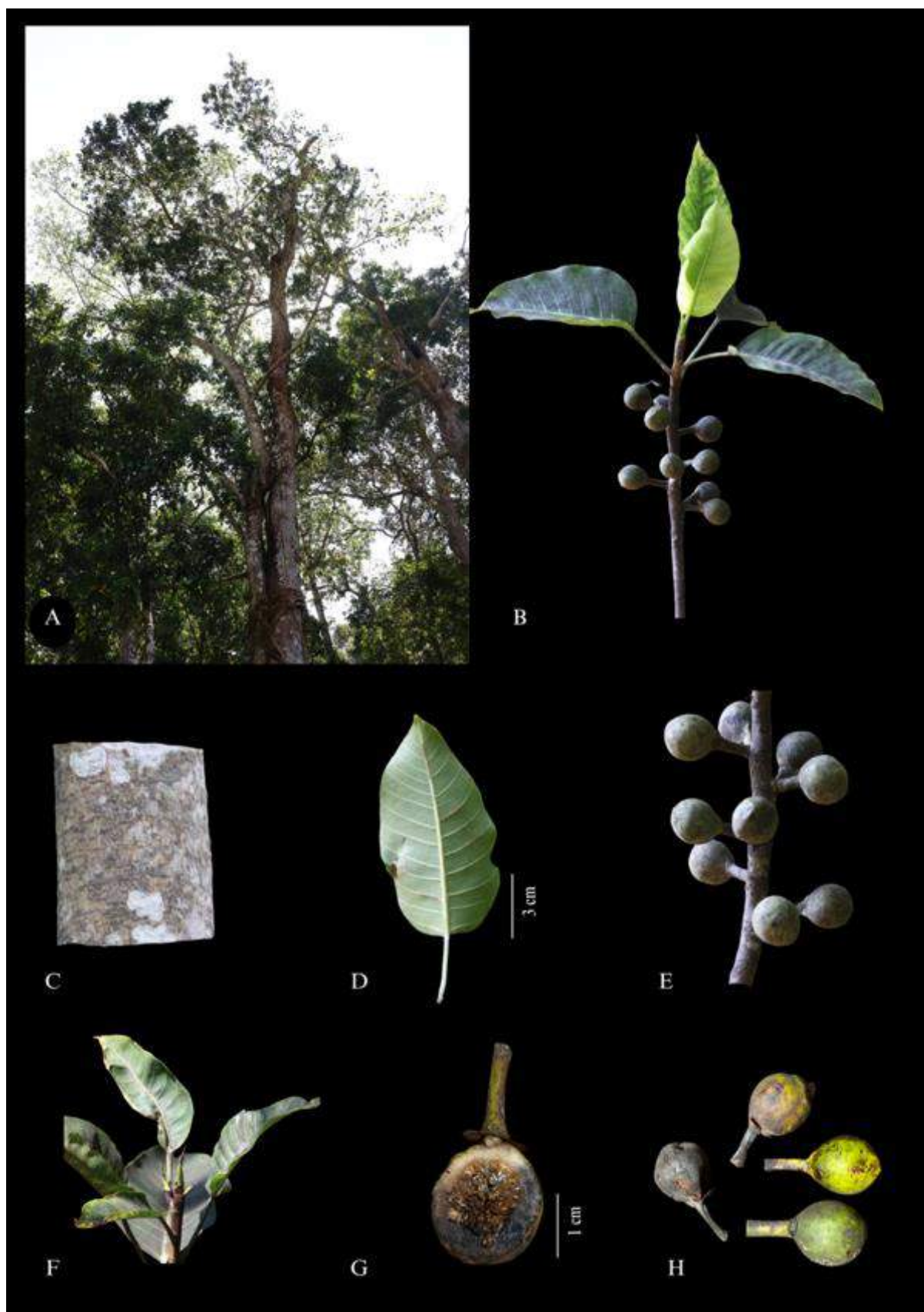


**Fig. 3.20.** *Ficus beddomei* King: A. Habit; B. Twig; C. Bark; D. Leaf abaxial side; E. Receptacles; F. Petal, G. Syconium L.S., H. Syconium.

**3.3.10. *Garcinia wightii* T.Anderson**, Fl. Brit. India [J. D. Hooker] 1(2): 265 (1874).

**Synonyms:** No Synonyms

**Vernacular Name:** Attukaruka, Kolivala, Pulimaranga (Malayalam)

**Family:** Clusiaceae

**Identifying Features:** A small, polygamodioecious riparian tree of the understory, up to 10 m tall, with glabrous, 4-angled branchlets. The leaves are simple, arranged in opposite, decussate pairs, approximately 12 x 3 cm, linear to linear-lanceolate with 8-18 pairs of faint lateral nerves. The flowers are yellow, and the fruit is a globose berry approximately 1 cm in diameter (Fig. 3.22).

**Flowering and Fruiting:** November – March

#### **IUCN Status Assessment**

The first IUCN Red List assessment (World Conservation Monitoring Centre, 1998) categorised it as Vulnerable (VU) under Criteria B1+2c. The subsequent assessment (Deepu & Geethakumary, 2020) resulted in an Endangered (EN) categorization under Criteria D due to a severely restricted population size (estimated at <250 mature individuals). The present study significantly increases the known spatial distribution (13 locations from 23 records), yielding AOO 88 km<sup>2</sup> and EOO 8,719 km<sup>2</sup>. However, the study's revised population estimate of 2,100 mature individuals still keeps the species highly vulnerable to stochastic events.

#### **Distribution**

The species is chiefly distributed along riparian forests of the Southern Western Ghats, with a strong concentration in the Kerala part (22 collection records) and only one confirmed location in Tamil Nadu. The estimated AOO – 88 km<sup>2</sup>, EOO – 8719 km<sup>2</sup> based on these 23 collection records (Fig. 3.21).

#### **Population**

The recent IUCN Red List assessment suggested a mature population below 250 individuals (Deepu & Geethakumary, 2020) based on then known only six sub populations, meeting the EN D criterion. The present study, based on a density of 4 per ha along riparian areas, revises the estimated total population to 2,100 mature individuals in the wild (based on 13 subpopulations and 23 collection records). Although this estimate exceeds the threshold for EN D, the population is highly fragmented and still falls below the Vulnerable

C1 threshold of <10,000 mature individuals with a projected continuing decline. The inferred 60–84% degradation of riparian habitats suggests a substantial corresponding decline is likely, especially due to severe flood events.

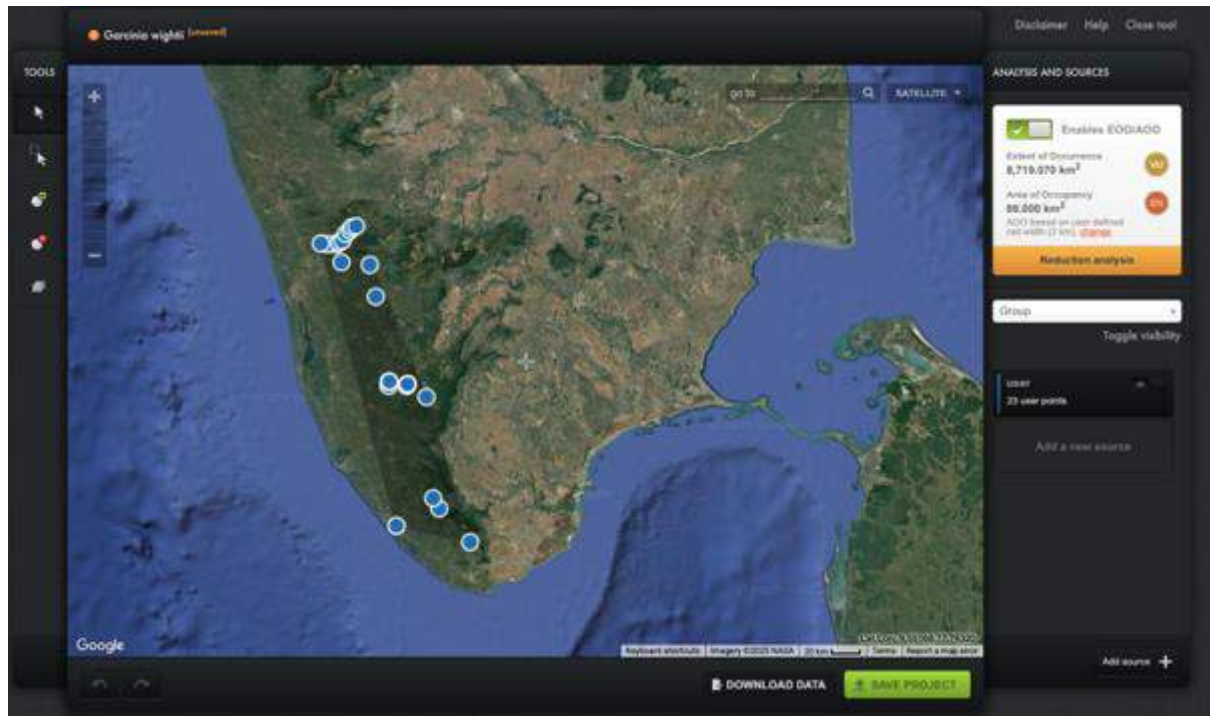


**Fig. 3.21.** Calculated AOO and EOO using GeoCAT for *Garcinia wightii*

### Habitat and Ecology

This is an understory tree species up to 10 m tall, restricted to low- to medium-elevation riparian evergreen forests. Given that low-elevation riparian forests are categorised as an Endangered Ecosystem (Bachan et al., 2022), the species' habitat faces extreme vulnerability.

### Threats

The main threat to the species is the conversion of riparian forests for plantations, dams and reservoirs, and agriculture. The loss of this specialised habitat is estimated to be 60–84% (Bachan et al., 2022). Although the species is resistant to normal riverine flooding, the climate change-induced mega-flood events (e.g., 2018-19, Bachan et al., 2019) pose a major threat, impacting these narrow, linear riparian populations



**Use and Trade**

This tree is a source of dye and gum.

**Conservation Actions**

Some subpopulations falls under protected areas. This species is also subject to ex situ conservation.

**Assessment Rationale**

The most recent assessment for the species was done by Deepu & Geethakumary (2020) and is as follows:

“The species is endemic to the Western Ghats in India. This is a tree species of about 10 m high. This tree species is known from six localities. It grows in the evergreen or semi-evergreen forests, particularly along stream banks. This species has a relatively small extent of occurrence (EOO of 7,260.266 km<sup>2</sup>) and a relatively small area of occupancy (AOO of 24 km<sup>2</sup>). The AOO is based on collections only, and this species is likely to be under collected. However, given our present knowledge about this species, the AOO is unlikely to exceed 500 km<sup>2</sup>. The species is known from six localities and is expected to have a population of less than 250 mature individuals, with less than 50 mature individuals per subpopulation. Therefore, the species is assessed as Endangered” (Deepu & Geethakumary, 2020).

**Discussion and Suggested Amendment to the IUCN Red List Assessment**

The species is assessed as Endangered (EN), primarily under criterion B2ab(iii) and secondarily meeting Vulnerable C1 criteria. The present study recommends a change in AOO 88 km<sup>2</sup> and EOO 8719 km<sup>2</sup>. The Area of Occupancy (AOO) is highly restricted at 88 km<sup>2</sup> (meeting the B2 threshold of <500 km<sup>2</sup>), and the species is known from only 13 severely fragmented locations. There is an inferred continuing decline in the quality and extent of its specialised riparian habitat (B2ab(iii)), which is estimated to have suffered 60–84% loss. The revised total population estimate of 2,100 mature individuals further supports a high threat category, as the population is small and highly susceptible to ongoing habitat loss and acute threats like climate-induced mega-floods. Conservation efforts should prioritise the immediate in situ protection and restoration of its specific riparian habitat.



**Fig. 3.22.** *Garcinia wightii* T.Anderson: A. Habit; B. Fruiting twig; C. Bark; D. Leaf; E. Calyx; F – G. Fruit; H. Fruit L.S.; I. Seed.

**3.3.11. *Goniothalamus wightii* Hook.f. & Thomson** Fl. Ind. [Hooker f. & Thomson] i.  
106. (1855).

**Synonyms:** No Synonyms

**Vernacular Name:** Malamthelli (Malayalam)

**Family:** Annonaceae

**Identifying Features:** *Goniothalamus wightii* is a glabrous shrub or small tree typically found in the lower tree strata, reaching up to 10 m in height. The leaves are simple, alternate, linear-lanceolate, measuring 7–16 x 2–4 cm, with glabrous surfaces and lateral nerves that distinctly loop at the margins. Flowers are solitary and pendent, borne on a pubescent pedicel up to 1 cm long. The flowers possess three broadly ovate sepals (up to 5 mm long) and six petals arranged in two whorls. The larger outer petals are ovate, flat, and clawed, covering the numerous stamens and carpels when young. The fruit is an aggregate of elliptic, yellow-orange monocarps (Fig. 3.23).

**Flowering and Fruiting:** January – June

**IUCN Status Assessment**

The species was initially assessed as Endangered (EN) under Criteria B1ab(iii)+2ab(iii) by Verspagen, et al. (2022), based on an estimated Area of Occupancy (AOO) of 20 km<sup>2</sup> and Extent of Occurrence (EOO) of 3,572 km<sup>2</sup> from five known locations. The present study updates the conservation status using 61 collection records, identifying 20 distinct locations. The re-calculated spatial metrics are significantly higher: AOO 160 km<sup>2</sup> and EOO 33,843 km<sup>2</sup>. Despite the increase in spatial metrics, the species retains the Endangered (EN) status, now supported primarily by Criteria B2ab(iii). This is because the AOO remains highly restricted at 160 km<sup>2</sup> (well below the 500 km<sup>2</sup> threshold for EN), and the species is known from only 20 severely fragmented locations (b) with an inferred continuing decline in habitat quality and extent (a and iii).

**Distribution**

The species is distributed in Kerala, Tamil Nadu and Karnataka, with an estimated AOO of 160 km<sup>2</sup> and EOO 33,843 km<sup>2</sup> (Fig. 3.24).



**Fig. 3.23.** *Goniothalamus wightii* Hook.f. & Thomson: A. Habit; B. Twig; C. Calyx front view; D. Petal; E. Calyx back view; F. Leaf abaxial side; G – I. Flower.



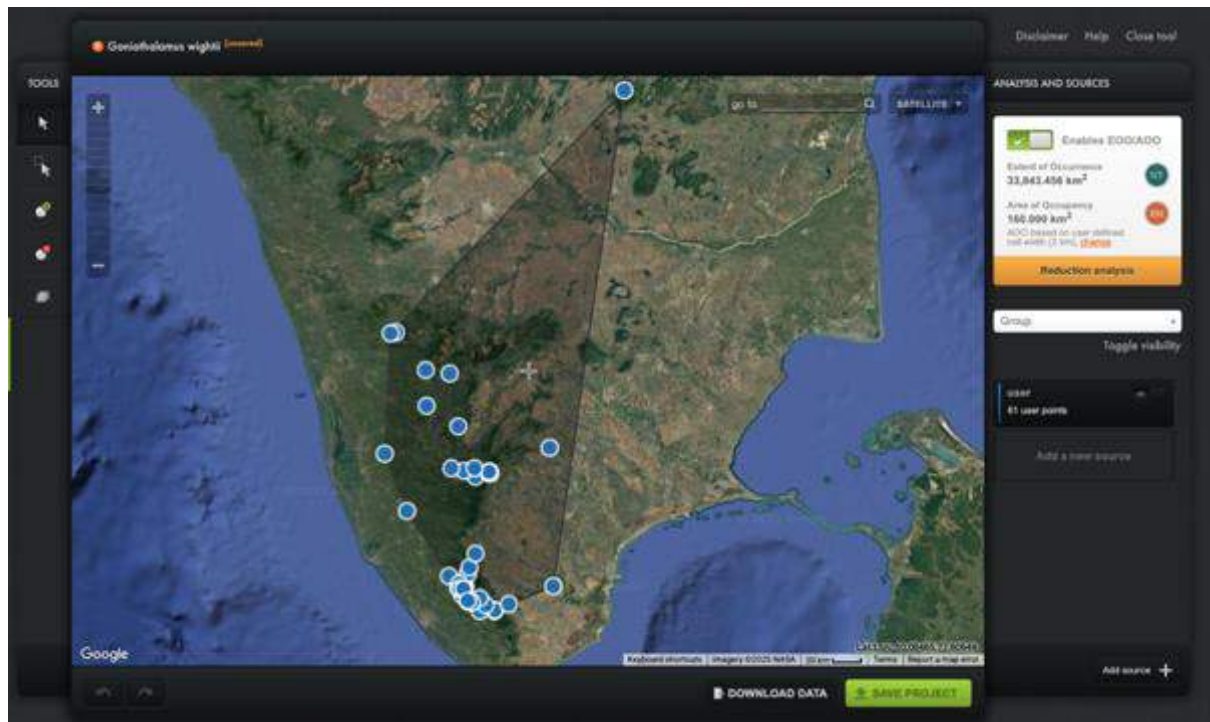


**Fig. 3.24. Calculated AOO and EOO using GeoCAT for *Goniothalamus wightii***

### Population

The population size and trend were previously unknown. Based on the 61 collection records and a density estimated at 0.223 individuals per ha in its habitat, the total mature population is estimated to be approximately 4,000 mature individuals in the wild, distributed across 20 known subpopulations. This small population size, combined with high fragmentation and a severe inferred decline rate, indicates a high degree of vulnerability (meeting the threshold for Vulnerable C(i).

### Habitat and Ecology

*Goniothalamus wightii* is a shrub or small tree species that occurs in medium to high elevation evergreen forests 800–1,400 m. The species have affinity with evergreen forest species such as *Cullenia exarillata*, *Palaquium ellipticum*, *Aglaia bourdillonii* etc.

### Threats

The primary threat to *Goniothalamus wightii* is habitat loss resulting from the conversion of its specialised evergreen forest environment. The main drivers of this loss include its conversion to monoculture forest plantations, expansion of agriculture, and the construction of dams and reservoirs. This cumulative loss is severe, with forest cover loss

in its key habitat regions estimated at 60–84%, leading to an inferred continuing decline in the species' already fragmented population.

### **Use and Trade**

No known use and trade information

### **Conservation Actions**

No specific conservation actions are currently undertaken.

### **Assessment Rationale**

The species was recently assessed by Verspagen, et al. (2022) based on inputs from the initial phases of the present study. The Assessment rationale is as follows:

“*Goniothalamus wightii* is a shrub or small tree species endemic to India. The extent of occurrence (EOO) is calculated at 3,572 km<sup>2</sup> and the area of occupancy (AOO) is 20 km<sup>2</sup> and is only known from five locations. It occurs in high elevation evergreen forests. The main threats to this species' habitat are conversion to monoculture forest plantations and agriculture. It is assessed as Endangered.”

### **Discussion**

The 2022 assessment correctly categorised *Goniothalamus wightii* as Endangered (EN) under Criteria B1ab(iii)+2ab(iii) based on the available data at that time. The present study, utilizing 61 collection records and identifying 20 distinct locations, drastically changes the spatial metrics. The AOO of 160 km<sup>2</sup> remains below the Endangered threshold of 500 km<sup>2</sup>. Although the EOO (33,843 km<sup>2</sup>) and number of locations (20) now exceed the EN thresholds for B1 and B2, the small AOO ensures that Criterion B2 is still met, but only the sub-criteria related to AOO must be cited.

### **Suggested Modification of Assessment Rationale**

The suggested modification retains the Endangered status but updates the data and simplifies the criteria to B2ab(iii).

“*Goniothalamus wightii* is a shrub or small tree species endemic to India. New occurrence records from the present study (61 collection records across 20 locations) have significantly increased the known range. However, the Area of Occupancy (AOO) remains highly restricted at 160 km<sup>2</sup> (satisfying the EN B2 threshold). The species is known from 20 fragmented locations and occurs in high-elevation evergreen forests. The primary threats to its habitat are conversion to monoculture forest plantations, agriculture, and

dams/reservoirs. This is leading to a continuing, inferred decline in the extent and quality of its habitat. Based on the severely restricted AOO and the continuing inferred decline in habitat quality, the species is assessed as Endangered (EN) under Criteria B2ab(iii).”

**3.3.12. *Humboldtia vahliana* Wight**, Icon. Pl. Ind. Orient. [Wight] iv. t. 1607.

**Synonyms:** *Batschia vahliana* (Wight) Kuntze, Revis. Gen. Pl. 1: 162 (1891)

**Vernacular Name:** Attuvanchi (Malayalam)

**Family:** Fabaceae

**Identifying Features:** A dioecious, medium-sized riparian tree (up to 20 m tall) with dark brown bark. Leaves are evenly pinnate, typically with three pairs of oblong-lanceolate leaflets (up to 22 x 6 cm). The rachis may be winged or wingless, and leaflets have 8-14 pairs of prominent lateral nerves. Flowers are borne in erect, axillary racemes. The calyx consists of oblong sepals (7 x 3 mm), and the corolla has obovate, clawed petals (10 x 5 mm). It possesses five stamens with glabrous, reddish filaments and a densely hairy ovary. The mature fruit is a compressed, oblong pod measuring 13–20 cm long, covered in rusty-pubescent; seeds are discoid (Fig. 3.25).

**Flowering and Fruiting:** February – April

**IUCN Status Assessment**

The species was first assessed as Endangered (EN) under Criteria B2ab(i,ii,iii,v) in 2015 (Ved, et al., 2015). The present study, based on 85 collection records, identifies 28 locations. The updated spatial metrics are: AOO 252 km<sup>2</sup> and EOO 27,395 km<sup>2</sup>. The AOO of 252 km<sup>2</sup> remains below the Endangered threshold (500 km<sup>2</sup>). Given this severely restricted AOO, fragmentation into 28 locations, and the inferred continuing decline in habitat quality (see Threats), the species retains its status as Endangered (EN), now supported by Criteria B2ab(iii).

**Distribution**

The species is endemic to the Southern Western Ghats, primarily distributed along the riparian forests of Kerala, Tamil Nadu, and Karnataka. The vast majority of records are from Kerala (77). The estimated sub population for the species 28 and the AOO 252 km<sup>2</sup> and EOO 27395 km<sup>2</sup> (Fig. 3.26).

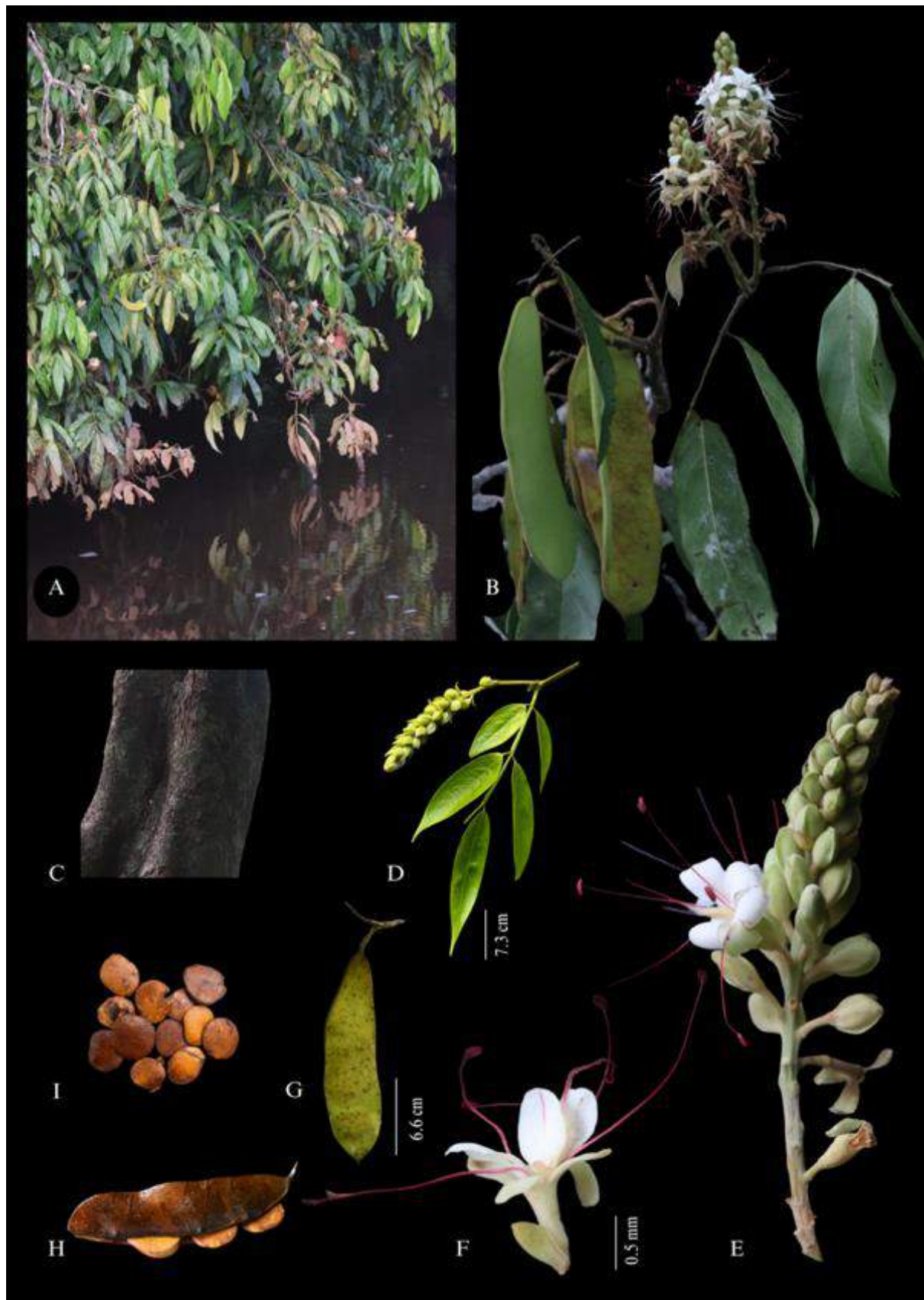


**Fig. 3.25.** *Humboldtia vahliana* Wight: A. Habit; B. Twig; C. Bark; D. Leaf with bud; E. Inflorescence; F. Flower; G. Immature pod; H. Mature pod; I. Seed.



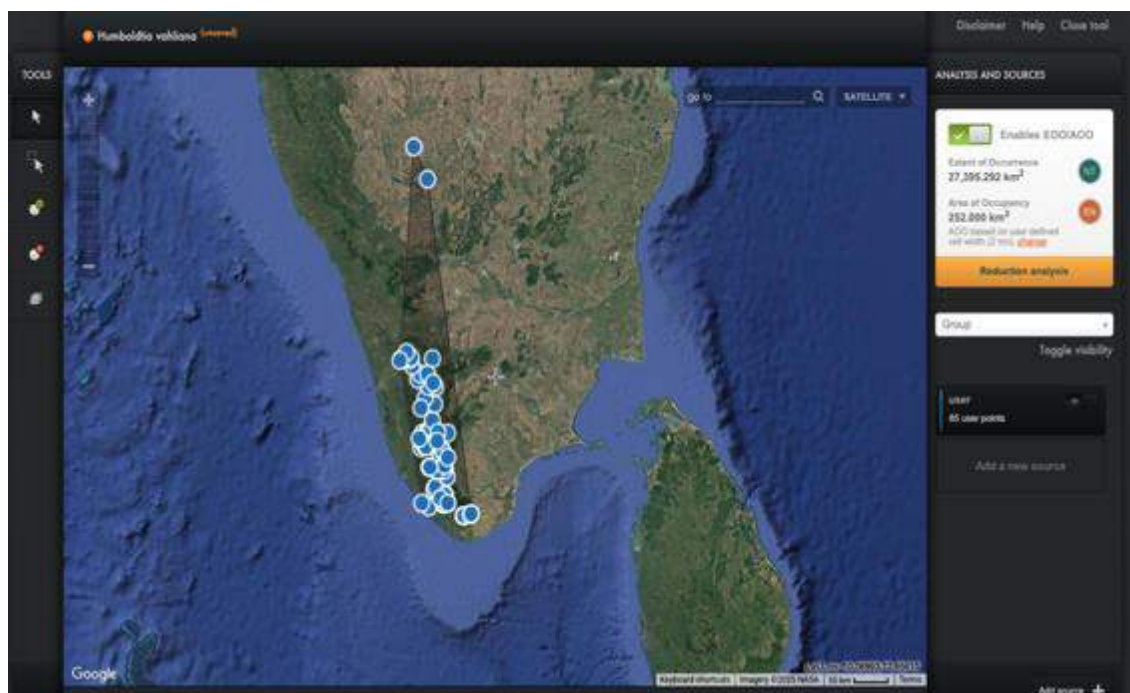


**Fig. 3.26.** Calculated AOO and EOO using GeoCAT for *Humboldtia vahliana*

## Population

The species population size was previously unknown (Ved, et al., 2015). The present study identified 28 subpopulations from 85 collection records. Subpopulations are severely fragmented, particularly in the Pathanamthitta and Thrissur districts of Kerala. The largest known subpopulation is located in the riparian forests along the Chalakudy river (Athriappilly Vazhachal region), but its size is estimated to be less than 250 mature individuals. The total estimated population in the wild is 8,000 mature individuals. The species' distribution is heavily concentrated in Kerala (77 records), followed by Tamil Nadu (6) and Karnataka (2).

## Habitat and Ecology

*Humboldtia vahliana* is an obligate riparian species, classified as a medium-sized arboreal tree characterised by its rough, dark brown bark interspersed with shades of grey. It is a characteristic canopy or sub-canopy tree of the low elevation riparian evergreen forests (100–700 m altitude) (Bachan, 2010; Bachan et al., 2022).

## Threats

The main threats stem from the catastrophic loss and degradation of its obligate low-elevation riparian forest habitat. This includes the conversion of riparian zones for forest

timber plantations, the construction of dams and reservoirs, and agricultural expansion. Habitat loss in this ecosystem is estimated to be 60–84% in the past, leading to the classification of the low-elevation riparian evergreen forest as an Endangered ecosystem itself (Bachan et al., 2022).

### **Use and Trade**

The bark of the species is valued in traditional medicine for treating various ailments, including ulcers, biliousness, leprosy, and epilepsy (Leela & Pillai, 2005). The unsustainable harvesting of the bark constitutes an additional threat to the wild population.

### **Conservation Actions**

Given that the bark constitutes the primary component used for medicinal purposes and is harvested in an unsustainable fashion, it is imperative to implement conservation strategies and awareness initiatives. Some progress and attention have been directed towards this issue through the identification and documentation of over 100 forest areas (MPCAs). The occurrence of this species in the wild has been verified in the MPCA regions of Triveni and Waynaad in Kerala. It is anticipated that the MPCA initiative will foster the conservation of such species.

### **Assessment Rationale**

The most recent assessment for the species was done during 2025 (Ved et al., 2015) and the assessment rationale is as follows:

“The whole population has been disturbed by unsustainable collection practices. It has been observed as well as inferred that these collection practices are ongoing in the natural habitat. Inference has been drawn regarding the decline in area of occupancy (AOO), extent of occurrence (EOO) and habitat quality based on observation as well as circumstantial evidence. The area of occupancy is c. 400 km<sup>2</sup> and is declining. The population is severely fragmented. The population is declining continuously due to habitat loss and no significant ex situ conservation efforts have been undertaken so far (P.S. Udayan pers. comm. 2015). Thus, the species has been assessed as Endangered.”

### **Discussion**

The 2025 rationale correctly identified the primary issues: unsustainable bark collection, population fragmentation, and a continuous decline due to habitat loss, assessing the species as Endangered (EN). However, the use of a broad Area of Occupancy (AOO) of

c. 400 km<sup>2</sup> and an unspecified Extent of Occurrence (EOO) is significantly revised by the present study. Our research, based on 85 collection records, calculated the AOO at 252 km<sup>2</sup> and the EOO at 27,395 km<sup>2</sup>, identifying 28 distinct locations. The updated EOO far exceeds the EN threshold of 5,000 km<sup>2</sup>, rendering the use of Criterion B1 (based on EOO) inappropriate. The AOO, however, has been refined and is now definitively 252 km<sup>2</sup>, which is well below the EN threshold of 500 km<sup>2</sup>.

Furthermore, the population data now specifies an estimated 8,000 mature individuals in the wild, with the largest subpopulation having less than 250 individuals. This small subpopulation size, coupled with the 60–84% habitat loss in its specialised riparian ecosystem, strongly justifies maintaining the Endangered status. Therefore, the assessment should be amended to focus solely on the restricted, severely fragmented AOO and the continuing decline inferred from specific threats (habitat loss and unsustainable harvesting), supporting the species under a revised set of criteria.

#### **Suggested Amendment to the IUCN Red List Assessment Rationale**

*Humboldtia vahliana* is an arboreal species endemic to India. The present study, based on 85 collection records, calculates the Area of Occupancy (AOO) at 252 km<sup>2</sup>. The whole population is severely fragmented into 28 known locations, with the largest subpopulation estimated at less than 250 mature individuals. Inference is drawn regarding a continuing, sharp decline in the extent and quality of its habitat due to the conversion of low-elevation riparian forests for timber plantations, agriculture, and dams/reservoirs (with an estimated past habitat loss of 60–84%). Additionally, the unsustainable collection of its bark for medicinal use contributes to population decline. Based on the restricted AOO, severe fragmentation, and inferred continuing decline, the species is assessed as Endangered (EN) under Criteria B2ab(iii).

#### **3.3.13. *Hydnocarpus pentandrus* (Buch.-Ham.) Oken, Allg. Naturgesch. 3(2): 1381 (1841).**

**Synonyms:** *Chilmoria pentandra* Buch.-Ham. in Trans. Linn. Soc. London 13: 501 (1822); *Hydnocarpus laurifolius* Sleumer in Bot. Jahrb. Syst. 69: 33 (1938), nom. superfl.; *Hydnocarpus wightianus* Blume in Rumphia 4: 22 (1849); *Munnicksia laurifolia* Dennst. in Schlüssel Hortus Malab.: 23 (1818), not validly publ.

**Vernacular Name:** Turavaka (Sanskrit); Toratti, Chalmogra yenne mara, Mirolhakai (Kannada); Kadukavath, Kantel, Kastel, Kowti, Ketu (Marathi); Kotti, Maravetti, Marotti, Neeratti, Niralam, Thamana (Malayalam)

**Family:** Achariaceae

**Identifying Features:** A medium-sized tree with white bark and puberulous branchlets. Its elliptic leaves, measuring 17-20 x 7-8 cm, have 8 prominent nerve pairs. The flowers, approximately 1 cm across, are found in peduncled axillary cymes. The flowers have broadly ovate, pubescent sepals; broadly ovate, ciliate, greenish-yellow petals; and scales that are half the length of the petals and densely hairy. The fruit is a globose berry, 5-7 cm across, with a thick, rough rind and an uneven surface (Fig. 3.27).

**Flowering and Fruiting:** March-August

#### **IUCN Status Assessment**

The first IUCN Red List assessment for the species was conducted in 2015, where it was categorised as Vulnerable (VU) under Criteria A2cd (Ved, et al., 2015). The number of locations was not specified in that past assessment. The present study, utilizing 91 collection records, identified 43 locations for the species. Based on these data, the Area of Occupancy (AOO) was estimated at 324 km<sup>2</sup>, and the Extent of Occurrence (EOO) 1,68,683 km<sup>2</sup>.

#### **Distribution**

The species *Hydnocarpus pentandrus* is distributed across the central and southern Western Ghats of India, spanning five states. It is concentrated primarily in the southern states, with the majority of collection records coming from Kerala (54 records), followed by Tamil Nadu (19 records), and Karnataka (13 records). The distribution range extends northward, with a smaller number of records also documented in Maharashtra (4 records) and Goa (1 record). This broad yet concentrated distribution suggests that while the species has successfully established itself across a significant latitudinal range within the Western Ghats, its core populations and abundance lie in the southern, perennially moist tracts of Kerala. The AOO estimated for the species is 324 km<sup>2</sup> and EOO is 168,683 km<sup>2</sup> (Fig. 3.28).

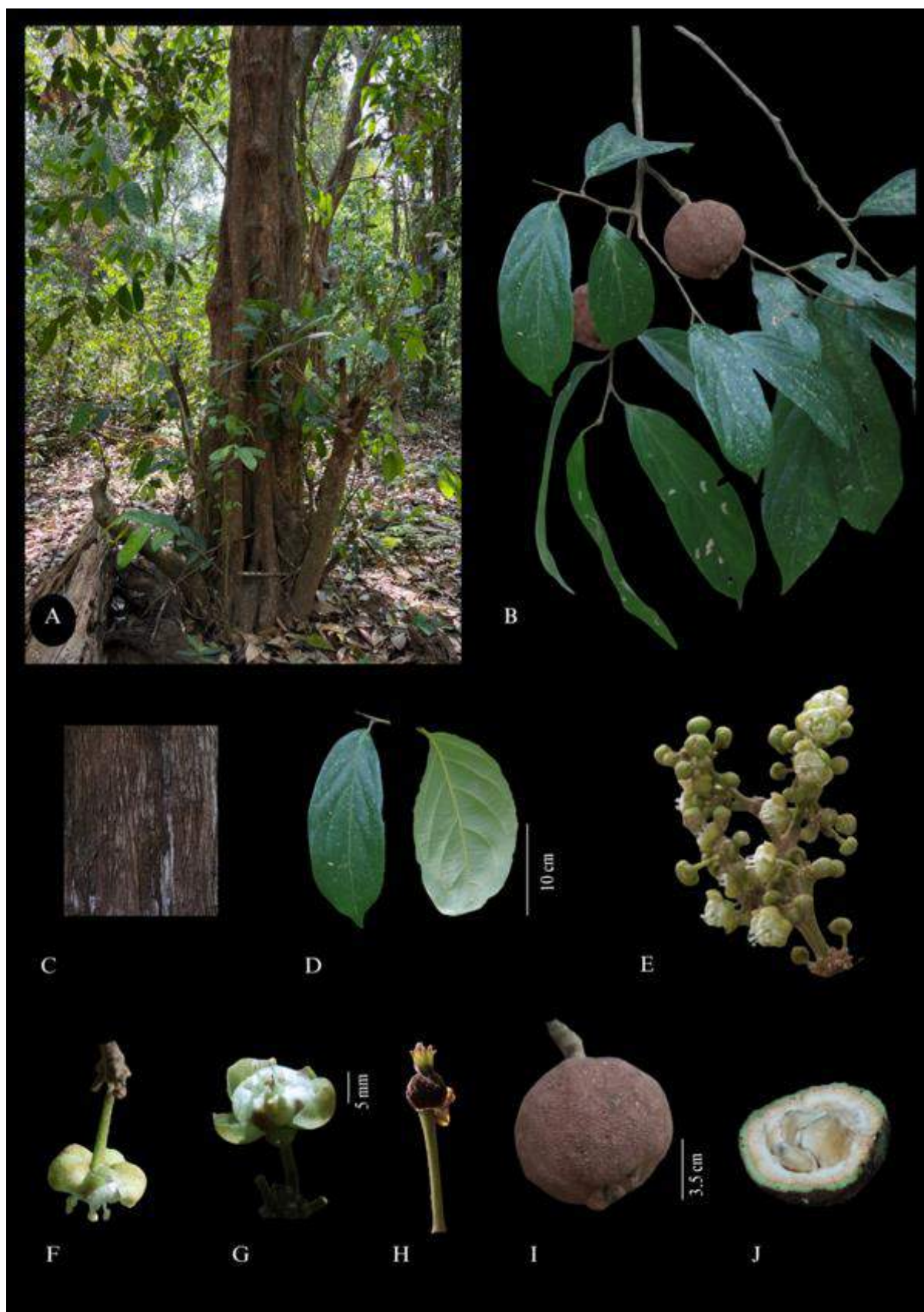


**Fig. 3.27.** *Hydnocarpus pentandrus* (Buch.-Ham.) Oken.: A. Habit; B. Twig; C. Bark; D. Leaf; E. Inflorescence; F. Calyx; G. Flower; H. Young fruit; I. Fruit; J. Seed.



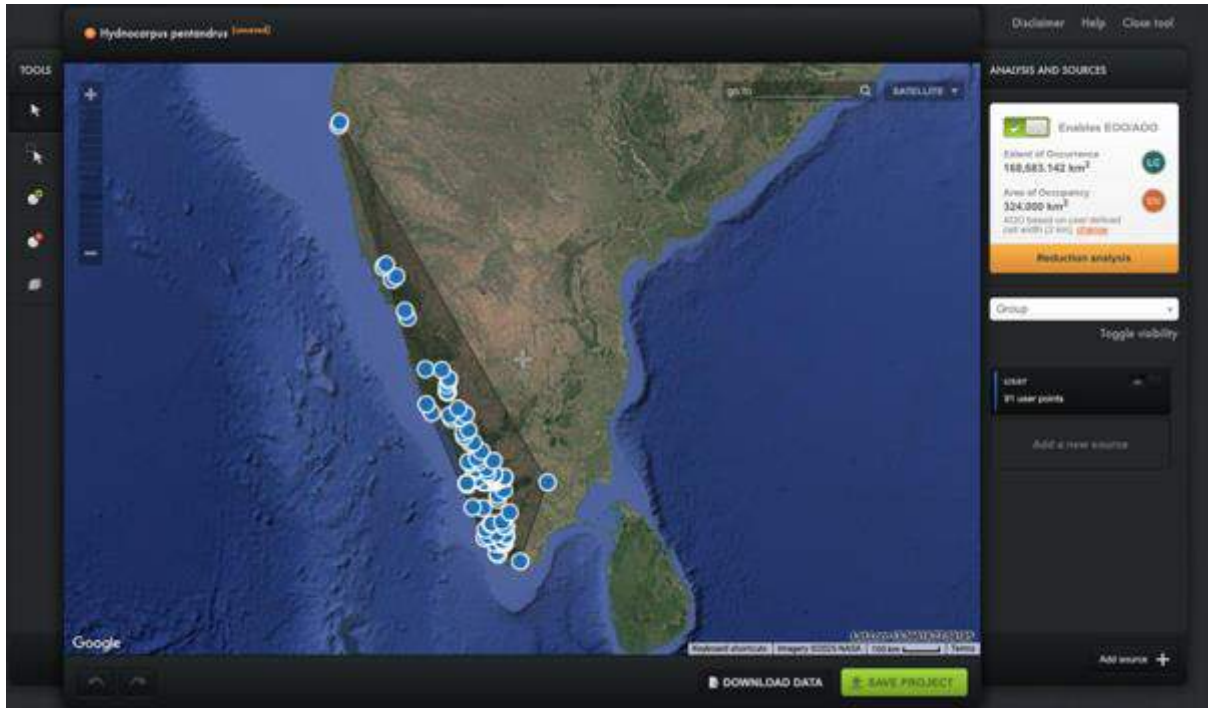


**Fig. 3.28.** Calculated AOO and EOO using GeoCAT for *Hydnocarpus pentandrus*

### Population

The population of *Hydnocarpus pentandrus* is distributed across the central and southern Western Ghats, spanning the five states of Maharashtra, Goa, Karnataka, Kerala, and Tamil Nadu. Historically, significant subpopulations were documented along the banks of aquatic systems in specific regions of Kerala, such as Tholnada, Anakulam, and Manikantanchal (Balasubramanyan et al., 1989). The present study confirms this wide distribution, identifying 91 collection records across the entire range, with the majority concentrated in Kerala (54 records), followed by Tamil Nadu (19), Karnataka (13), Maharashtra (4), and Goa (1). The species' habitat ranges from low to high elevation forests, including valuable coastal sacred groves. Based on the study's data, the population is structured into 43 identified subpopulations, with an enumerated population density of 0.8 individuals per hectare. This leads to a total estimated population of 25,500 mature individuals in the wild.

### Habitat and Ecology

This species is ecologically versatile, inhabiting a range of forest types, from moist deciduous to evergreen forests, spanning coastal to high-altitude zones of the Western Ghats. It is predominantly found in low-elevation moist forests and is a characteristic

component of coastal sacred groves. The species is also an important wild tree component within human-modified landscapes, including villages and forest peripheries.

### **Threats**

The principal threats to *H. pentandrus* are driven by anthropogenic pressure. These include habitat destruction and severe fragmentation, exacerbated by infrastructural development, agricultural encroachment, and the expansion of human settlements. Additionally, the species faces biological pressures from unsustainable harvesting of its parts (likely for oil/medicinal use) and predation of its seeds/fruits by squirrels, which limits natural regeneration.

### **Use and Trade**

The extracted seed oil is utilized in the therapeutic management of leprosy, rheumatic arthritis, helminthic infections, diabetes, edema, and various dermatological conditions. The fruit of this species is employed within the frameworks of Ayurvedic, Sidha, and traditional medicinal practices. This species is subjected to trade at local, regional, and national scales. The fruit is commercially recognised as Marotti and is exchanged in substantial quantities.

### **Conservation Actions**

This species is currently subjected to extensive trade, necessitating regulatory measures and heightened awareness to ensure sustainable harvesting of its fruits and seeds. It is imperative that this species receives protection through both in situ and ex situ conservation strategies. Significant attention and initiatives have been directed towards the identification and documentation of over 100 forest areas (MPCAs). The existence of this species in the wild has been corroborated within the MPCA regions of Agumbe, Charmadi, Devimane, Kollur, Kudremukha, Subramanya, and Talacauveri in Karnataka, as well as Anapady in Kerala. It is anticipated that the MPCA initiative will foster the in situ conservation of such species.

### **Assessment Rationale**

The recent assessment of the species was assessed by Ved et al. (2015) and the assessment rationale is as follows:

“This species is endemic to southern India. The change in population has been calculated based on broad observations of the participants in the CAMP workshop, which was

supported by the observations of individual experts who are working on the species directly in the field. A c. 40% population reduction is estimated due to the combined effects of unregulated collection of the species and forest degradation over the last 66 years (three generations). The species has high market demand and the level of exploitation is high and unsustainable. No significant ex situ conservation efforts have been taken so far. It is found in some sacred groves in Kerala (P.S. Udayan pers. comm. 2015). Hence, the species is assessed as Vulnerable.

### **Discussion**

The recent assessment for *Hydnocarpus pentandrus* as Vulnerable (VU) relied on an estimated 40% population reduction based on broad observations, meeting Criterion A2c,d. (Ved et al., 2015). However, the quantitative data from the present study suggests that the species does not currently meet the necessary thresholds to qualify for a threatened category, thus requiring an amendment to categorise it as Near Threatened (NT). The study confirms a robust total population size of 25,500 mature individuals and a wide distribution across five states, fragmented into 43 subpopulations. This substantial population and broad geographic range exceed the quantitative thresholds required for Vulnerable status (VU D: <10,000 individuals and VU A: 30-50% decline). While the species is undeniably facing severe threats from unsustainable harvesting for its high-demand oil/seeds and ongoing habitat loss/fragmentation, the high total population size introduces uncertainty regarding whether the actual decline rate over the last three generations is severe enough to definitively reach the 30% threshold required for VU status. Therefore, the assessment is amended to Near Threatened (NT), indicating that the species is close to qualifying for Vulnerable under Criterion A2c,d, and that urgent conservation measures are required to prevent it from moving into a threatened category in the near future.

### **Suggested Amendment the IUCN Rationale**

*Hydnocarpus pentandrus* is endemic to the Western Ghats of India, occurring across five states. The species is confirmed to be widespread, structured into 43 highly fragmented subpopulations, with a total estimated population of 25,500 mature individuals (based on the present study). While the population size does not qualify for any threatened category, the species is known to be subject to a continuing decline due to the severe, unsustainable harvesting of its seeds/fruit for market demand and the ongoing degradation and



fragmentation of its moist forest habitat. Based on the known, serious nature of these threats, the population is suspected to be undergoing a rate of decline that may soon approach the 30% threshold required for Vulnerable status. Hence, the species is assessed as Near Threatened (NT) as it almost qualifies for Vulnerable under Criteria A2c,d.

**3.3.14. *Impatiens parasitica* Bedd., Madras J. Lit. Sci. Ser. II, xx. (1859) 66.**

**Synonyms:** No Synonyms

**Vernacular Name:**

**Family:** Balsaminaceae

**Identifying Features:** An epiphytic succulent herb with unevenly thickened, reddish stems and elliptic-ovate leaves measuring 6 x 3.5 cm on a 4 cm long petiole. It produces 2-4-flowered, axillary cymes on a glabrous 2 cm long peduncle. The flowers are 2.5 cm long with a greenish lip at the mouth, scarlet elsewhere, and a reddish, striate 12 mm spur. The sepals are green, linear, acute, and 3 mm long. The two-lobed wings have a larger, flat lower lobe that enters the spur of the lip and are red. The fruit is a capsule 5 mm long (Fig. 3.29).

**Flowering and Fruiting:** November – January

**IUCN Status Assessment**

The IUCN Red list assessment of *Impatiens parasitica* is being done first time (Devika & Bachan, 2024). The species were assessed with multiple criteria which resulted in Vulnerable category under the criteria A2c with an AOO 156 km<sup>2</sup>, EOO 12812 km<sup>2</sup>.

**Distribution**

The species is endemic to the southern Western Ghats particularly in Kerala and Tamil Nadu with an estimated AOO of 156 km<sup>2</sup> and EOO 12,812 km<sup>2</sup> (Fig. 3.30).

**Population**

*Impatiens parasitica* is classified as an epiphytic succulent herb that is typically found adhering to the bark of canopy trees within the tropical high-elevation evergreen and mountain Shola forests situated in the southern Western Ghats of South West India, at altitudes ranging from 1,000 to 2,200 m above sea level.



**Fig. 3.29.** *Impatiens parasitica* Bedd.: A – B. Habit; C. Flowering plant; D. Leaf abaxial side; E. Root; F. Capsule with pedicel; G. Flower in anterior view; H. Flower in lateral view.

The species is represented by 21 distinct subpopulations dispersed across four high-altitude landscapes in the southern Western Ghats. The majority of these subpopulations are located within the Munnar landscape (11 subpopulations), followed by the Annamalai landscape (five), Nilgiris (three), and Periyar (two). The estimated mature population is less than 40,000 individuals, as derived from the identified 21 subpopulations (Devika & Bachan, 2023). The habitats at elevated altitudes have been repurposed primarily for tea, eucalyptus, and Black Wattle plantations (Bachan & Devika 2021; Sasmitha et al., 2021).

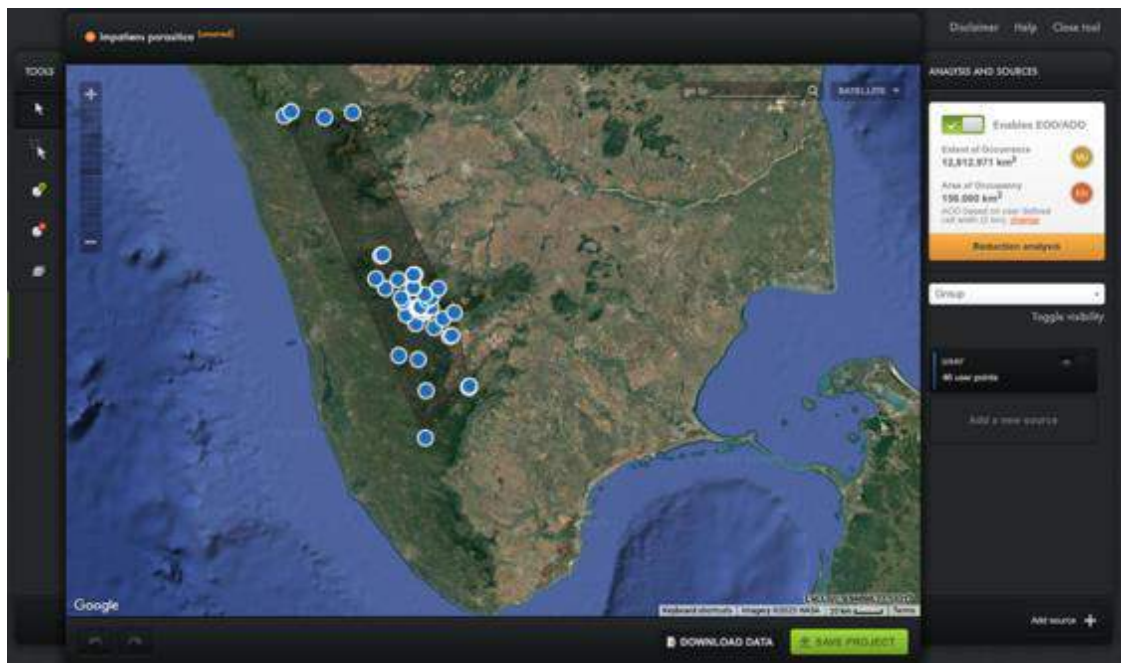


**Fig. 3.30. Calculated AOO and EOO using GeoCAT for *Impatiens parasitica***

The remaining habitats have been adversely impacted by timber extraction, the construction of dams and reservoirs, as well as the establishment of forest plantations. A suspected decline of approximately 30% in population has occurred over the last three generations, attributable to habitat loss. The degradation of habitats continues as a result of timber extraction, infrastructural development, and urbanization.

### Habitat and Ecology

*Impatiens parasitica* is an epiphytic succulent perennial herb that is typically found affixed to the branches of canopy trees, occasionally on barks, or infrequently on moist rocks that exhibit substantial moss coverage within the tropical high-elevation evergreen and mountain Shola forests of the southern Western Ghats. The species demonstrates a preference for mountain evergreen forests, which can be found at elevations reaching up to 2,400 m (Eravikulam National Park, Devika & Bachan, 2023). Furthermore, the species

has been observed at an elevation of 1,000 m within evergreen forest habitats (Bachan, 2010) or pseudo-shola formations at elevations between 1,100 and 1,400 m (Devika & Bachan, 2023), with the most favoured habitat range identified as between 1,400 and 2,200 m. The species is commonly found affixed to a variety of tree species, including *Heritiera papilio*, *Palaquium ellipticum*, *Cullenia exarillata*, *Litsea stocksii*, *Cryptocarya lawsonii*, and *Dysoxylum binectariferum* (Devika & Bachan, 2023).

### **Threats**

The habitats of this species are primarily subjected to clearance for the establishment of tea and monoculture plantations, urban development, infrastructure advancements, and forest fires.

### **Use and Trade**

Currently, there exists a lack of information pertaining to the utilization and trade of this species.

### **Conservation Actions**

Presently, there are no conservation strategies that are specific to either the species or its habitat. Only 30% of the population resides within designated protected areas. This species is known to occur in three protected regions.

### **Assessment Rationale**

The recent assessment for the species was done by Devika and Bachan (2023) and the assessment rationale is as follows:

“*Impatiens parasitica* is characterized as an epiphytic succulent perennial herb that is commonly found attached to branches of canopy trees amidst significant moss growth within the tropical high-elevation evergreen and mountain Shola forests of the southern Western Ghats, at altitudes ranging from 1,000 to 2,400 m above sea level. The area of occupancy (AOO) is estimated as 112 km<sup>2</sup>, while the extent of occurrence (EOO) encompasses 9,793 km<sup>2</sup>. This species comprises 21 subpopulations that are geographically restricted to four high-altitude landscapes within the southern Western Ghats, namely Munnar, Anamalais, Nilgiris, and Periyar. The estimated population of mature individuals is approximately 40,000, and these individuals are typically associated with tree species such as *Heritiera papilio*, *Palaquium ellipticum*, *Cullenia exarillata*, *Litsea stocksii*, *Cryptocarya lawsonii*, and *Dysoxylum binectariferum*. There is a suspected population

decline of approximately 30% that has occurred due to habitat loss over the last three generations, and the threats to this species remain ongoing.”

### **Discussion**

The initial Vulnerable (VU) assessment stemmed from early input of the present study, with recent updates increasing collection records but confirming 21 constant subpopulations. This stability in the number of locations, which is critical for fragmentation analysis, demonstrates the assessment's robustness regarding the species' severe restriction. The high fragmentation and reliance on micro-habitats justify the VU status under Criterion A2c (inferred population decline). Consequently, the amendment only requires updating the AOO (156 km<sup>2</sup>) and EOO (12,812 km<sup>2</sup>) to reflect the most accurate spatial metrics.

**3.3.15. *Litsea oleoides* (Meisn.) Hook.f.,** Fl. Brit. India [J. D. Hooker] 5(13): 175 (1886).

**Synonyms:** *Tetranthera oleoides* Meisn. in A.P.de Candolle, Prodr. 15(1): 195 (1864); *Malapoenna oleoides* Kuntze in Revis. Gen. Pl. 2: 573 (1891).

**Vernacular Name:** Chevukodi (Malayalam), Arambamaram (Tamil)

**Family:** Lauraceae

**Identifying Features:** A large canopy tree with brownish bark and oblong leaves, measuring 14-18 x 6-7 cm, that are acute at both ends and pale on the underside. The leaves have 9-12 pairs of non-prominent nerves and a petiole 2-2.5 cm long. The flowers are arranged in long axillary racemes, with umbellules that are 6-7 mm across on peduncles of approximately 6 mm. The umbellules contain 3-6 flowers with pedicels, orbicular and pubescent bracts, and 9 stamens with hairy filaments and sessile glands at the base. Female flowers have three series of staminodes with glandular bases. The fruit is a glabrous, globose berry, 2-2.5 cm across, and red with white spots (Fig. 3.32).

**Flowering and Fruiting:** October – April

### **IUCN Status Assessment**

The first IUCN Red List assessment for the species was conducted in 2023 (de Kok, 2023), where it was categorised as Vulnerable (VU) under Criteria B1ab(iii)+2ab(iii). This assessment was based on seven locations, with an estimated Area of Occupancy (AOO) of 28 km<sup>2</sup> and an Extent of Occurrence (EOO) of 14,504 km<sup>2</sup>. The present study, utilizing 41



collection records, significantly expanded the known distribution by identifying 21 locations for the species. The re-calculation of spatial metrics resulted in an estimated AOO 160 km<sup>2</sup> and EOO 1,40,646 km<sup>2</sup>.

### Distribution

The species is distributed in Kerala, Tamil Nadu, Karnataka, Maharashtra states of India (Fig. 3.31).

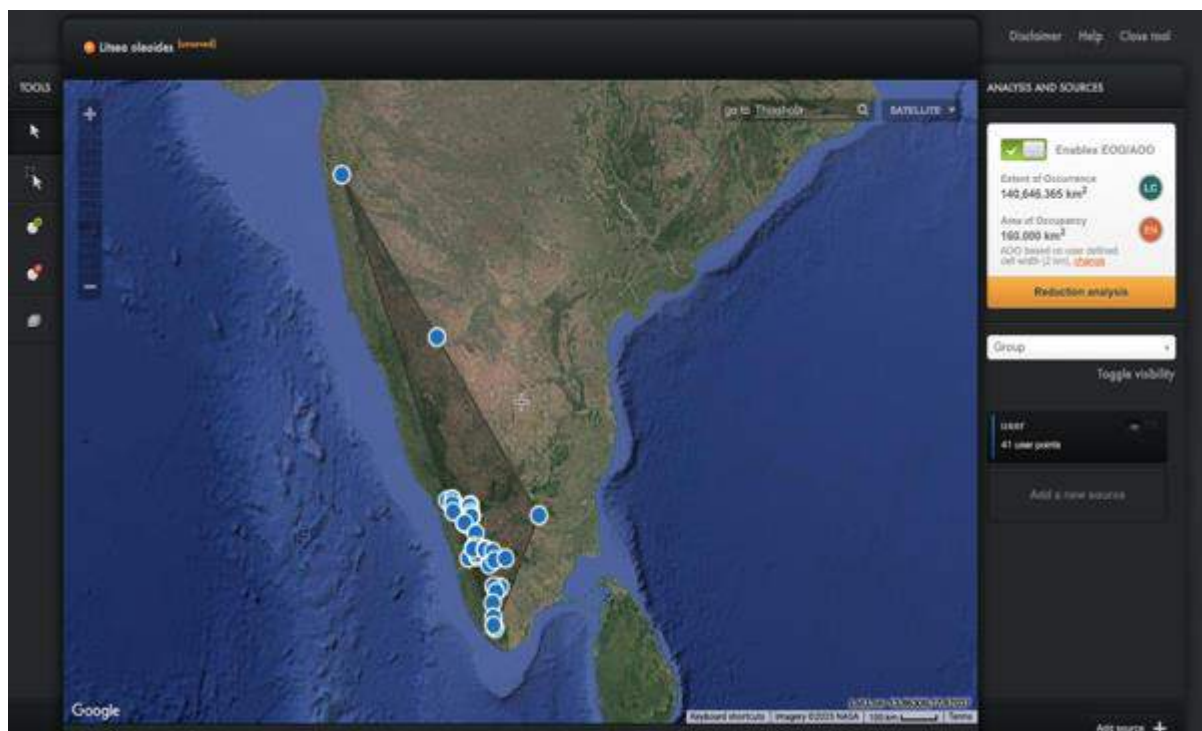


Fig. 3.31. Calculated AOO and EOO using GeoCAT for *Litsea oleoides*

### Population

There is no previous information on the population of the species. The present study estimated a density of 1.02 per hectare. The estimated number of mature individuals based on the AOO is 16000 for the species. The species is having 21 sub populations known from 41 collection records of which majority are from Kerala (27), Tamil Nadu (12), Karnataka (1) and Maharastra (1).

### Habitat and Ecology

This species is a tree between 20-35 m tall. It grows in evergreen forests at elevations from 800–2,300 m. The species seen associated with evergreen forest species such as *Cullenia exerillata*, *Cryptocaya lawsonii*, *Syzygium gardneri*, *Syzygium lateum*, *Elaeocarpus tuberculatus*, *Cinnamomum sulphuratum*, *Antidesma montana*.

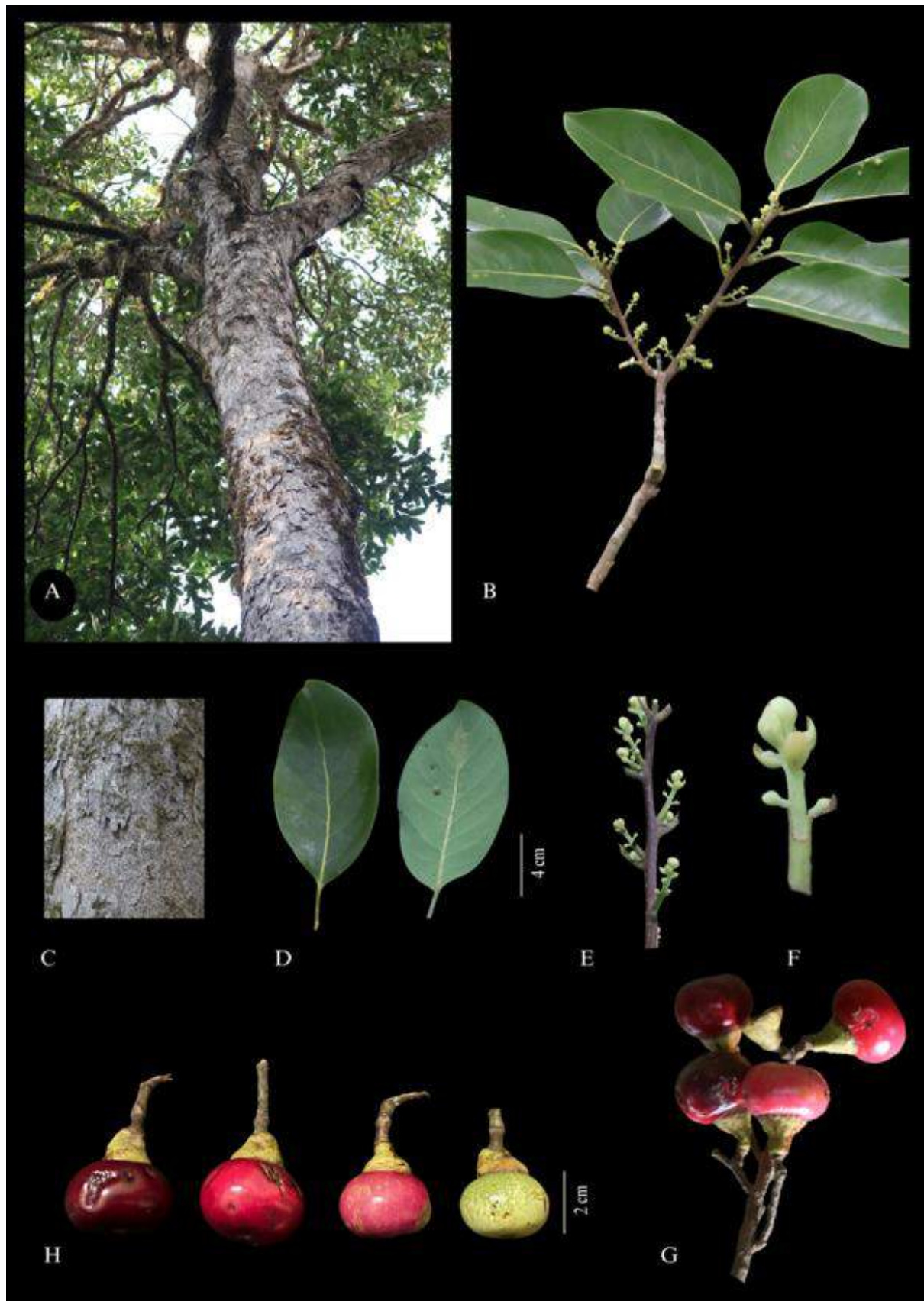


**Fig. 3.32.** *Litsea oleoides* (Meisn.) Hook.f.: A. Habit; B. Flowering twig; C. Bark; D. Leaf; E. Inflorescence; F. Flower; G. Fruit; H. Mature fruits.

**Threats**

The species had been extracted as timber during the colonial period and also for plywood industries in the post independent period. The major threats to this species are deforestation and habitat destruction through conversion to forest timber plantations, dams and reservoirs, agriculture and infrastructure development.

**Use and Trade**

The species had been extracted for timber during the colonial period and also for plywood industries. Other use of the species is unknown.

**Conservation Actions**

About 30% of the population are within Protected areas. This species is not kept in any ex-situ collection (BGCI, 2019).

**Assessment Rationale**

The *Litsea oleoides* is arecently assessed by de Kok (2023) and the assessment rationale is as follows:

“This tree species is known from many collections from about seven localities in the Western Ghats in the Indian states of Kerala and Tamil Nadu. It grows in evergreen forests between 1,700–2,300 m altitude and these forests are under threat of deforestation and habitat destruction. This species has a small extent of occurrence (EOO of 14,504 km<sup>2</sup>) and a small area of occupancy (AOO of 28 km<sup>2</sup>). The AOO is based on collections only and this species is likely to be under collected. However, given our present knowledge about this species, the AOO is unlikely to exceed 2,000 km<sup>2</sup>. Given that it is only known from seven locations (one at least from a protected area), that it has a small AOO and EOO, and the threats to its habitat, it is considered as Vulnerable.”

**Discussion**

The IUCN assessment rationale's metrics were precautionary but highly underestimated. The present study, utilizing 41 collection records, provides definitive evidence that the species' Extent of Occurrence (EOO) is far larger than previously thought, surging from 14,504 km<sup>2</sup> to 140,646 km<sup>2</sup>. This revised EOO exceeds the Endangered threshold and invalidates the use of Criterion B1. Crucially, the number of known locations has also expanded significantly, from seven to 21. Despite this expansion, the calculated Area of Occupancy (AOO) is now 160 km<sup>2</sup>, which still remains well below the Endangered



threshold of 500 km<sup>2</sup>. The current data confirms that while the species is more geographically widespread than previously thought, its actual occupation area is highly restricted and severely fragmented into 21 small subpopulations. The primary threats, deforestation and habitat destruction for plantations, dams, and agriculture, remain operative and continue to drive an inferred decline in habitat extent and quality. Therefore, the species still qualifies as Endangered (EN), but the rationale must be simplified to rely solely on the restricted AOO an Amended IUCN Assessment Rationale.

#### **Proposed Amendment to IUCN Assessment**

*Litsea oleoides* is a tree species endemic to the Western Ghats of India. The present study, based on 41 collection records, calculates the species' Area of Occupancy (AOO) at 160 km<sup>2</sup>, which is below the Endangered threshold of 500 km<sup>2</sup>. The species is known from 21 fragmented locations, occurring in medium to high-elevation evergreen forests (800–2,300 m). The main threats deforestation and habitat destruction for timber plantations, dams, and agriculture are ongoing, leading to a continuing inferred decline in the extent and quality of its habitat. Based on the severely restricted AOO, the fragmentation into 21 locations, and the inferred continuing decline, the species is assessed as Endangered (EN) under Criteria B2ab(iii).

#### **3.3.16. *Medinilla anamalaiana* Sasidh. & Sujanapal, Sida 20(1): 110 (2002).**

##### **Synonyms:**

##### **Vernacular Name:**

##### **Family:** Melastomataceae

**Identifying Features:** Epiphytic climbing subshrub with sparingly branched, fleshy, acutely quadrangular or subquadrangular stems, 20-35 cm long, and reddish-brown young shoots. It has membranous leaves of two sizes, larger one measuring 7-11.5 x 3-5 cm, and a smaller one measuring 4-6 x 2.5-3.5 cm. The flower pink, 4-merous in the axils or from leafless nodes in horizontal rows on short pedicels. Hypanthium 5-8 mm long, yellowish-white, turbinate, wavy along the rim. The fruit is a globose, glabrous berry, approximately 4 mm across. Berry 5-8 mm across, turbinate, yellowish-green and seeds many. This species is allied to other species by the appearance of its leaves and reddish-brown tender

shoots, but is distinguished by its succulent quadrangular or subquadrangular branches and 3-nerved membranous leaves with obtusely acuminate apices (Fig. 3.34).

**Flowering and Fruiting:** January – June

### IUCN Status Assessment

The IUCN Red list assessment of *Medinilla anamalaiana* is being done first time (Devika & Bachan, 2023) based on the initial input from this study. The species were assessed with multiple criteria which resulted in Endangered category under the criteria D. The present study is the first comprehensive ecological and conservation account for the species.

### Distribution

The species is endemic to the southern Western Ghats particularly in Kerala and Tamil Nadu with an estimated AOO of 48 km<sup>2</sup> and EOO 8772 km<sup>2</sup> (Fig. 3.33).

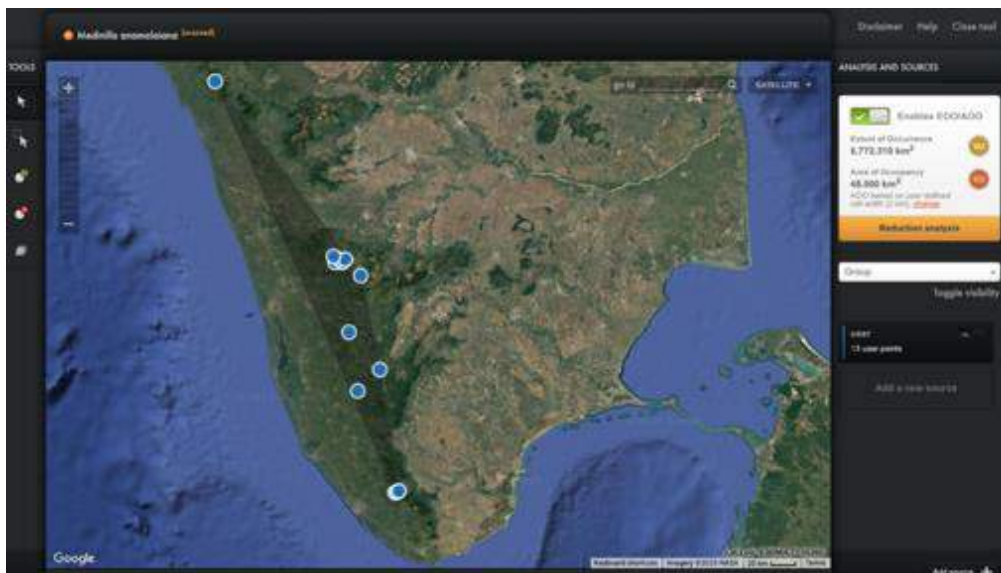


**Fig. 3.33.** Calculated AOO and EOO using GeoCAT for *Medinilla anamalaiana*

### Population

*Medinilla anamalaiana* is characterised as an epiphytic shrub residing on the canopy trees of rainforest ecosystems. This species comprises eight distinct subpopulations, substantiated by 13 collection records across four ecoregions within the southern Western Ghats, 10 in Kerala and 3 in Tamil Nadu. The most substantial subpopulation is situated in the Kerala segment of the Anamalai landscape, which encompasses the designated type locality. The estimated population size for this species ranges between 200 and 500 mature individuals, with a recorded density of two individuals per hectare (Devika & Bachan, 2023).



**Fig. 3.34.** *Medinilla anamalaiana* Sasidh. & Sujanapal: A. Habit; B. Twi; C. Bark; D. Leaf; E. Leaf abaxial side; F. Flowering twig; G. Bud; H. Flower; I. Pistil.

**Habitat and Ecology**

*Medinilla anamalaiana* is an epiphytic subshrub that establishes itself on both canopy and subcanopy trees within the tropical rainforest environments of the southern Western Ghats, specifically at elevations ranging from 500 to 1,200 m above sea level. This species is typically observed in isolated subpopulations and exhibits a notably low abundance. The tree species associated with *Medinilla anamalaiana* includes *Cryptocarya lawsonii*, *Gymnanthemum arborea*, *Reinwardtiodendron anamalaiense*, *Elaeocarpus glandulosus*, *Turpinia malabarica*, *Drypetes wightii*, *Palaquium ellipticum*, and *Calophyllum polyanthum*. There exists a notable decline in habitat quality attributable to anthropogenic activities such as the establishment of tea and coffee plantations, the construction of dams and reservoirs, and the selective felling of mature trees as part of timber extraction operations.

**Threats**

The habitat of *Medinilla anamalaiana* has experienced extensive conversions for the purposes of establishing tea and coffee plantations as well as constructing dams and reservoirs. The selective harvesting of mature trees for the plywood and softwood industries, as part of forest management strategies, has significantly impacted the population, primarily due to the resulting loss of both canopy and subcanopy trees, which serve as the natural hosts for this species. Furthermore, incidences of forest fires have been documented within the studied habitat (Devika & Bachan, 2023).

**Use and Trade**

Currently, there exists a lack of information pertaining to the use and trade of this particular species.

**Conservation Actions**

The species has been documented within three distinct protected areas, which include the Agasthyamalai Biosphere Reserve, the Parambikulam Tiger Reserve, and the Periyar Tiger Reserve. All recorded subpopulations are susceptible to degradation. It is imperative to enhance habitat quality, foster awareness, and implement site-specific management plans aimed at protection and the recovery of the species.

### Assessment Rationale

The species is assessed for the first time by Devika & Bachan (2023) based on input from this study and the published assessment rationale is as follows:

“*Medinilla anamalaiana* is recognized as an epiphyte that thrives on the canopy trees of tropical rainforests within the southern Western Ghats, specifically at elevations ranging from 500 to 1,200 m. The species possesses an area of occupancy (AOO) of 48 km<sup>2</sup> and an extent of occurrence (EOO) measuring 8,772 km<sup>2</sup>. It is represented by eight subpopulations, corroborated by 11 collection records across four ecoregions in the southern Western Ghats. The species is found within three protected areas. The predominant subpopulation is located in the Kerala region of the Anamalai landscape, which includes the type locality. The estimated population for this species is between 200 and 500 mature individuals, with an abundance of two individuals per hectare. The degradation of habitat is linked to the cultivation of tea and coffee, the establishment of dams, and the selective extraction of canopy trees for plywood production, while these areas remain vulnerable to forest fires. The limited abundance of this species, along with its reliance on climax rainforest trees, indicates a highly specialized ecological niche. Consequently, the species is classified as Endangered (EN).”

### Discussion

The *Medinilla anamalaiana* is assessed Endangered (EN) under Criterion D based on the study (Devika & Bachan, 2023), which highlights the acute conservation urgency for this tropical evergreen forest epiphyte. The present study provides the first comprehensive ecological data confirming the species' reliance on threatened canopy/subcanopy host trees. Its extremely low population (200-500 mature individuals) and restricted AOO (48 km<sup>2</sup>) confirm its micro-endemic status in the Southern Western Ghats. This research is vital for creating site-specific management plans against threats like habitat conversion and selective logging of its hosts.

#### 3.3.17. *Meiogyne pannosa* (Dalzell) J.Sinclair, Sarawak Mus. J. v. 604 (1951).

**Synonyms:** *Desmos pannosus* (Dalzell) Saff. in Bull. Torrey Bot. Club 39: 506 (1912); *Polyalthia pannosa* (Dalzell) Finet & Gagnep. in Mém. Soc. Bot. France 4: 97 (1906); *Unona pannosa* Dalzell in Hooker's J. Bot. Kew Gard. Misc. 3: 207 (1851); *Annona asiatica* B.Heyne ex Wall. in Numer. List: n.º 6475 (1832); *Unona asiatica* B.Heyne ex

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Steud. in Nomencl. Bot., ed. 2, 2: 730 (1841), pro syn.; *Uva mollis* Kuntze in Deutsche Bot. Monatsschr. 21: 173 (1903); *Uvaria mollis* Wall. in Numer. List: n.º 6475 (1832), not validly publ.

**Vernacular Name:** Panthalmaram (Malayalam)

**Family:** Annonaceae

**Identifying Features:** A small tree, up to 8 m high, with hirtus branchlets. Its ovate leaves, with an acuminate apex and rounded base, have 6 or 7 pairs of nerves and are hirtus on the underside and glabrous above, with petioles about 5 mm long. The sessile, dull yellow flowers are axillary and have ovate, acute, fulvous tomentose sepals (about 6 x 4 mm). The outer petals are spreading, while the inner ones are erect, ovate-lanceolate, and fulvous tomentose. The carpels are densely hairy. The fruitlets are globose, fulvous tomentose, about 12 x 8 mm, and contain two to a few globose seeds (Fig.3.35).

**Flowering and Fruiting:** July-December

#### **IUCN Status Assessment**

The conservation status of *Meiogyne pannosa* was assessed for the first time in 2022 (Verspagen et al., 2022). The species was categorised as Near Threatened (NT) under Criteria B2ab(iii). This assessment, which resulted from the application of multiple criteria, was based on 13 locations, with an estimated Area of Occupancy (AOO) of 72 km<sup>2</sup> and an Extent of Occurrence (EOO) of 29,455 km<sup>2</sup>. The present study significantly increased the known distribution by identifying 26 locations for this species. The resulting re-calculation of spatial metrics yielded an estimated AOO – 312 km<sup>2</sup>, EOO 109649 km<sup>2</sup>.

#### **Distribution**

The species is endemic to the southern Western Ghats particularly in Kerala, Tamil Nadu, Karnataka, Maharashtra with an estimated AOO of 312 km<sup>2</sup> and EOO 109649 km<sup>2</sup> (Fig.3.36).

#### **Population**

The size and trajectory of the population for this particular species remain indeterminate so far. The present study estimated a population density of 0.15 per ha and which estimated a total of 12000 mature individuals for the species. The species is distributed across the Western Ghats with 26 sub populations recorded from 90 collections. The highest being Kerala (45), then Tamil Nadu (25), Karnataka (16) and least at Maharastra (4).



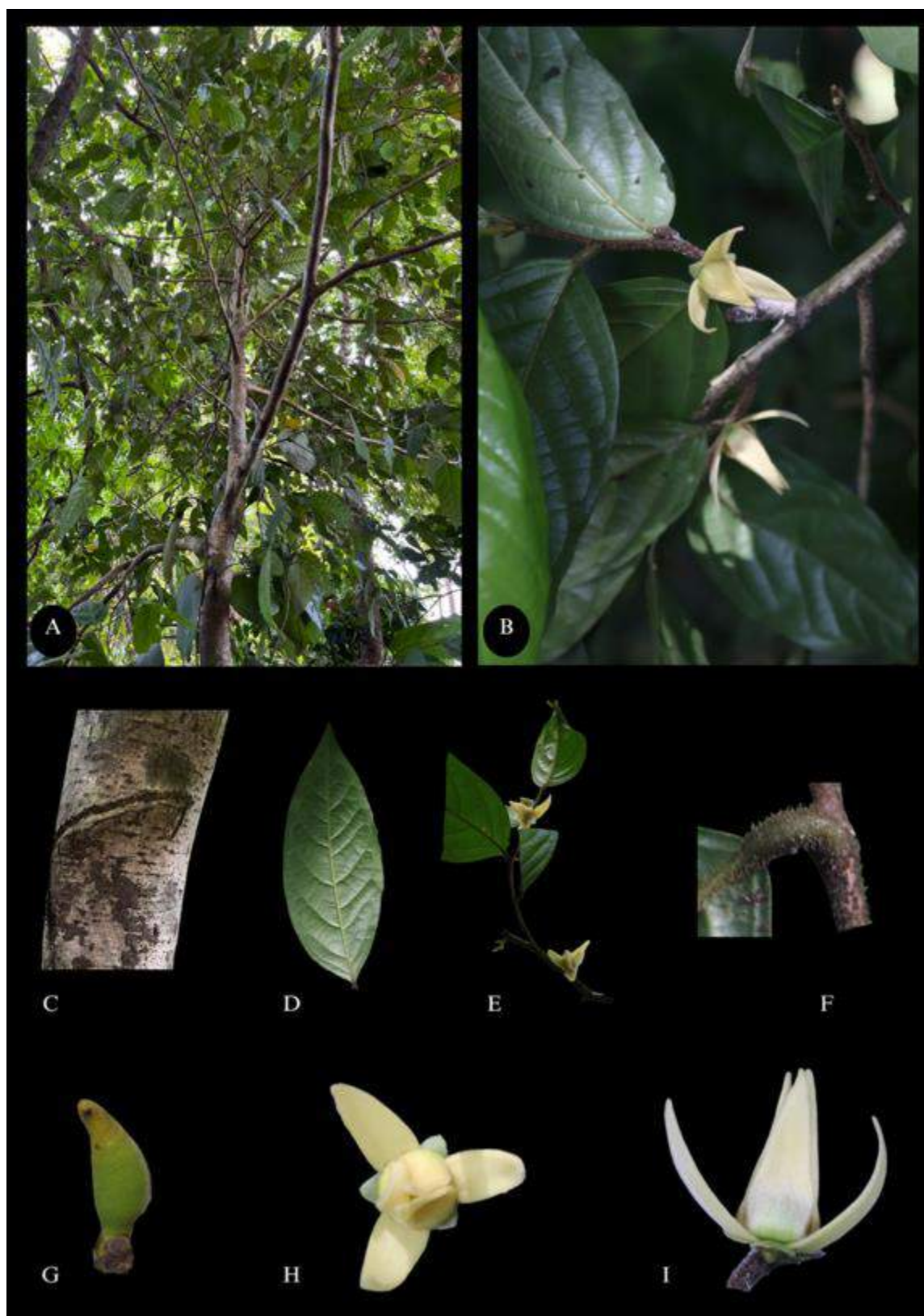


**Fig. 3.35.** *Meiogyne pannosa* (Dalzell) J.Sinclair: A. Habit; B. Twi; C. Bark; D. Leaf abaxial side; E. Flowering twig; F. Node; G. Fruit; H - I. Flower.



**Fig. 3.36. Calculated AOO and EOO using GeoCAT for *Meiogyne pannosa***

### Habitat and Ecology

This species is found predominantly within moist evergreen or semi-evergreen forest ecosystems, reaching elevations of up to 1,100 m (van Heusden, 1994).

### Threats

The potential threat of habitat degradation due to the loss of forest cover is a concern for all species within the genus *Meiogyne* (Hansen et al., 2013). This species inhabits regions that have experienced habitat deterioration resulting from forest plantations, agricultural development, dam construction, and urbanization.

### Use and Trade

Currently, there is no use and trade information regarding this species.

### Conservation Actions

At present, no targeted conservation initiatives are being implemented.

### Assessment Rationale

The species was recently by Vespagen et al. (2022) based on initial inputs from the present study and the published assessment rationale is as follows:

“*Meiogyne pannosa* is a species of tree or shrub that is indigenous to India. It exhibits an extent of occurrence (EOO) of 29,455 km<sup>2</sup> and a minimum area of occupancy (AOO) of 72 km<sup>2</sup> based on existing collections, although it is plausible that this species has been



under-sampled. There are roughly 13 distinct locations identified. This species is situated in ecosystems that have undergone habitat loss due to forest plantations, dam constructions, agricultural expansion, and urbanization. The decline in locations could precipitate a threat status for this species in the foreseeable future. It is presently classified as Near Threatened.”

#### **Discussion on the Assessment Rationale for *Meiogyne pannosa***

The original 2022 assessment classified *Meiogyne pannosa* as Near Threatened (NT) under Criteria B2ab(iii) based on 13 locations and an AOO of 72 km<sup>2</sup>. However, the present study's comprehensive data significantly shifts the species' conservation outlook, providing evidence that it no longer meets the quantitative criteria for a threatened or Near Threatened category. The research found that the species is far more widespread, with the number of known locations doubling to 26 across four states, and the Extent of Occurrence (EOO) surging to 109,649 km<sup>2</sup>. This revised EOO invalidates the use of the B criteria thresholds. Furthermore, the calculated AOO is 312 km<sup>2</sup> and the estimated population is 12,000 mature individuals, both well above the critical thresholds for a threatened status. Although the threats cited in the original rationale (habitat loss from plantations, dams, and urbanization) remain relevant, the species' broad distribution and larger, fragmented population suggest a greater inherent resilience. Therefore, based on the robust new data, the species is more appropriately classified as Least Concern (LC), as it fails to meet any of the quantitative criteria for NT or VU.

#### **3.3.18. *Ochna gamblei* King ex Brands, Indian Trees 128 (1906).**

**Synonyms:** *Ochna obtusata* var. *gamblei* (King ex Brandis) Kanis in Blumea 16: 34 (1968); *Ochna beddomei* Gamble in Fl. Madras: 165 (1915).

**Vernacular Name:** Ramatana champaka (Hindi); Narole, Ramatana champaka (Kannada); Kuka moi, Chitti moi (Telugu)

**Family:** Ochnaceae

**Identifying Features:** Large shrubs to small trees with thick, brown or grey or whitish and stiff, erect branches and stout branchlets. Leaves crowded at the ends of branchlets, broadly elliptic, obtuse, or ovate shape, measuring 5-13 cm by 3-8 cm. They have a waxy, whitish, or glaucous appearance with irregular nerves and serrated edges. The flowers are yellow,

fragrant, and about 4 cm across, blooming in clusters. They have five sepals, 5-12 petals, stamens 35-70 in number. Fruits are compound, consisting of 3-6 oblong-ovoid, black drupes. Seeds are erect and oblong (Fig.3.38).

**Flowering and Fruiting:** February – July

### IUCN Status Assessment

The conservation status of *Ochna gamblei* was assessed for the first time in 2023 (Bachan & Devika, 2023). The species was categorised as Endangered (EN) under criteria A2ac; D. This classification was based on nine locations, with an estimated Extent of Occurrence (EOO) of 82,226 km<sup>2</sup> and an Area of Occupancy (AOO) of 36 km<sup>2</sup>. The present study, utilizing 15 collection records, identified 11 locations for this species. The re-calculation of spatial metrics yielded an estimated AOO 56 km<sup>2</sup>, and a significantly larger EOO 239657 km<sup>2</sup>.

### Distribution

The species is endemic to South India particularly in Kerala, Tamil Nadu, Karnataka, Andhra Pradesh and Chhattisgarh with an estimated AOO of 56 km<sup>2</sup> and EOO 239657 km<sup>2</sup> (Fig. 3.37).

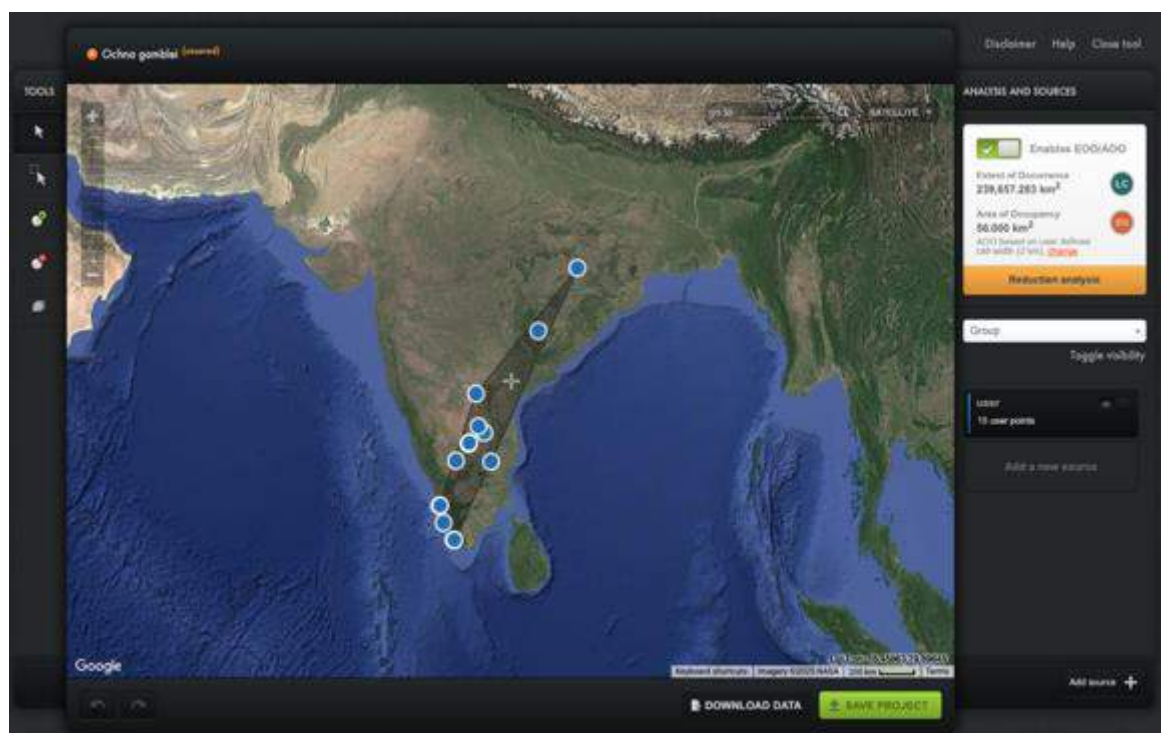


**Fig. 3.37. Calculated AOO and EOO using GeoCAT for *Ochna gamblei***

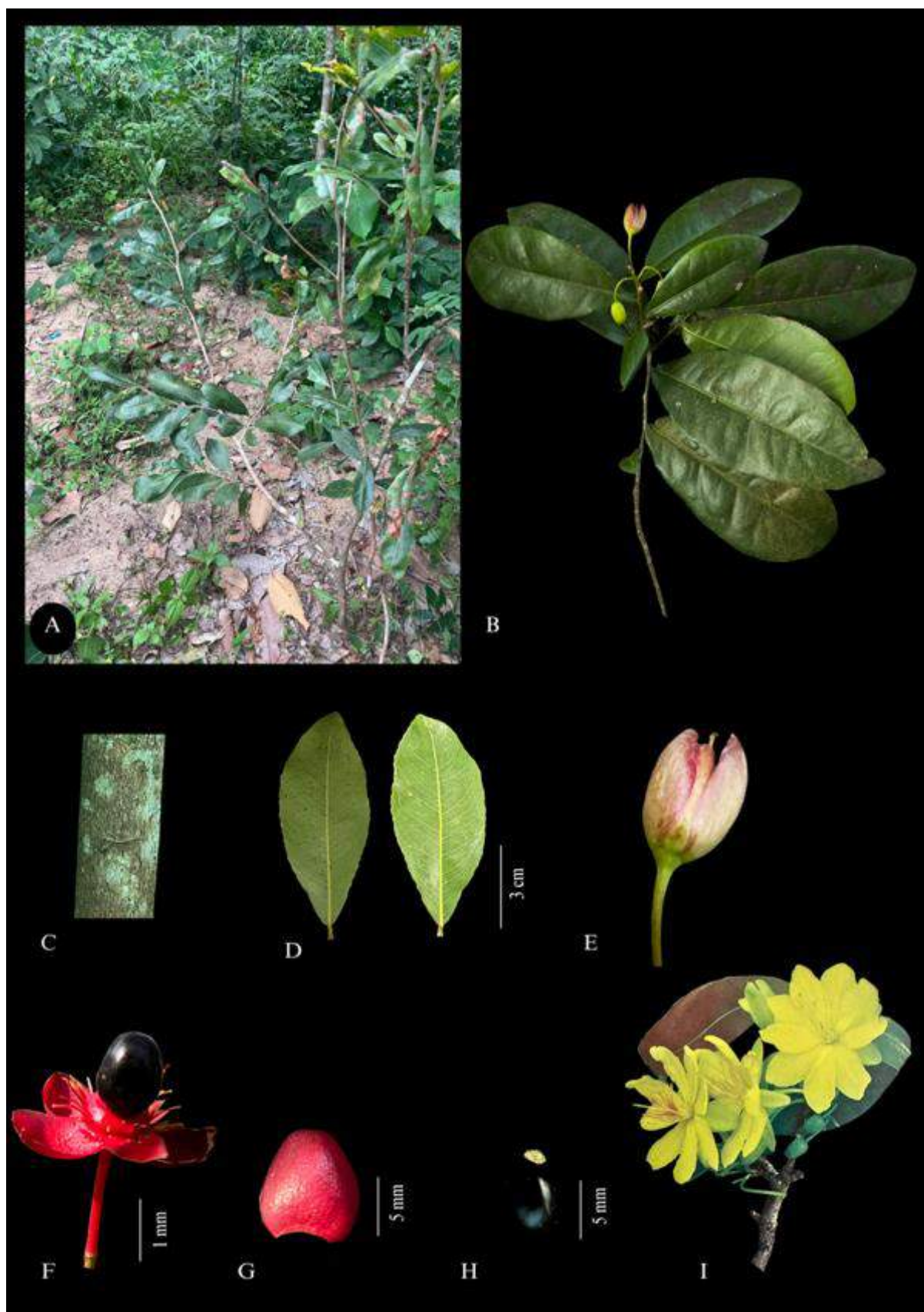


**Fig. 3.38.** *Ochna gamblei* King ex Brandis.: A. Habit; B. Twig; C. Bark; D. Leaf; E. Bud; F. Calyx with fruit; G. Sepal; H. Seed; I. Flowering twig.

**Population**

A total of eleven mature specimens were documented within a coastal sacred grove situated in Alappuzha, Kerala (Sunil & Sivadasan, 2009). However, recent observations have verified the existence of merely four mature individuals at this site. Additionally, one specimen originates from an alternative coastal region, Thrissur, Kerala (Bachan & Nair, 2020). The species is known to reach maturity within a time frame of 3 to 4 years, with an estimated generation length ranging from 8 to 10 years. An overall reduction in population is projected to be around 50% across the last three generations. Current estimates indicate that the population comprises fewer than 150 mature individuals.

**Habitat and Ecology**

*Ochna gamblei* represents a small arboreal species or a large shrub, primarily inhabiting sandy coastal sacred groves and arid hillocks within Southern India (Bachan & Nair, 2020).

**Threats**

The primary threat to this species arises from the reclamation of habitats, including coastal sand dunes, sacred groves, and hillocks, for infrastructure development purposes. Furthermore, the species has been overlooked due to its classification as a large shrub or small tree that holds minimal local significance (Sunil & Sivadasan, 2009; Bachan & Nair, 2020).

**Use and Trade**

Currently, there exists a lack of available information regarding the trade and utilization of this particular species.

**Conservation Actions**

The natural habitats of this species, namely coastal sacred groves, sand dunes, and inland hillocks, are experiencing intense pressure from reclamation activities aimed at infrastructure development. Although a limited number of locations are safeguarded as sacred groves by local communities, the species remains largely neglected, primarily owing to its diminished local use and importance. Few individuals of the species are restored in its natural habitat as part of the study in coasts of Kodungallur.

**Assessment Rationale**

The recent assessment of the species is done by Bachan and Devika (2023) and the published assessment rationale is as follows:

“*Ochna gamblei* is a 3 to 4 m high, large shrub or small tree that occurs in coastal sacred groves, sand dunes or inland hillocks in South India. It has a restricted distribution with an extent of occurrence (EOO) 82,226 km<sup>2</sup> and an area of occupancy (AOO) 36 km<sup>2</sup>. The species has been reported only from nine locations with less than 150 individuals. The population reduction in two subpopulations is 41% in 10 years, and the overall estimated population reduction is approximately 50% in the last three generations. It is known to occur in areas that have been subjected to severe habitat loss due to reclamation for infrastructure development. The coastal sand dunes and associated sacred groves have been subjected to heavy reclamation in the past few decades. The species is neglected due to less local significance and being a small tree even within sacred groves protected by the local people. All the nine locations are outside protected areas. Urgent awareness and conservation measures are recommended. This species is assessed as Endangered.”

### Discussion

The recent assessment of *Ochna gamblei* based on the initial input from the present study as Endangered (EN) under Criteria A2ac; D is strongly reinforced by the latest inputs of the present study, necessitating only a quantitative update to the rationale. The species' status is primarily driven by its critically small population, estimated at fewer than 150 mature individuals, which remains the key factor qualifying it for EN under Criterion D. This threat is compounded by the projected 50% population reduction over the last three generations, directly linked to the rapid, ongoing reclamation of its specialised habitats (coastal sacred groves and sand dunes) for infrastructure development. The study confirms this severe restriction with a revised Area of Occupancy (AOO) of 56 km<sup>2</sup> and 11 fragmented locations. While the Extent of Occurrence (EOO) is large, this metric is irrelevant given the species' reliance on the stringent A and D criteria. The Endangered (EN) classification is thus fully validated and robust.

**3.3.19. *Prioria pinnata* Roxb. ex DC. Breteler**, Wageningen Agr. Univ. Pap. 99(3): 52 (1999).

**Synonyms:** *Hardwickia pinnata* Roxb. ex DC. in Prodr. 2: 487 (1825); *Kingiodendron pinnatum* (Roxb. ex DC.) Harms in H.G.A.Engler & K.A.E.Prantl, Nat. Pflanzenfam., Nachtr. 1: 194 (1897).

**Vernacular Name:** Kulavu, Chukennappayin, Churali, Ennappayin, Kiyavu, Kulavu, Madayan-samranni, Malabar mahogany (Malayalam); Kolavu, Koda Palai, Madayan Samprani (Tamil);

Chou Paini, Enne Mara, Yenna Mara (Kannada)

**Family:** Fabaceae

**Identifying Features:** A large evergreen tree reaching up to 30 m high, with rough, brown bark that exudes an oily and sticky resin. The leaves are imparipinnate, 6-10 cm long, with 5-9 leaflets and 8-12 pinnate lateral nerves. The small, bisexual flowers are white, with an almost absent calyx tube, 5 broadly ovate, imbricate lobes, and no petals. The disc is very small, and there are 10 equal stamens with filiform filaments that are villous at the base and versatile anthers. The half-inferior, sessile ovary is villous at the base with 2 ovules, and it has a subulate style and a minute, oblique stigma. The fruit is a dark brown, indehiscent, ovate-ellipsoid pod, up to 5 x 2 cm, that is turgid, beaked, and prominently veined, containing a single, pendulous seed (Fig.3.39).

**Flowering and Fruiting:** February-December

#### **IUCN Status Assessment**

The first IUCN Red List assessment for the species, conducted in 1998 (CAMP Workshops on Medicinal Plants, 1997), categorised it as Endangered (EN) under criteria A1cd. This assessment was based solely on limited data and very few collection records, with all other data noted as requiring updating. The recent assessment (Devika & Bachan, 2023) based on inputs from the present study down-listed the species to the Vulnerable (VU) category under criteria A1acd. This status was determined based on 14 known locations. The present study, incorporating 66 collection records, significantly expanded the known distribution by identifying 26 locations for the species. The re-calculation of spatial metrics yielded an estimated AOO of 240 km<sup>2</sup> and an EOO of 127,1998 km<sup>2</sup>.

#### **Distribution**

The species is distributed in Kerala, Tamil Nadu, Karnataka of India and Sri Lanka. The estimated AOO is 240 km<sup>2</sup> and EOO is 127,1998 km<sup>2</sup> (Fig.3.40).



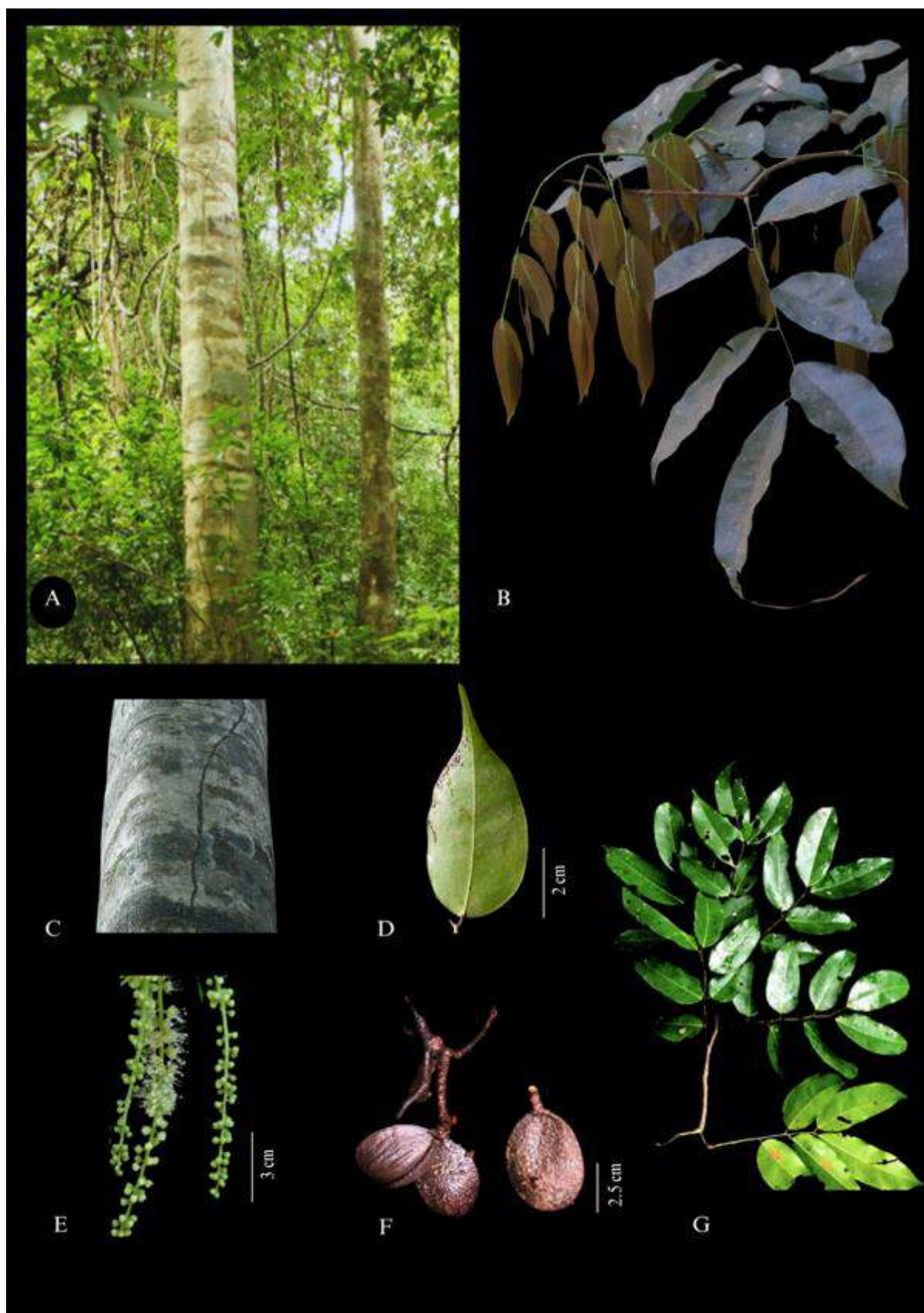


**Fig. 3.39.** *Prioria pinnata* (Roxb. ex DC.) Breteler: A. Habit; B. Twig; C. Bark; D. Leaf abaxial side; E. Inflorescence; F. Seed; G. Leaf.



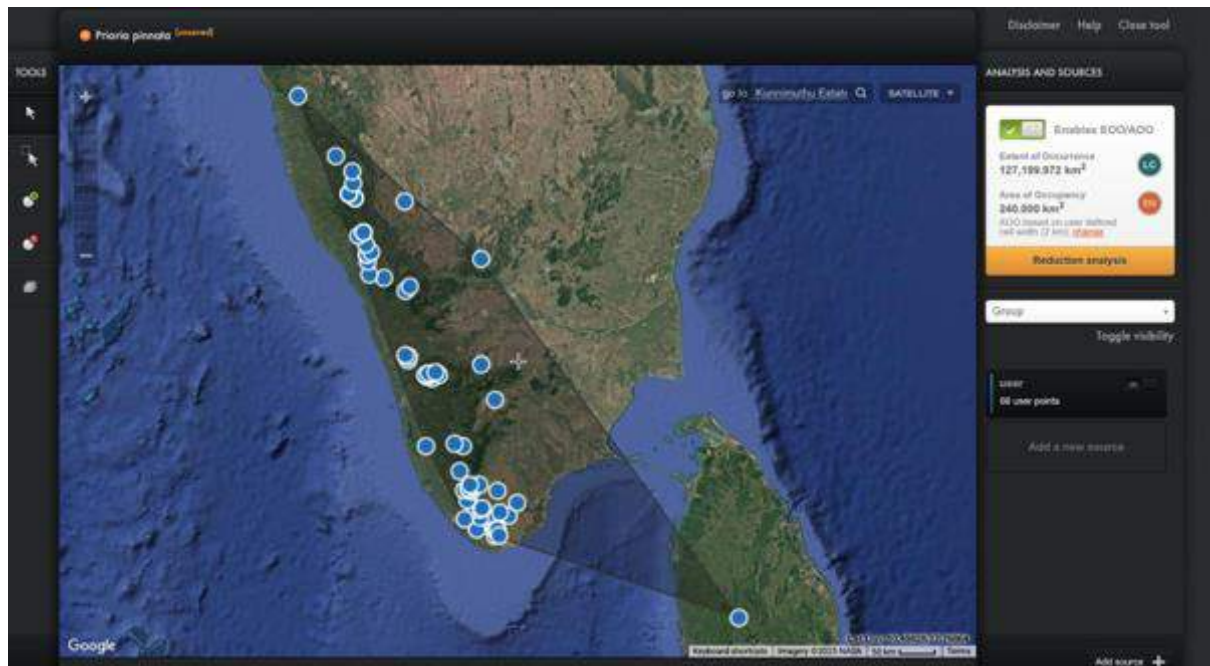


**Fig. 3.40.** Calculated AOO and EOO using GeoCAT for *Prioria pinnata*

### Population

*Prioria pinnata* is represented by 26 distinct subpopulations across eight significant landscapes within the central and southern Western Ghats. The optimal habitat for this species consists of forest ecosystems situated at elevations ranging from 130 to 950 m, which has historically undergone substantial degradation. Traditionally, this species was exploited for its oil; however, such practices have nearly ceased in contemporary contexts (Devika & Bachan, 2021). Currently, the estimated population of 1,200 mature individuals across the 26 subpopulations remains stable, attributed to various conservation initiatives. Over the last three generations (90 years), the species has experienced a decline of no less than 50% due to the practice of oil tapping.

### Habitat and Ecology

*Prioria pinnata* can attain heights of up to 35 m within the low (150 m) to medium (950 m) elevation rainforest ecosystems of the central and southern Western Ghats. This species is commonly found in association with other flora such as *Hopea ponga*, *Hopea parviflora*, *Dipterocarpus indicus*, *Vateria indica*, *Tetrameles nudiflora*, and *Diospyros crumenata*. It serves as a significant element of the closed canopy within these forested environments, which have historically been subjected to traditional oil extraction methods employed by

local and indigenous communities. Consequently, it is referred to locally as "Kulavu" or "Ennappayin" (Devika & Bachan, 2021). The medium elevation habitats facilitate continuity among current locations, notwithstanding the severe fragmentation of primary habitats at lower elevations. The practice of oil extraction has largely diminished due to the advent of alternative resources and heightened awareness among communities. The species is currently exhibiting favorable regeneration patterns, with several recovery initiatives underway (Devika & Bachan 2021).

### **Threats**

Historically, the traditional practice of oil extraction posed a considerable threat to the species; however, this practice has ceased due to the availability of alternative oil sources. The degradation of low elevation rainforest ecosystems, which occurred in the past, continues to represent a significant threat. The species' expanded distribution into medium elevation rainforest habitats contributes to the continuity of its ecological niche. Observations indicate that seed germination and regeneration rates appear to be quite robust (Jose et al., 2018; Devika & Bachan, 2021).

### **Use and Trade**

During the colonial era, timber from this species was utilised for the construction of railway sleepers. Historically, the species was also harvested for its oil.

### **Conservation Actions**

*Prioria pinnata* exhibits distribution across 14 locations within the low to medium elevation rainforest habitats of the central and southern Western Ghats. Previous activities related to forest extraction and traditional oil tapping constituted significant threats; however, current research suggests a positive trajectory for population recovery. The rates of seedling germination and establishment are reported to be quite favorable. A comprehensive management plan, focused on the detailed niche profile of the species, has been developed and integrated into the forest management strategy within the Vazhachal forest region (Bachan et al., 2019). Seedlings have been reintroduced at four locations as part of in situ restoration efforts and at two ex situ sites (Jose et al., 2017) also as part of the present study. It is recommended that systematic monitoring of both species and habitat be undertaken for this particular species.

### Assessment Rationale

The recent assessment for the species is done by Devika and Bachan (2023) based in inputs form the present study and the assessment rationale is as follows:

“*Prioria pinnata* is an endemic large legume tree up to 35 m high in the low to medium elevation tropical rainforest of the central and southern Western Ghats, India. The present area of occupancy (AOO) is 88 km<sup>2</sup> and extent of occurrence (EOO) is 18,874 km<sup>2</sup>. The recent studies brought out 24 collection localities from 14 locations within eight important landscape of its distribution range (Devika & Bachan, 2021). The species was considered threatened, chiefly due to large scale conversion of low elevation forest and traditional tapping of oil. This led to a decline of over 50% in three generations (90 years). However, the traditional harvest of the "Ennappayin" oil has ceased because of other alternatives for lamp oil. Distribution into the medium elevation ensures continuity of its habitat even though the primary low elevation forest are heavily fragmented (Devika & Bachan, 2021). The species shows a good regeneration and establishment and in situ restoration are in place (Jose et al., 2017). A niche profile-based area specific species management plan is in place (Devika & Bachan, 2021). The species is assessed here as Vulnerable.”

### Discussion

The recent assessment of *Prioria pinnata* as Vulnerable (VU) under Criteria A1acd based on initial inputs form this study should be retained, as this criterion is well-supported, while the use of the B criteria should be discarded based on the present updates. The rationale is based on a confirmed past population decline of over 50% (A1) attributed primarily to the traditional practice of oil tapping (a, d) and large-scale low-elevation habitat conversion (c). The present study's expanded data (66 collection records and 26 locations) invalidates the use of the B criteria by confirming a large EOO ( $\approx 130,000$  km<sup>2</sup>) and an AOO ( $\approx 240$  km<sup>2</sup>) that fails to meet the B2 thresholds for Vulnerable status ( $< 2,000$  km<sup>2</sup>). However, the down-listing from Endangered to Vulnerable is justified by the positive conservation factors: the primary threat (oil tapping) has ceased, the estimated 1,200 mature individuals population is currently stable, and the species exhibits good regeneration and restoration efforts are in place. The final rationale must therefore focus solely on the A1acd criterion while incorporating the most up-to-date, higher spatial metrics and the evidence of recovery and management success.

**3.3.20. *Strobilanthes kunthiana* (Nees) T.Anderson ex Benth.,** Fl. Hongk. 262, in nota. (1861).

**Synonyms:** *Phlebophyllum kunthianum* Nees in N.Wallich, Pl. Asiat. Rar. 3: 83 (1832); *Phlebophyllum angustifolium* Benth. ex C.B.Clarke in J.D.Hooker, Fl. Brit. India 4: 434 (1884); *Ruellia kunthiana* Wall. in Numer. List: n.º 2367 (1830), not validly publ.

**Vernacular Name:** Neelkurunji (Malayalam)

**Family:** Acanthaceae

**Identifying Features:** A bushy shrub flagship of the montane grasslands, which blooms once in 12 years. It has glabrous, reddish branches and elliptic, coriaceous leaves up to 6 x 3 cm, which are glabrous on the upper side. It produces 2-5 cylindric spikes, 3-5 cm long, on axillary peduncles. The spikes have 2-3 elliptic, tomentose involucre bracts, ovate-acuminate, tawny pubescent floral bracts (12 x 4 mm), and linear-lanceolate bracteoles (7 x 1.5 mm). The many flowers have a 10 mm long calyx with acuminate lobes and a hairy, blue corolla that is 25 mm long (Fig. 3.42).

**Flowering and Fruiting:** September-January (Once in 12 years)

#### **IUCN Status Assessment**

The IUCN Red list assessment of *Strobilanthes kunthiana* is done first time (Bachan & Devika, 2024). The species were assessed with multiple criteria which resulted in Vulnerable category under the criteria A2c.

#### **Distribution**

The species is distributed in Kerala, Tamil Nadu and Karnataka, with an estimated AOO of 292 km<sup>2</sup> and EOO 37536 km<sup>2</sup> (Fig. 3.41).

#### **Population**

*Strobilanthes kunthiana* is a shrub to 3 m high, exclusively found within the high-altitude montane grasslands of the shola grassland ecosystems in southwest India, at elevations ranging from 1,340 to 2,600 m. This species exhibits a semelparous reproductive strategy, characterised by synchronous blooming and fruiting occurring at a 12-year interval towards the conclusion of its life cycle, with deviations from this cycle being infrequently observed one year prior or subsequent (Matthew, 1971). The species has been documented with a total of 24 collection records derived from 14 distinct subpopulations (Carine et al., 2004).

The current assessment based on this study has revealed an increase to 106 collection records encompassing 34 subpopulations distributed across 14 ecoregions within the high-altitude mountain ranges of southwest India. Of these, 33 subpopulations are located in the Western Ghats, while one is situated in the Yercaud region of the Shevaroy Hills within the Eastern Ghats. The majority of the subpopulations are concentrated in the Nilgiris of Tamil Nadu, followed by the Munnar-Idukki region in Kerala, as well as the Palani-Kodaikanal hills and the Anamalai hills, both in Tamil Nadu. A suspected reduction of 40% in population size and area of occupancy has been noted (Bachan & Devika, 2024), primarily attributed to land conversion for tea cultivation and the establishment of high-altitude softwood plantations (*Eucalyptus*, *Black Wattle*) (Saju, 2012; Bachan & Devika 2021; Sasmitha et al., 2021) over the preceding three generations. The potential habitat converted irreversibly for the species based on this study is 16 %, the degraded area suitable for ecorestoration is 31 % and the potential conservation area is 54 %.

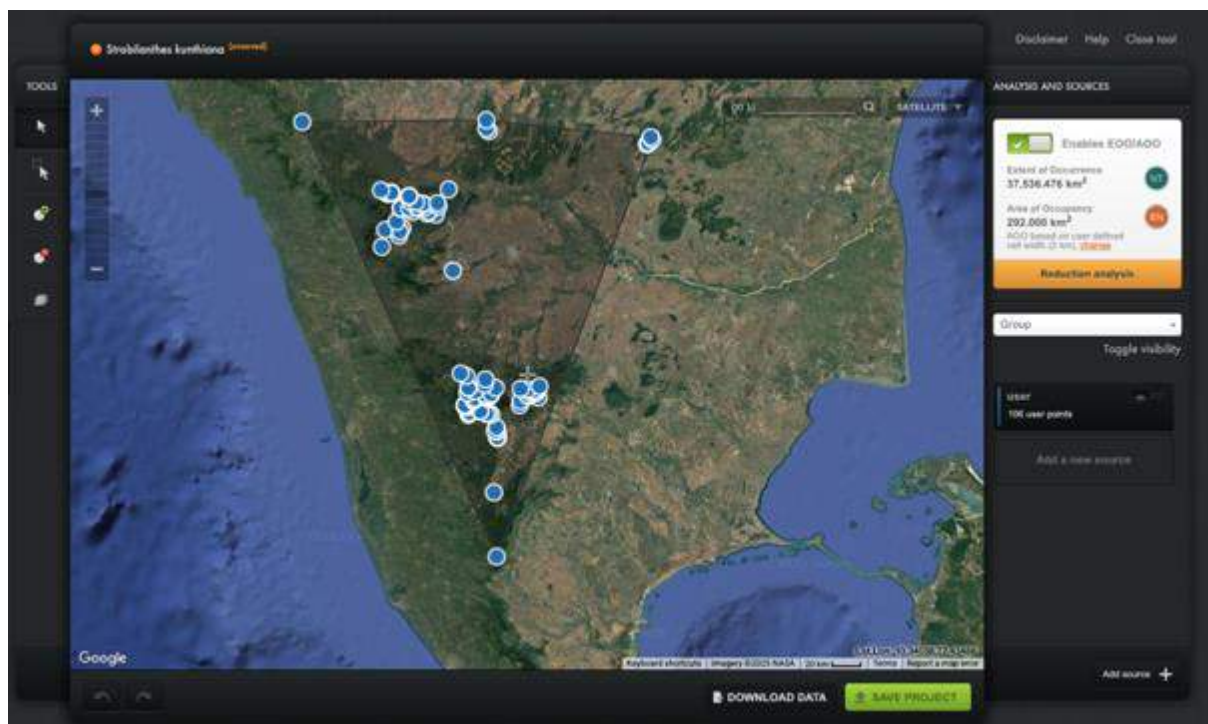


**Fig. 3.41. Calculated AOO and EOO using GeoCAT for *Strobilanthes kunthiana***



**Fig. 3.42.** *Strobilanthes kunthiana* (Nees) T.Anderson ex Benth.: A. Habit; B. Twig; C. Leaf abaxial side; D. Leaf adaxial side; E. Inflorescence; F. Anther; G. Flower; H. Flower L.S. I. Seed.



### Habitat and Ecology

*Strobilanthes kunthiana* is an endemic shrub species that is exclusively found in the natural high-altitude montane grasslands of southwest India, occupying altitudes that range from 1,340 to 2,600 m. This species is typically observed in subpopulations comprising a substantial number of individuals interspersed with other native grasses and sedges characteristic of montane grassland ecosystems. The species exhibits a semelparous reproductive cycle with a blooming interval of 12 years, a phenomenon that has been documented from 1832 to 2023 across 34 localities in 14 ecoregions within five distinct landscapes, including the Nilgiri hills, the Palani-Kodaikanal hills, and the Anamalai hills in the Tamil Nadu sector of the Western Ghats, the Munnar-Idukki landscape in Kerala, as well as the Yercaud-Shevaroy hills in the Eastern Ghats. The species is commonly associated with endemic grasses such as *Chrysopogon zeylanicus*, *Eulalia phaeothrix*, *Dicanthium polytychum*, and *Arundinella purpurea*, alongside sedges like *Juncus effusus*, terrestrial orchids such as *Habenaria heyneana* and *Satyrium nepalense*, as well as various other herbaceous plants including *Peristylus aristatus*, *Eriocaulon dalziel*, *Brachycorythis splendens*, *Swertia corymbosa*, and *Drosera peltata*, in addition to shrubs such as *Hypericum mysorensense* and *Osbeckia leschenaultiana*.

### Threats

The transformation of grassland habitats occupied by *Strobilanthes kunthiana* into tea and softwood plantations, particularly those comprising Eucalyptus, was a primary factor contributing to habitat decline during the colonial era. Afforestation initiatives involving non-native tree species, such as Eucalyptus and Black Wattle (*Acacia mearnsii*), implemented by the forest department, perpetuated habitat conversion throughout the 1960s and 1990s (Augustine, 2018). These activities were prevalent across all five landscapes inhabited by the species. Ongoing infrastructure development, including road construction and transportation expansion, remains a significant driver of habitat conversion. The traditional seasonal practice of controlled burning by indigenous communities, once perceived as a threat, has subsequently been recognised as essential for the management of grasslands and has been adopted as a management strategy by the forest department (Saju, 2012). The frequency of controlled burns for the management of these grasslands, with an emphasis on the conservation of the Nilgiri Tahr (a threatened and endemic mountain goat species), warrants further investigation in relation to the ecological



dynamics of *Strobilanthes kunthiana* and the interactions between grassland and shola forest ecosystems. The invasion of Black Wattle (*Acacia mearnsii*) from adjacent plantations into the grasslands represents a pressing contemporary concern for the species, in addition to the challenges associated with managing tourism and the development of tourism-related infrastructure.

### **Use and Trade**

Currently, there exists a lack of documented information regarding the uses and trade of this species. The blooming of its flowers draws considerable attention from tourists and is celebrated as a significant event in the high-altitude mountainous regions.

### **Conservation Actions**

Management activities aimed at habitat preservation are being implemented within protected areas such as the Kurinjimala Sanctuary and Eravikulam National Park in Kerala (Saju, 2012). However, specific conservation plans tailored to this species have yet to be developed. Notably, approximately sixty percent of the population resides within designated protected areas.

### **Assessment Rationale**

The first and recent IUCN RD List Assessment of *Strobilanthes kunthiana* is done by Bachan and Devika (2024) and the assessment rationale published is as follows:

*Strobilanthes kunthiana* is a shrub endemic to the region, reaching heights of up to 3 meters, exclusively located in the high-altitude montane grasslands of the shola grassland ecosystems across five mountain ranges in southwest India, situated at elevations ranging from 1,340 to 2,600 m. This species is renowned for its extensive flowering, which imparts a purplish-blue hue to the mountainous grasslands and is commonly referred to as Neelakurinji (Blue *Strobilanthes*) blooms. The species exhibits semelparity, characterized by conspicuous synchronous blooming and fruiting occurring every twelve years at the conclusion of its life cycle, a phenomenon documented since 1832 and continuing to the present year, 2022. The area of occupancy (AOO) for this species is recorded at 220 km<sup>2</sup>, while the extent of occurrence (EOO) is noted to be 25,510 km<sup>2</sup>. Within the high-altitude mountain ranges of southwest India, the species is represented by 34 subpopulations distributed across 14 ecoregions, as corroborated by 93 distinct records. Of these, 33 subpopulations are located in the Western Ghats, with one additional subpopulation found in the Eastern Ghats (specifically in Yercaud, Shevaroy Hills). The majority of these

subpopulations are concentrated in the Nilgiris of Tamil Nadu, followed by those in Munnar-Idukki, Kerala, Palani-Kodaikanal, and the Anamalai mountain ranges. The habitats of *Strobilanthes kunthiana* have been adversely affected by the establishment of tea and softwood plantations, afforestation initiatives, infrastructure expansion, road construction, and transportation networks. The encroachment of the Black Wattle from nearby plantations poses significant threats to the species, alongside challenges posed by tourism management and infrastructure development. It is estimated that there has been a 40% decline in both population and AOO over the last three generations, with a continued downward trend. Consequently, this species is classified as Vulnerable A2c in the current assessment.”

### **Discussion on the IUCN Assessment**

The recent and first assessment of *Strobilanthes kunthiana* as Vulnerable (VU) under Criterion A2c is appropriate and strongly supported by the data stemmed from this present study, reflecting the ongoing and historical pressure on its unique habitat. The rationale correctly identifies a suspected 40% reduction in population and AOO over the last three generations (A2) (Bachan & Devika, 2024), directly linking this decline to the conversion of montane grasslands (c) for tea and high-altitude softwood plantations (Eucalyptus, Black Wattle) (Saju, 2012; Bachan & Devika 2021; Sasmitha et al., 2021). The present study's extensive data, comprising 106 collection records across 34 subpopulations, confirms the species' broad but fragmented distribution across the high-altitude Western Ghats. However, the expansion of records and subpopulations does not invalidate the VU status, as the species remains exclusively tied to the highly threatened shola-grassland ecosystem, and the causal threats (tea, afforestation, infrastructure, and Wattle invasion) are persistent. The semelparous 12-year flowering cycle makes population recovery inherently slow, ensuring that the Vulnerable A2c classification remains the most accurate reflection of the species' genuine and ongoing conservation risk.

**3.3.21. *Syzygium densiflorum*** Wall. ex Wight & Arn., Prodr. Fl. Ind. Orient. 329 (1834).

**Synonyms:** *Eugenia arnottiana* Wight in Ill. Ind. Bot. 2: 17 (1841), nom. superfl.; *Syzygium arnottianum* Walp. in Repert. Bot. Syst. 2: 180 (1843), nom. superfl.

**Vernacular Name:** Ayuri, Karayambu, Kuruthmaram, Kuruthal, Kurunjavai, Njavai, Pillanjavai (Malayalam)

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**Family:** Myrtaceae

**Identifying Features:** An evergreen tree up to 20 m high, with a blackish-grey, rough bark and terete branchlets, confined to montane shola forests. The tree has simple, opposite, exstipulate leaves with slender, grooved, glabrous petioles ranging from 0.3-2 cm long. The leaf lamina, measuring 3.5-9 x 1.8-3.7 cm, features numerous parallel and closely-set lateral nerves. The bisexual flowers are creamy white, 1-1.2 cm long, and sessile, forming dense clusters in compact, terminal trichotomous cymes. The flower's calyx tube is 5-6 mm long and turbinate with 4 lobes, but lacks a thick disc. The free petals are deciduous, and there are many free stamens that are bent inwards at the middle while in the bud. The inferior ovary is 2-celled with many ovules, a single style, and a simple stigma. The fruit is a dark purple, fleshy, oblong-ovoid berry with 1-1.5 cm (Fig. 3.43).

**Flowering and Fruiting:** December-April

#### **IUCN status assessment**

The first IUCN Red list assessment of *Syzygium densiflorum* was done during 1998 and it was considered Vulnerable under criteria B1+2c (World Conservation Monitoring Centre, 1998). The assessment was based solely on seven collection records and all the other relevant data were mentioned as need updatation. The present study identified 19 subpopulations for the species based on 82 collection records and a multi criteria based the IUCN assessment was published (Devika & Bachan, 2025).

#### **Distribution**

The species is endemic to the southern Western Ghats, India, particularly in the montane Shola forests of Kerala, Tamil Nadu and Karnataka. The species occur in an AOO of 220 km<sup>2</sup> and EOO of 29096 km<sup>2</sup>. The species is represented equally from Kerala (42 records) and Tamil Nadu (40 records) (Fig. 3.44).

#### **Population**

This particular tree species is estimated to possess a population size of fewer than 20,000 mature individuals, a figure derived from the known 19 subpopulations exhibiting a density of 9.6 individuals per hectare. The species is currently undergoing a persistent decline in population numbers attributed to the conversion of land for agricultural purposes and the exploitation of forest resources for local use.



**Fig. 3.43.** *Syzygium densiflorum* Wall. ex Wight & Arn.: A. Habit; B. Twig; C. Inflorescence; D. Immature fruit; E. Fruiting twig; F & G. Mature fruits.

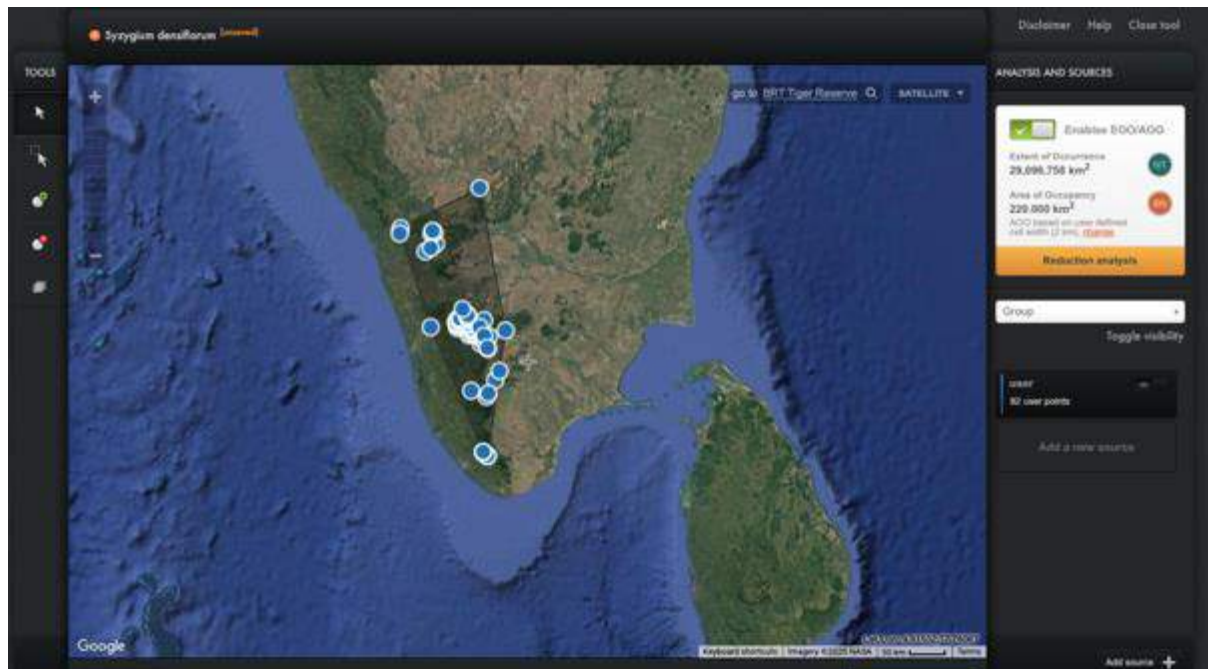


**Fig. 3.44.** Calculated AOO and EOO using GeoCAT for *Syzygium densiflorum*

Consequently, this has resulted in a population reduction of approximately 30% over the course of three generations, equivalent to a time span of 120 years.

### Habitat and Ecology

*Syzygium densiflorum* is classified as a canopy tree endemic to the high-elevation tropical montane evergreen shola forests located within the southern Western Ghats mountain range, which is recognised as a biodiversity hotspot in Sri Lanka, at altitudes ranging from 1,500 to 2,400 m. The species coexists with other flora such as *Syzygium sahyadricum*, *Cinnamomum* sp., *Phoebe* sp., *Elaeocarpus glandulosus*, and *Rhododendron arboreum*, among others (Devika & Bachan, 2023). Regeneration status for this species is notably poor. The fruits of this species serve as a nutritional resource for various avian species, insects, Malabar Giant Squirrels, and Nilgiri Langurs (Ramasubbu et al., 2016).

### Threats

The habitat within this region has been extensively cleared primarily for purposes related to forestry and the establishment of agro-monoculture plantations, as well as for the construction of dams and reservoirs. The factors contributing to historical population reductions remain unabated, despite the fact that the majority of the population is situated within protected areas. The protected areas located in both landscapes where the species is

found (Munnar and Nilgiris) comprise a mosaic of habitats interspersed with high-elevation tea, eucalyptus, and wattle plantations. Local inhabitants frequently utilise these habitats, particularly for the collection of firewood. Empirical observations of the species have revealed both controlled and uncontrolled fire incidents occurring in grassland areas, including those within protected areas, which have been detrimental to the survival of mature individuals (Devika & Bachan, 2023).

### **Use and Trade**

The fruits of this species are consumable, and the indigenous populations residing in the Nilgiri hills utilise the leaves as a traditional remedy for diabetes (Ramasubbu et al., 2016).

### **Conservation Actions**

Currently, there are no conservation plans specifically tailored to the species or its habitat. Notably, more than 50% of the population exists within designated protected areas.

### **Assessment Rationale**

The recent IUCN Assessment for the species was done based on the present study (Devika & Bachan, 2025) and the published IUCN Assessment rationale is as follows:

“*Syzygium densiflorum* is characterized as a canopy tree endemic to the tropical montane shola forests of the southern Western Ghats mountains in southwest India, thriving at altitudes between 1,500 and 2,400 meters. The area of occupancy (AOO) is quantified as 124 km<sup>2</sup>, while the extent of occurrence (EOO) measures 8,023 km<sup>2</sup>. The species comprises 18 subpopulations with an estimated population size of fewer than 20,000 mature individuals, confined to four distinct ecoregions extending from Coorg to Agasthyamalai. The majority of the population is concentrated within the Eravikulam and Anaimudishola national parks located in the Munnar landscape. This species is associated with several ecologically significant shola forest species, including *Syzygium sahyadricum*, *Cinnamomum sp.*, *Phoebe sp.*, *Elaeocarpus glandulosus*, and *Rhododendron arboreum*. The species is undergoing a continuous decline attributable to habitat conversion for plantation purposes and other anthropogenic uses of the forest. This has culminated in a population decline of 30% over three generations, equivalent to 120 years. Therefore, this species is classified as Vulnerable (VU)”.

## Discussion

The official classification of *Syzygium densiflorum* as Vulnerable (VU) is accurate but the accompanying rationale must be amended to rely on the most robust criteria based on the latest updates inferred from this present study. The present study's data, based on 82 collection records across 19 subpopulations, provides an Area of Occupancy (AOO) ranging from 124 km<sup>2</sup> (Rationale) to 220 km<sup>2</sup>. In either case, the AOO is severely restricted ( $\leq 2,000$  km<sup>2</sup>), qualifying the species for Vulnerable under the B2 criterion. The rationale may be revised to state the classification as Vulnerable (VU) under B2ab(iii), where the qualification rests on the severely restricted AOO, the small number of known subpopulations, and a continuing decline (b(iii)) in the extent and quality of its specialised montane shola habitat. Conversely, the 30% population reduction noted is insufficient to trigger the A criterion ( $\geq 50\%$  required for VU), and the population estimate of fewer than 20,000 mature individuals is too high to meet Criterion D1 ( $< 10,000$  required for VU). Therefore, the VU status is correct, but only through the continued threat to its highly restricted montane forest habitat.

### 3.3.22. *Syzygium occidentale* (Bourd.) Gandhi, Fl. Hassan Dist. [Saldanha & Nicolson] 282 (1976).

**Synonyms:** *Eugenia occidentalis* Bourd. in Indian Forester 30: 195 (1904); *Jambosa occidentalis* (Bourd.) Gamble in Fl. Madras: 474 (1919).

**Vernacular Name:** Attuchamba, Karinjara (Malayalam)

**Family:** Myrtaceae

**Identifying Features:** A large shrub to small tree, typically found along rocky river courses, with linear-lanceolate or linear-oblong leaves measuring 10-20 x 1.5-2 cm. The leaves have an acute base and an acuminate apex, with many indistinct nerves that form intramarginal nerves. The petiole is short, up to 1 cm long. The plant produces terminal cymes up to 10 cm broad with white-yellow flowers. The calyx tube is 15 mm long and funnel-shaped, with four ovate, obtuse lobes that are 6 mm across. The flowers have four orbicular, white petals, 8 mm broad, and white-yellow filaments that are 25 mm long. The style is 3.5 cm long, and the fruit is a globose berry measuring 2 x 2 cm (Fig. 3.46).

**Flowering and Fruiting:** December – May



### IUCN Status Assessment

The first IUCN Red List assessment for the species, conducted in 1998 (World Conservation Monitoring Centre, 1998), categorised it as Vulnerable (VU) under criteria A1d. This initial assessment did not report data for AOO or EOO. The recent assessment (Bachan & Devika, 2023) re-categorised the species as Endangered (EN) under criteria A2c+4c; B2ab(i,ii,iii,iv,v). This assessment identified 14 locations, with an estimated AOO - 24 km<sup>2</sup> and EOO - 8,154 km<sup>2</sup>. Critically, nine of these 14 locations were subsequently washed out by flood events in 2018 and 2019. The present study, utilizing 35 collection records, identified 15 locations for the species. The re-calculation of spatial metrics resulted in an estimated AOO – 108 km<sup>2</sup> and an EOO -14,124 km<sup>2</sup>.

### Distribution

The *Syzygium occidentale* is endemic to the Western Ghats, India, particularly in Kerala Tamil Nadu and Karnataka. The species has an estimated AOO of 108 km<sup>2</sup> and EOO of 15054 km<sup>2</sup> (Fig. 3.45).

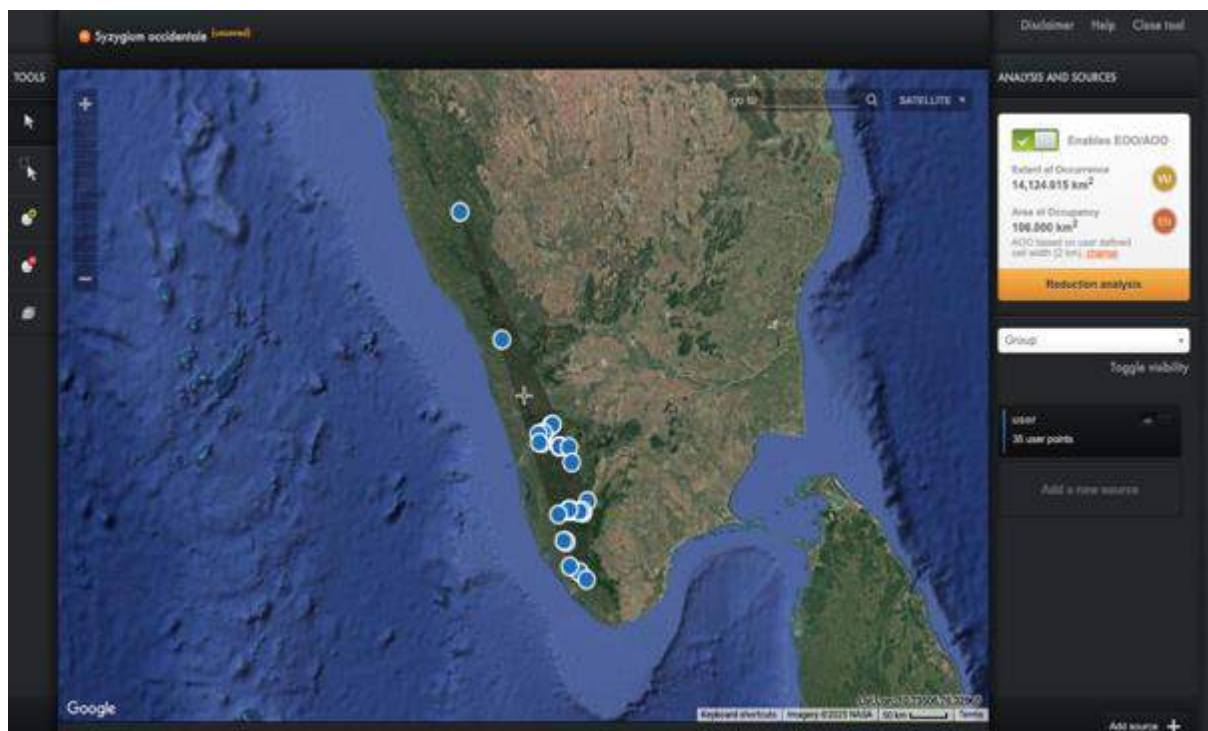


**Fig. 3.45. Calculated AOO and EOO using GeoCAT for *Syzygium occidentale***



**Fig. 3.46.** *Syzygium occidentale* (Bourd.) Gandhi: A. Habit; B. Twig; C. Bark; D. Leaf; E. Bud; F. Stamen; G. Flower; H. & I. Fruits; J. Fruit L.S.

**Population**

*Syzygium occidentale* has been reported from 14 locations of low to medium elevation river stretches within six distinct ecoregions of the southern Western Ghats in South India. Of these 14 sites, nine were severely impacted by flooding events during the years 2018 and 2019 (Bachan, 2010; Bachan et al., 2019). The operations of reservoirs and the resultant submergence represent significant threats to both the species and its ecological niches (Bachan & Devika, 2020). The reduction in population is quantified at 57%, as determined by a decrease in area of occupancy (AOO), while the extent of occurrence (EOO) has diminished by 20%.

**Habitat and Ecology**

This species is classified as an obligate rheophytic evergreen riparian large shrub or diminutive tree species endemic to low to medium elevation riverine environments in the southern Western Ghats.

**Threats**

The primary threats to this species arise from habitat degradation associated with submergence and flash floods triggered by dam-related operations. Climate change has exacerbated heavy rainfall and flooding, in conjunction with reservoir management, resulting in the destruction of 57% of the known population (Bachan, 2010; Bachan et al., 2019; Bachan & Devika, 2020, 2022).

**Use and Trade**

Currently, there is an absence of documented use and trade information pertaining to this species.

**Conservation Actions**

There are currently no specific conservation measures implemented. However, policies advocating for the regulation of dam water operations to safeguard habitats have been established (Bachan et al., 2019), and an ecological restoration initiative for the riparian habitat has been integrated into the management frameworks of the Forest Department and the Kerala State Biodiversity Board (Bachan et al., 2019).

**Assessment Rationale**

The recent IUCN Red List assessment for the species is done by Bachan & Devika (2023) and the assessment rationale published is as follows:

“*Syzygium occidentale* is recognized as an obligate riparian rheophytic small tree species endemic to the southern Western Ghats of India. Its geographical distribution is markedly confined to low to medium elevation evergreen riparian forests situated between altitudes of 60–750 m. Research indicates a 57% decline in population attributed to climate change-induced flooding events in 2018 and 2019, compounded by dam operations. The extent of occurrence (EOO) has experienced a 20% reduction, alongside a 57% decrease in area of occupancy (AOO). The number of locations has diminished from 14 to five, thereby signifying the endangerment of both the species and its habitat amidst ongoing threats (Bachan et al., 2019; Bachan & Devika, 2020, 2022). The estimated EOO is calculated at 15054 km<sup>2</sup>, with an AOO of 108 km<sup>2</sup>. Consequently, the species is categorized as Endangered due to its limited distribution and the vulnerability of its habitat, in conjunction with the observed population decline.”

#### **Discussion on the IUCN Assessment Rationale**

The first assessment considered *Syzygium occidentale* as Vulnerable (1998) where population information and vulnerability of the unique representing habitat were not considered. The categorization of *Syzygium occidentale* as Endangered (EN) under Criteria A2c+4c; B2ab(i,ii,iii,iv,v) (Bachan & Devika, 2023) is robustly supported and necessary, reflecting the extreme vulnerability of this obligate riparian species. The classification is primarily driven by the catastrophic and ongoing population decline: the data confirms a 57% reduction in population size and Area of Occupancy (AOO), largely due to the unmitigated threats of dam operations and climate-change-induced flash floods (Bachan et al, 2019; Bachan & Devika, 2021), which qualifies the species for EN under Criteria A2c and A4c ( $\geq 50\%$  required). Furthermore, the species independently qualifies under the B2 criterion as the AOO is severely restricted (108 km<sup>2</sup>), and the number of functional locations has been reduced to a critical five (down from 14), confirming severe fragmentation and a continuing decline across all distribution metrics (B2ab(i-v)). The use of the Endangered (EN) (Bachan & Devika, 2023) status is therefore justified on multiple grounds, underscoring the severe and immediate risk faced by this small tree endemic to low-elevation river courses.



**3.3.23. *Syzygium palghatense*** Gamble, Bull. Misc. Inform. Kew 1918(7): 240 (1918).

**Synonyms:** *Eugenia beddomei* Duthie

**Vernacular Name:** Sevappunjaaval (Malayalam)

**Family:** Myrtaceae

**Identifying Features:** Tree grows up to 15 m tall in hilltop of the medium elevation wind exposed sub montane regions. Known from only two locations so far. It has smooth bark that appears greyish on the outside and muddy brown on the inside, with branchlets subtetragonous. Leaves are arranged in an opposite or subopposite pattern 3.5-8 x 2-3.5 cm, elliptic to elliptic-oblong, sparsely gland dotted on lower surface. flowers are arranged in cymes, 2-3 cm long. The calyx tube is funnel-shaped and measures 8-12 mm long. The petals are creamy white and measure 2.5 mm across. Stamens are up to 8 mm long. The berry 10-13 x 4-5 mm has a characteristic inverted cone or obconic shape with a hollow depression at its top. It is crowned by the persistent calyx limb and becomes noticeably ribbed as it dries (Fig. 3.48).

**Flowering and Fruiting:** January – June

#### Distribution

The *Syzygium palghatense* is endemic to the Western Ghats, India, particularly in Kerala. The species occur in an AOO of 12 km<sup>2</sup> and EOO of 7 km<sup>2</sup> (Fig. 3.47).

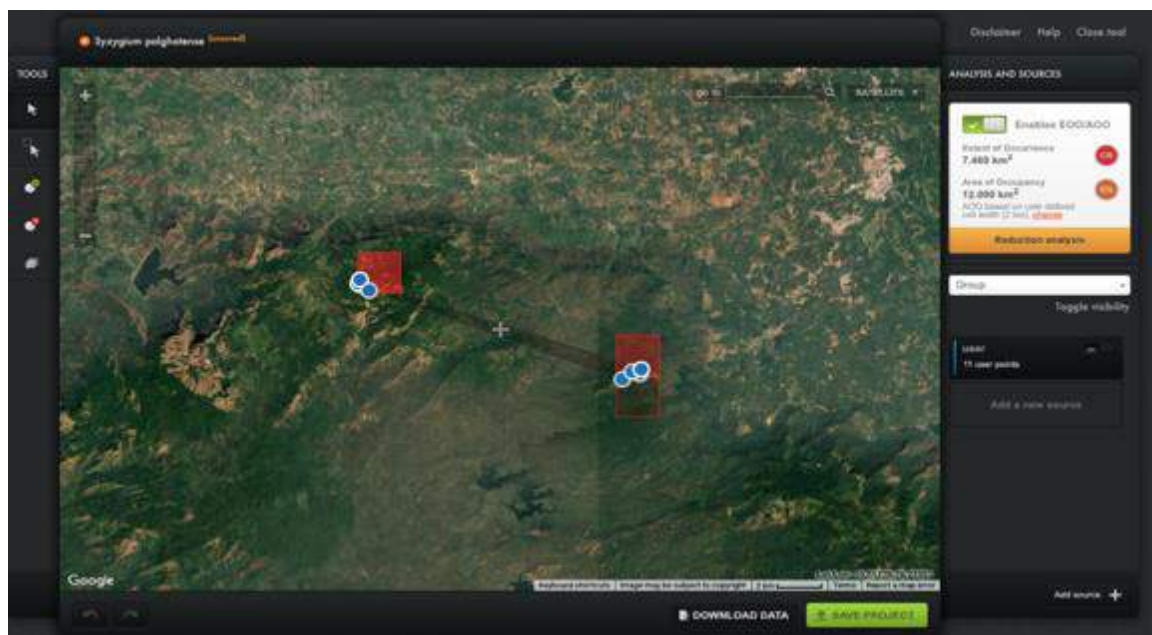


**Fig. 3.47.** Calculated AOO and EOO using GeoCAT for *Syzygium palghatense*

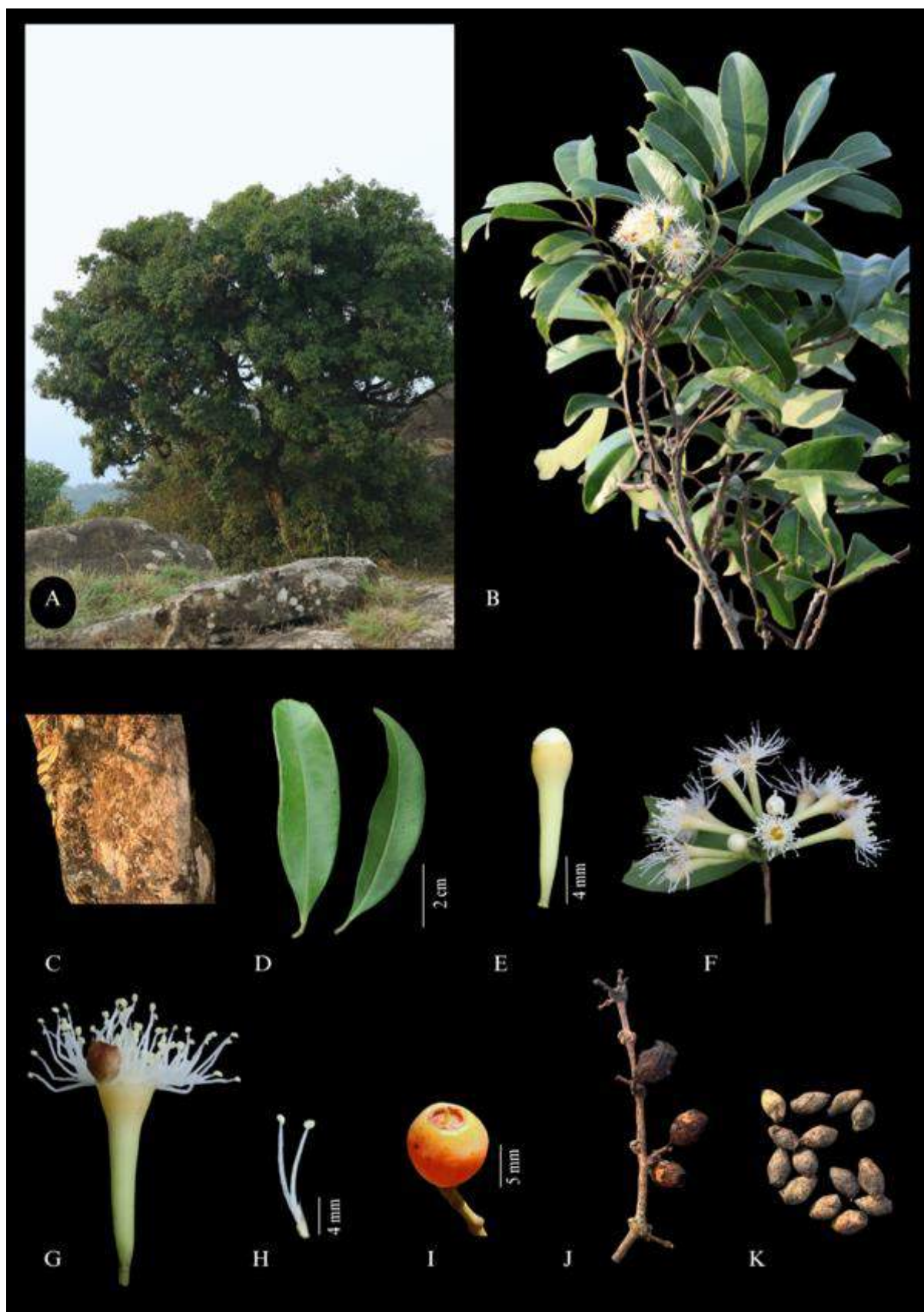


**Fig. 3.48.** *Syzygium palghatense* Gamble: A. Habit; B. Twig; C. Bark; D. Leaf; E. Bud; F. Inflorescence; G. Flower; H. Stamen; I. Fruit; J – K. Dry fruits and seeds.

### **IUCN Status Assessment**

The first IUCN Red list assessment was done for the species during 1998 and it was considered Critically Endangered under criteria B1+2abcde (World Conservation Monitoring Centre, 1998). The assessment was based solely on one collection record from Palghat Hills and all the other data were mentioned as need updation. The present study add on more data on species location, population and habitat ecology, which resulted the species in Critically Endangered under criteria B1ab(iii)+2ab(iii); D (Bachan & Devika, 2023).

### **Population**

Earlier assessment had no population information (World Conservation Monitoring Centre, 1998). The present study contributed population information and are as follows. *Syzygium palghatense* was rediscovered in 2002 at its type locality after an interval of 140 years. To date, there exist only 11 collection records from the same locality, with the number of mature trees reported being a mere three. The incidence of fruit set is exceedingly low, with only two saplings recorded thus far (Sujanapal & Sasidharan, 2002).

### **Habitat and Ecology**

*Syzygium palghatense* is characterised as an evergreen tree reaching heights of up to 15 m, and it has been observed within the tropical evergreen submontane forest at Pandaravarai peak in the Palakkad hills of Kerala, which is situated in the southern Western Ghats. Thus far, only three mature specimens have been documented from this site, located at altitudes ranging from 1,100 to 1,524 m. The flowering and fruiting period occurs from January to June, yet the fruit set remains exceedingly low, with merely two saplings identified within a 1 km<sup>2</sup> area (Sujanapal & Sasidharan, 2002). The present study documented three mature individuals and two saplings in the Nelliampathi hills of the Nenmara forest Division from similar habitat.

### **Threats**

The species is endemic to a singular locality within the southern Western Ghats. To date, only three mature specimens have been documented, and the area has historically experienced timber extraction activities. This species exists within old teak plantations and is vulnerable to forest fires, despite its presence within a protected area.



### **Use and Trade**

No information regarding utilization and trade is available.

### **Conservation Actions**

The species is recorded with merely three mature individuals from a solitary location in the Anamalai region of the Southern Western Ghats. This locality lies within the confines of the Parambikulam Tiger Reserve; however, the area has been subjected to extensive timber extraction and commercial timber plantation activities. The small natural forest fragment is susceptible to the adverse effects stemming from the old timber plantation and the threat of forest fires.

### **Assessment Rationale**

The recent IUCN assessment for the species was done by Bachan and Devika (2023) based on inputs from the present study and the assessment rationale is as follows:

“*Syzygium palghatense* is classified as a small to medium evergreen tree, achieving heights of up to 15 meters, and is reported solely from a single site in the Anamalai region of the southern Western Ghats. This species was presumed extinct until its rediscovery near the type locality after a period of 140 years. Currently, only three mature individuals have been documented at altitudes ranging between 1,100 and 1,524 m within the confines of the Parambikulam Tiger Reserve in Kerala. The extent of occurrence (EOO) and area of occupancy (AOO) are measured at 4 km<sup>2</sup>. The incidence of fruiting is exceedingly low, and the area remains at risk of forest fires. Therefore, site-specific monitoring and restoration efforts are imperative for the effective conservation of this species. Consequently, the species is evaluated as Critically Endangered (CR).”

### **Discussion on the IUCN Assessment of *Syzygium palghatense***

The assessment of *Syzygium palghatense* as Critically Endangered (CR) (Bachan & Devika, 2023) is exceptionally robust and mandatory, even with the vital new discovery. The present study's input is crucial, confirming the existence of a second subpopulation with three additional mature individuals and two saplings, bringing the known global population to only six mature individuals across two locations. Despite the welcome rediscovery after 140 years (Sujanapal & Sasidharan, 2002), and the second sub population with this study, this total population figure is still drastically below the threshold of  $\leq 50$  mature individuals required for the CR classification under Criterion D. Furthermore, the

total number of locations (2) is well within the CR threshold of  $\leq 5$  locations under Criterion B. The existence of two tiny subpopulations, one of which is confirmed to have new saplings, is positive evidence against imminent extinction and validates localised regeneration. However, with the entire species confined to an Area of Occupancy (AOO) of only 4 km<sup>2</sup> and facing severe threats from timber extraction, adjacent plantations, and recurrent forest fires, its status remains critically imperiled. Therefore, the CR classification under B2ab(iii) + D is essential, making site-specific monitoring and targeted in situ restoration efforts at both vulnerable sites the highest conservation priority.

**3.3.24. *Syzygium parameswaranii*** M.Mohanan & A.N.Henry, J. Bombay Nat. Hist. Soc. 84(2): 409 (1988).

**Synonyms:** No Synonyms

**Vernacular Name:**

**Family:** Myrtaceae

**Identifying Features:** A small tree, up to 5 m tall, with ovate leaves measuring 4-5.5 x 2-3 cm. The leaves are glabrous, obtusely acute to obtuse, glaucous beneath, and green on the upper surface when dried, with up to 18 pairs of less prominent nerves. The plant produces terminal cymes up to 5 cm across, with 8-12 flowers that have pedicels 8 mm long. The calyx is 4 mm broad with triangular lobes (1 x 1.5 mm), and the orbicular petals are 3 x 3 mm. The flowers also have filaments 2.5 mm long and a style 9 mm long. The fruit was not observed (Fig. 3.49).

**Flowering and Fruiting:** January – April

#### **IUCN Status Assessment**

The first IUCN Red list assessment was done for the species during 1998 and it was considered Endangered under criteria B1+2c (World Conservation Monitoring Centre, 1998). The assessment was based solely on two collection records and all the other data were mentioned as need updatation. The present study identified four locations for the species based on 33 collection records and assessed as Endangered category under the criteria B1ab(iii,v)+2ab(iii,v); C2a(i) and the IUCN assessment was published (Bachan & Devika, 2023).

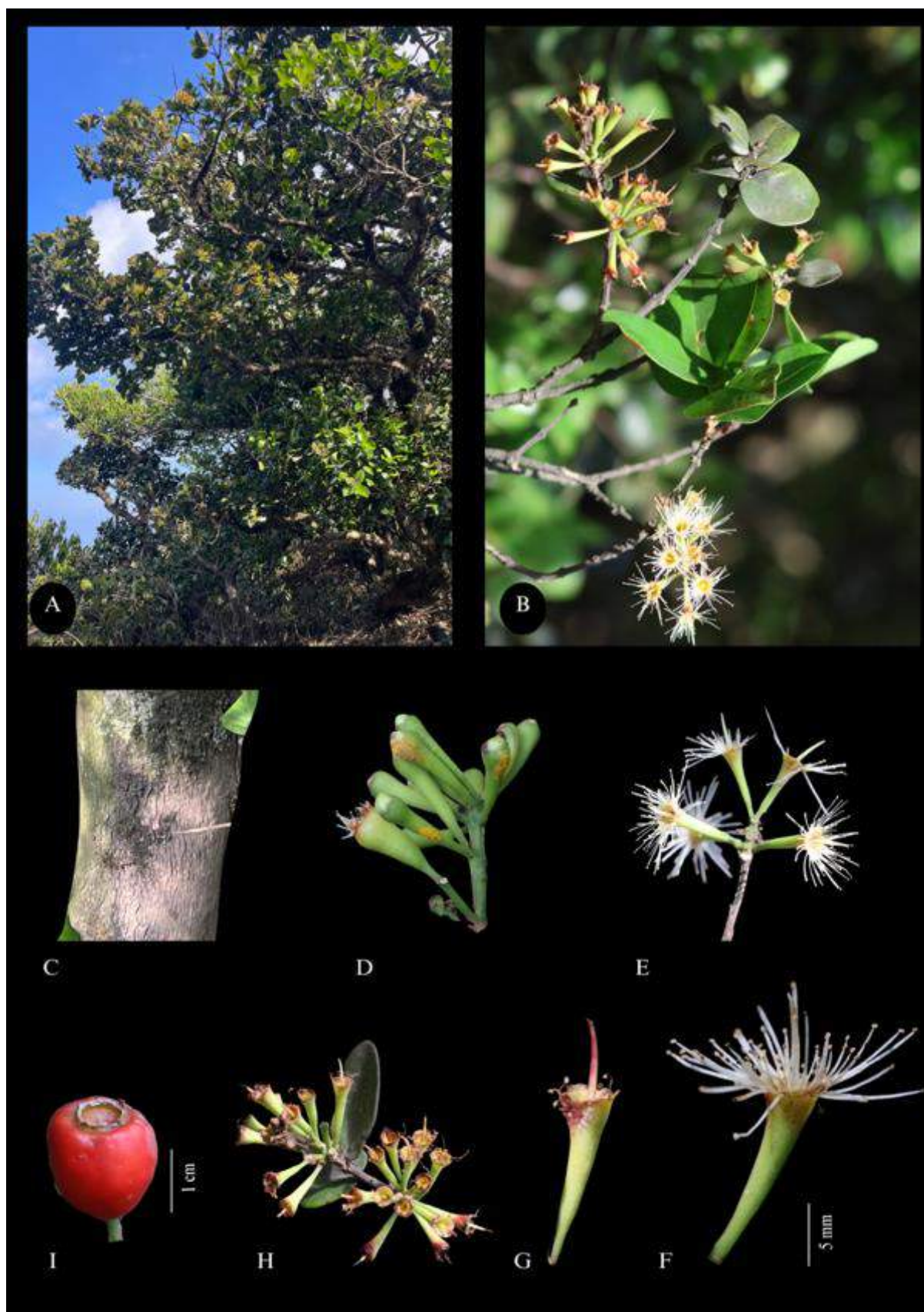


**Fig. 3.49.** *Syzygium parameswaranii* M.Mohanani & A.N.Henry: A. Habit, B. Twig, C. Bark; D. Bud, E. Inflorescence; F. Flower; G. Pistil; H. I. Fruit.

## Distribution

The *Syzygium parameswaranii* is endemic to the Western Ghats, India, particularly in Kerala and Tamil Nadu. The species occur in an AOO of 72 km<sup>2</sup> and EOO of 3541 km<sup>2</sup> (Fig. 3.50).

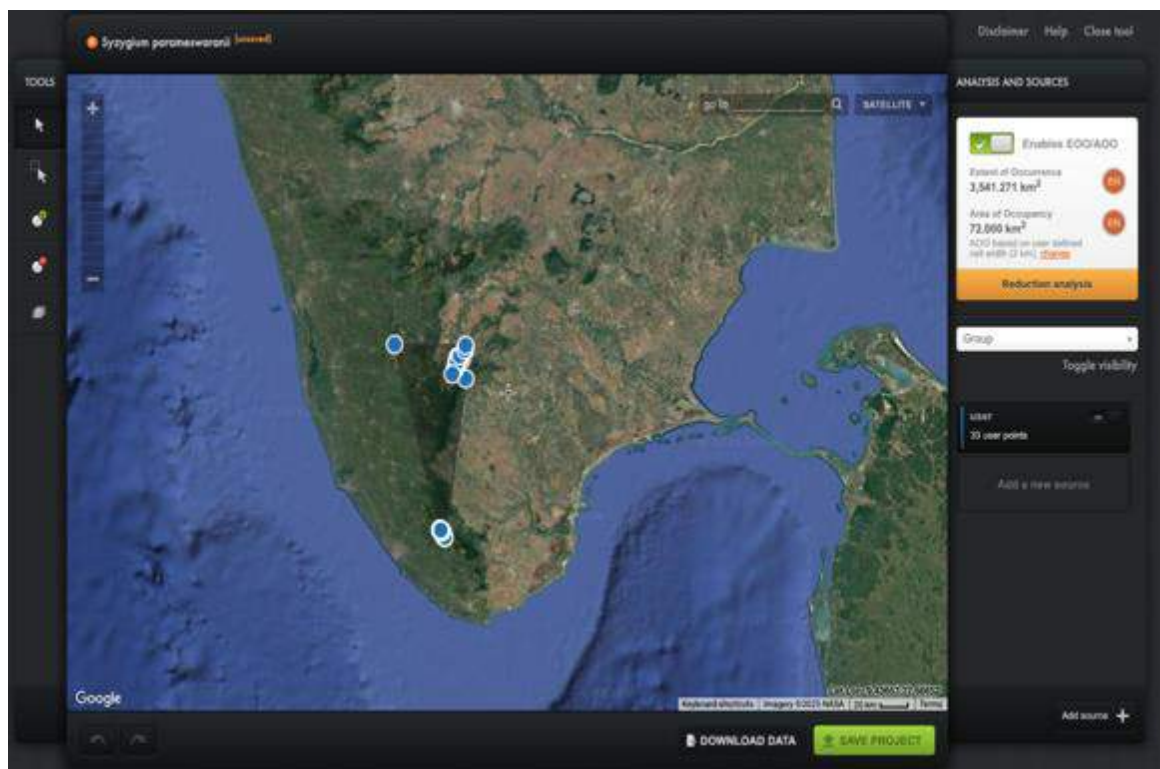


**Fig. 3.50. Calculated AOO and EOO using GeoCAT for *Syzygium parameswaranii***

## Population

Earlier assessment had no population information (World Conservation Monitoring Centre, 1998). The present study contributed population information and are as follows. *Syzygium parameswaranii* has been documented in four distinct locations across three contiguous landscapes in the Southern Western Ghats, confined within a specific altitudinal range of 1,200–1,800 m. The species is represented by 33 collection records within this exceptionally limited distribution, with an estimated population of mature individuals falling below 250. The population is more on the Tamil Nadu side (26 collection records) and Kerala (7), notably, the largest subpopulation at Megamalai consists of approximately 100 individuals. The current demographic trend of the population remains indeterminate; however, the region has undergone significant alteration for the development of tea plantations and the establishment of dams. An

infestation by *Anselmella kerrichi* has resulted in a reproductive rate decline of 75–95% affecting both flowers and fruits (Reghunath & Ramasubbu, 2020). The precise implications of this infestation on future population dynamics are yet to be elucidated (Bachan & Devika, 2023).

### **Habitat and Ecology**

*Syzygium parameswaranii* is confined to the tropical montane evergreen forests situated within the Agasthyamalai, Periyar, and Megamalai landscapes, occurring at elevations ranging from 1,200–1,800 m. This species can be characterised as a diminutive tree, attaining heights of up to 6 m within montane shola forest fragments. The co-occurring species include *Elaeocarpus munroi*, *Maesa indica*, *Nothapodytes nimmoniana*, various *Syzygium* sp, and *Litsea* sp.

### **Threats**

*Syzygium parameswaranii* is confined to a restricted altitudinal range of 1,200–1,800 m across four locations within three landscapes in the southern Western Ghats. The habitat is fragmented due to the establishment of tea plantations and dams. Reports indicate that an infestation by the insect *Anselmella kerrichi* has led to a significant reduction in the reproduction rate, estimated between 75–93% (Reghunath & Ramasubbu, 2020).

### **Use and Trade**

Currently, there exists no documented information pertaining to the use and trade of this species.

### **Conservation Actions**

The species is devoid of site-specific conservation and management strategies, as well as comprehensive population data and monitoring efforts, despite its presence in three critical protected areas, including the Agasthyamalai biosphere reserve. Mature individuals have been identified across all four locations, and research addressing reproduction decline due to insect infestation has been conducted.

### **Assessment Rationale**

The species is assessed recently (Bachan & Devika, 2023) based on inputs from this study and the published IUCN assessment rationale is as follows:

“*Syzygium parameswaranii* is endemic to the Megamalai, Periyar, and Agasthyamalai landscapes of the southern Western Ghats in India. This species is observed in the

undergrowth of montane shola evergreen forests, reaching heights of up to 6 m, and is found within a narrow altitudinal range of 1,200–1,800 m. Although numerous collection records exist, the species' distribution is highly restricted to four locations. The estimated area of occupancy (AOO) is calculated to be 44 km<sup>2</sup>, while the extent of occurrence (EOO) is approximated at 659 km<sup>2</sup>. The habitat has been significantly altered for tea cultivation and dam construction, leading to a persistent decline in habitat quality. The remaining habitat is situated within three significant protected areas across the Kerala and Tamil Nadu regions. A reduction in reproductive success of 75–93% due to insect infestation has been documented. The estimated number of mature individuals is fewer than 250, with the largest subpopulation at Megamalai comprising around 100 individuals. Hence, the species is assessed here as Endangered.

### **Discussion on the IUCN Assessment and Conservation**

The classification of *Syzygium parameswaranii* as Endangered (EN) under Criteria B1ab(iii,v)+2ab(iii,v); C2a(i) (Bachan & Devika, 2023) is critical, owing directly to the decisive population and threat inputs provided by the present study. The initial 1998 assessment, based on minimal data, has been comprehensively upgraded by the current research, which now confirms 33 collection records, yet highlights an extremely restricted distribution across only four locations. The species meets both the B1 (EOO 659 km<sup>2</sup>) and B2 (AOO 44 km<sup>2</sup>) thresholds for Endangered, driven by the continuing decline in habitat quality due to fragmentation by tea plantations and dams (iii). Crucially, the study established the species' dire demographic state, estimating a total population of fewer than 250 mature individuals, with no subpopulation exceeding 100. This figure decisively qualifies the species for EN under Criterion C2a(i). Furthermore, the identification of a novel and severe threat, a 75-93% decline in reproductive success caused by the *Anselmella kerrichi* insect infestation (Reghunath & Ramasubbu, 2020). adds a layer of immediate, ongoing decline (v) that underscores the necessity of the Endangered status. The conservation priority must, therefore, shift immediately to developing site-specific monitoring management and seedling production strategies within the protected areas to address this ecological threat and prevent further habitat degradation.



### 3.3.25. *Syzygium sahyadricum* Sujanapal, Robi & Sasidh. Phytotaxa 174(5): 286 (2014).

**Synonyms:** No Synonyms

**Vernacular Name:** Pottinjavai, Pillanjavai (Malayalam)

**Family:** Myrtaceae

**Identifying Features:** A tree reaching up to 12 m high, with pale brown, smooth bark, a blush pink inner layer, and quadrangular branchlets. It has opposite leaves measuring 4.5–6.5 × 2–3 cm, and pale-yellow tender leaves with horizontal secondary nerves. The flowers are white in a reduced metabotryoid, pedunculate inflorescence that is flattened towards the apex. The fruit is a fleshy, single-seeded drupe that is oblate or obovoid, approximately 4–8 × 4 mm, and dark purple when ripe (Fig. 3.52).

**Flowering and Fruiting:** December – May

#### IUCN Status Assessment

The conservation status of *Syzygium sahyadricum* is being assessed for the first time in this study (Devika et al., *In press*). The species was categorised as Endangered (EN) under Criteria A2c. This classification, which resulted from the application of multiple criteria, was based on 10 known locations derived from 19 collection records.

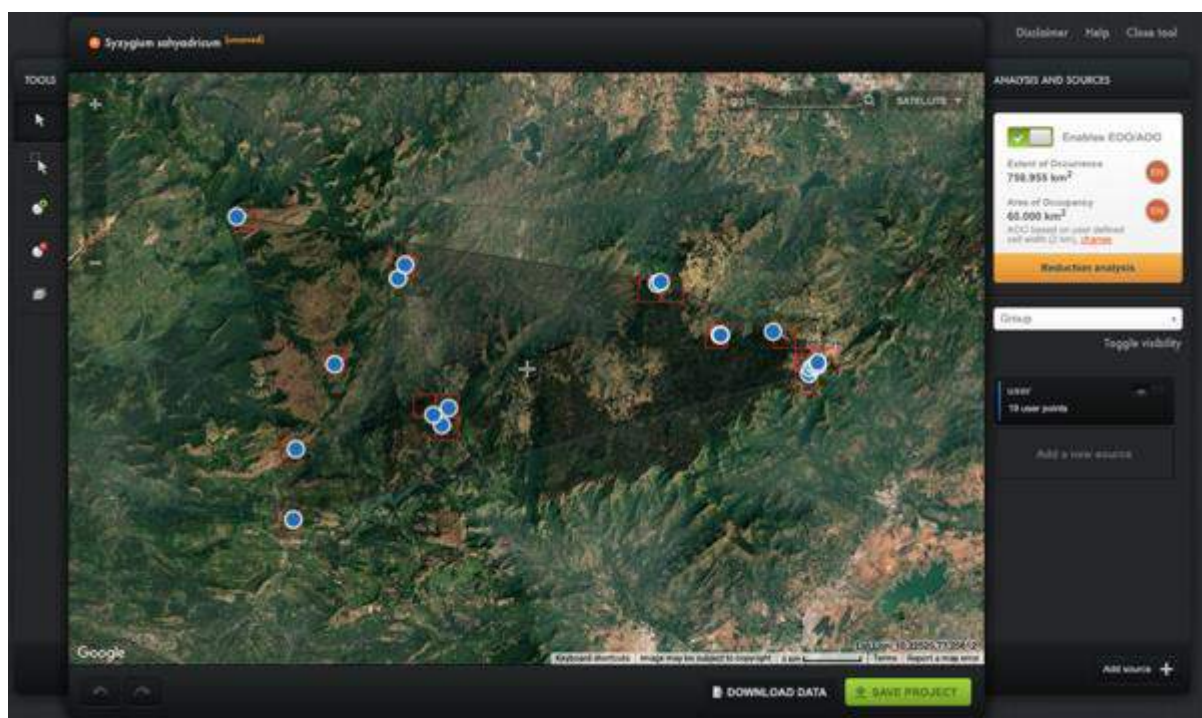


**Fig. 3.51.** Calculated AOO and EOO using GeoCAT for *Syzygium sahyadricum*





**Fig. 3.52.** *Syzygium sahyadricum* Sujanapal, Robi & Sasidh.: A. Habit, B. Twig, C. Leaf abaxial side, D & G. Inflorescence, E. Infructescence, F. Fruit.

### **Distribution**

The *Syzygium sahyadricum* is endemic to Western Ghats of South West India, particularly in Kerala and Tamil Nadu. The estimated AOO of the species is 60 km<sup>2</sup> and EOO is 758 km<sup>2</sup> (Fig. 3.51).

### **Population**

The species is exclusively found in the elevated regions of the Anamalai-Munnar landscapes situated in Kerala and the adjacent Kodaikanal-Palani hills located in Tamil Nadu, which form part of the Western Ghats. A substantial portion of the population resides within the Shola forests of Eravikulam National Park and Anaimudi Shola National Park, as well as the Munnar area, while the remaining individuals inhabit the contiguous Kodaikanal-Palani hills in Tamil Nadu. The estimated number of mature individuals of the tree is based on the present study is 4,000-8000, derived from the identified 10 subpopulations, with an abundance of approximately 16 individuals per hectare in its habitat and density of 1.72 per hectare. Historically, there has been a significant 50% decline in the population due to the transformation of habitats for tea cultivation, industrial plantations, and infrastructure expansion.

### **Habitat and Ecology**

*Syzygium sahyadricum* is classified as a canopy tree reaching heights of 20 m, inhabiting the high elevation tropical montane evergreen shola forests located within the Southern Western Ghats, at altitudes ranging from 1,800 to 2,400 m. The species is documented across 10 subpopulations within two distinct ecoregions of the Southern Western Ghats in South West India, specifically on the Eravikulam plateau of the Anamalai-Munnar landscape in Kerala and the shola forests of the Kodaikanal-Palani hills in Tamil Nadu. These ecoregions are ecologically interconnected, sharing high elevation shola grassland ecosystems. The species coexists with notable shola forest flora, including *Syzygium densiflorum*, *Elaeocarpus recurvatus*, various *Cinnamomum* sp, *Phoebe* sp, *Elaeocarpus glandulosus*, *Rhododendron arboreum*, among others (Devika & Bachan, 2023). The fruits produced by the species are consumable and serve as a vital food source for avian and mammalian fauna.

### **Threats**

The habitats of *Syzygium sahyadricum* are primarily subjected to clearance for the establishment of forest and agricultural monoculture plantations, such as tea, Eucalyptus,

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and Black Wattle, as well as for infrastructure development. Additionally, sporadic forest fires occurring within the associated grasslands adversely impact the species.

### **Use and Trade**

Currently, there exists a lack of comprehensive data regarding the utilization and commercial trade of this species.

### **Conservation Actions**

At present, there are no specific conservation strategies tailored to either the species or its habitat. Approximately 60% of the population resides within designated protected areas.

### **Assessment Rationale**

*Syzygium sahyadricum* is categorised as a canopy tree endemic to the tropical montane shola forests prevalent in the Anamalai-Munnar and Kodaikanal-Palani landscapes of the Southern Western Ghats mountain range in South West India, thriving at altitudes between 1,800 and 2,400 m. The area of occupancy (AOO) is quantified at 60 km<sup>2</sup>, while the extent of occurrence (EOO) is recorded at 758.9 km<sup>2</sup>. The species is represented by a mere 10 known subpopulations, with an estimated population of mature individuals numbering 4,000-8000, confined to two ecoregions within the Southern Western Ghats. The principal population resides within the Eravikulam and Anaimudi Shola National Parks in the Anamalai-Munnar landscape of Kerala, with the remaining individuals found in the adjacent Kodaikanal hills of Tamil Nadu. The species is associated with significant shola forest species such as *Syzygium densiflorum*, *Elaeocarpus recurvatus*, and *Rhododendron arboreum* among others. The habitats have historically been cleared for the cultivation of tea and other agro-industrial plantations, including Eucalyptus and Black Wattle, alongside infrastructure development, which persists to this day. A historical reduction in population of at least 50% is inferred. Consequently, the species is classified herein as Endangered (EN).

### **Discussion on the IUCN Assessment Rationale and Conservation**

The assessment of *Syzygium sahyadricum* as Endangered (EN) (Devika et al., *In press*) is well updated, confirmed by the convergence of multiple IUCN criteria demonstrating severe historical decline and critically restricted distribution, with the present study providing essential population census data to anchor the rationale. The EN status is primarily justified by Criterion A2c, as a historical reduction of at least 50% in the mature

population is inferred, directly attributed to the severe habitat conversion for tea and industrial plantations (c), thereby meeting the EN threshold. This is further reinforced by Criterion B, as the species is spatially imperiled: both its Area of Occupancy (AOO) of 60 km<sup>2</sup> and Extent of Occurrence (EOO) of 758.9 km<sup>2</sup> are well below the respective EN thresholds. Although the estimated mature population (4,000-8,000 individuals) does not qualify under Criteria C or D, the population is highly vulnerable due to its confinement to only 10 subpopulations within a specialised montane shola forest niche. The threat from continuing habitat clearance and sporadic fires persists, ensuring a decline in habitat quality (B1ab(iii)+2ab(iii)) that solidifies the Endangered status. Therefore, while 60% of the population is within Protected Areas, the conservation priority must involve site-specific management and fire regulation within the shola fragments of Eravikulam and Anaimudi Shola National Parks to secure the remaining populations.

### **3.4. Discussion**

The conservation of global biodiversity hinges on robust, empirically grounded assessments of threatened flora in critical hotspots. This chapter presents a detailed discussion synthesizing the findings from a comprehensive analysis of 1,264 collection records and in-depth conservation assessments for 25 of the most imperiled plant species endemic to the Southern Western Ghats, a globally recognised biodiversity hotspot. The collective data presented herein underscores the critical and indispensable role of recent fieldwork in accurately refining IUCN Red List assessments, many of which are published in the IUCN Red List, precisely quantifying contemporary population dynamics, and informing urgent, targeted conservation strategies. By providing a synthesis that links historical botanical records with contemporary demographic and threat data, this research establishes a foundational, data-driven framework for evidence-based conservation policy and management in this ecologically vital mountain range. Careful taxonomic scrutiny of both historic collection records and new documentary evidences forms the foundation for this chapter of the doctoral work. This foundation is built upon rigorous fieldwork-based contributions, which include updated taxonomic details (such as photographs and herbarium specimens) and, most critically, quantified population data collected through dedicated phytosociological sampling.

### 3.4.1. Collection History Analysis

The analysis of 1,264 scrutinised collection records spanning nearly 150 years for the 25 target species reveals a non-linear but telling trajectory of botanical exploration in the Southern Western Ghats. Historically, collection activity was sparse, with only 71 records dating to the period pre-1950 (5.6% of the total) (Appendix I). This paucity reflects the logistical challenges of early exploration and the reliance on general botanical surveys rather than species-specific targeted searches. The period between 1950 and 2000 saw a significant increase to 571 records, coinciding with the rise of regional floristic studies and the establishment of major institutional herbaria in India. However, the most active collection phase occurred post-2000, accounting for 522 records, a testament to the increased capacity for ecological monitoring and the focused research drive following the global recognition of biodiversity loss. Critically, the current study, defined by records from 2020 onwards, contributes 142 records (11.2% of the total). This substantial recent contribution highlights a paradigm shift from broad-scale documentation to focused, taxon-centric field verification, which is essential for grounding modern conservation status assessments. The average number of records per species is approximately 50.6, suggesting that while some species, like *Elaeocarpus munroi* (the most recorded species), are relatively well-documented, a significant portion of the threatened flora still relies on a thin historical dataset, emphasizing the disproportionate value of each new discovery. The least collected species in the dataset highlight an extreme level of rarity and vulnerability, suggesting conservation statuses far more severe than mere under-sampling. While the recent, dedicated fieldwork demonstrates robust search intensity, the continued paucity of records for this group implies that their distribution is fundamentally constrained by profound ecological specialization and demographic scarcity. This constraint is likely tied to Grenellian niche factors the unique, highly specific microclimatic and edaphic conditions required for a species' survival. The rarest species, including *Aglaia malabarica* (10), *Syzygium palghatense* (11), *Cryptocarya anamalayana* (13), *Medinilla anamalaiana* (13), and *Ochna gamblei* (15), all have fewer than 16 records, signifying a critical lack of documentary evidence and restriction to rare, specific ecosystems. The low collection counts for these species reflect low population numbers due to Eltonian niche factors, which govern the species' interactions and population dynamics. Even species with slightly higher collection counts, *Syzygium sahyadricum* (19), *Garcinia wightii* (23), *Aporosa bourdillonii* (25), *Diospyros crumenata* (28), and *Syzygium parameswaranii* (33) are still

fundamentally restricted. Their inability to exploit broader environments leads to small population sizes vulnerable to bottlenecks. The lack of extensive collection records is thus a direct indicator of biological rarity, underscoring that these species are primary candidates for Critically Endangered (CR) status based on Criterion D (very small population size) and Criterion B (restricted distribution). The low collection frequency strongly implies that their respective number of subpopulations (locations) is minimal. Even if a species has 28 records (like *Diospyros crumenata*) or only 11 records (like *Syzygium palghatense*), if those collections originate from only two or three locations, the species immediately meets the Critically Endangered (CR) or Endangered (EN) thresholds for geographical fragmentation. This signifies that the low collection count is not just an arbitrary measure of scarcity, but a direct manifestation of a critically limited and highly vulnerable geographical range under Criterion B.

### **3.4.2. Contribution to Demography and Population**

The spatial distribution of the 1,264 collection records confirms the undisputed ecological prominence of the Southern Western Ghats, with a strong concentration of endemic threatened flora within two major states. Kerala emerges as the primary repository for these 25 species, accounting for 60.4% (764 records) of all collections. This dominance is followed by Tamil Nadu at 29.4% (371 records), and Karnataka at 8.4% (106 records). This pronounced concentration across the Western Ghats, particularly in the southern montane ecosystems of the Agasthyamalai, Anamalai-Munnar, and Wayanad regions, reflects the unique evolutionary processes driven by the region's high rainfall, altitude, and complex geological history. The collection data, while concentrated in these three major states, also shows marginal records in adjacent areas (e.g., Maharashtra, Andhra Pradesh, Goa), suggesting a potential spillover or historical range that requires validation. However, the overwhelming majority of records firmly establish the endemic core within the shola forests and riverine systems of Kerala and Tamil Nadu. This geographic focus allows for prioritization of conservation resources within specific high-biodiversity national parks and reserves, such as Eravikulam, Periyar, and the Parambikulam-Anamalai complex, which serve as crucial sanctuaries for these restricted-range species.

The quantitative inputs provided by this study represent a foundational advancement for the conservation of these endemic species, transitioning their conservation status from

being based on broad, inferential criteria to empirical, demographic-based assessments. The study's most significant contribution is the establishment of contemporary, reliable population data for all 25 species based on rigorous phytosociological sampling. This data, which was largely nonexistent or outdated prior to this work, establishes a crucial benchmark against which all future population monitoring can be compared, allowing researchers to track population trends (decline, stability, or increase) with scientific accuracy. The population data was new and empirical for the vast majority of the 25 species, enabling the application of the IUCN Criterion C (small population size and decline) and Criterion D (very small or restricted population) for the first time. The most important contributions include: the ultra-rare species like *Syzygium palghatense*, for which the fieldwork provided the first contemporary census, revealing a total mature population of only six known individuals across two locations, immediately triggering the Critically Endangered (CR) Criterion D; species such as *Syzygium parameswaranii*, where the mature population was quantified at fewer than 250 individuals to apply Criterion C2a(i); and other species, like *Syzygium occidentale*, where the sampling provided density and abundance figures that allowed for the quantification of population decline at 57%, directly supporting the Endangered (EN) Criterion A2c (Bachan & Devika, 2022). In essence, this work provided the empirical census figures for a significant portion of the 25 species, moving them definitively from the realm of inferred rarity to quantified imperilment, which is the gold standard for global threat assessment.

### **3.4.3. Contribution to IUCN Assessment**

The most profound academic contribution of this research lies in its direct and transformative impact on the robustness and accuracy of IUCN Red List assessments. The heavy reliance on historical records alone has often led to inaccurate "Data Deficient" or outdated "Vulnerable" classifications for many endemic species (Betts et al., 2020; Bates et al., 2024). By conducting targeted field validation (evidenced by the 11.2% recent contribution of new collection records), this study provided the crucial, contemporary data necessary to apply the most severe and definitive conservation criteria. The overall assessment of the 25 threatened species resulted in one Critically Endangered (CR), 14 Endangered (EN), eight Vulnerable (VU), and two Near Threatened (NT) taxa.



This distribution of threat levels, particularly the identification of *Syzygium palghatense* (Sujanapal & Sasidharan, 2002; Bachan & Devika, 2023) as Critically Endangered (owing to its highly restricted distribution to only two locations), aligns with the growing body of literature emphasizing the acute vulnerability of endemic species in biodiversity hotspots (Myers et al., 2000; Mittermeier et al., 2011). The narrow distribution and habitat specialization of several taxa assessed here exemplify the broader pattern of extinction risk concentration among narrowly endemic trees and shrubs in tropical montane and riparian systems (Rivers et al., 2011; Bickford et al., 2011).

The study's findings moved *Syzygium palghatense*, which was effectively lost to science for over 140 years, to Critically Endangered (CR) status based on the empirical finding of only six mature individuals (three newly discovered by the study) across two locations (Criterion D). Similarly, the Endangered (EN) classification of species like *Syzygium occidentale* was definitively refined using Criterion A, supported by census data confirming a 57% population decline due to specific environmental disasters. Even for species like the flagship *Strobilanthes kunthiana*, the field data provided a precise population census and verification of its synchronised 12-year flowering cycle, which is vital for monitoring its population resilience and reproductive bottleneck. Collectively, the study shifts assessments from broad, inferential metrics (e.g., historical B criteria based on EOO) to demographic and threat-based criteria (A, C, and D), providing a higher standard of scientific certainty essential for conservation policy.

The taxonomic scrutiny and consequent reassessment of these 25 threatened taxa have important implications for regional conservation planning and for the application of IUCN Red List criteria. The direct policy impact of this work is demonstrated by the high rate of submission and publication: 18 of the 25 endemic and threatened species were subject to assessments substantially revised or conducted for the first time. Of these, 15 assessments have already been published by the authors in the official IUCN Red List. The discovery that nine species in the focal set *Cryptocarya lawsonii*, *Ficus beddomei*, *Goniothalamus wightii*, *Impatiens parasitica*, *Medinilla anamalaiana*, *Meiogyne pannosa*, *Ochna gamblei*, *Strobilanthes kunthiana*, and *Syzygium sahyadricum* had not previously been evaluated (NE) underscores a persistent gap in the global threat database: taxonomic incompleteness (Jarić et al., 2016; Bland et al., 2017). Providing first IUCN assessments for these taxa reduces this gap and supplies a baseline for conservation action. Similar initiatives elsewhere have demonstrated that systematic taxonomic revisions and field

surveys often reveal numerous unassessed endemics that warrant urgent conservation attention (Nic Lughadha et al., 2020).

Furthermore, assessments for two other significant species, *Elaeocarpus munroi* and *Syzygium sahyadricum*, have been submitted to the IUCN, completed the review process by the IUCN team, and are currently in press. For the seven species previously assessed by others (*Aglaia malabarica*, *Aporosa bourdillonii*, *Dipterocarpus indicus*, *Garcinia wightii*, *Humboldtia vahliana*, *Hydnocarpus pentandrus*, and *Litsea oleoides*), this study recommends revisions in Area of Occupancy (AOO) and Extent of Occurrence (EOO) estimates, as well as category and criteria change for *Dipterocarpus indicus* and *Humboldtia vahliana*. These recommendations stem from expanded field data, demonstrating that reassessments based on refined geospatial datasets can lead to significant adjustments in extinction risk classification (Gaston & Fuller, 2009; Rivers et al., 2011). For example, updated occurrence data indicate that *Dipterocarpus indicus*, an emblematic species of evergreen forests, shows both range contraction and habitat pressure consistent with criteria A and B thresholds for Endangered status (Ashton, 2014). Similarly, *Humboldtia vahliana*, a keystone mutualist, shows restricted subpopulations affected by hydrological alterations, warranting a criteria revision under B2ab parameters. In contrast, *Diospyros crumenata*, previously categorised as Critically Endangered, now shows evidence of an expanded distribution, with new records from Karnataka (Shashwathi & Krishnamurthy, 2024; Kumar, 2023) indicating increased mature individuals and locations. Accordingly, this study recommends reclassification of the species as Endangered under criterion D. Such category changes underscore the dynamic nature of Red List assessments, which depend on the best available data and must be revised as new evidence emerges (IUCN, 2022). This widespread revision and new submission success confirms the study's efficacy in updating the global conservation knowledge base for the threatened flora of the Western Ghats.

#### **3.4.4. Conservation Outputs and the Future of Endemic Flora**

The central output of this research transcends passive knowledge generation, culminating in a set of data-driven conservation imperatives meticulously tailored to the unique and synergistic threats facing the endemic flora. The study powerfully argues that relying solely on generic Protected Area status is insufficient; instead, it demands a shift toward

species-specific management plans anchored by empirical data. This proactive approach identifies multiple conservation archetypes across the 25 species: The first archetype is defined by Threat-Mitigation Focus, exemplified by rheophytic obligates like *Syzygium occidentale*. For this species, the primary conservation output is the identification of dam operations and flood events as the dominant, human-mediated threat (Bachan et al., 2019). Management must therefore prioritise policy advocacy for regulated water release and riparian habitat restoration. The second is Reproductive Bottleneck Management, demonstrated by the discovery of a 75-93% reproductive decline due to the *Anselmella kerrichi* insect infestation in *Syzygium parameswaranii* (EN) (Reghunath & Ramasubbu, 2020). This mandates an urgent shift toward entomological and phytosanitary research to safeguard reproductive success, establishing a critical new threat management priority. The third is Micro-Habitat Protection, vital for the ultra-rare endemics like *Syzygium palghatense* (CR). Here, the conservation output is the absolute necessity of site-specific protection for its six known mature individuals, requiring intensive in situ monitoring and physical defenses against localised threats like forest fires and invasive species. Lastly, Taxonomic Monitoring is crucial for mass-flowering species like *Strobilanthes kunthiana*, where the critical output is a predictive monitoring schedule synchronised with its 12-year life cycle, allowing managers to target seedling establishment.

These outputs collectively form the basis for a proactive, evidence-based regional conservation strategy, prioritizing direct threat mitigation over passive protection for the most imperiled components of the Western Ghats flora. This comprehensive taxonomic group, encompassing endemic trees (e.g., *Syzygium* species, *Dipterocarpus indicus*), shrubs (*Strobilanthes kunthiana*), and epiphytic herbs (*Impatiens parasitica*) highlights that vulnerability is not confined to a single life form. The Ultra-Endemics such as *Aglaia malabarica*, *Syzygium palghatense* (CR), and *Syzygium parameswaranii* (EN) represent an immediate conservation emergency, with their tiny populations and restricted ranges making them acutely susceptible to a single stochastic event. The Ecological Specialists, such as the rheophytic *Syzygium occidentale* and the montane shola specialist *Syzygium sahyadricum*, further showcase how habitat specificity exacerbates threat levels, particularly as climate change acts as a primary threat multiplier, impacting niche fidelity and reproductive success.

The implications of these findings extend beyond individual species to broader ecological and management perspectives, particularly regarding habitat preservation and restoration.

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The conservation status of other narrowly endemic species, such as *Elaeocarpus venustus*, Critically Endangered due to its confinement to the Agasthyamalai Biosphere Reserve, highlights the urgent need for site-specific habitat management to mitigate ongoing threats like deforestation, fragmentation, and climate variability (Ramesh et al., 2017; Krishnan et al., 2020). Integrating updated species assessments into regional conservation frameworks can guide prioritization of habitats for protection and restoration, aligning with ecosystem-based approaches promoted under the UN Decade on Ecosystem Restoration (Aronson et al., 2020). Such integration also reinforces the role of endemic plant conservation in maintaining ecological resilience and supporting faunal diversity in the Western Ghats (Das et al., 2022). Overall, this study highlights the synergistic importance of taxonomy, spatial ecology, and conservation assessment. By coupling field-verified taxonomic clarification with updated IUCN Red List evaluations, it contributes essential evidence for adaptive conservation planning, providing a replicable model for other biodiversity hotspots where data deficiency, outdated taxonomy, and habitat loss continue to constrain conservation prioritization (Bachman et al., 2020).

### 3.5. Summary

This chapter synthesised the findings from a comprehensive analysis of 1,264 collection records and empirical conservation assessments for 25 critically imperiled plant species endemic to chiefly the Southern Western Ghats, thereby establishing a data-driven framework for evidence-based regional conservation policy. The collection history confirmed a crucial, recent shift toward taxon-centric field verification, with the current study contributing 11.2% of all known records. The extreme paucity of records for ultra-endemics such as *Aglaia malabarica* and *Syzygium palghatense* (CR) was demonstrated to reflect intrinsic biological rarity dictated by highly restricted Grinnellian niche factors and low population numbers driven by Eltonian niche dynamics rather than simple under-sampling. The study's most significant contribution is the provision of contemporary phytosociological data for all 25 species, establishing a vital monitoring benchmark. This empirical foundation allowed for a definitive transition in threat classification from broad inferential criteria (B) to demographic (D, C) and decline (A) criteria. This rigorous approach resulted in the assessment of one Critically Endangered (CR), 14 Endangered (EN), eight Vulnerable (VU), and two Near Threatened (NT) taxa, with 15 of these

assessments officially published by the authors in the IUCN Red List. Nine previously Not Evaluated (NE) species received their first formal assessments, closing a critical gap in the global threat database.

The research validates the need to move beyond generic Protected Area management toward proactive, species-specific management plans. The findings define distinct conservation archetypes from mitigating hydrological threats for rheophytic obligates to managing severe reproductive bottlenecks in fragmented populations providing the essential scientific certainty to guide targeted resource prioritization and adaptive conservation strategies for the long-term survival of this unique flora.



# Chapter 4

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Niche Modelling and Prediction of Potential Areas to Elucidate  
Grinnellian Niche and Integration of Eltonian Factors Using Classified  
Vegetation Layers

## **Chapter 4**

# **Niche Modelling and Prediction of Potential Areas to Elucidate Grinnellian Niche and Integration of Eltonian Factors Using Classified Vegetation Layers**

### **4.1. Introduction**

The ecological niche is a fundamental concept for understanding species occurrence in relation to their natural habitat, environment, and other biotic factors. Grinnell (1971) proposed this concept as the ultimate distributional unit of a species, determined primarily by its functional and structural limitations, which are chiefly influenced by physical variables. Consequently, it later became known as the Grinnellian niche, emphasizing environmental factors. According to Gallopin (1998), although Grinnell mentioned relationships with other biotic variables, the clear establishment of biotic factors and species interaction in defining a species' 'niche' is attributed to Elton (1927). The ecological niche encompasses both the physical space (habitat) and the functional role an organism occupies, determined by its relationship with the surrounding abiotic environment and biotic interactions.

Beyond the theoretical understanding of a species' 'niche' through Grinnellian and Eltonian factors, its practical understanding, measurement, or delineation remained largely descriptive rather than empirical. The concept advanced significantly with Hutchinson's (1957) explanation of the ecological niche as a 'hypervolume' delimited by 'n' environmental variables that affect a species, within which the species can persist indefinitely. Hutchinson defined the 'fundamental niche' as the hypervolume composed of environmental variable values suitable for a species' survival, whereas the 'realised niche' is the reduced hypervolume in which the species actually exists. When considering Grinnell's (1971) emphasis on environmental factors and Elton's (1927) focus on species interaction factors, Hutchinson's (1957) explanations encompass both. Thus, the 'fundamental niche' is often considered the 'pre-competitive' or 'virtual' niche, and the 'realised niche' is the 'post-competitive' or 'actual' niche. Generally, the potential or fundamental niche of a species can be measured by habitat suitability based on environmental factors, while the actual niche is limited by species interaction factors within the fundamental hypervolume defined by environmental variables. This forms the



fundamental assumption for this doctoral work regarding the conceptual framework and approaches used to measure a species' niche. Although the concept of a niche generally deals with delineating the spatial boundaries where a species can potentially or actually exist, the inherent complexity of factors governing a species' niche and its dynamic nature offers enormous and kaleidoscopic permutations for species to adapt and evolve. Understanding this through simple methods and approaches is essential for conservation planning and species recovery, especially for threatened species in the current climate change paradigm (Bachan & Devika, 2025). The foundational explanations provided by Grinnell (1971), Elton (1927), and Hutchinson (1957) brought greater clarity to both the theoretical understanding and empirical enumeration of a species' niche. Given its highly complex and overlapping nature, the use of computational techniques and tools for defining niches based on Grinnellian factors, or understanding the 'Fundamental niche' using climatic data, coupled with GIS-based modelling and interpretation, has made it more straightforward and practical. Debate continues regarding the extent to which Species Distribution Modelling (SDM) accurately represents the Grinnellian and Eltonian factors that define a species' niche.

MaxEnt-based modelling has emerged as a superior method for predicting where species might live compared to traditional regression models (Elith et al., 2006; Peterson et al., 2011; Sahana et al., 2022). Because of its effectiveness, it's now widely used to identify potential habitats for various species. This approach is particularly valuable for understanding and predicting species invasion (Thuiller et al., 2005; Jaryan et al., 2013; Changjun et al., 2021; Dorji et al., 2022). While global and Indian studies have utilised niche modelling for habitat prediction (Barber et al., 2012; Jalal & Singh, 2017), there's a noticeable gap in research focusing on endemic and threatened tree species (Irfan-Ullah 2007; Giriraj et al., 2008; Nagaraju et al., 2013; Remya et al., 2015; Baruah et al., 2019; Palkar et al., 2020; Namitha et al., 2022; Malik et al., 2022; Devika & Bachan, 2021; Bachan & Devika, 2022). A common critique of Species Distribution Models (SDMs) is their primary reliance on bioclimatic variables, which mainly describe the Grinnellian niche (the environmental conditions a species can tolerate) (Peterson, 2001; Pearson & Dawson, 2003; Lissovsky & Dudov, 2021). To create more accurate regional SDM predictions, experts recommend including factors beyond climate, such as terrain, altitude, land use, and other local variables (Rotenberry et al., 2006). Incorporating these additional elements, which represent aspects of the Eltonian niche (how a species interacts with its

biotic environment, including other species and resources), significantly improves prediction accuracy. Furthermore, standardizing data sets for specific regional areas, like landscape units and biodiversity hotspots, could greatly enhance conservation efforts for endangered tree species (Rotenberry et al., 2006; Devika & Bachan, 2022).

This chapter addresses these research gaps by investigating the potential habitats of 25 selected angiosperm species in the Western Ghats. We use MaxEnt modelling and adopt a comprehensive approach that integrates both Grinnellian niche factors (represented by bioclimatic layers) and Eltonian niche factors (including elevation, slope, aspect and classified vegetation layers). As a novel contribution, we will overlay these predicted habitat regions with classified vegetation layers (Bachan & Devika, 2022; Devika & Bachan, 2023; Devika & Bachan, 2024; Bachan & Devika, 2025). These vegetation layers are crucial because they directly represent the associated species and community composition of the target threatened tree species, determined through detailed phytosociological sampling in their original habitats. This integration offers a robust and comprehensive representation of the Eltonian niche.

Ultimately, this chapter aims to i. Identify the specific bioclimatic factors that shape each species' niche. ii. Predict each species' distribution under current climatic scenarios, based on bioclimatic parameters, to define their 'Fundamental Niche' (referred to as potential habitat) using species distribution modelling. iii. Refine these predictions by incorporating Eltonian factors, utilizing classified vegetation layers as a potential tool for incorporating species interaction and community composition in spatial predictions. iv. Further refine these predictions to pinpoint ecoregion or landscape level to have a practical understanding of the irreversibly lost potential habitats, potential areas for suitable for conservation, potential areas need ecorestoration efforts to aid effective conservation and species recovery. By integrating both Grinnellian and Eltonian niche factors, this research provides a powerful model and proposes Nature-based Solutions (NbS) for highly specific conservation planning, directly addressing the needs of threatened tree species and ensuring Ecosystem based Adaptation (EbA) their habitats in the context of climate change.

## 4.2. Methodology

### 4.2.1. Species Occurrence Data Collection

Species occurrence data for selected threatened angiosperms were compiled from both primary field surveys and secondary data sources, a standard approach in ecological niche modelling to ensure comprehensive geographic coverage (Peterson et al., 2011). Field surveys were conducted in all the important forest landscapes of the Western Ghats, concurrent with the historical collection records of the selected 25 species. A GPS (Garmin) device was used to capture precise geocoordinates of individual or population-level occurrences (Bachan & Devika, 2022; Devika & Bachan, 2023; Devika & Bachan, 2024). The data pertaining to species occurrences is critical in Ecological Niche Modelling (ENM), which relies, either directly or indirectly, on the precision and resilience of the underlying model (Hijmans & Graham, 2006; Varela et al., 2014).

The species occurrence geographical data were collected through herbarium specimen records, research articles and digital resources such as E-flora Kerala, India Biodiversity Portal (<https://indiabiodiversity.org/>). The use of such biodiversity databases and digitised herbarium collections is a common practice for augmenting species data for modelling purposes (Graham et al., 2004; Meyer & Kreft, 2017). In instances where occurrence data were not accessible, Google Earth Pro were used to obtain the corresponding latitude and longitude coordinates based on locality descriptions (Xu et al., 2021; Mathur et al., 2023). To ensure the integrity of potential habitat predictions, the authenticity of each occurrence record was deemed critical. Records were meticulously scrutinised for accuracy against original floristic literature, herbarium vouchers, and extensive field data. When utilizing data from online databases (such as GBIF and the India Biodiversity Portal), only those records validated by the original authors, or substantiated with herbarium records, voucher specimens, photographic evidence, or peer-reviewed documentation, were included; all erroneous entries were removed (Table 4.1). Subsequently, these coordinates were transformed into decimal degrees to facilitate their application in modelling. The finalised occurrence records were compiled in Microsoft Excel into a CSV database (.csv) and were carefully filtered to enhance data quality (Loiselle et al., 2008).

#### 4.2.2. Bioclimatic Variables

The 19 bioclimatic variables for current (Hijmans et al., 2005; Frick & Hijmans, 2017) climatic scenarios 1970-2000 were sourced from WorldClim version 2.1 (<http://www.worldclim.org>) with 2.5 m spatial resolution (Soberón, & Peterson, 2005; Guisan et al., 2007; Peterson et al., 2011) (Table 4.2). The variables were clipped to the extent of the Western Ghats of the Western Ghats – Sri Lanka biodiversity hotspot using QGIS (Version 3.38). Raster stack creation and projection alignment were performed to ensure uniformity across predictor layers. Later each layer was saved in ASCII file format.

**Table 4.1. Status of occurrence points sourced from GBIF & online sources for each species after scrutiny**

| SL. No. | Species Name                   | No. of occurrence points used from GBIF after scrutiny | Total occurrence points developed for the species |
|---------|--------------------------------|--------------------------------------------------------|---------------------------------------------------|
| 1       | <i>Aglaia malabarica</i>       | 0                                                      | 10                                                |
| 2       | <i>Aporosa bourdillonii</i>    | 4                                                      | 25                                                |
| 3       | <i>Cryptocarya anamalayana</i> | 0                                                      | 13                                                |
| 4       | <i>Cryptocarya lawsonii</i>    | 9                                                      | 42                                                |
| 5       | <i>Diospyros crumenata</i>     | 7                                                      | 28                                                |
| 6       | <i>Dipterocarpus indicus</i>   | 39                                                     | 90                                                |
| 7       | <i>Elaeocarpus munroi</i>      | 20                                                     | 128                                               |
| 8       | <i>Elaeocarpus recurvatus</i>  | 6                                                      | 50                                                |
| 9       | <i>Ficus beddomei</i>          | 5                                                      | 61                                                |
| 10      | <i>Garcinia wightii</i>        | 0                                                      | 23                                                |
| 11      | <i>Goniothalamus wightii</i>   | 1                                                      | 61                                                |
| 12      | <i>Humboldtia vahliana</i>     | 20                                                     | 85                                                |
| 13      | <i>Hydnocarpus pentandrus</i>  | 47                                                     | 91                                                |
| 14      | <i>Impatiens parasitica</i>    | 8                                                      | 46                                                |
| 15      | <i>Litsea oleoides</i>         | 0                                                      | 41                                                |
| 16      | <i>Medinilla anamalaiana</i>   | 2                                                      | 13                                                |

|    |                                |    |     |
|----|--------------------------------|----|-----|
| 17 | <i>Meiogyne pannosa</i>        | 43 | 90  |
| 18 | <i>Ochna gamblei</i>           | 4  | 15  |
| 19 | <i>Prioria pinnata</i>         | 24 | 66  |
| 20 | <i>Strobilanthes kunthiana</i> | 34 | 106 |
| 21 | <i>Syzygium densiflorum</i>    | 36 | 82  |
| 22 | <i>Syzygium occidentale</i>    | 3  | 35  |
| 23 | <i>Syzygium palghatense</i>    | 0  | 11  |
| 24 | <i>Syzygium parameswaranii</i> | 0  | 33  |
| 25 | <i>Syzygium sahyadricum</i>    | 0  | 19  |

**Table 4.2. Bioclimatic variables used for modelling the potential suitable habitat of selected angiosperms**

| Code  | Variables                                                  | Units |
|-------|------------------------------------------------------------|-------|
| BIO1  | Annual Mean Temperature                                    | °C    |
| BIO2  | Mean Diurnal Range (Mean of monthly (max temp - min temp)) | °C    |
| BIO3  | Isothermality (BIO2/BIO7) (×100)                           | /     |
| BIO4  | Temperature Seasonality (standard deviation ×100)          | /     |
| BIO5  | Max Temperature of Warmest Month                           | °C    |
| BIO6  | Min Temperature of Coldest Month                           | °C    |
| BIO7  | Temperature Annual Range (BIO5-BIO6)                       | °C    |
| BIO8  | Mean Temperature of Wettest Quarter                        | °C    |
| BIO9  | Mean Temperature of Driest Quarter                         | °C    |
| BIO10 | Mean Temperature of Warmest Quarter                        | °C    |
| BIO11 | Mean Temperature of Coldest Quarter                        | °C    |
| BIO12 | Annual Precipitation                                       | mm    |
| BIO13 | Precipitation of Wettest Month                             | mm    |
| BIO14 | Precipitation of Driest Month                              | mm    |

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|        |                                                      |    |
|--------|------------------------------------------------------|----|
| BIO15  | Precipitation Seasonality (Coefficient of Variation) | /  |
| BIO16  | Precipitation of Wettest Quarter                     | mm |
| BIO17  | Precipitation of Driest Quarter                      | mm |
| BIO 18 | Precipitation of Warmest quarter                     | mm |
| BIO 19 | Precipitation of Coldest quarter                     | mm |

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#### 4.2.3. Addressing Multicollinearity

The processed bioclimatic layers were then analysed to address the issue of multicollinearity, which can lead to unstable model parameters, inflate variance, and complicate the interpretation of variable importance in species distribution models (Dormann et al., 2013). This analysis was conducted using the R statistical software (Version 4.4.1) (R Core Team, 2024). This approach effectively addressed the issue of multicollinearity by eliminating bioclimatic variables exhibiting strong correlations (Pearson's correlation coefficient  $r^2 > 0.75$ ). In order to enhance predictive efficiency, we opted to retain one of the two variables characterised by high correlation, prioritizing the one with greater biological relevance or interpretability to the study species (Kumar & Stohlgren 2009; Peterson et al., 2011; Ma & Sun 2018). The correlation analysis helped us identify which bioclimatic variables were significantly correlated (Fig. 4.1). After removing one among the two highly correlated variables, we were left with two distinct combinations, each containing eleven bioclimatic layers. This process was crucial to avoid multicollinearity, an issue that can skew model results (Ma & Sun, 2018; Kumar & Stohlgren, 2009; Devika & Bachan, 2025). Consequently, the 25 selected species were grouped into these two combinations for habitat prediction (Table 4.3).

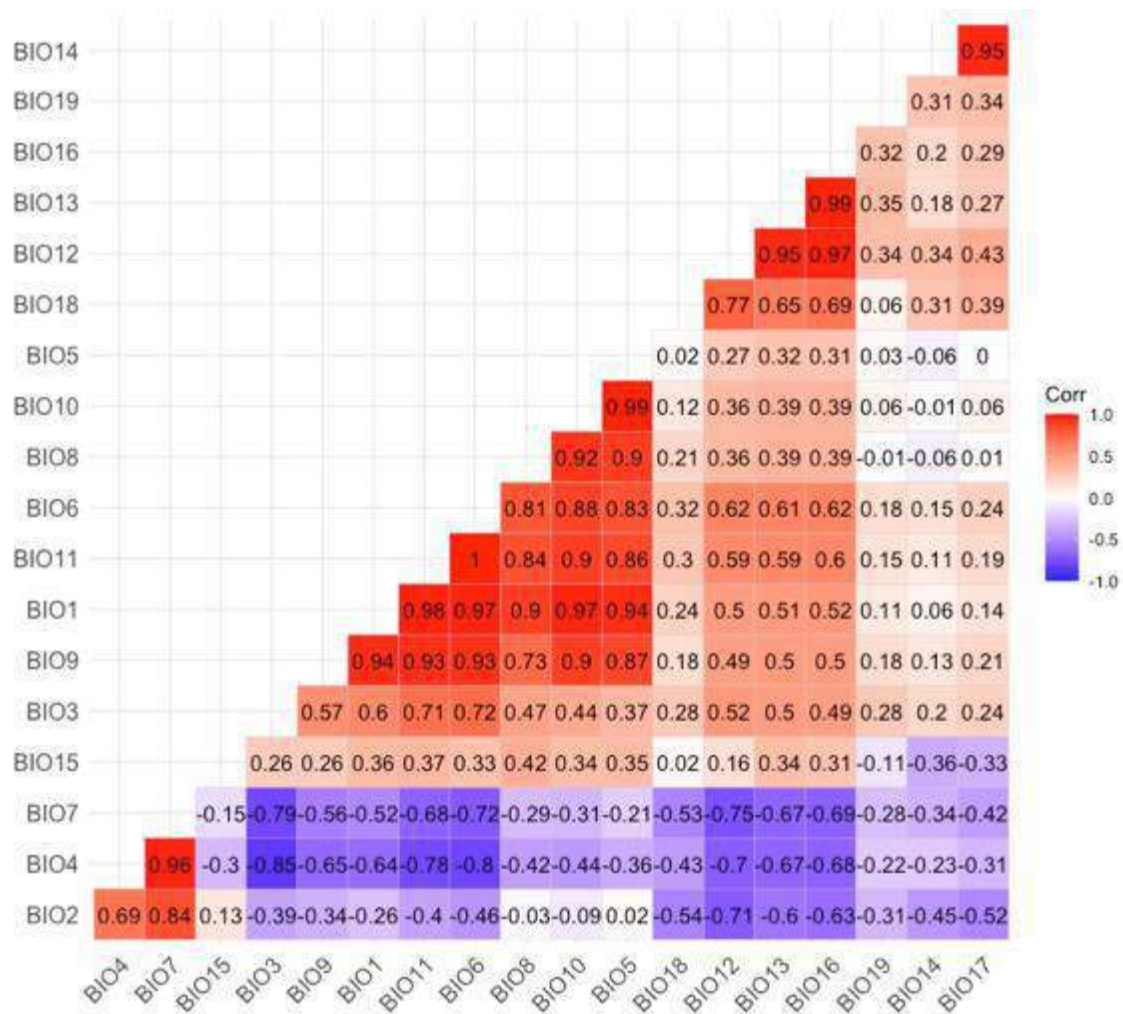


**Fig. 4.1. Correlations between different bioclimatic variables used for Ecological Niche Modelling**

**Table 4.3. MaxEnt settings and bioclimatic layers used for each species after addressing multicollinearity**

| Sl. No                                                                                                                                                                          | Species Name                | No. of Occurrence records used | Replication method | Background Points used |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|--------------------------------|--------------------|------------------------|
| <i>Bioclimatic Variables used for species after removing highly correlated variables. Combination 1- BIO2, BIO3, BIO4, BIO8, BIO9, BIO10, BIO13, BIO14, BIO15, BIO18, BIO19</i> |                             |                                |                    |                        |
| 1                                                                                                                                                                               | <i>Aporosa bourdillonii</i> | 25                             | Cross validation   | 5000                   |



|                                                                                                                                                                                  |                                |     |                  |        |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|-----|------------------|--------|
| 2                                                                                                                                                                                | <i>Cryptocarya anamalayana</i> | 13  | Cross validation | 5000   |
| 3                                                                                                                                                                                | <i>Cryptocarya lawsonii</i>    | 44  | Bootstrap        | 10,000 |
| 4                                                                                                                                                                                | <i>Dipterocarpus indicus</i>   | 90  | Bootstrap        | 10,000 |
| 5                                                                                                                                                                                | <i>Ficus beddomei</i>          | 61  | Bootstrap        | 10,000 |
| 6                                                                                                                                                                                | <i>Garcinia wightii</i>        | 23  | Cross validation | 5000   |
| 7                                                                                                                                                                                | <i>Humboldtia vahliana</i>     | 86  | Bootstrap        | 10,000 |
| 8                                                                                                                                                                                | <i>Hydnocarpus pentandrus</i>  | 91  | Bootstrap        | 10,000 |
| 9                                                                                                                                                                                | <i>Litsea oleoides</i>         | 41  | Bootstrap        | 10,000 |
| 10                                                                                                                                                                               | <i>Meiogyne pannosa</i>        | 90  | Bootstrap        | 10,000 |
| 11                                                                                                                                                                               | <i>Ochna gamblei</i>           | 15  | Cross validation | 5000   |
| 12                                                                                                                                                                               | <i>Prioria pinnata</i>         | 66  | Bootstrap        | 10,000 |
| 13                                                                                                                                                                               | <i>Syzygium occidentale</i>    | 35  | Bootstrap        | 10,000 |
| <i>Bioclimatic Variables used for species after removing highly correlated variables. Combination 2 - BIO2, BIO3, BIO4, BIO8, BIO9, BIO10, BIO13, BIO14, BIO15, BIO18, BIO19</i> |                                |     |                  |        |
| 14                                                                                                                                                                               | <i>Aglaia malabarica</i>       | 10  | Cross validation | 5000   |
| 15                                                                                                                                                                               | <i>Diospyros crumenata</i>     | 28  | Bootstrap        | 5000   |
| 16                                                                                                                                                                               | <i>Elaeocarpus munroi</i>      | 128 | Bootstrap        | 10,000 |
| 17                                                                                                                                                                               | <i>Elaeocarpus recurvatus</i>  | 50  | Bootstrap        | 10,000 |
| 18                                                                                                                                                                               | <i>Goniothalamus wightii</i>   | 61  | Bootstrap        | 10,000 |
| 19                                                                                                                                                                               | <i>Impatiens parasitica</i>    | 46  | Bootstrap        | 10,000 |
| 20                                                                                                                                                                               | <i>Medinilla anamalaiana</i>   | 13  | Cross validation | 5000   |
| 21                                                                                                                                                                               | <i>Strobilanthes kunthiana</i> | 106 | Bootstrap        | 10,000 |
| 22                                                                                                                                                                               | <i>Syzygium densiflorum</i>    | 82  | Bootstrap        | 10,000 |
| 23                                                                                                                                                                               | <i>Syzygium palghatense</i>    | 11  | Cross validation | 5000   |
| 24                                                                                                                                                                               | <i>Syzygium parameswaranii</i> | 33  | Bootstrap        | 10,000 |
| 25                                                                                                                                                                               | <i>Syzygium sahyadricum</i>    | 19  | Cross validation | 5000   |

#### **4.2.4. Non-bioclimate Variables**

A number of non-bioclimate variables have been considered to accommodate the characteristics of the tropical monsoonal rainforest regime, such as elevation, slope, and aspect (Tesfamariam et al., 2022; Gebrewahid et al., 2024). The elevation data used here were obtained from WorldClim, which is derived from Shuttle Radar Topography Mission (SRTM) elevation data with 2.5 m spatial resolution (<https://www.worldclim.org/data/worldclim21.html>). In addition to this, non-bioclimate variables such as slope and aspect (2.5 m) were also used (Jarvis et al., 2008) (<https://srtm.csi.cgiar.org>).

#### **4.2.5. Ecological Niche Modelling**

The Maximum Entropy (MaxEnt) model (Version 3.4.4) was employed for the purposes of ecological niche modelling (Phillips et al., 2006). MaxEnt represents a sophisticated machine-learning algorithm that employs a maximum entropy methodology to forecast the most probable distribution of a species based on its known occurrence records and a set of environmental variables. This algorithm operates by estimating the most uniform probability distribution throughout the study area, which is constrained by the environmental parameters at the species' occurrence sites (Phillips et al., 2006). This presence-only algorithm is extensively regarded as one of the most precise and robust method for modelling species distribution, particularly for taxa that are threatened, where the procurement of reliable absence data is often challenging or unattainable (Phillips & Dudík, 2008; Elith et al., 2011). Its principal advantages encompass its exceptional predictive efficacy, its capacity to model intricate non-linear responses of species to environmental variables, and its efficiency even in scenarios involving limited sample sizes (Merow et al., 2013; Elith et al., 2011).

In light of these advantages, MaxEnt has been effectively and extensively employed by researchers worldwide to delineate the spatial extent of potential habitats for a diverse array of taxa. This includes predicting the distribution of invasive species (Gong et al., 2020; Changjun et al., 2021), threatened flora (Giriraj et al., 2008; Nagaraju et al., 2013; Yang et al., 2013; Remya et al., 2015; Priti et al., 2016; Mirhashemi, 2023; Konwar et al., 2023), and various fauna (Kalle et al., 2013; Sony et al., 2018; Srinivasulu et al., 2021; Jianhui et al., 2023; Yibin, 2023). Within the context of the Western Ghats, this approach has been instrumental in predicting the spatial extent of potential habitat with bioclimate suitability

for present climatic scenarios, as demonstrated by studies on both flora and fauna in the region (Hosseini et al., 2024; Athamanakath et al., 2024; Kishore et al., 2024).

#### **4.2.6. Model Calibration & Evaluation**

The modelling settings and procedures were used based on the number of occurrence points available for each selected species. Depending on the sample size, either cross-validation or bootstrap replication methods were employed appropriately for each species (Table 4.3). The number of background points was chosen based on the number of occurrence records per species (Phillips et al., 2006). For species with 10-30 occurrence records, 5,000-10,000 background points were used to balance environmental space coverage and computational efficiency, while for species with more than 30 but fewer than 100 records, 10,000 to 20,000 background points were selected to better capture ecological variation, particularly in higher-resolution datasets or larger spatial extents (Merow et al., 2013; Guisan et al., 2017). The model was replicated 10 times with maximum number of iterations were 500, convergence threshold 0.00001 with an applied threshold level of 1 (Phillips et al., 2006; Singh et al., 2021). The output data format was in cloglog; hence, it gives a probability presence value between 0 and 1. The details of the bioclimatic layers selected, number of occurrence records used, replication method and background points used were provided in the table (4.3).

The non-bioclimatic variables like elevation, slope, and aspect to account for the unique characteristics of the tropical monsoonal mountain rainforest regime were also used. We evaluated the model's effectiveness using the Area Under the Curve (AUC). Models with an AUC greater than 0.75 are generally considered to have potential utility (Elith 2002). According to Swets (1988) interpretative scale of AUC value shows AUC 0.90–1.00 (Excellent), AUC 0.80–0.90 (Very Good), AUC 0.70–0.80 (Good), AUC 0.60–0.70 (Fair), AUC 0.50–0.60 (Poor). Thuiller et al. (2005) further categorised model performance based on AUC values: random ( $AUC < 0.8$ ), fair ( $0.8 \leq AUC < 0.9$ ), good ( $0.9 \leq AUC < 0.95$ ), and very good ( $0.95 \leq AUC < 1.0$ ). To determine the relative importance of each variable, we calculated it using the Jackknife test for AUC. The results showed that 24 of our species models achieved an AUC greater than 0.9 (categorised as "Excellent"), and one species model had an AUC between 0.8 and 0.9 (categorised as "Very Good"). Therefore, all the models were deemed a good fit and possess potential utility (Benham et al., 2011; Adhikari et al., 2012; Bachan & Devika, 2022; Devika & Bachan, 2023, 2024).

#### 4.2.7. Overlaying with Classified Vegetation Layer: Eltonian Niche Factors

The MaxEnt output provides potential habitat areas for species based on bioclimatic suitability. These areas represent the 'fundamental niche' as defined by Hutchinson (1957), primarily determined by environmental parameters or, in this context, Grinnellian niche factors. However, these predicted zones can include non-forested areas, irreversibly converted forest regions, degraded forest areas, or even areas with different potential or primary vegetation types. To address this, we can refine these predicted potential areas into actual potential zones by utilizing classified vegetation layers that contain known species composition and land use data. This approach allows us to incorporate Eltonian niche factors (species interaction factors) and, in doing so, transform the fundamental niche of a species into a more accurate 'realised niche' (Bachan & Devika, 2022, 2025; Devika & Bachan, 2024, 2025).

**Table 4.4. Classified vegetation layers used for delineation of conservation and restoration area**

| SL. No. | Output                                | Layers Used                      |
|---------|---------------------------------------|----------------------------------|
| 1       | Conservation Area (Forest Species)    | Dry Evergreen                    |
|         |                                       | Montane Forest                   |
|         |                                       | Primary Moist Deciduous          |
|         |                                       | Primary Wet Evergreen            |
|         |                                       | Secondary Wet Evergreen          |
| 2       | Conservation Area (Grassland Species) | Montane Grassland                |
| 3       | Restoration Area                      | Secondary Moist Deciduous        |
|         |                                       | Degraded Potential Wet Evergreen |
| 4       | Completely Lost Habitat               | Forest Plantations               |
|         |                                       | Commercial Plantation            |
|         |                                       | Waterbody                        |
|         |                                       | Non forest and Agriculture areas |

The QGIS (Version 3.18) platform were used to processes the MaxEnt output superimposed with classified vegetation layer (Renard et al., 2010) (<https://indiabiodiversity.org/map>). The classified vegetation layer was used to finetune the predicted area into conservation areas, restoration areas and converted habitats (Table 4.4). We consider the areas of forest cleared for agricultural and industrial crops, infrastructure construction, dam and reservoir construction, and urban residential areas as irreversibly lost habitats for the species. The partially degraded forests were considered restoration sites and comparatively undisturbed forests as potential conservation areas for the species. All these were brought under landscape and ecoregion level (Singh, 1977).

#### **4.2.8. Statistical Analysis**

To identify statistically significant variables influencing the 25 target species, Principal Component Analysis (PCA) was performed in R (Breiman et al., 1984; Das, 2015). The analysis revealed six variables that were significant for explaining species distribution. The percentage contribution of each variable to the second principal component was plotted, including the significance threshold, and the overall contributions were visualised in a radial PCA plot (Suwal et al., 2018; Senay et al., 2019).

To test the hypothesis that the 25 species, belonging to four distinct vegetation subgroups, are defined by specific bioclimatic parameters, a Multivariate Analysis of Variance (MANOVA) was conducted in R (Vernes et al., 2016). Subsequently, univariate ANOVAs were applied to calculate the p-values for each variable across species (Abapihi et al., 2021). To evaluate the conservation importance of different ecoregions, PCA was further used to relate the number of species, species representation, and the extent of suitable habitats. Metrics included (i) the area of intact primary forest (for conservation), (ii) the extent of degraded forest suitable for ecological restoration, and (iii) the area of irreversible habitat loss. The first and second principal components identified the most significant ecoregions, which were visualised in a PCA biplot (Kim et al., 2025).

### 4.3. Results

This section presents the results of ecological niche modelling conducted for 25 threatened angiosperm species endemic to the Western Ghats, using the MaxEnt algorithm under current climatic conditions. Model performance was evaluated based on the Area Under the Curve (AUC), providing insights into the discriminatory power and predictive accuracy of each model. The contribution of environmental variables to habitat suitability was assessed through the Jackknife test of training gain, allowing the identification of key bioclimatic and topographic predictors shaping each species' Grinnellian niche (Appendix II). For each species, spatial predictions of suitable habitats were generated and visualised as habitat suitability maps. The MaxEnt model outputs are represented as a color gradient, where red indicates maximum habitat suitability and blue represents the least suitable or unsuitable habitats, with intermediate shades reflecting varying degrees of ecological suitability. The patterns of ecological specialization, range restriction, and ecoregion level habitat preferences were interpreted here with conservation relevance.

#### 4.3.1. Grinnellian Niche of *Aglaia malabarica* Using Bioclimatic Factors

The MaxEnt model for *Aglaia malabarica*, under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.990 (Fig. 4.2). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *A. malabarica* (Fig. 4.3). Among the 13 bioclimatic variables assessed Temperature Seasonality SD (53.7%), and Precipitation of Coldest Quarter (25%) contributed most to the model. This is followed by Mean Diurnal Range (8.2%) Precipitation of Warmest Quarter (3.4%), Isothermality (2.1%) (Appendix II). The Slope also emerged as an important non-bioclimatic variable, contributing 6.7% to model gain, indicating that topographic constraints partly define the niche of this species.

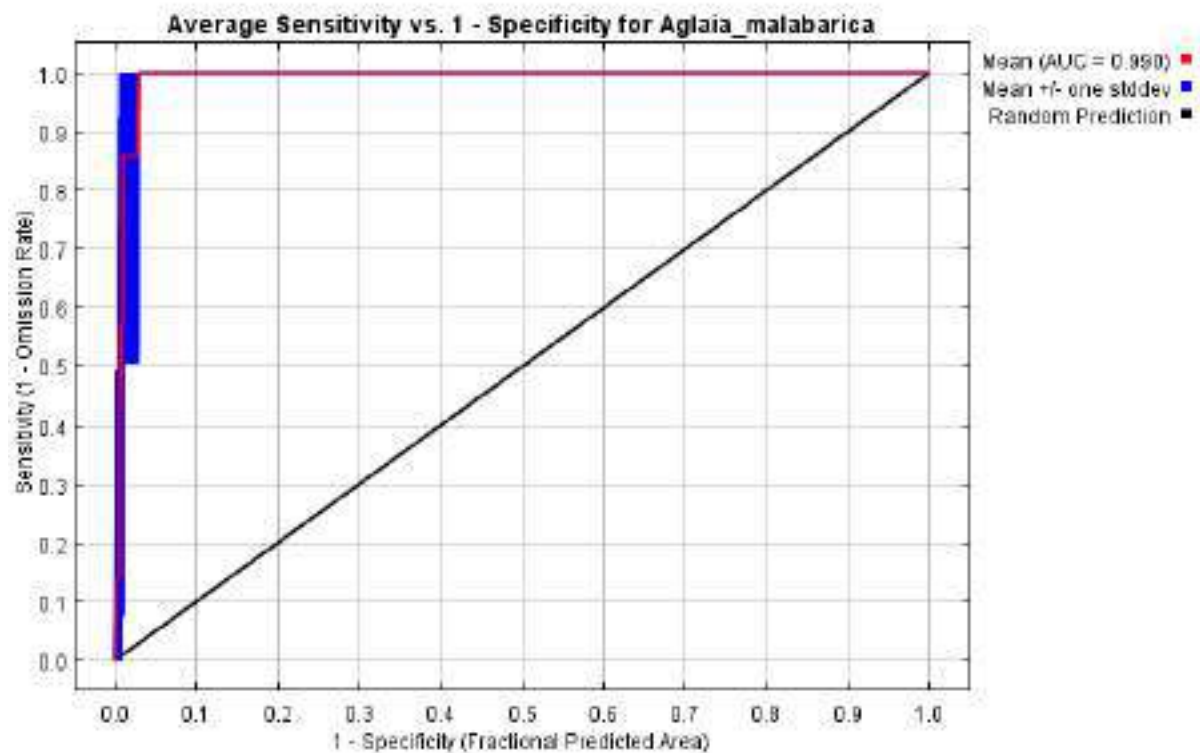


Fig. 4.2. Area Under Curve indicating model performance of *Aglaia malabarica*

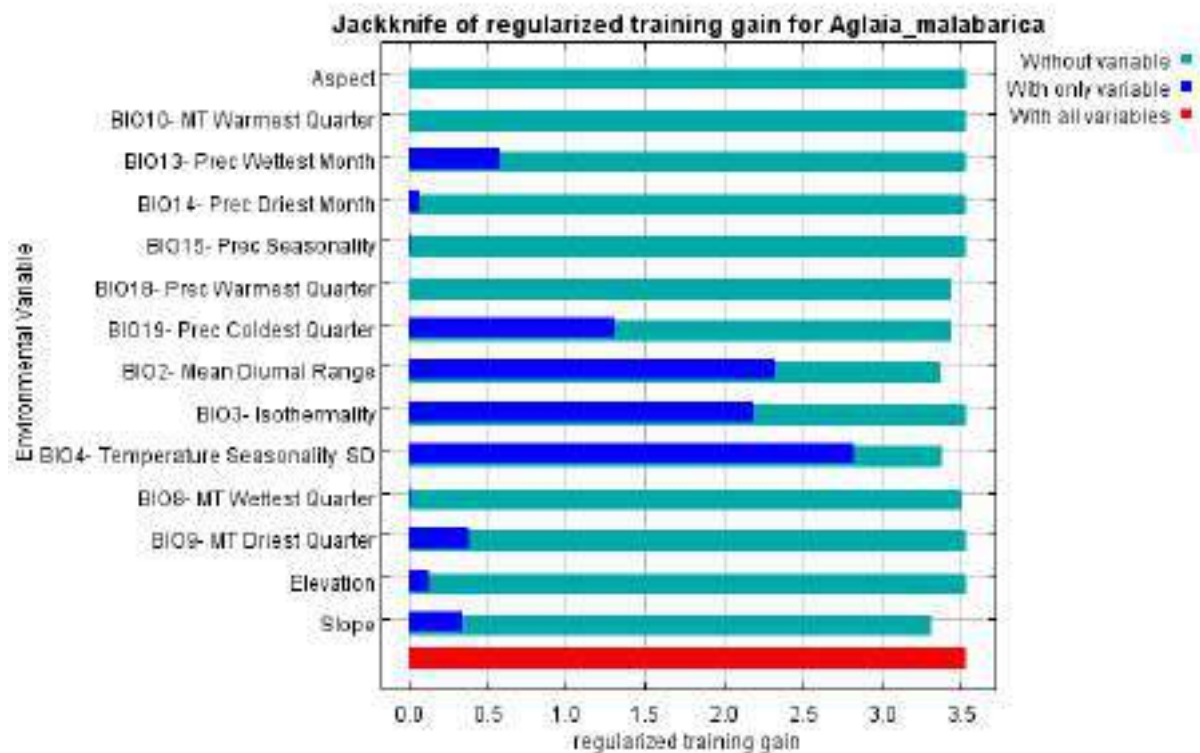


Fig. 4.3. Jackknife test of training gain showing bioclimatic variables of importance



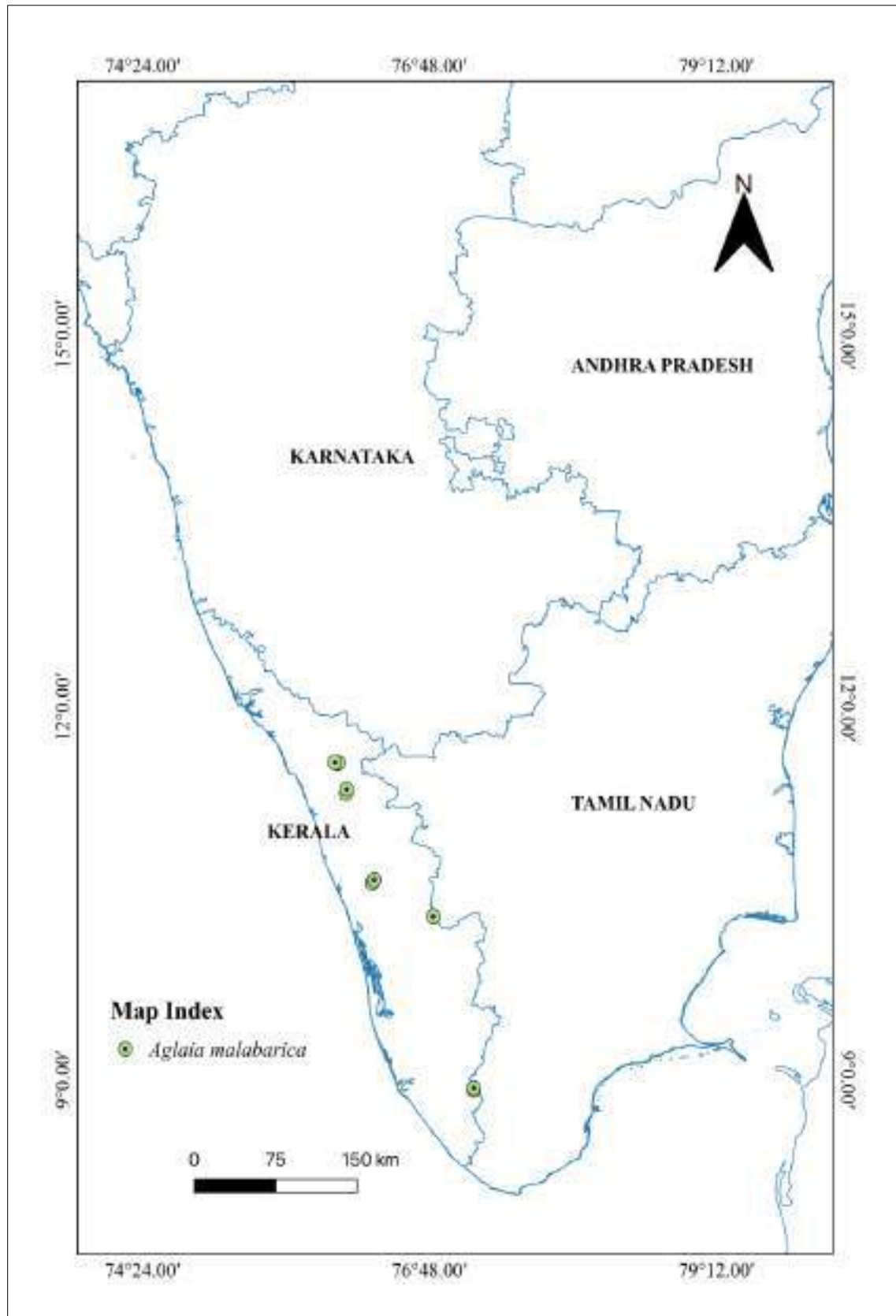


**Fig. 4.4.** Actual distribution of *Aglaia malabarica*

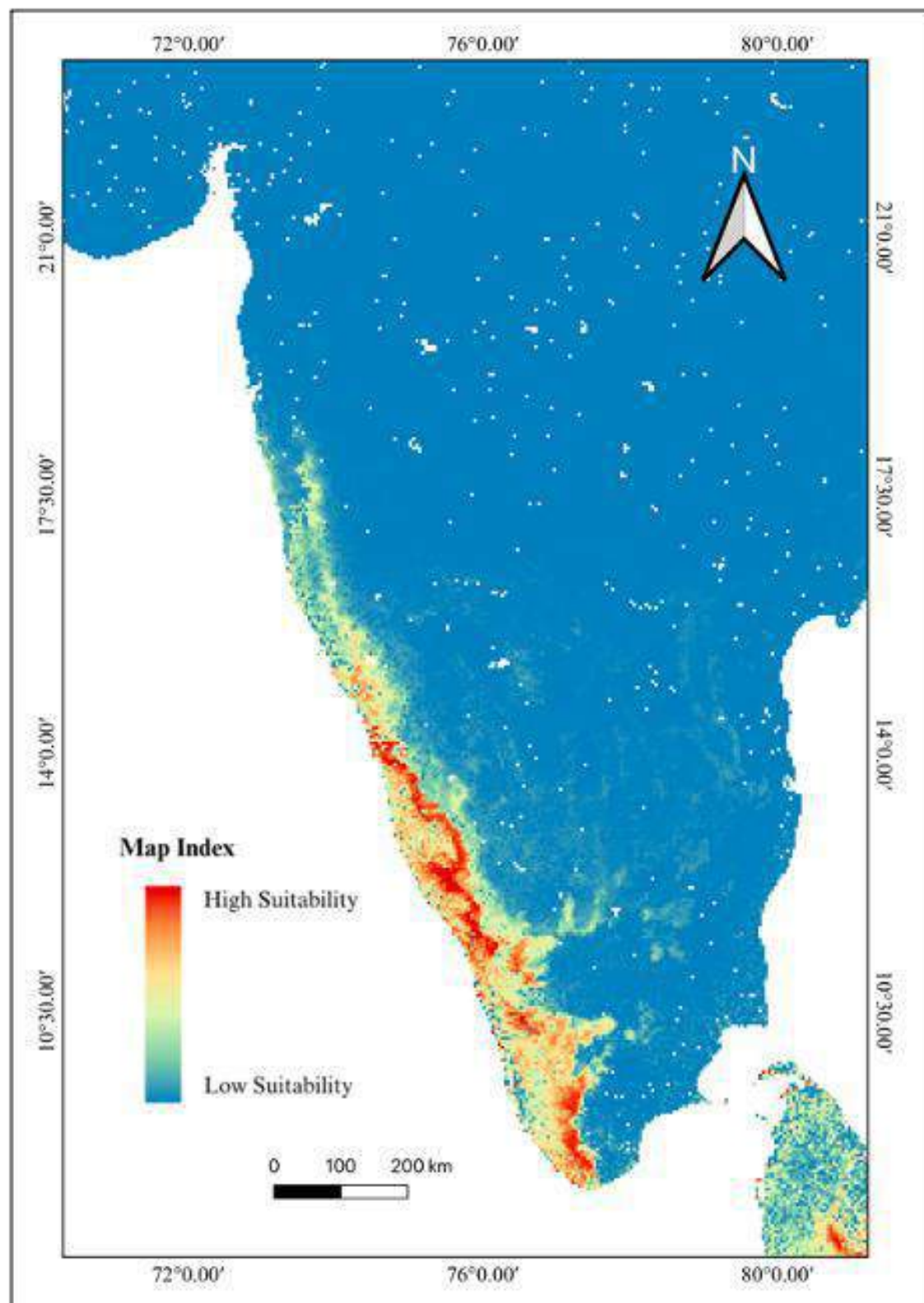


**Fig. 4.5. Predicted habitat suitability of *Aglaia malabarica* using MaxEnt model under present climate scenario**

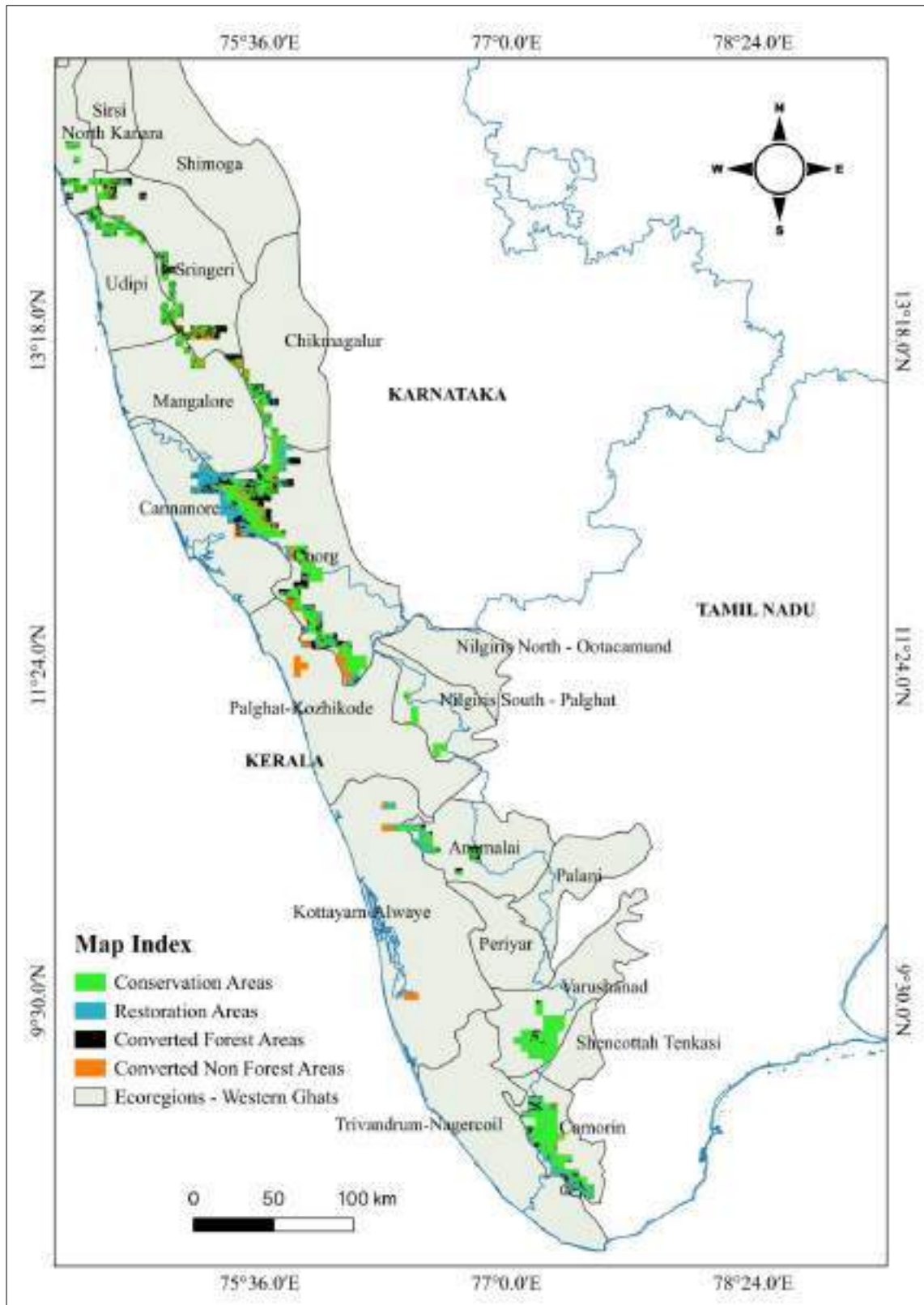


**Fig. 4.6. Refined predicted area of *Aglaia malabarica* into potential conservation, restoration and irreversibly lost habitats at ecoregion level**

### Eltonian Niche of *Aglaia malabarica* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *A. malabarica* is currently restricted to five sub populations within the Western Ghats, endemic to Kerala (Fig. 4.4). Under the current climate scenario, the MaxEnt model predicts a total of 7133.10 km<sup>2</sup> of highly suitable habitat for *A. malabarica* in the Western Ghats. This predicted distribution spans over 13 distinct ecoregions (Fig. 4.5). The highest suitability predictions were concentrated in the Coorg (2390.99 km<sup>2</sup>), Comorin (1028.51 km<sup>2</sup>), Sringeri (644.18 km<sup>2</sup>), Cannanore (602.73 km<sup>2</sup>) and Varushanad (595.1 km<sup>2</sup>) ecoregions (Table 4.5).

**Table 4.5. Ecoregion wise habitat prediction for *Aglaia malabarica* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No. | Ecoregion                 | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|---------|---------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1       | Anamalai                  | 295.05                            | 145.28                               | 96.96                               | 43.49                                    | 9.32                                         |
| 2       | Cannanore                 | 602.73                            | 69.26                                | 404.54                              | 97.82                                    | 31.12                                        |
| 3       | Chikmagalur               | 327.33                            | 191.69                               | 45.80                               | 67.78                                    | 22.07                                        |
| 4       | Comorin                   | 1028.51                           | 669.03                               | 240.92                              | 86.30                                    | 32.26                                        |
| 5       | Coorg                     | 2390.99                           | 1350.43                              | 326.66                              | 412.17                                   | 301.73                                       |
| 6       | Kottayam-<br>Alwaye       | 147.61                            | 27.65                                | 36.83                               | 0.88                                     | 82.25                                        |
| 7       | Mangalore                 | 123.36                            | 81.03                                | 8.02                                | 11.93                                    | 22.38                                        |
| 8       | Nilgiris<br>South-Palghat | 147.20                            | 122.14                               | 7.98                                | 0.97                                     | 16.11                                        |
| 9       | North Kanara              | 195.10                            | 140.83                               | 13.20                               | 41.07                                    | 0.00                                         |
| 10      | Palghat-<br>Kozhikode     | 92.15                             | 0.00                                 | 6.14                                | 0.28                                     | 85.73                                        |
| 11      | Sringeri                  | 644.18                            | 279.03                               | 46.83                               | 240.57                                   | 77.74                                        |

|              |            |                |                |                |                |               |
|--------------|------------|----------------|----------------|----------------|----------------|---------------|
| 12           | Udipi      | 543.79         | 357.93         | 56.95          | 113.58         | 15.32         |
| 13           | Varushanad | 595.10         | 547.00         | 27.11          | 20.90          | 0.09          |
| <b>Total</b> |            | <b>7133.10</b> | <b>3981.31</b> | <b>1317.92</b> | <b>1137.75</b> | <b>696.12</b> |

The initial modelling of the potential distribution for *A. malabarica*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 7133.10 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.6). A total of Conservation area spanning 3981.31 km<sup>2</sup>, Potential Ecorestoration area of 1317.92 km<sup>2</sup>, irreversibly converted forest habitat 1137.75 km<sup>2</sup> and converted non-forested human-dominated areas 696.12 km<sup>2</sup> were enumerated for the species. The ecoregions such as Coorg (1350.42 km<sup>2</sup>), Comorin (669.03 km<sup>2</sup>) and Varushanad (547 km<sup>2</sup>), Udipi (357.92 km<sup>2</sup>) represent maximum potential conservation areas suitable for *A. malabarica*. The degraded habitats are also represented by ecoregions such as Cannanore (404.53 km<sup>2</sup>), Coorg (326.66 km<sup>2</sup>), Comorin (240.91 km<sup>2</sup>) and Anamalai (96.96 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 16 % of converted forest habitat to the species are represented with Coorg (412.16 km<sup>2</sup>), Sringeri (240.57 km<sup>2</sup>), Udipi (113.58 km<sup>2</sup>), Cannanore (97.82 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific, ecosystem-based conservation strategies and ecosystem restoration interventions tailored to *A. malabarica*'s ecological niche.

#### 4.3.2. Grinnellian Niche of *Aporosa bourdillonii* Using Bioclimatic Factors

The MaxEnt model for *Aporosa bourdillonii*, under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.997 (Fig. 4.7). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *A. bourdillonii* (Fig. 4.8). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (33.1%) and Precipitation of Coldest Quarter (19.1%) contributed most to the model. This is followed by Isothermality (17.7%), Precipitation of Driest Quarter (6.7%), Precipitation of Wettest Quarter (4.6%) and Mean Diurnal Range (4.3%) (Appendix II). The Slope also emerged as an important non-bioclimatic variable, contributing 14.1% to model gain, indicating that topographic constraints partly define the niche of this species.

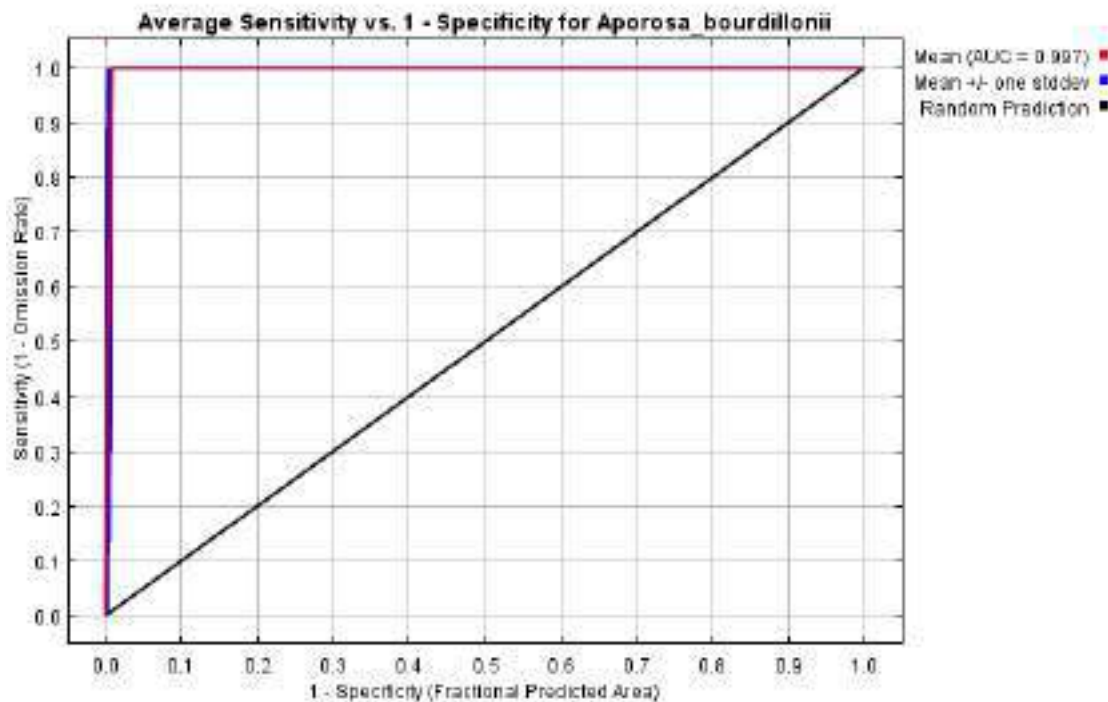


**Fig. 4.7.** Area Under Curve indicating model performance of *Aporosa bourdillonii*

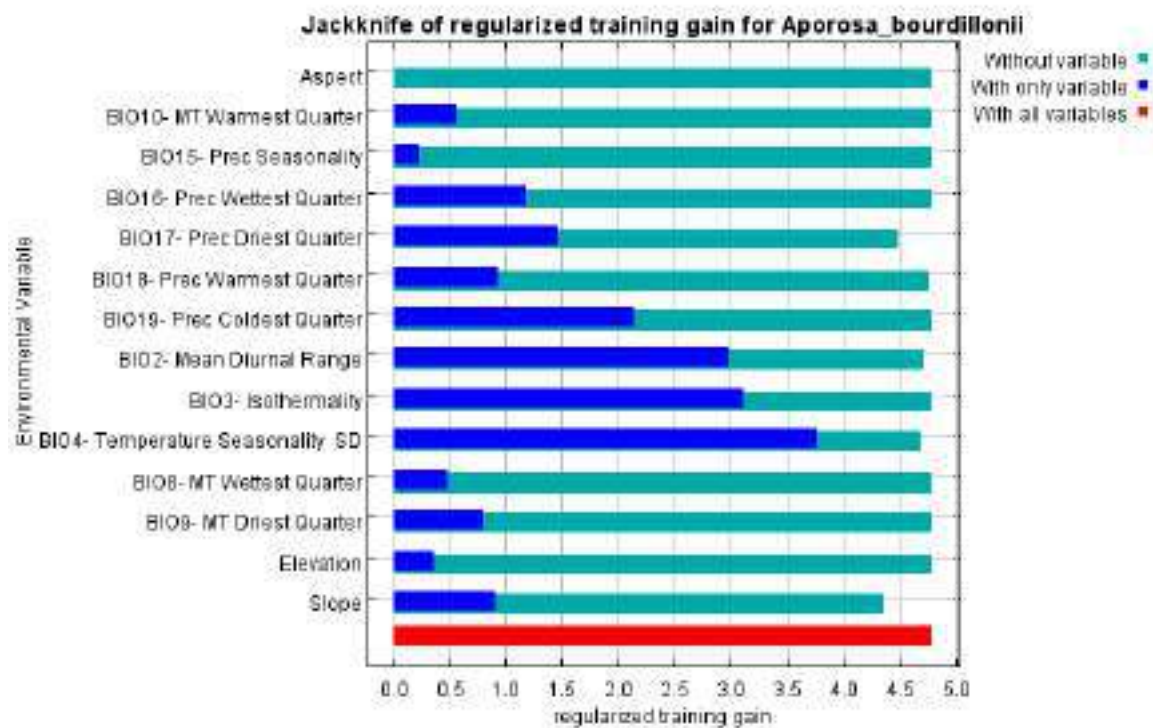


Fig. 4.8. Jackknife test of training gain showing bioclimatic variables of importance



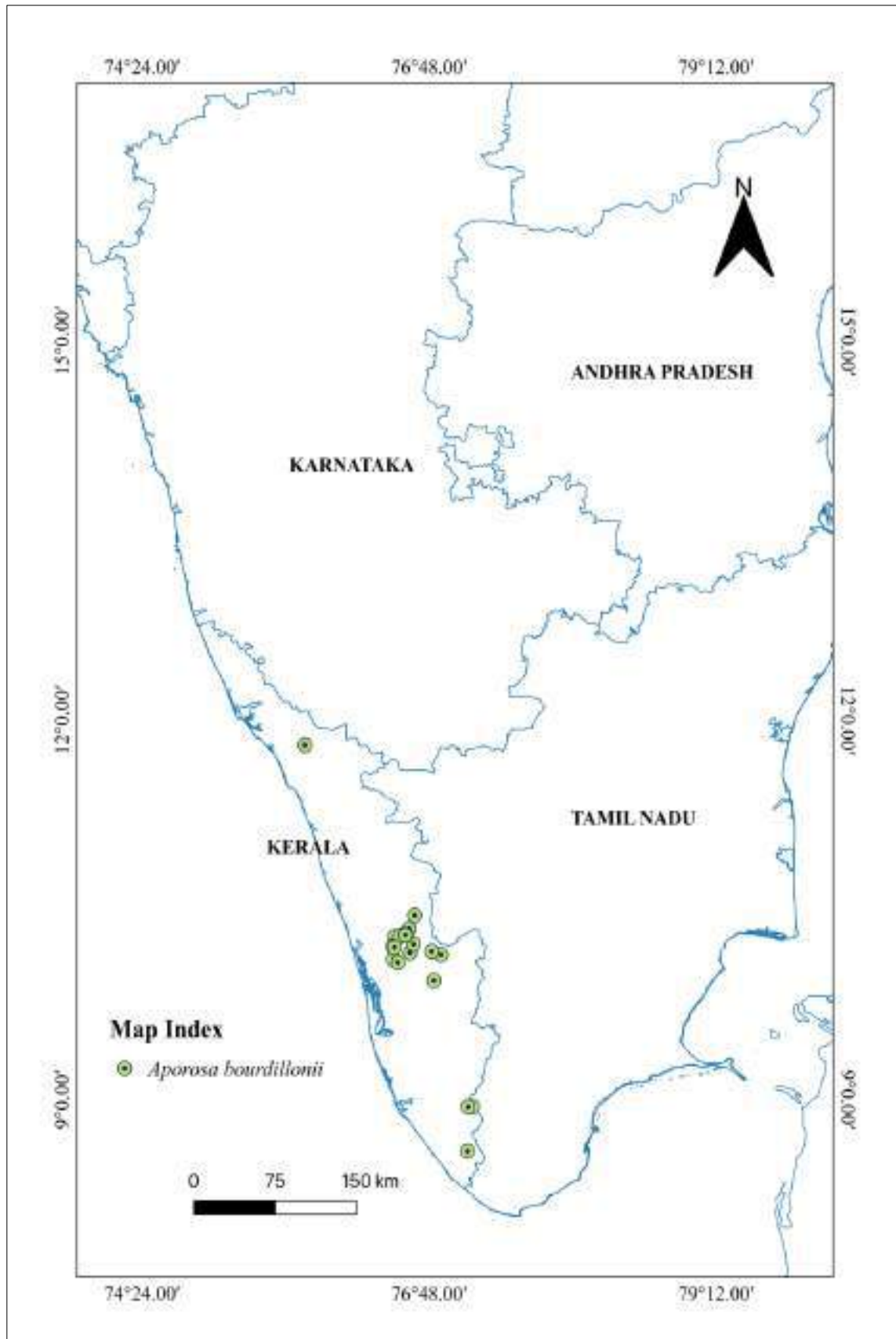


Fig. 4.9. Actual distribution of *Aporosa bourdillonii*

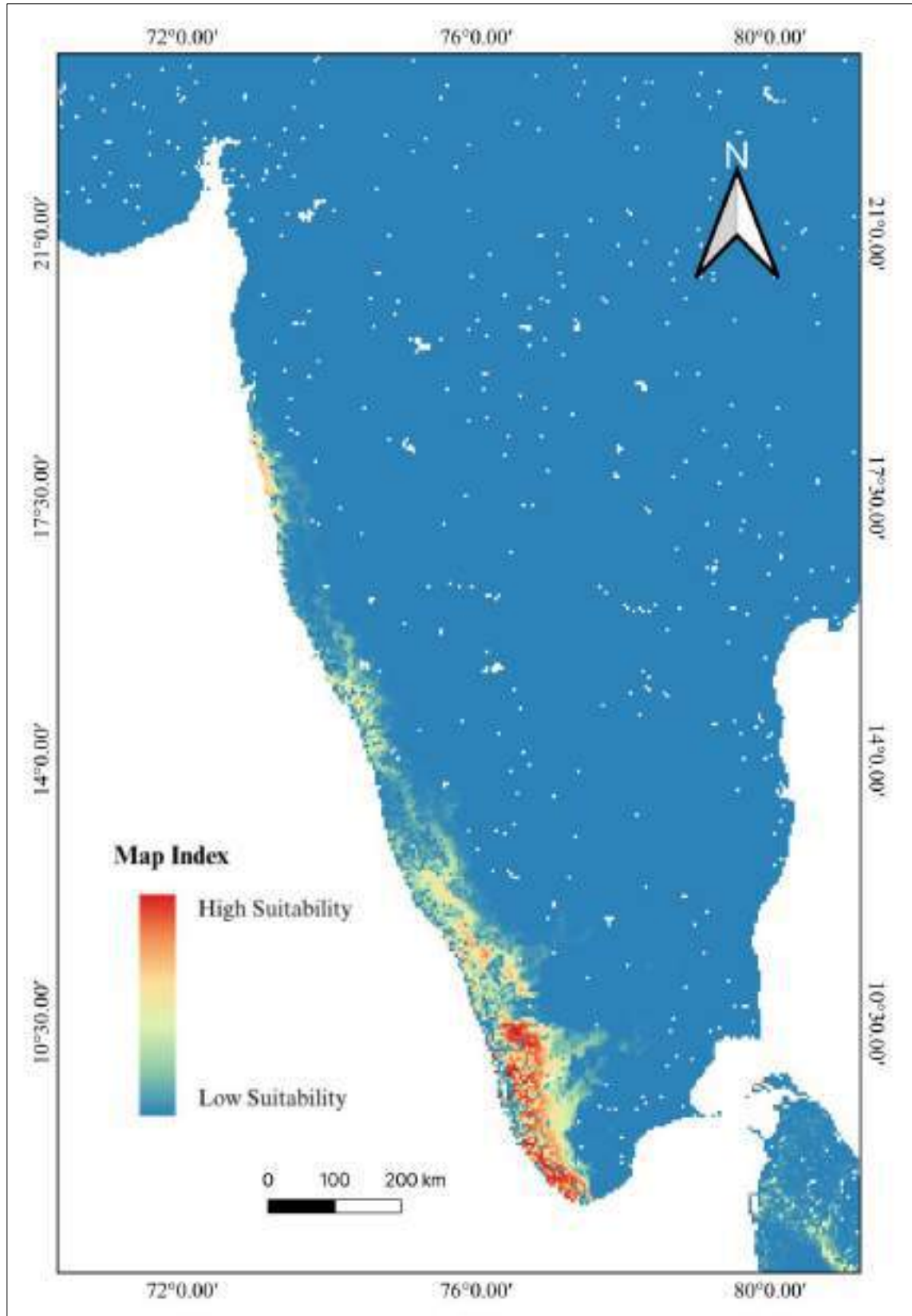


**Fig. 4.10. Predicted habitat suitability of *Aporosa bourdillonii* using MaxEnt model under present climate scenario**

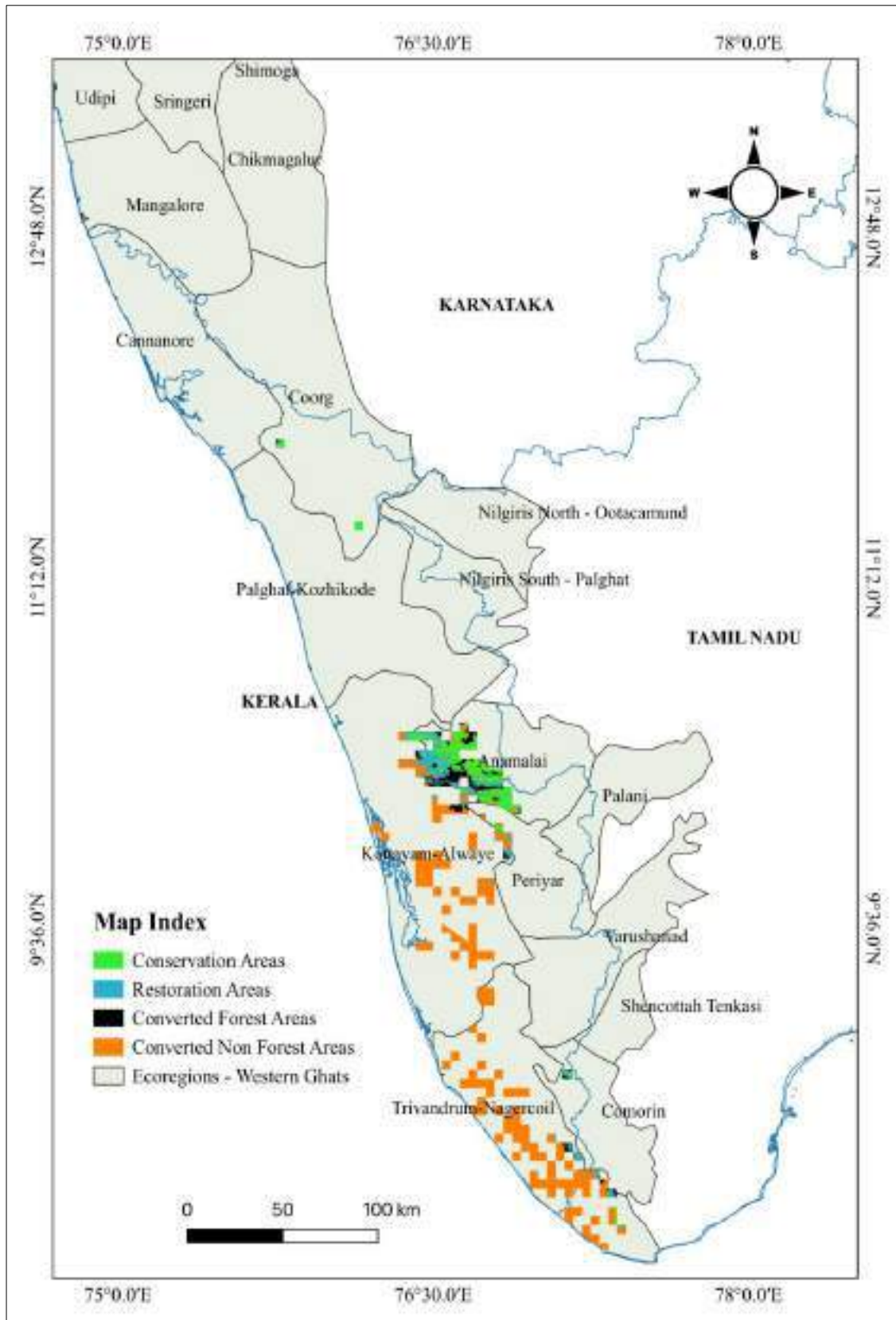


**Fig. 4.11. Refined predicted area of *Aporosa bourdillonii* into potential conservation, restoration and irreversibly lost habitats at ecoregion level**

### Eltonian Niche of *Aporosa bourdillonii* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *A. bourdillonii* is currently restricted to the 12 subpopulations within the Western Ghats, particularly in parts of Kerala (Fig. 4.9). Under the current climate scenario, the MaxEnt model predicts a total of 3815.22 km<sup>2</sup> of highly suitable habitat for *A. malabarica* in the Western Ghats (Fig. 4.10.). This predicted distribution spans over six distinct ecoregions (Fig. 4.11). The highest suitability predictions were concentrated in the Trivandrum-Nagercoil (3815.22 km<sup>2</sup>), Kottayam-Alwaye (1241.95 km<sup>2</sup>), Anamalai (957.36 km<sup>2</sup>) and Periyar (62.14 km<sup>2</sup>) ecoregions (Table 4.6).

**Table 4.6. Ecoregion wise habitat prediction for *Aporosa bourdillonii* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No.      | Ecoregion              | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest Area (Km <sup>2</sup> ) |
|--------------|------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1            | Anamalai               | 957.36                            | 506.11                               | 210.97                              | 160.90                                   | 79.38                                        |
| 2            | Comorin                | 49.95                             | 8.74                                 | 18.51                               | 12.75                                    | 9.94                                         |
| 3            | Coorg                  | 41.43                             | 33.67                                | 4.16                                | 2.33                                     | 1.28                                         |
| 4            | Kottayam-Alwaye        | 1241.96                           | 32.11                                | 146.77                              | 72.76                                    | 990.32                                       |
| 5            | Periyar                | 62.14                             | 11.91                                | 14.14                               | 1.64                                     | 34.46                                        |
| 6            | Trivandrum - Nagercoil | 1462.40                           | 15.48                                | 48.48                               | 22.01                                    | 1376.43                                      |
| <b>Total</b> |                        | <b>3815.23</b>                    | <b>608.02</b>                        | <b>443.02</b>                       | <b>272.38</b>                            | <b>2491.81</b>                               |

The initial modelling of the potential distribution for *A. bourdillonii* utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 3815.22 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers, delineated the area into distinct land-use categories crucial for conservation

planning (Fig. 4.11). A total of Conservation area spanning 608.01 km<sup>2</sup>, Potential Ecorestoration area of 443.01 km<sup>2</sup>, irreversibly converted forest habitat (272.38 km<sup>2</sup>) and converted non-forested human-dominated areas (2491.81 km<sup>2</sup>). The ecoregions such as Anamalai (506.11 km<sup>2</sup>), Coorg (33.66 km<sup>2</sup>), Kottayam-Alwaye (32.11 km<sup>2</sup>) and Trivandrum - Nagercoil (15.47 km<sup>2</sup>) represent maximum potential conservation areas suitable for *A. bourdillonii*. The degraded habitats are also represented by ecoregions such as Anamalai (210.97 km<sup>2</sup>), Kottayam-Alwaye (146.76 km<sup>2</sup>) and Trivandrum - Nagercoil (48.48 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 7 % of converted forest habitat to the species are represented with Anamalai (160.9 km<sup>2</sup>), Kottayam-Alwaye (72.75 km<sup>2</sup>), Trivandrum - Nagercoil (22.00 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *A. bourdillonii*'s ecological niche.

#### **4.3.3. Grinnellian Niche of *Cryptocarya anamalayana* Using Bioclimatic Factors**

The MaxEnt model for *Cryptocarya anamalayana*, an endangered medium-elevation rainforest tree, under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.993 (Fig. 4.12). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *C. anamalayana* (Fig. 4.13). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (77%) and Isothermality (6.2%) contributed most to the model. This is followed by Precipitation of Coldest Quarter (2.6%), Precipitation of Warmest Quarter (2.4 %) and Mean Diurnal Range (1.2%). The Slope and Elevation also emerged as an important non-bioclimatic variable, contributing 8.3% and 2% respectively to model gain, indicating that topographic constraints partly define the niche of this species.

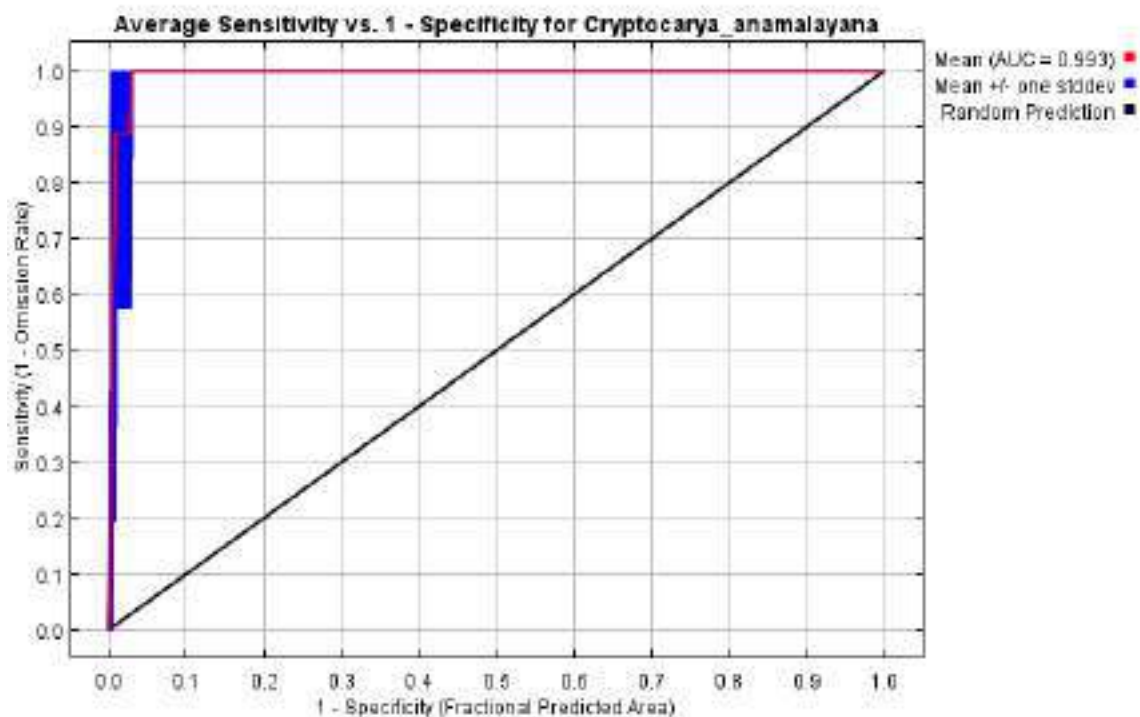


Fig. 4.12. Area Under Curve indicating model performance of *Cryptocarya anamalayana*



Fig. 4.13. Jackknife test of training gain showing bioclimatic variables of importance



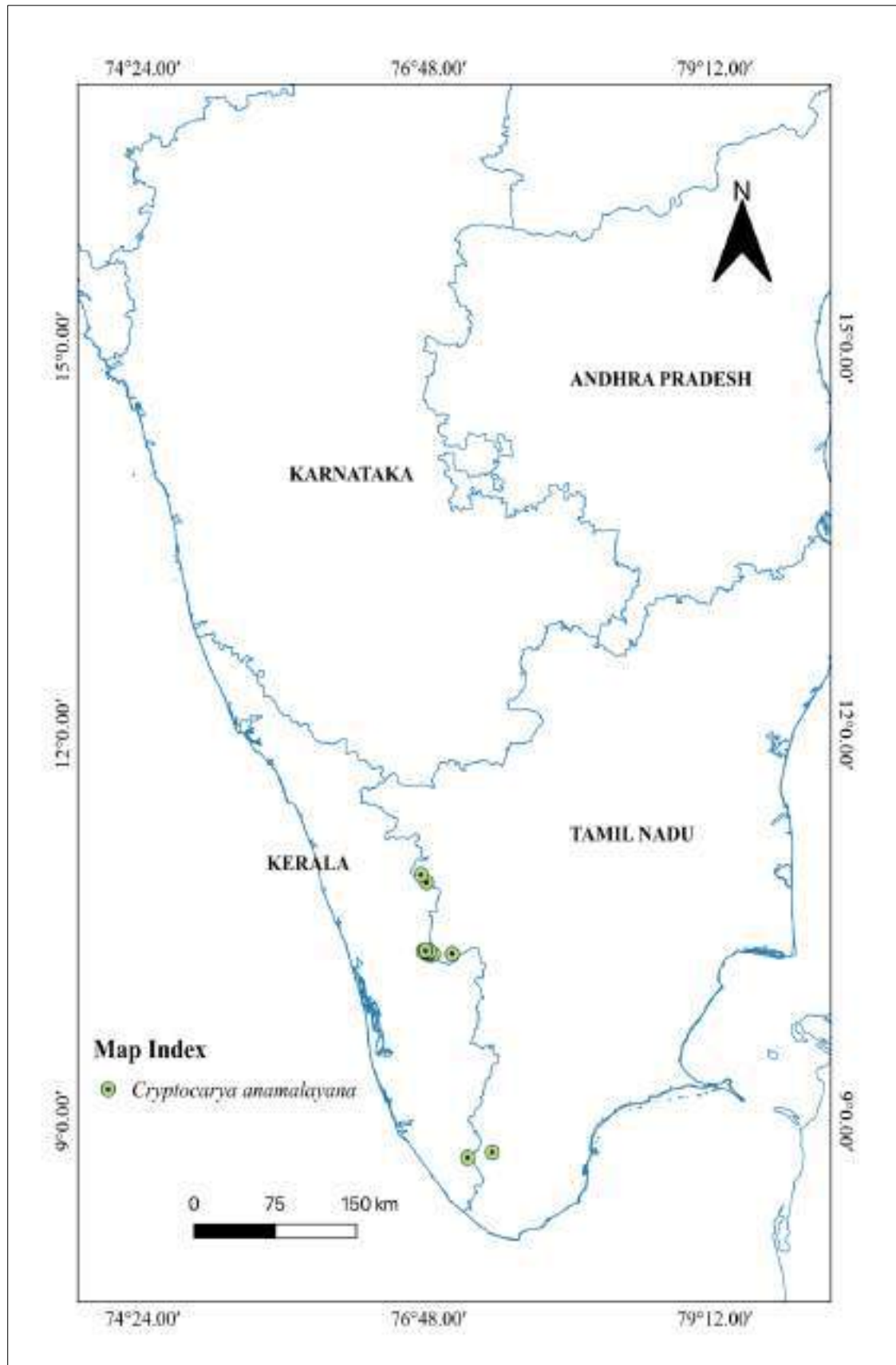


Fig. 4.14. Actual distribution of *Cryptocarya anamalayana*



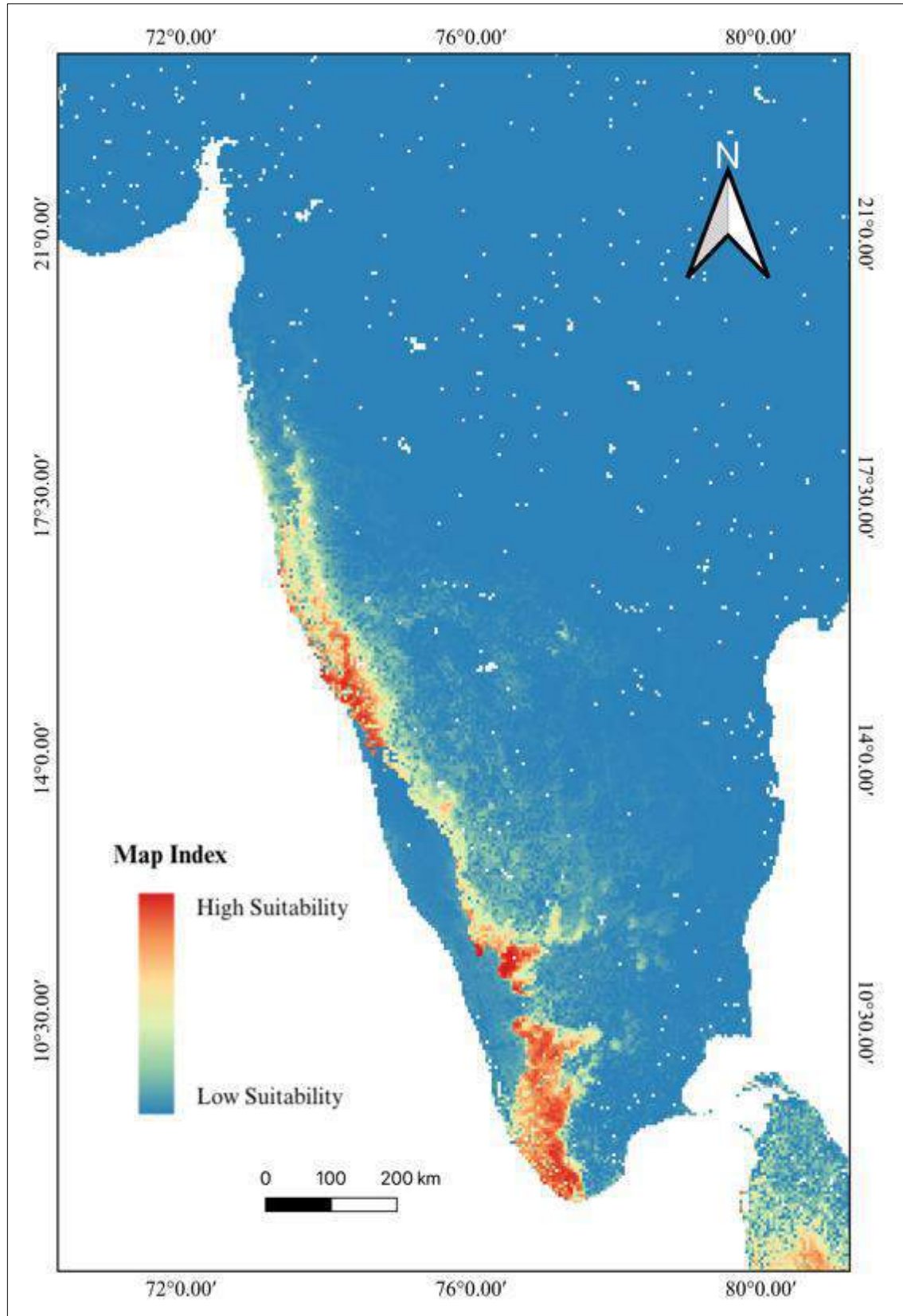


**Fig. 4.15.** Predicted habitat suitability of *Cryptocarya anamalayana* using MaxEnt model under present climate scenario

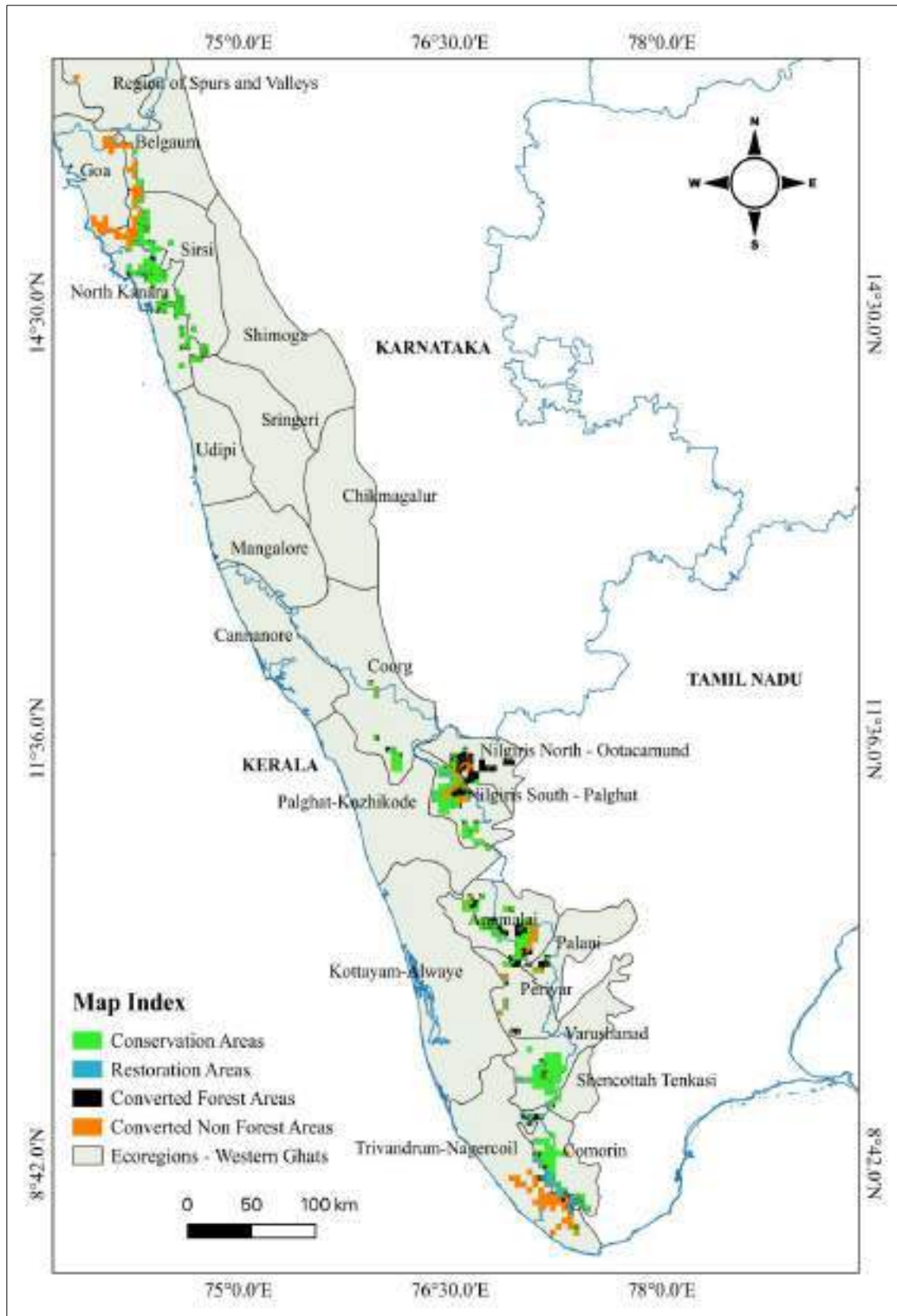


**Fig. 4.16.** Refined predicted area of *Cryptocarya anamalayana* into potential conservation, restoration and irreversibly lost habitats at ecoregion level

### Eltonian Niche of *Cryptocarya anamalayana* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *C. anamalayana* is currently restricted to the five subpopulations within the Western Ghats, particularly in parts of Kerala and Tamil Nadu (Fig. 4.4.). Under the current climate scenario, the MaxEnt model predicts a total of 7344.13 km<sup>2</sup> of highly suitable habitat for *C. anamalayana* in the Western Ghats. This predicted distribution spans over 17 distinct ecoregions (Fig. 4.15.). The highest suitability predictions were concentrated in the Anamalai (932.41 km<sup>2</sup>), North Kanara (904.2 km<sup>2</sup>), Nilgiris South-Palghat (897.66 km<sup>2</sup>), Trivandrum-Nagercoil (804.12 km<sup>2</sup>) and Comorin (754.55 km<sup>2</sup>) ecoregions (Table 4.7).

**Table 4.7. Ecoregion wise habitat prediction for *Cryptocarya anamalayana* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No. | Ecoregion                 | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|---------|---------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1       | Anamalai                  | 932.41                            | 512.05                               | 35.30                               | 216.10                                   | 168.96                                       |
| 2       | Belgaum                   | 189.11                            | 55.06                                | 7.74                                | 10.19                                    | 116.12                                       |
| 3       | Comorin                   | 754.55                            | 420.19                               | 223.74                              | 75.23                                    | 35.39                                        |
| 4       | Coorg                     | 249.82                            | 172.26                               | 21.75                               | 29.11                                    | 26.70                                        |
| 5       | Goa                       | 292.04                            | 0.67                                 | 5.36                                | 0.61                                     | 285.40                                       |
| 6       | Nilgiris North-Ootacamund | 462.51                            | 69.67                                | 4.05                                | 319.01                                   | 69.78                                        |
| 7       | Nilgiris South-Palghat    | 897.67                            | 524.15                               | 77.03                               | 114.28                                   | 182.20                                       |
| 8       | North Kanara              | 904.20                            | 584.47                               | 65.10                               | 119.66                                   | 134.97                                       |

|              |                            |                |                |               |                |                |
|--------------|----------------------------|----------------|----------------|---------------|----------------|----------------|
| 9            | Palani                     | 116.44         | 32.83          | 0.84          | 57.04          | 25.73          |
| 10           | Palghat-Kozhikode          | 15.55          | 10.93          | 0.00          | 0.25           | 4.37           |
| 11           | Periyar                    | 223.35         | 40.66          | 55.41         | 62.34          | 64.93          |
| 12           | Region of Spurs and Valley | 20.56          | 0.00           | 0.00          | 0.00           | 20.56          |
| 13           | Shencottah Tenkasi         | 71.38          | 46.80          | 14.84         | 5.91           | 3.84           |
| 14           | Sirsi                      | 681.19         | 412.74         | 35.00         | 73.47          | 159.98         |
| 15           | Sringeri                   | 37.57          | 31.56          | 0.00          | 6.01           | 0.00           |
| 16           | Trivandrum-Nagercoil       | 804.12         | 33.93          | 123.57        | 62.49          | 584.14         |
| 17           | Varushanad                 | 691.67         | 583.52         | 73.61         | 26.37          | 8.17           |
| <b>Total</b> |                            | <b>7344.13</b> | <b>3531.48</b> | <b>743.33</b> | <b>1178.08</b> | <b>1891.23</b> |

The initial modelling of the potential distribution for *C. anamalayana*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 7344.13 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.16.). A total of Conservation area spanning 3531.48 km<sup>2</sup>, Potential Ecorestoration area of 743.33 km<sup>2</sup>, irreversibly converted forest habitat (1178.08 km<sup>2</sup>) and converted non-forested human-dominated areas (1891.23 km<sup>2</sup>). The ecoregions such as North Kanara (584.46 km<sup>2</sup>), Varushanad (583.51 km<sup>2</sup>), Nilgiris South- Palghat (524.14 km<sup>2</sup>), Anamalai (512.04 km<sup>2</sup>), Comorin (420.18 km<sup>2</sup>) and Sirsi (412.74 km<sup>2</sup>) represent maximum potential conservation areas suitable for *C. anamalayana*. The degraded habitats are also represented by ecoregions such as Comorin (223.74 km<sup>2</sup>), Trivandrum-Nagercoil (123.57 km<sup>2</sup>), Nilgiris South-Palghat (77.03 km<sup>2</sup>) and Varushanad (73.60 km<sup>2</sup>). These areas are considered here as

potential ecorestoration areas for the species. Among the total 16 % of converted forest habitat to the species are represented with Nilgiris North-Ootacamund (319.00 km<sup>2</sup>), Anamalai (216.10 km<sup>2</sup>), North Kanara (119.65 km<sup>2</sup>) and Nilgiris South- Palghat (114.28 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *C. anamalayana*'s ecological niche.

#### **4.3.4. Grinnellian Niche of *Cryptocarya lawsonii* Using Bioclimatic Factors**

The MaxEnt model for *C. lawsonii* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.990 (Fig. 4.17). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *C. lawsonii* (Fig. 4.18). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (65.9%) and Isothermality (7.2 %) contributed most to the model. This is followed by Precipitation of Coldest Quarter (4.5%), Precipitation of Driest Quarter (3.9%), Precipitation of Warmest Quarter (1.9%). The Elevation and Slope also emerged as an important non-bioclimatic variable, contributing 7.4% and 5.3% respectively, to model gain, indicating that topographic constraints partly define the niche of this species.

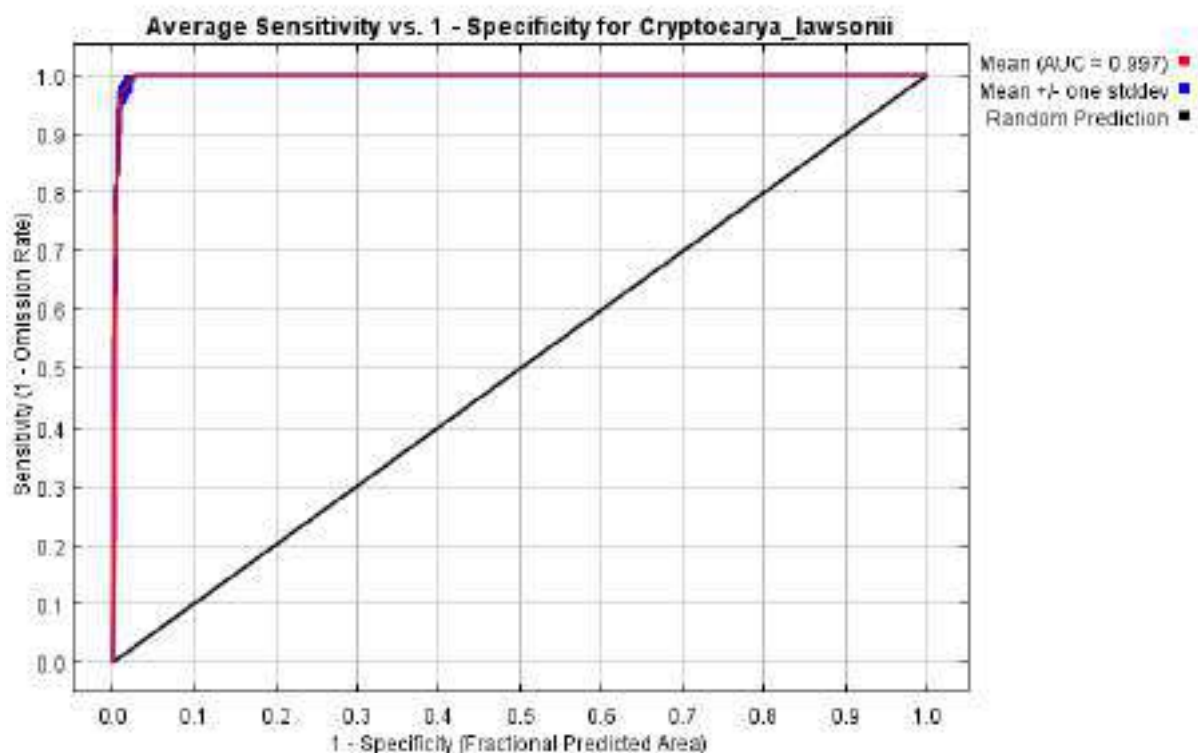


Fig. 4.17. Area Under Curve indicating model performance of *Cryptocarya lawsonii*

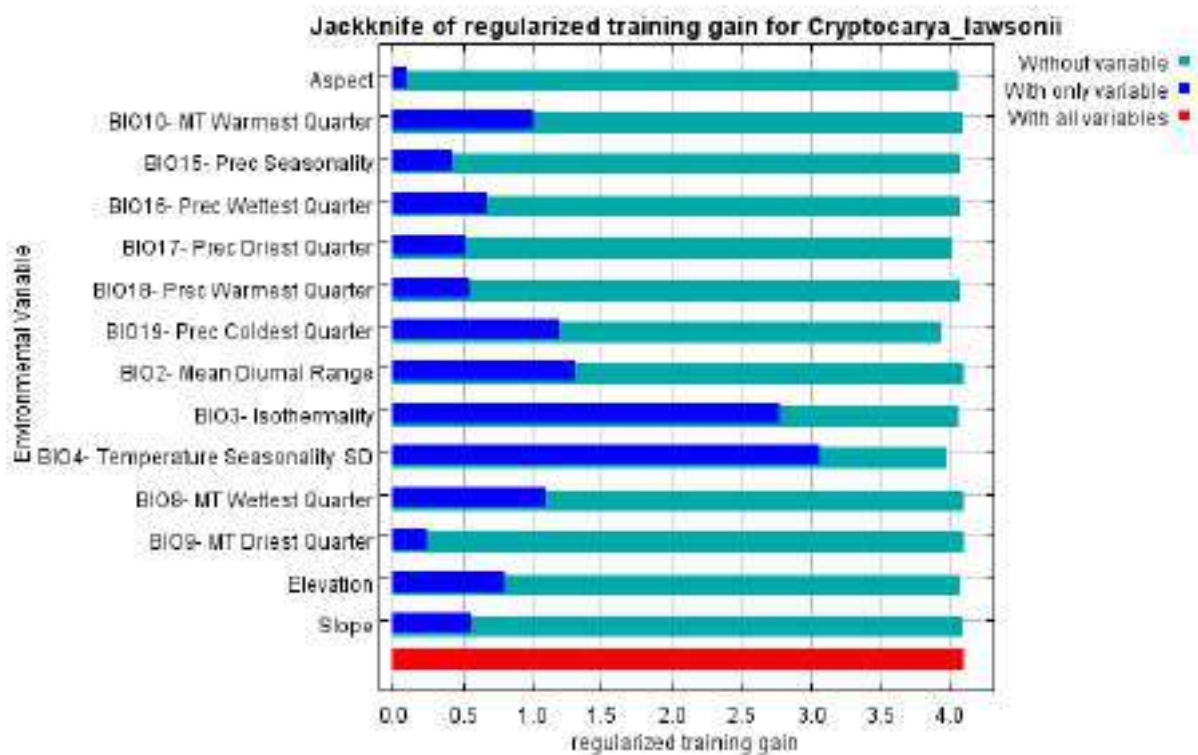


Fig. 4.18. Jackknife test of training gain showing bioclimatic variables of importance

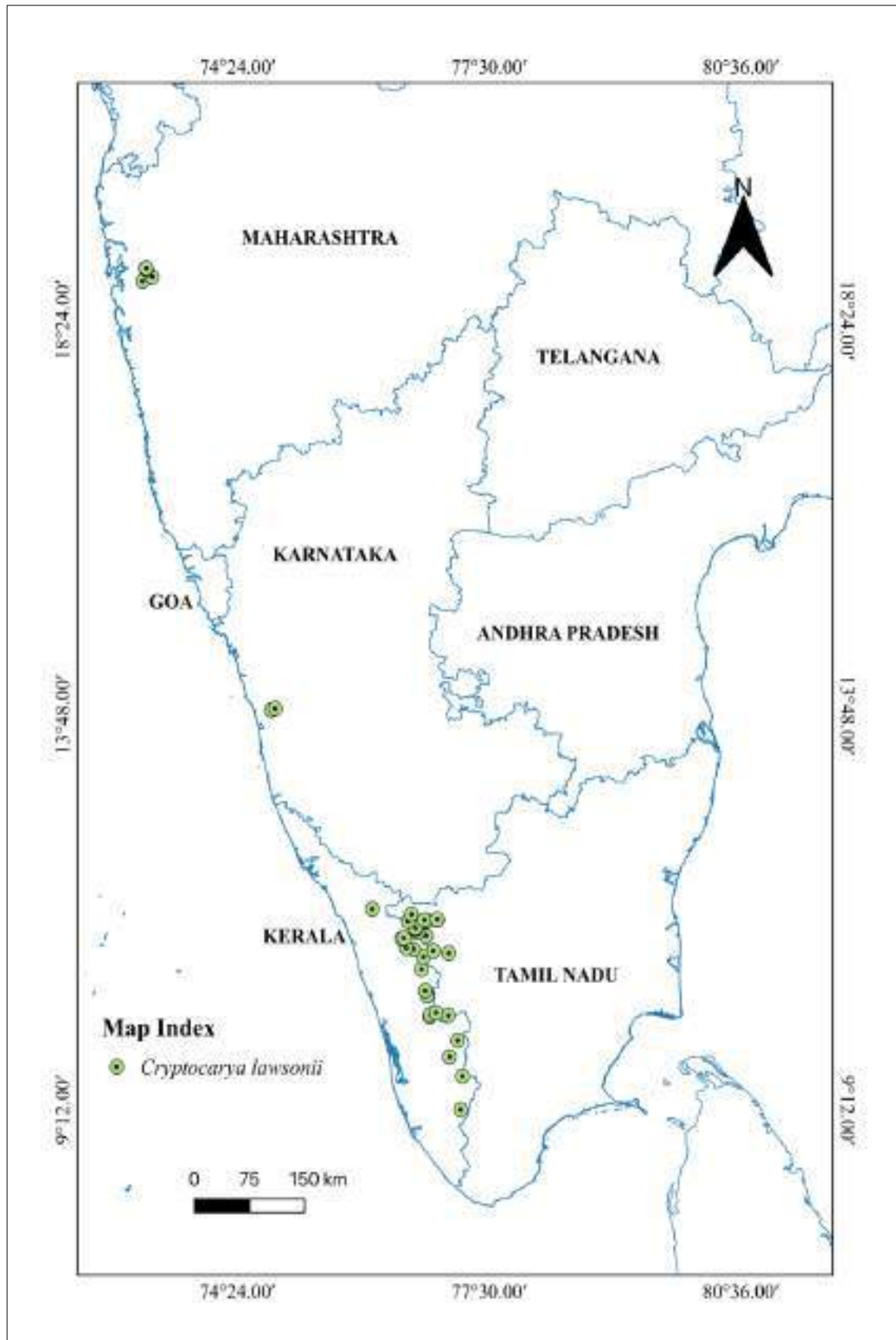


Fig. 4.19. Actual distribution of *Cryptocarya lawsonii*



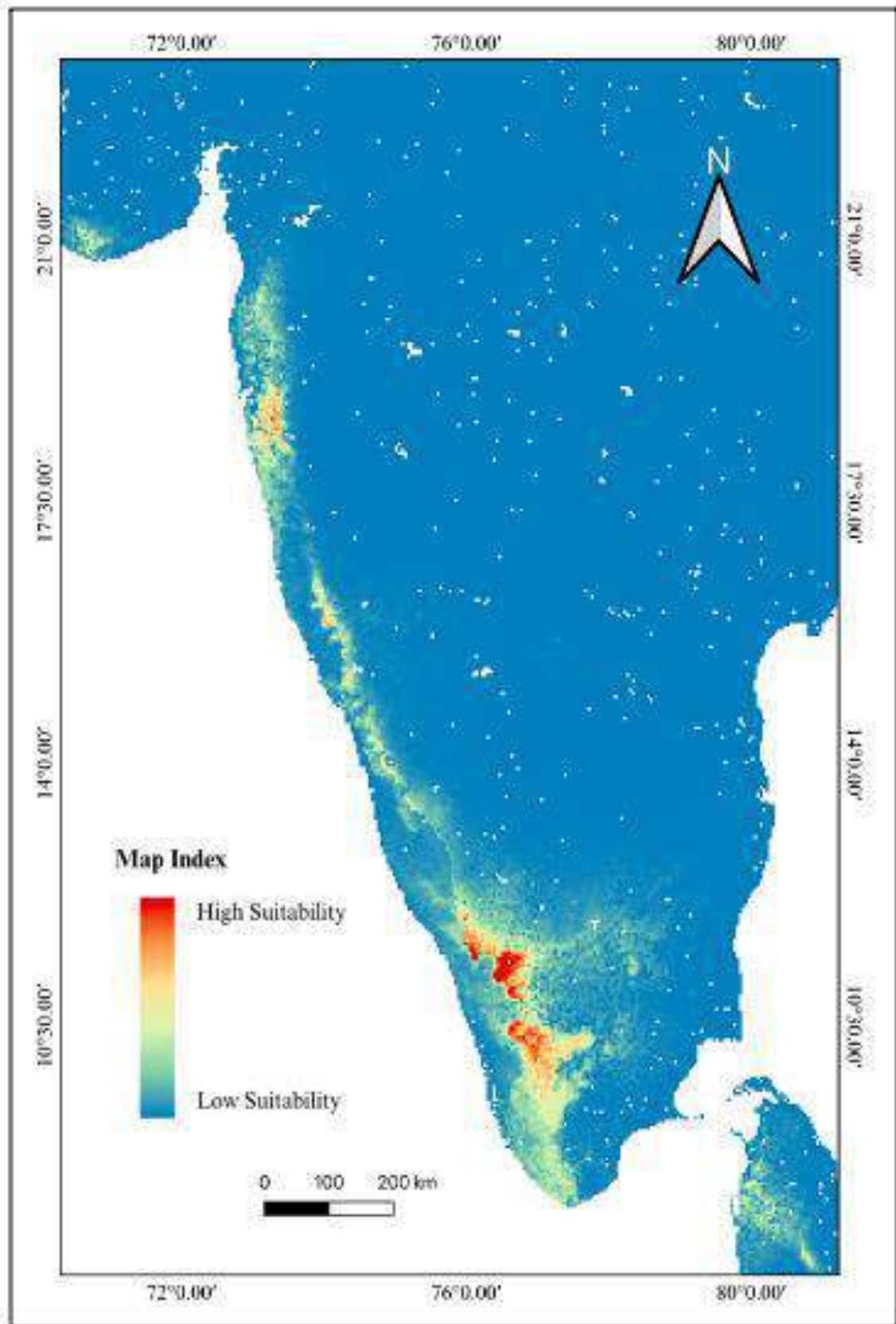


**Fig. 4.20.** Predicted habitat suitability of *Cryptocarya lawsonii* using MaxEnt model under present climate scenario

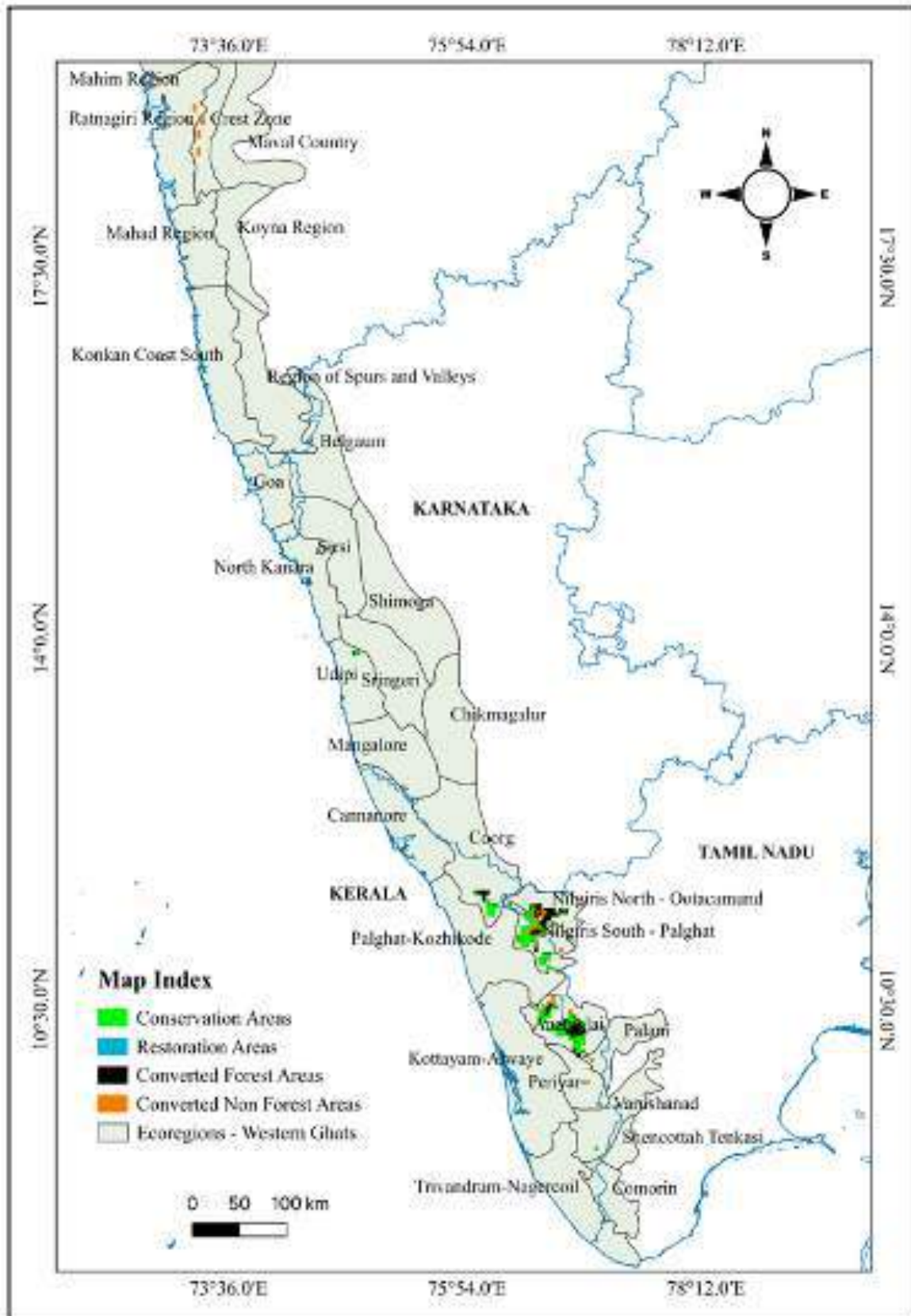


Fig. 4.21. Refined predicted area of *Cryptocarya lawsonii* into potential conservation, restoration and irreversibly lost habitats at ecoregion level

### Eltonian Niche of *Cryptocarya lawsonii* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *C. lawsonii* is currently restricted to the 13 subpopulations within the Kerala, Tamil Nadu, Karnataka and Maharashtra region (Fig. 4.19). Under the current climate scenario, the MaxEnt model predicts a total of 3315.79 km<sup>2</sup> of highly suitable habitat for *C. lawsonii* in the Western Ghats. This predicted distribution spans over 11 distinct ecoregions (Fig. 4.20). The highest suitability predictions were concentrated in the Anamalai (1203.87 km<sup>2</sup>), Nilgiris South-Palghat (958.25 km<sup>2</sup>), Nilgiris North-Ootacamund (457.510 km<sup>2</sup>) and Coorg (313.15 km<sup>2</sup>) ecoregions (Table 4.8).

**Table 4.8. Ecoregion wise habitat prediction for *Cryptocarya lawsonii* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No. | Ecoregion                 | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|---------|---------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1       | Anamalai                  | 1203.87                           | 621.28                               | 70.12                               | 361.67                                   | 150.80                                       |
| 2       | Coorg                     | 313.15                            | 169.57                               | 17.50                               | 101.71                                   | 24.38                                        |
| 3       | Crest Zone                | 118.25                            | 0.00                                 | 0.00                                | 0.00                                     | 118.25                                       |
| 4       | Nilgiri South-Palghat     | 958.25                            | 521.08                               | 69.60                               | 154.04                                   | 213.52                                       |
| 5       | Nilgiris North-Ootacamund | 457.51                            | 79.19                                | 2.55                                | 310.36                                   | 65.41                                        |
| 6       | Palani                    | 20.86                             | 10.38                                | 0.00                                | 0.00                                     | 10.48                                        |
| 7       | Palghat-Kozhikode         | 27.94                             | 10.97                                | 1.80                                | 5.75                                     | 9.41                                         |
| 8       | Periyar                   | 85.17                             | 9.48                                 | 16.13                               | 25.49                                    | 34.07                                        |
| 9       | Ratnagiri                 | 55.95                             | 0.00                                 | 0.00                                | 0.00                                     | 55.95                                        |

|              |            |                |                |               |               |               |
|--------------|------------|----------------|----------------|---------------|---------------|---------------|
| 10           | Udipi      | 55.56          | 38.07          | 5.03          | 12.46         | 0.00          |
| 11           | Varushanad | 19.29          | 16.65          | 2.64          | 0.00          | 0.00          |
| <b>Total</b> |            | <b>3315.80</b> | <b>1476.67</b> | <b>185.37</b> | <b>971.48</b> | <b>682.28</b> |

The initial modelling of the potential distribution for *C. lawsonii*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 3315.79 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning. A total of Conservation area spanning 1476.66 km<sup>2</sup>, Potential Ecorestoration area of 185.36 km<sup>2</sup>, irreversibly converted forest habitat (971.48 km<sup>2</sup>) and converted non-forested human-dominated areas (682.27 km<sup>2</sup>). The ecoregions such as Anamalai (621.28 km<sup>2</sup>), Nilgiri South-Palghat (521.07 km<sup>2</sup>), Coorg (169.56 km<sup>2</sup>), Nilgiris North-Ootacamund (79.18 km<sup>2</sup>) represent maximum potential conservation areas suitable for *C. lawsonii*. The degraded habitats are also represented by ecoregions such as Anamalai (70.11 km<sup>2</sup>), Nilgiri South-Palghat (69.60 km<sup>2</sup>), Coorg (17.49 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 29 % of converted forest habitat to the species are represented with Anamalai (361.67 km<sup>2</sup>), Nilgiris North-Ootacamund (310.36 km<sup>2</sup>), Nilgiri South-Palghat (154.04 km<sup>2</sup>), Coorg (101.70 km<sup>2</sup>), Periyar (25.48 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *C. lawsonii*, ecological niche.

#### 4.3.5. Grinnellian Niche of *Diospyros crumenata* Using Bioclimatic Factors

The MaxEnt-based niche modelling revealed the important bioclimatic parameters that define the niche of the Critically Endangered tree *D. crumenata*. The prediction provided its potential areas in the Western Ghats mountains based on the Grinnellian niche factors. The AUC obtained for the model was 0.995, indicating accurate and very good performance of the prediction (Fig.4.22).

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *D. crumenata* (Fig. 4.23). Among which the MaxEnt

model showed that Temperature Seasonality SD (69.6%) contributes the most. This is followed by Precipitation of Wettest Month (5.5%), Isothermality (3.7%), Mean Temperature of Wettest Quarter (3.4%), Mean Diurnal Range (3.3%), Precipitation of Coldest Quarter (3%), Precipitation of Driest Month (1.6%), Precipitation of Warmest Quarter (1.1%) and Precipitation Seasonality (0.5%). The Slope and Elevation also emerged as an important non-bioclimatic variable, contributing 5.5% and 2.1% respectively, to model gain, indicating that topographic constraints partly define the niche of this species.

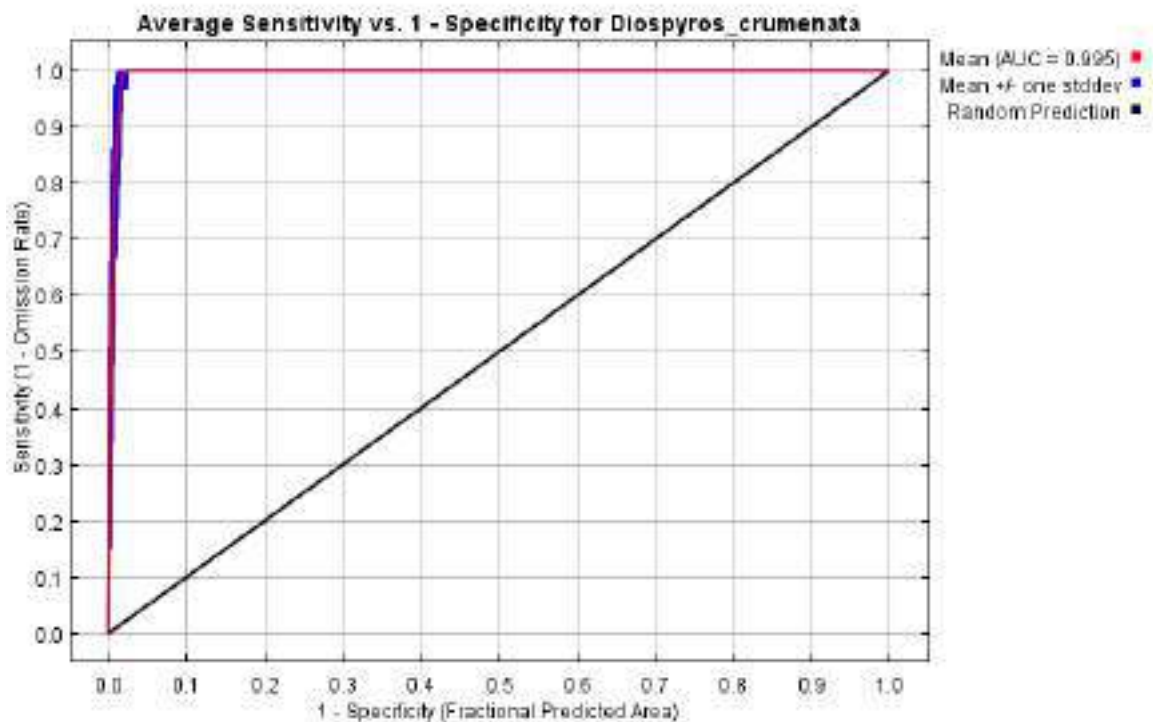


**Fig. 4.22.** Area Under Curve indicating model performance of *Diospyros crumenata*

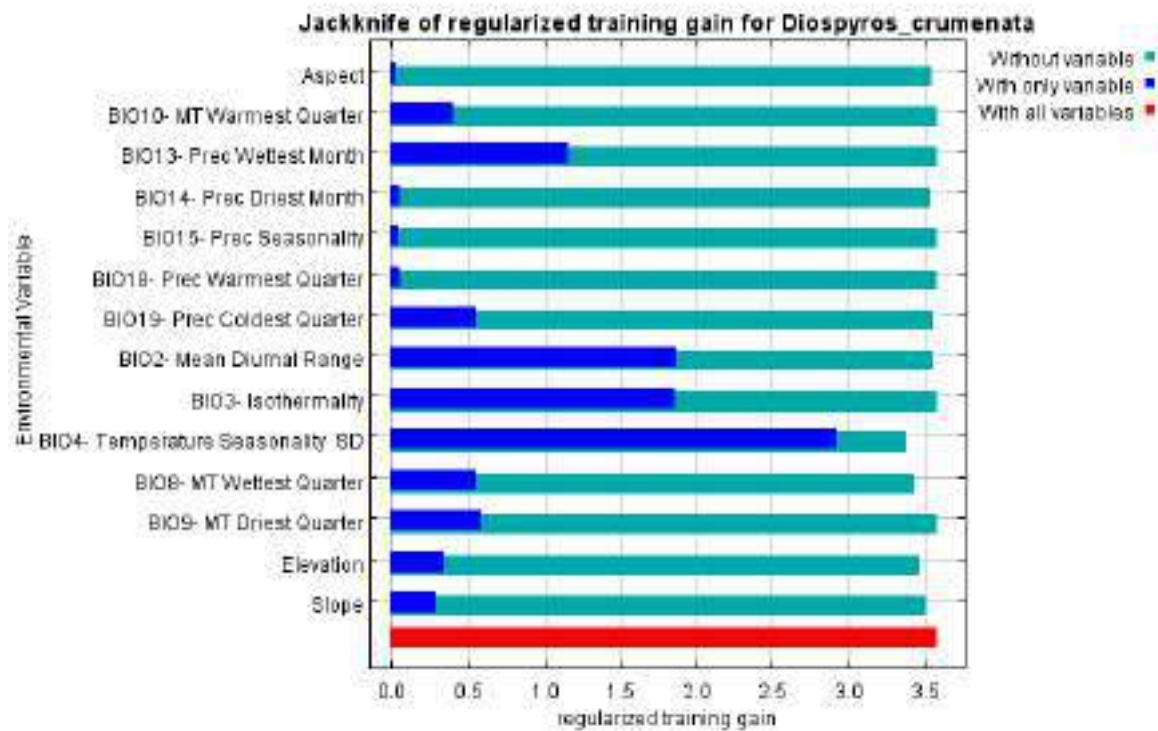


**Fig. 4.23. Jackknife test of training gain showing bioclimatic variables of importance**



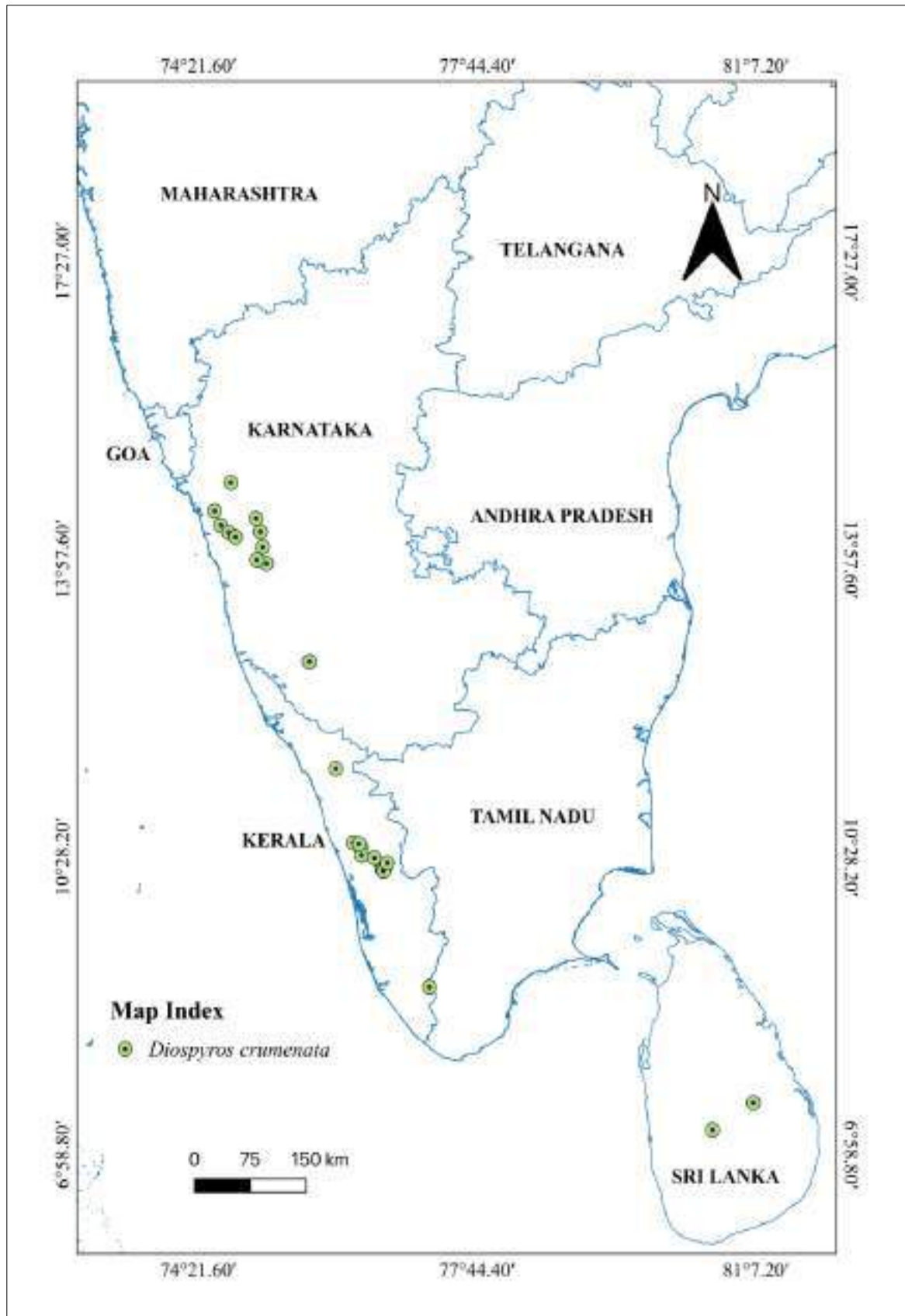


Fig. 4.24. Actual distribution of *Diospyros crumenata*



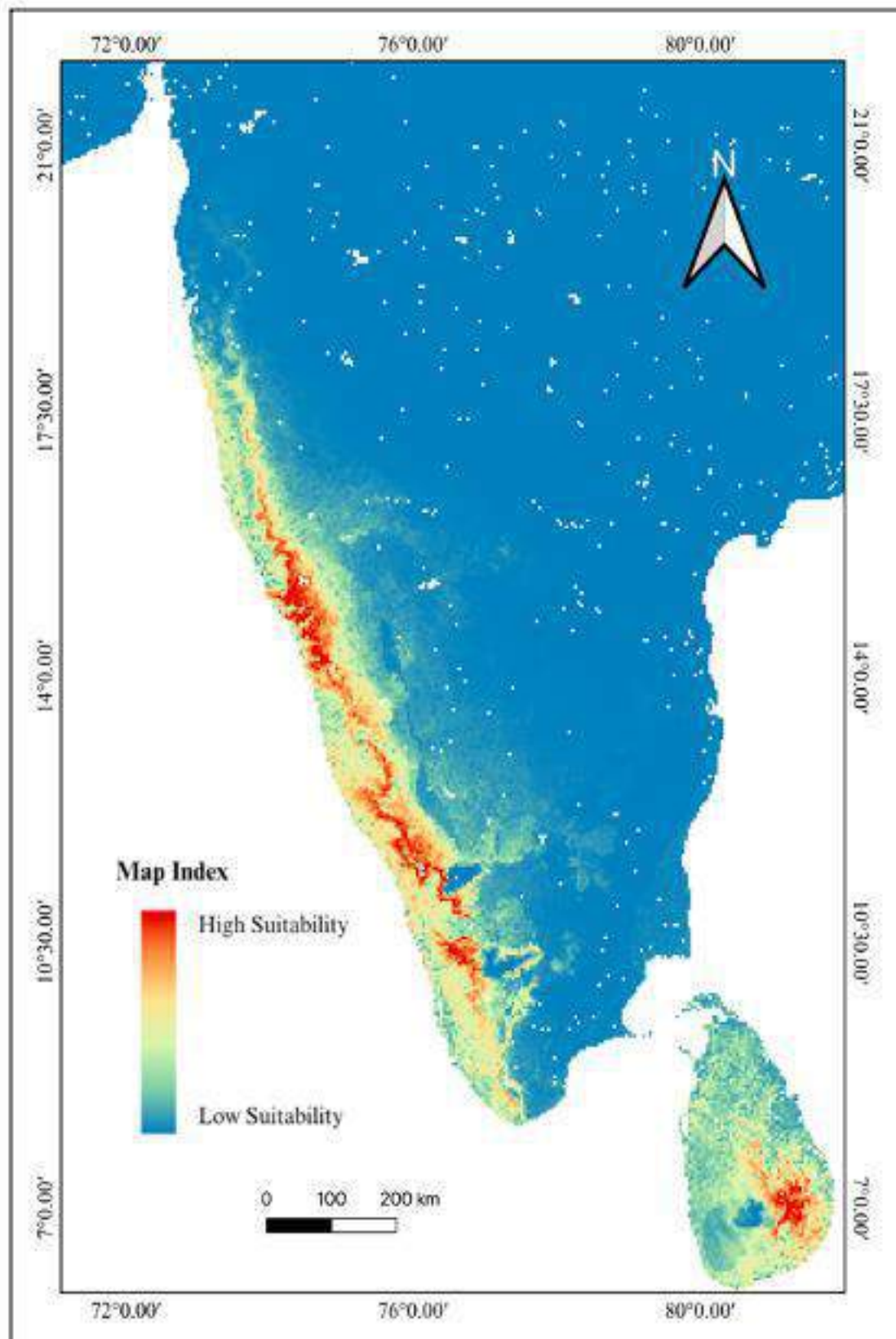


**Fig. 4.25. Predicted habitat suitability of *Diospyros crumenata* using MaxEnt model under present climate scenario**

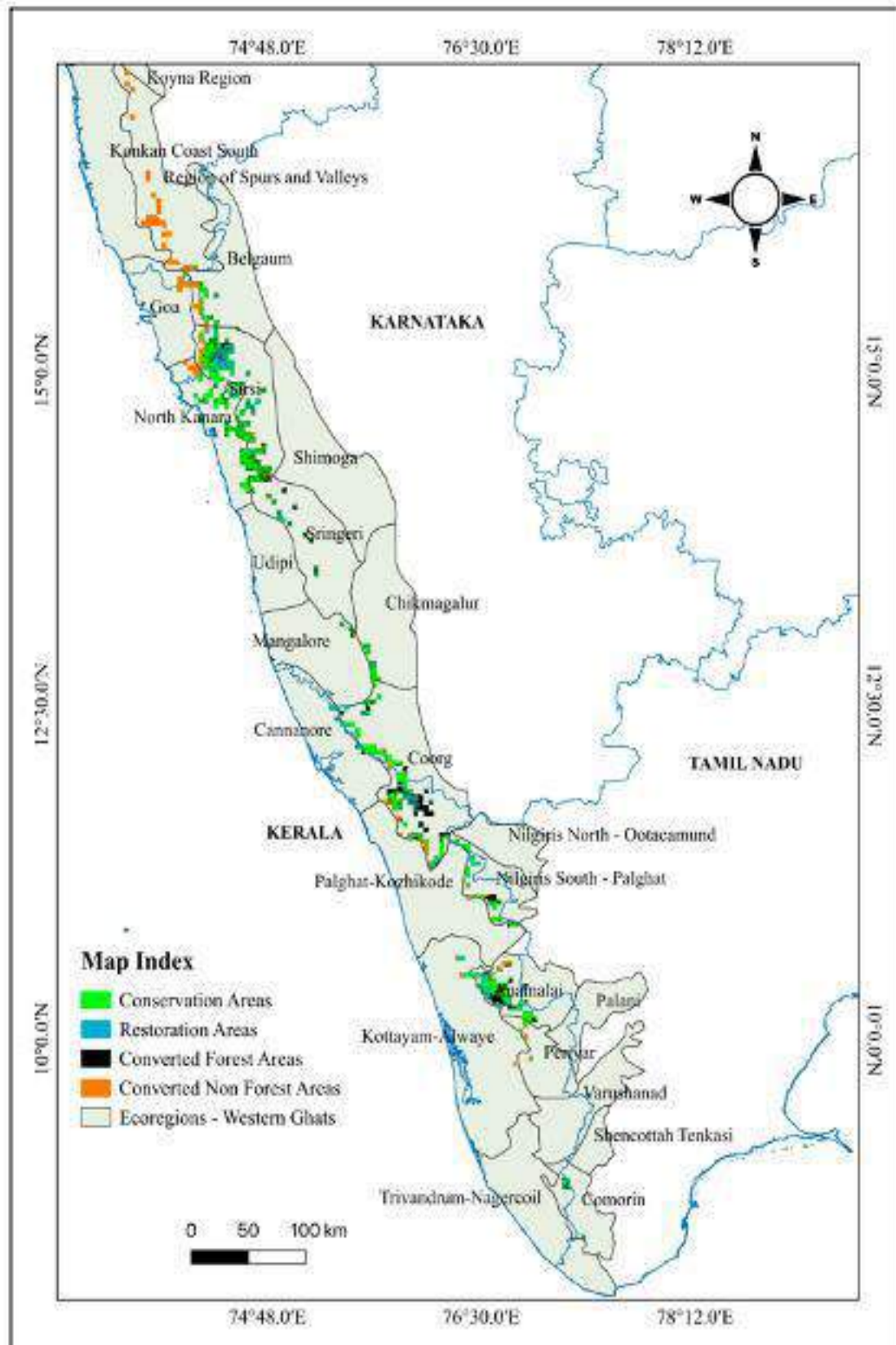


Fig. 4.26. Refined predicted area of *Diospyros crumenata* into potential conservation, restoration and irreversibly lost habitats at ecoregion level

### Eltonian Niche of *Diospyros crumenata* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Diospyros crumenata* is currently restricted to the 12 subpopulations within the Kerala, Tamil Nadu, Karnataka (India) and Srilanka (Fig. 4.26). Under the current climate scenario, the area with the highest predicted habitat suitability, represented by the red area, covers 7052.25 km<sup>2</sup> (Fig. 4.25). This predicted habitat suitability spans the southern Western Ghats, encompassing 16 ecoregions, including six where the tree's actual distribution is documented (Fig. 4.26). The maximum prediction for habitat suitability were observed in Coorg (1565.65 km<sup>2</sup>), Sirsi (1553.64 km<sup>2</sup>), Anamalai (847.13 km<sup>2</sup>), North Kanara (780.23 km<sup>2</sup>), and Region of Spurs and Valley (529.85 km<sup>2</sup>), which together represent 74% of the total predicted area. Among these, the first four areas are significant for the actual distribution of *D. crumenata*. The areas with the fewest predictions are Periyar (86.84%), Comorin (82.92%), and Palghat-Kozhikode (65.03%) ecoregions of the Western Ghats (Table 4.9).

**Table 4.9. Ecoregion wise habitat prediction for *Diospyros crumenata* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No. | Ecoregion    | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|---------|--------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1       | Anamalai     | 847.13                            | 384.47                               | 189.95                              | 185.44                                   | 87.27                                        |
| 2       | Belgaum      | 309.91                            | 137.97                               | 30.27                               | 39.78                                    | 101.88                                       |
| 3       | Cannanore    | 110.01                            | 15.50                                | 76.98                               | 16.09                                    | 1.45                                         |
| 4       | Chickmagalur | 148.98                            | 114.07                               | 17.26                               | 14.23                                    | 3.42                                         |
| 5       | Comorin      | 82.92                             | 34.47                                | 27.49                               | 20.91                                    | 0.06                                         |
| 6       | Coorg        | 1565.65                           | 706.16                               | 244.70                              | 432.68                                   | 182.11                                       |
| 7       | Goa          | 108.19                            | 4.18                                 | 7.57                                | 1.48                                     | 94.96                                        |

|    |                                  |                |                |                |                |                |
|----|----------------------------------|----------------|----------------|----------------|----------------|----------------|
| 8  | Kottayam-<br>Alwaye              | 106.78         | 28.56          | 39.32          | 3.88           | 35.01          |
| 9  | Mangalore                        | 56.68          | 21.22          | 11.78          | 16.95          | 6.74           |
| 10 | Nilgiri South<br>- Palghat       | 380.02         | 202.20         | 84.87          | 62.71          | 30.24          |
| 11 | North Kanara                     | 780.23         | 551.08         | 57.56          | 85.17          | 86.42          |
| 12 | Palghat -<br>Kozhikode           | 65.03          | 18.84          | 17.36          | 5.29           | 23.53          |
| 13 | Periyar                          | 86.84          | 35.72          | 15.12          | 0.68           | 35.32          |
| 14 | Region of<br>Spurs and<br>Valley | 529.85         | 2.62           | 4.00           | 1.65           | 521.57         |
| 15 | Sirsi                            | 1553.64        | 815.65         | 340.24         | 272.09         | 125.66         |
| 16 | Sringeri                         | 320.39         | 125.69         | 72.86          | 116.34         | 5.50           |
|    | Total                            | <b>7052.25</b> | <b>3198.41</b> | <b>1237.33</b> | <b>1275.37</b> | <b>1341.14</b> |

The initial modelling of the potential distribution for *Diospyros crumenata*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 7052.25 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating Eltonian niche factors (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning. A total of Conservation area spanning 3198.4 km<sup>2</sup>, Potential Ecorestoration area of 1237.33 km<sup>2</sup>, irreversibly converted forest habitat (1275.37 km<sup>2</sup>) and converted non-forested human-dominated areas (1341.14 km<sup>2</sup>). The ecoregions such as Sirsi (815.65 km<sup>2</sup>), Coorg (706.16 km<sup>2</sup>), North Kanara (551.08 km<sup>2</sup>), and Anamalai (384.47 km<sup>2</sup>) represent maximum potential conservation areas suitable for *D. crumenata*. The degraded habitats are also represented by ecoregions such as Sirsi (340.24 km<sup>2</sup>), Coorg (244.70 km<sup>2</sup>), Anamalai (189.95 km<sup>2</sup>), and Nilgiri South-Palghat (84.87 km<sup>2</sup>). These areas are considered here as potential ecorestoration regions for the species. Among the total 18% converted forest habitat to the species are represented

with Coorg (432.68 km<sup>2</sup>), Sirsi (272.09 km<sup>2</sup>), Anamalai (185.44 km<sup>2</sup>), Sringeri (116.34 km<sup>2</sup>). Spatially explicit identification of these categories at the landscape and ecoregional scales is critical for developing effective species-specific conservation and ecorestoration strategies.

#### **4.3.6. Grinnellian Niche of *Dipterocarpus indicus* Using Bioclimatic Factors**

The MaxEnt model for *Dipterocarpus indicus* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.994 (Fig. 4.27). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *D. indicus* (Fig. 4.28). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (51%) and Precipitation of Coldest Quarter (22.5%) contributed most to the model. This is followed by Isothermality (9.7%), Precipitation of Wettest Quarter (2.4%) and Precipitation of Warmest Quarter (1.2%) (Appendix II). The Slope and Elevation also emerged as an important non-bioclimatic variable, contributing 7.8% and 2.9% respectively to model gain, indicating that topographic constraints partly define the niche of this species.

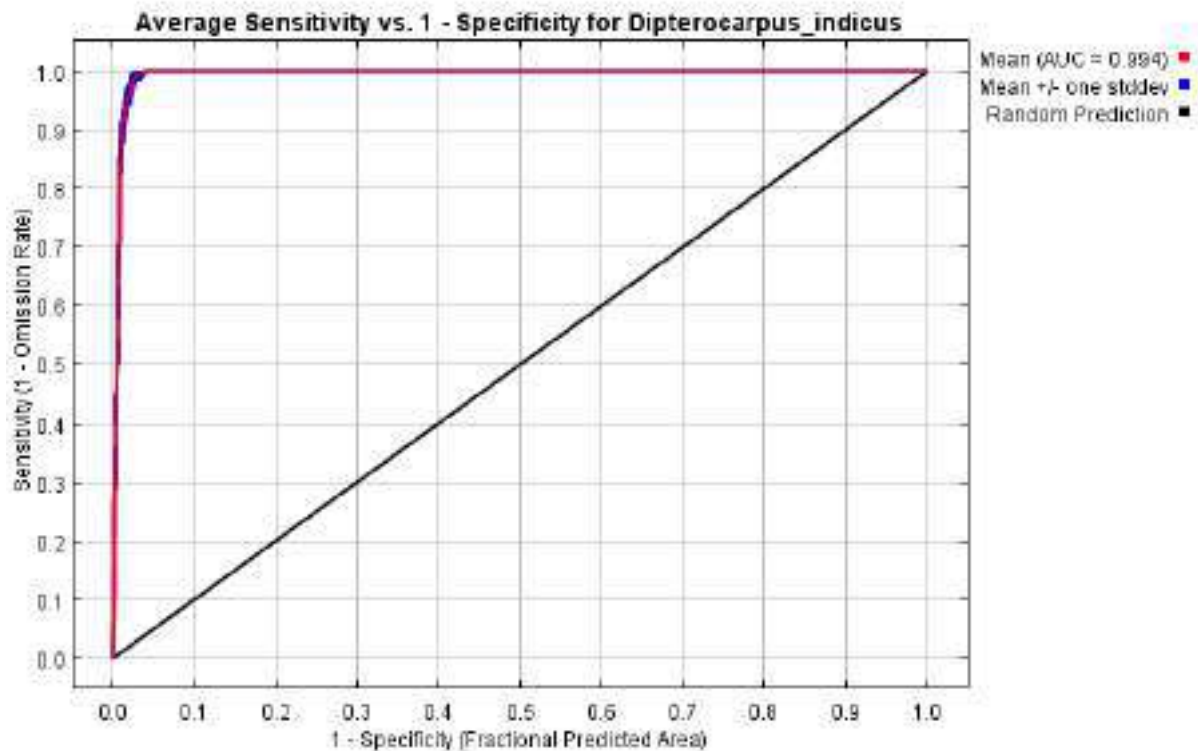


Fig. 4.27. Area Under Curve indicating model performance of *Dipterocarpus indicus*

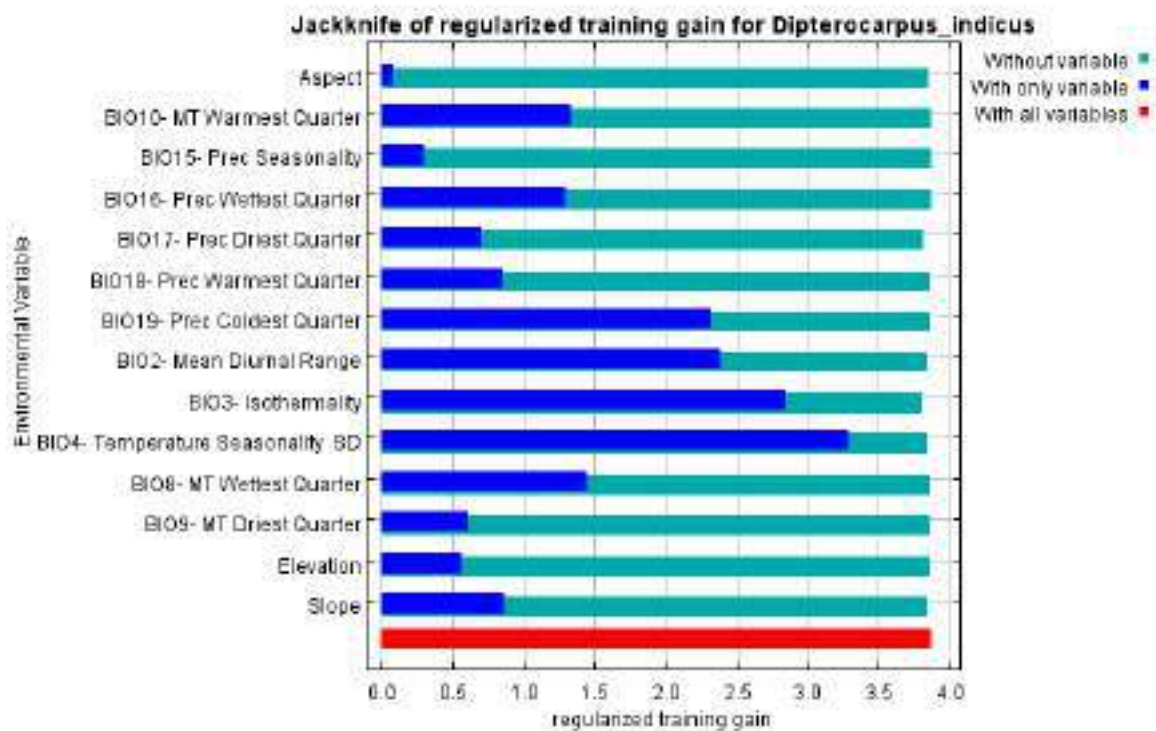


Fig. 4.28. Jackknife test of training gain showing bioclimatic variables of importance



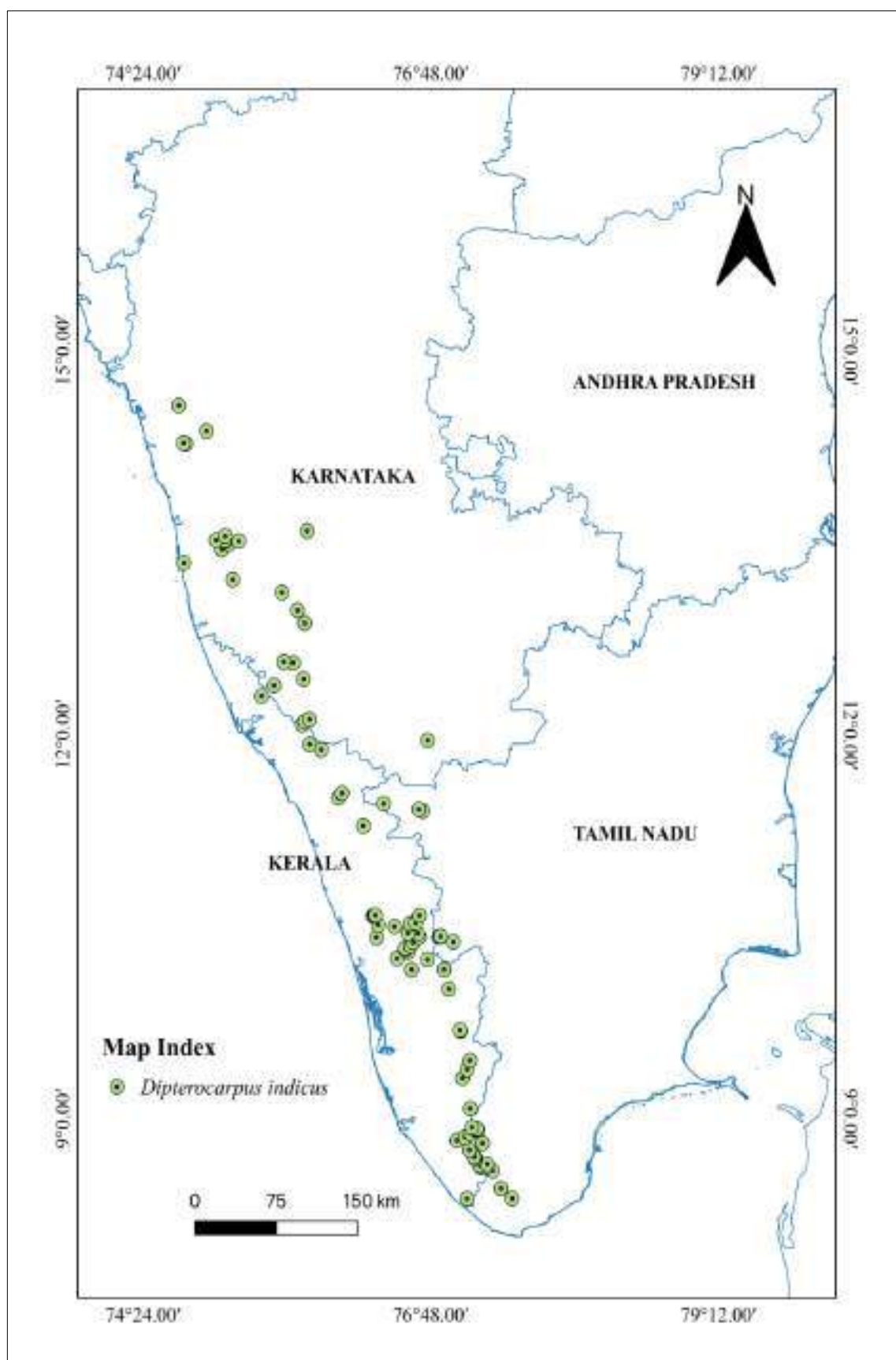


Fig. 4.29. Actual distribution of *Dipterocarpus indicus*



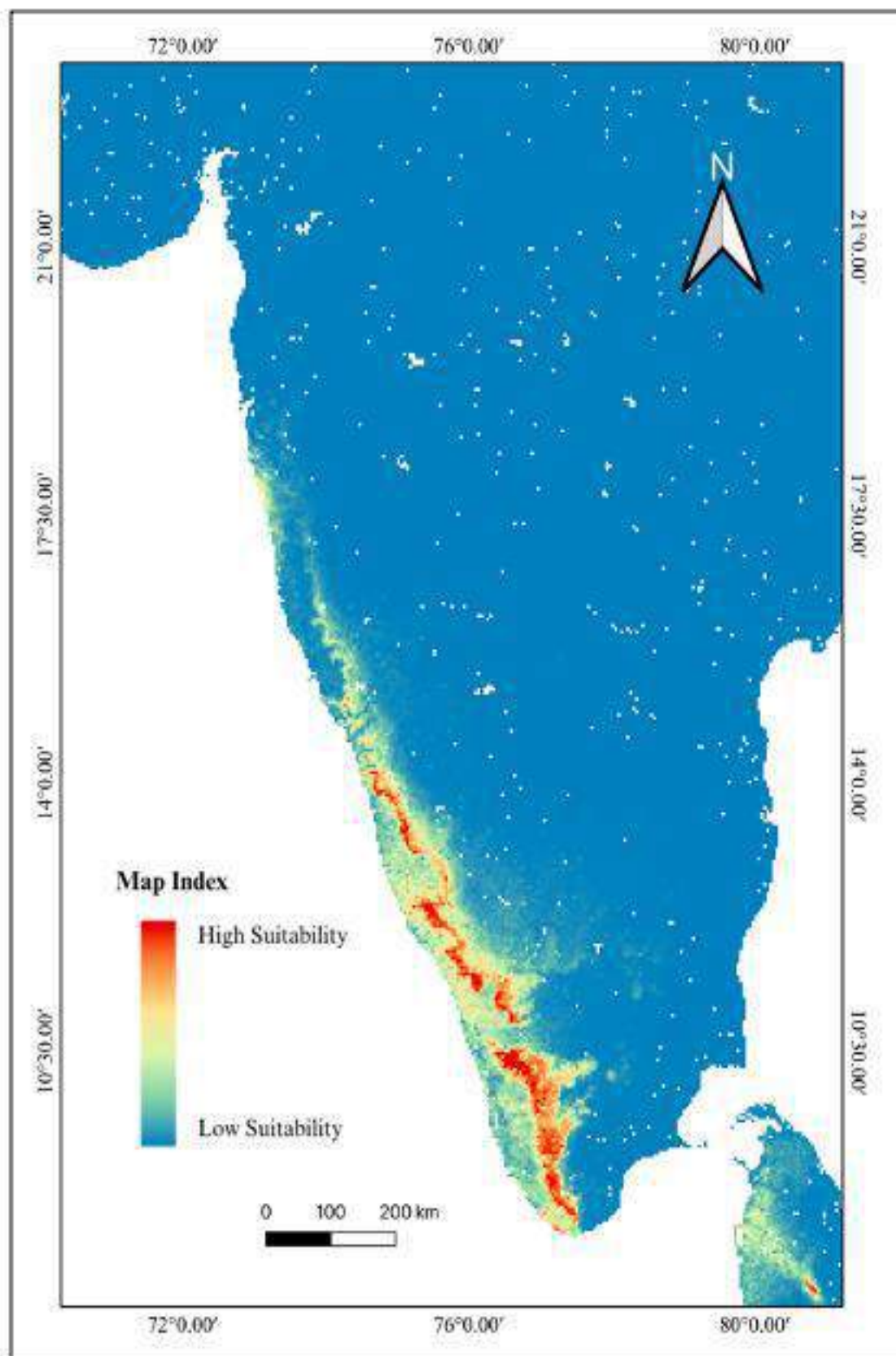


**Fig. 4.30.** Predicted habitat suitability of *Dipterocarpus indicus* using MaxEnt model under present climate scenario

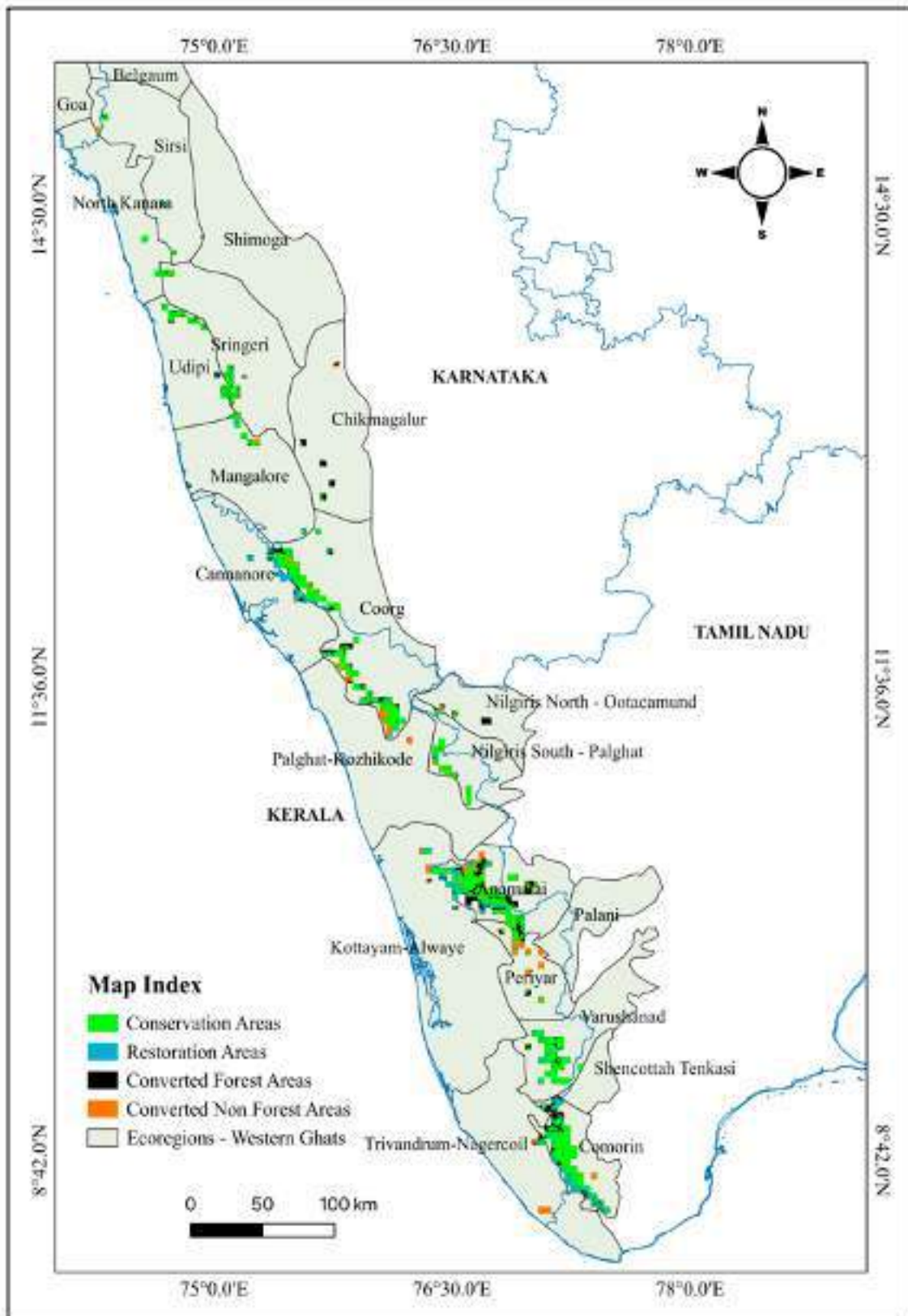


Fig. 4.31. Refined predicted area of *Dipterocarpus indicus* into potential conservation, restoration and irreversibly lost habitats at ecoregion level

### Eltonian Niche of *Dipterocarpus indicus* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Dipterocarpus indicus* is currently restricted to the 56 subpopulations within the Western Ghats, particularly in parts of Kerala, Tamil Nadu and Karnataka (Fig. 4.29). Under the current climate scenario, the MaxEnt model predicts a total of 5884.63 km<sup>2</sup> highly suitable habitat for *Dipterocarpus indicus* in the Western Ghats (Fig. 4.30). This predicted distribution spans over 17 distinct ecoregions (Fig. 4.31). The highest suitability predictions were concentrated in the Coorg (1255.38 km<sup>2</sup>), Anamalai (1241.98 km<sup>2</sup>), Comorin (1024.11 km<sup>2</sup>), Varushanad (542.26 km<sup>2</sup>), Periyar (263.55 km<sup>2</sup>), Nilgiris South – Palghat (252.85 km<sup>2</sup>) and Udipi (231.05 km<sup>2</sup>) ecoregions (Table 4.10).

**Table 4.10. Ecoregion wise habitat prediction for *Dipterocarpus indicus* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No. | Ecoregion                      | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|---------|--------------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1       | Anamalai                       | 1241.99                           | 641.31                               | 213.95                              | 269.78                                   | 116.95                                       |
| 2       | Cannanore                      | 179.28                            | 14.10                                | 132.44                              | 25.07                                    | 7.67                                         |
| 3       | Chikmagalur                    | 91.81                             | 7.09                                 | 6.92                                | 66.37                                    | 11.43                                        |
| 4       | Comorin                        | 1024.11                           | 566.65                               | 284.76                              | 143.60                                   | 29.11                                        |
| 5       | Coorg                          | 1255.38                           | 797.87                               | 142.87                              | 141.57                                   | 173.07                                       |
| 6       | Kottayam -<br>Alwaye           | 181.88                            | 32.50                                | 86.21                               | 20.47                                    | 42.71                                        |
| 7       | Mangalore                      | 124.46                            | 82.38                                | 20.27                               | 11.00                                    | 10.81                                        |
| 8       | Nilgiris North<br>- Ootacamund | 72.43                             | 14.31                                | 4.83                                | 41.21                                    | 12.09                                        |
| 9       | Nilgiris South<br>- Palghat    | 252.85                            | 173.97                               | 39.55                               | 6.64                                     | 32.69                                        |
| 10      | North Kanara                   | 38.54                             | 36.40                                | 00.00                               | 2.14                                     | 0.00                                         |

|              |                           |                |                |                |               |               |
|--------------|---------------------------|----------------|----------------|----------------|---------------|---------------|
| 11           | Palghat -<br>Kozhikode    | 17.86          | 00.00          | 00.00          | 1.01          | 16.85         |
| 12           | Periyar                   | 263.56         | 64.07          | 37.05          | 27.04         | 135.40        |
| 13           | Sirsi                     | 67.24          | 35.51          | 7.54           | 12.62         | 11.56         |
| 14           | Sringeri                  | 197.50         | 137.37         | 17.38          | 33.85         | 8.90          |
| 15           | Trivandrum -<br>Nagercoil | 102.43         | 12.84          | 15.77          | 12.41         | 61.41         |
| 16           | Udipi                     | 231.06         | 170.30         | 22.17          | 38.58         | 0.00          |
| 17           | Varushanad                | 542.27         | 421.22         | 81.96          | 35.07         | 4.01          |
| <b>Total</b> |                           | <b>5884.63</b> | <b>3207.89</b> | <b>1113.67</b> | <b>888.42</b> | <b>674.65</b> |

The initial modelling of the potential distribution for *Dipterocarpus indicus*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 5884.63 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.31.). A total of Conservation area spanning 3207.89 km<sup>2</sup>, Potential Ecorestoration area of 1113.66 km<sup>2</sup>, irreversibly converted forest habitat (888.42 km<sup>2</sup>) and converted non-forested human-dominated areas (674.65 km<sup>2</sup>). The ecoregions such as Coorg (797.87 km<sup>2</sup>), Anamalai (641.30 km<sup>2</sup>), Comorin (566.64 km<sup>2</sup>), Varushanad (421.22 km<sup>2</sup>), Nilgiris South – Palghat (173.97 km<sup>2</sup>) and Udipi (170.30 km<sup>2</sup>) represent maximum potential conservation areas suitable for *D. indicus*. The degraded habitats are also represented by ecoregions such as Comorin (284.76 km<sup>2</sup>), Anamalai (213.94 km<sup>2</sup>), Coorg (142.86 km<sup>2</sup>), Cannanore (132.43 km<sup>2</sup>), Kottayam – Alwaye (86.21 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 15 % of converted forest habitat to the species are represented with Anamalai (269.77 km<sup>2</sup>), Comorin (143.59 km<sup>2</sup>), Coorg (141.57 km<sup>2</sup>), Chikmagalur (66.36 km<sup>2</sup>), Nilgiris North – Ootacamund (41.20 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Dipterocarpus indicus* ecological niche.

#### 4.3.7. Grinnellian Niche of *Elaeocarpus munroi* Using Bioclimatic Factors

The MaxEnt model for *Elaeocarpus munroi* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.995 (Fig. 4.32). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Elaeocarpus munroi* (Fig. 4.33). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (48.2 %) and Precipitation of Coldest Quarter (22.5%) contributed most to the model. This is followed by Isothermality (9.6%), Precipitation Seasonality (2.8%) and Precipitation of Driest Month (0.5%) (Appendix II). The Elevation also emerged as an important non-bioclimatic variable, contributing 17.6% to model gain, indicating that topographic constraints partly define the niche of this species.

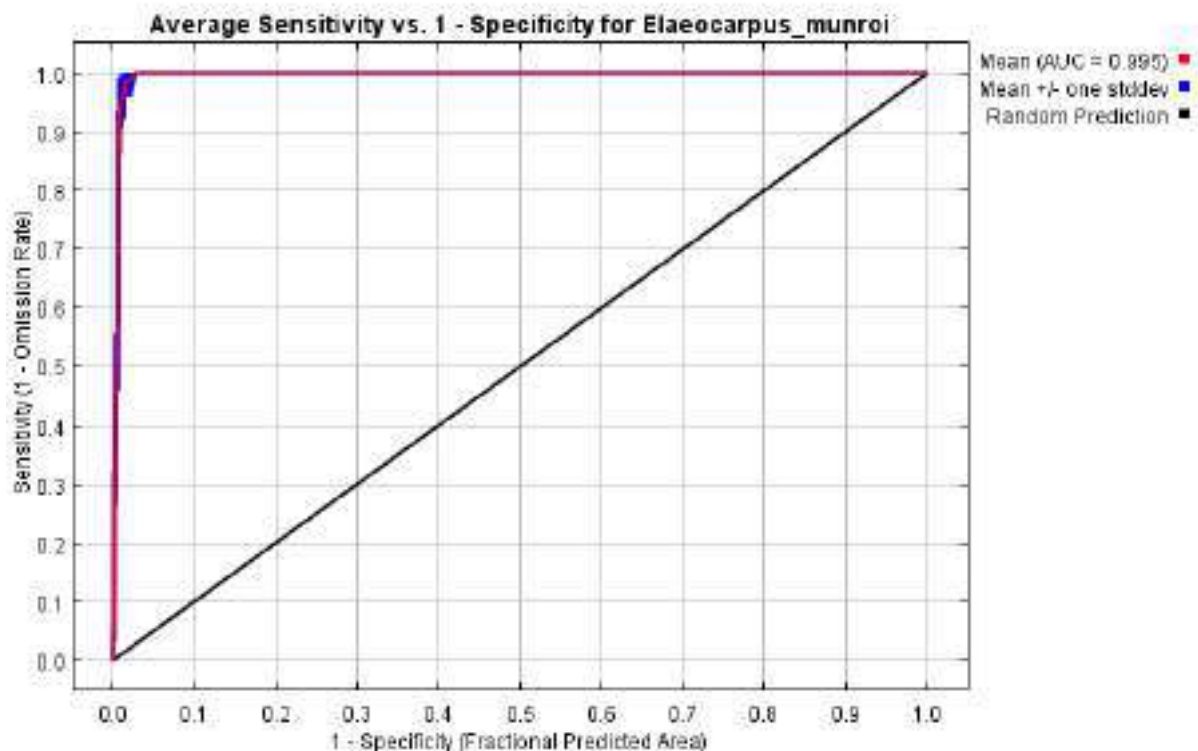


**Fig. 4.32.** Area Under Curve indicating model performance of *Elaeocarpus munroi*

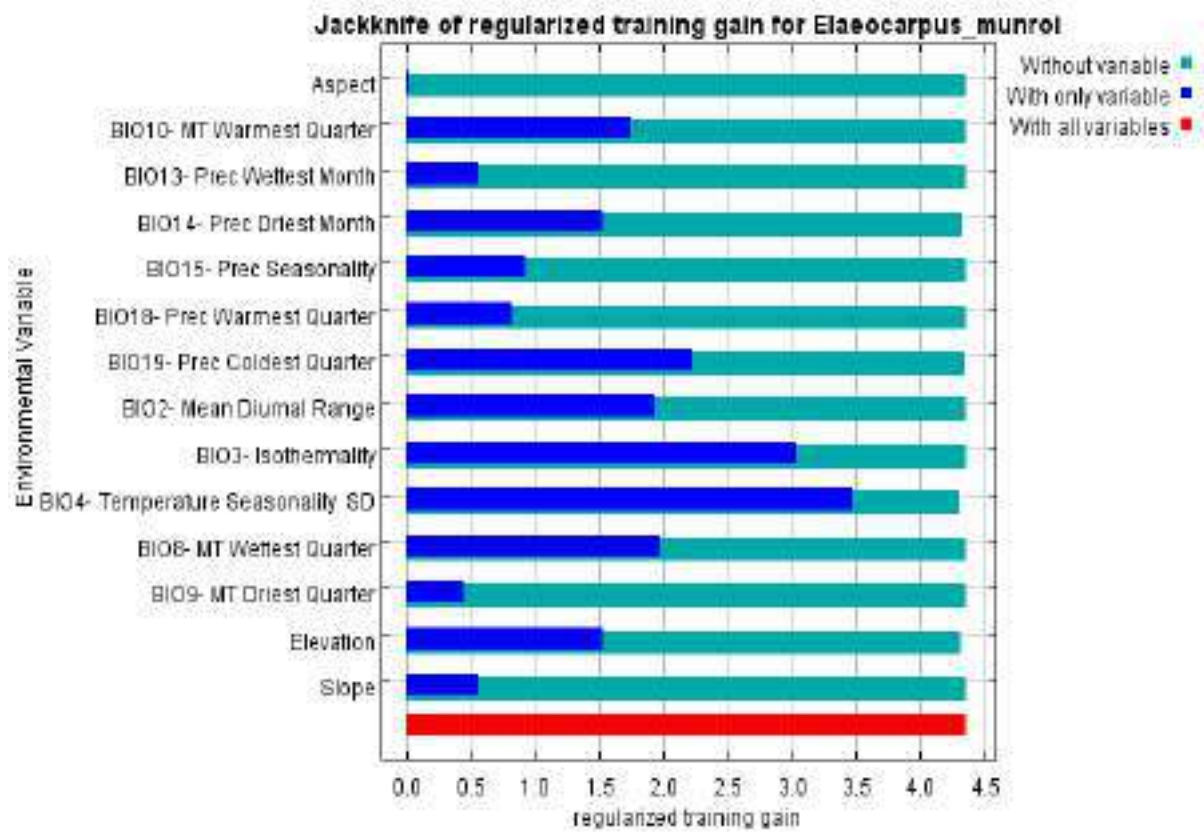


**Fig. 4.33. Jackknife test of training gain showing bioclimatic variables of importance**



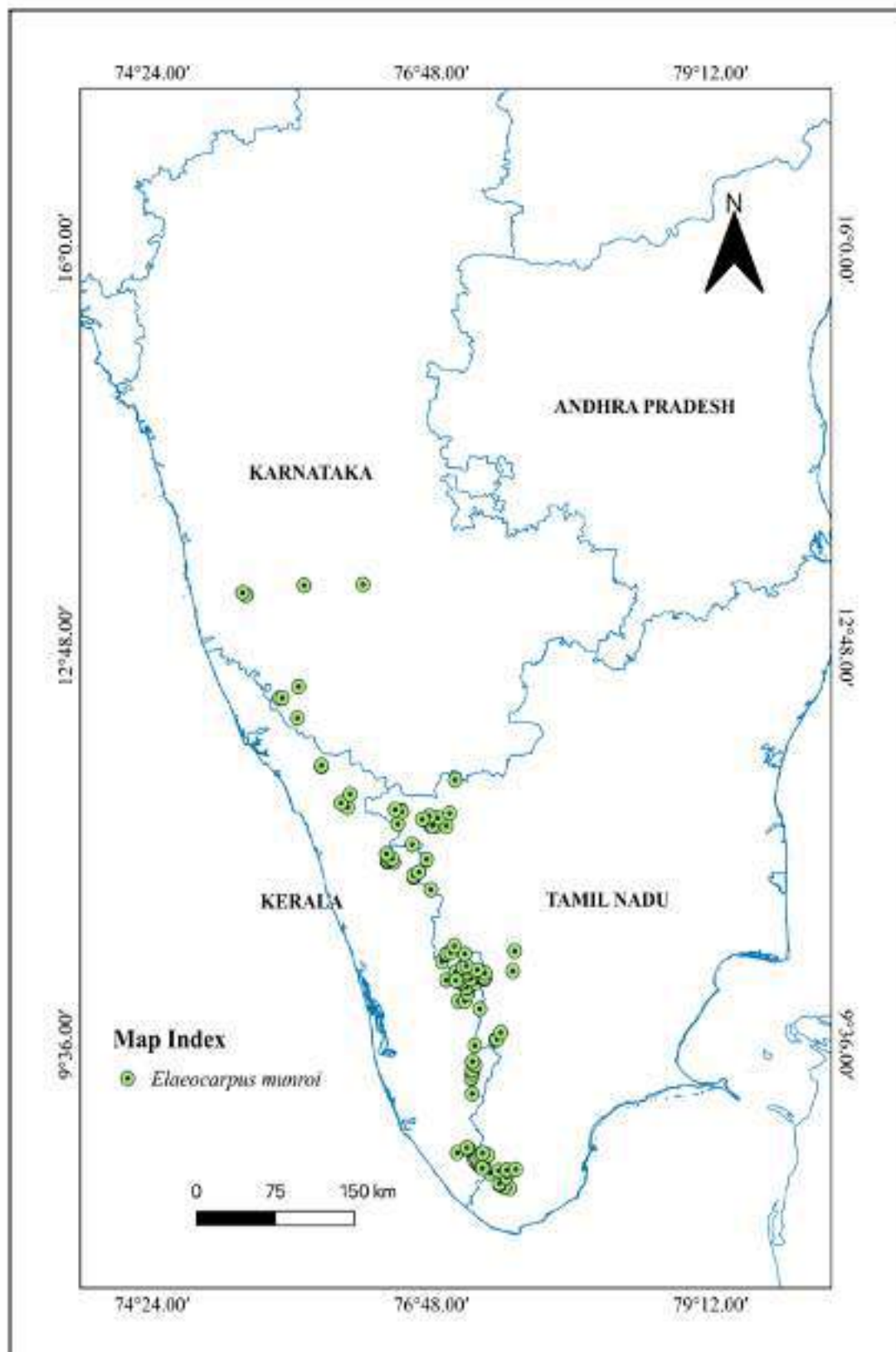


Fig. 4.34. Actual distribution of *Elaeocarpus munroi*



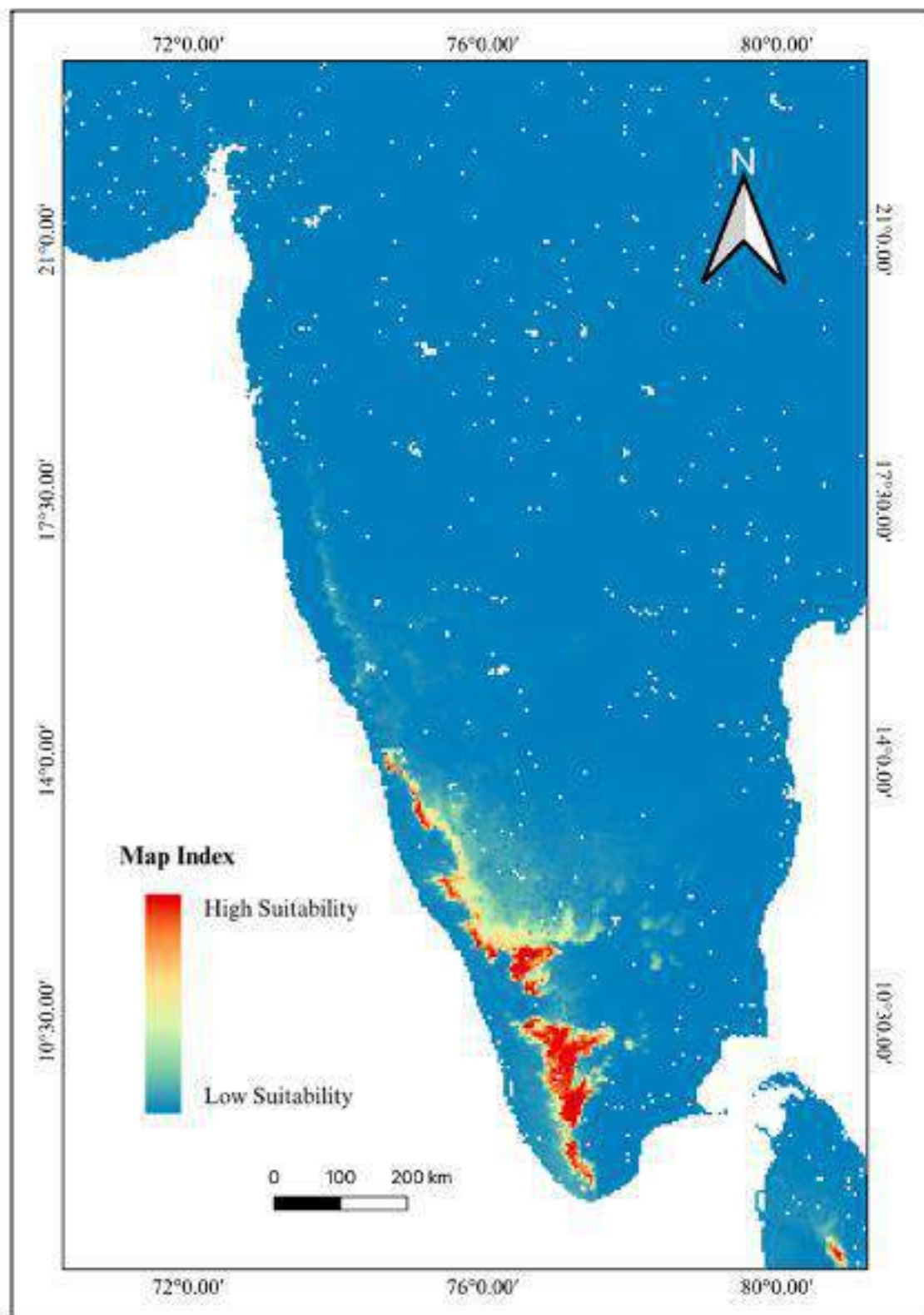


**Fig. 4.35. Predicted habitat suitability of *Elaeocarpus munroi* using MaxEnt model under present climate scenario**

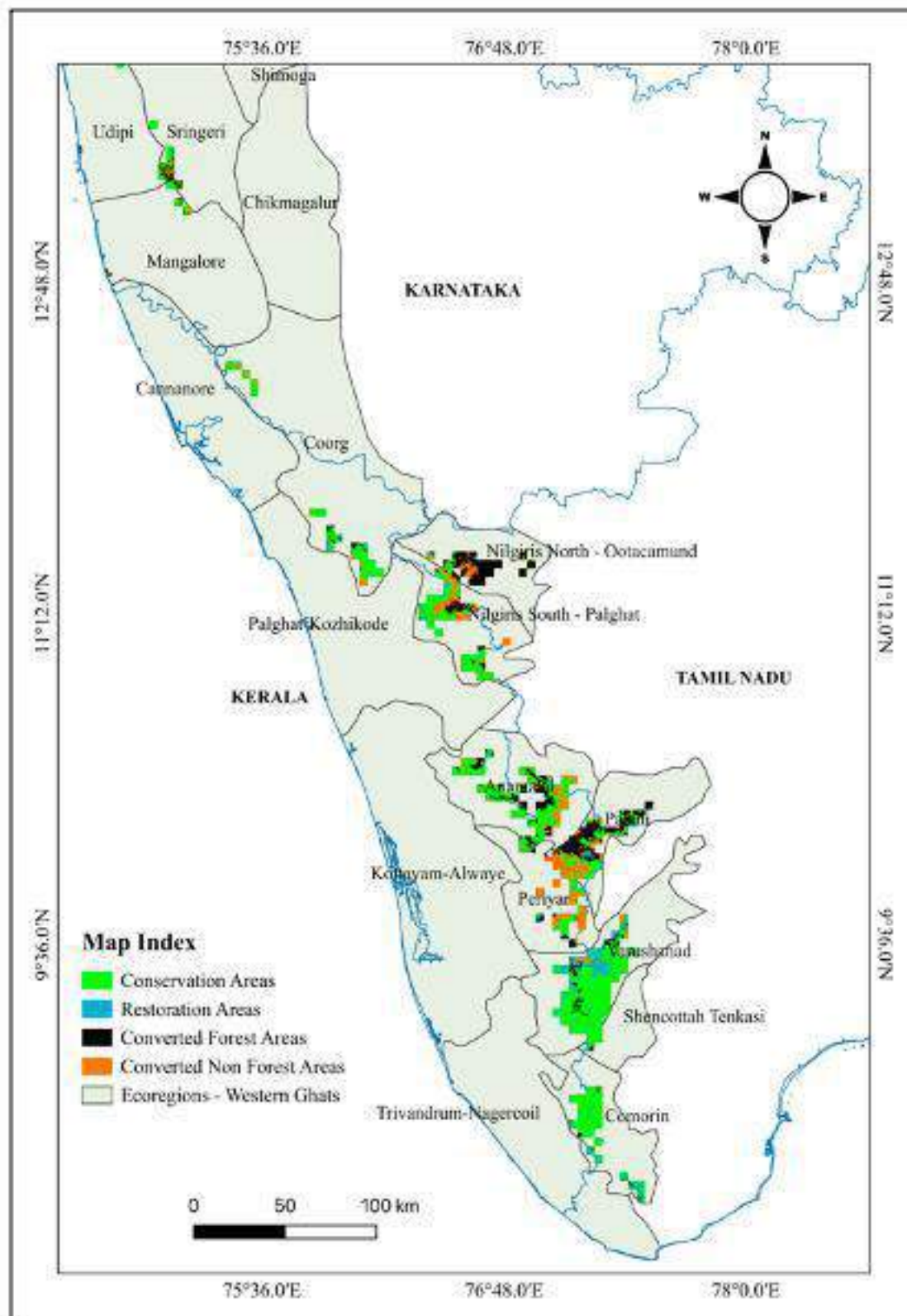


**Fig. 4.36. Refined predicted area of *Elaeocarpus munroi* into potential conservation, restoration and irreversibly lost habitats at ecoregion level**

### Eltonian Niche of *Elaeocarpus munroi* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Elaeocarpus munroi* is currently restricted to the 42 subpopulations within the Western Ghats, particularly in parts of Kerala, Tamil Nadu and Karnataka (Fig. 4.34). Under the current climate scenario, the MaxEnt model predicts a total of 6122.124 km<sup>2</sup> of highly suitable habitat for *Elaeocarpus munroi* in the Western Ghats (Fig. 4.35). This predicted distribution spans over 12 distinct ecoregions. The highest suitability predictions were concentrated in the Anamalai (1012.12 km<sup>2</sup>), Comorin (538.952 km<sup>2</sup>), Coorg (439.507 km<sup>2</sup>) and Mangalore (53.005 km<sup>2</sup>) ecoregions (Table 4.11).

**Table 4.11. Ecoregion wise habitat prediction for *Elaeocarpus munroi* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No. | Ecoregion                         | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|---------|-----------------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1       | Anamalai                          | 1012.12                           | 591.17                               | 27.243                              | 215.997                                  | 177.705                                      |
| 2       | Comorin                           | 538.952                           | 422.28                               | 89.982                              | 20.686                                   | 6                                            |
| 3       | Coorg                             | 439.507                           | 310.85                               | 31.918                              | 28.645                                   | 68.093                                       |
| 4       | Mangalore                         | 53.005                            | 39.11                                | 0.001                               | 5.559                                    | 8.33                                         |
| 5       | Nilgiris<br>North -<br>Ootacamund | 442.94                            | 43.02                                | 8.664                               | 317.607                                  | 73.649                                       |
| 6       | Nilgiris<br>South -<br>Palghat    | 715.049                           | 405.18                               | 43.286                              | 79.935                                   | 186.648                                      |
| 7       | Palani                            | 779.94                            | 226.76                               | 36.467                              | 327.44                                   | 189.273                                      |
| 8       | Periyar                           | 459.103                           | 150.85                               | 37.929                              | 49.852                                   | 220.466                                      |

|              |                       |                 |                 |                |                |               |
|--------------|-----------------------|-----------------|-----------------|----------------|----------------|---------------|
| 9            | Shencottah<br>Tenkasi | 57.874          | 42.86           | 6.095          | 5.087          | 3.828         |
| 10           | Sringeri              | 150.386         | 82.77           | 5.087          | 40.988         | 21.532        |
| 11           | Udipi                 | 83.348          | 61.85           | 0.907          | 15.825         | 4.765         |
| 12           | Varushanad            | 1389.9          | 1014.9          | 257.43         | 71.659         | 45.911        |
| <b>Total</b> |                       | <b>6122.124</b> | <b>3391.635</b> | <b>545.009</b> | <b>1179.28</b> | <b>1006.2</b> |

The initial modelling of the potential distribution for *Elaeocarpus munroi*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 6122.124 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.36). A total of Conservation area spanning 3391.63 km<sup>2</sup>, Potential Ecorestoration area of 545.00 km<sup>2</sup>, irreversibly converted forest habitat (1179.28 km<sup>2</sup>) and converted non-forested human-dominated areas (1006.2 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Varushanad (1014.9 km<sup>2</sup>), Anamalai (591.17 km<sup>2</sup>), Comorin (422.28 km<sup>2</sup>), Nilgiris South – Palghat (405.18 km<sup>2</sup>) and Coorg (310.85 km<sup>2</sup>) represent maximum potential conservation areas suitable for *E. munroi*. The degraded habitats are also represented by ecoregions such as Varushanad (257.43 km<sup>2</sup>), Comorin (89.98 km<sup>2</sup>), Nilgiris South – Palghat (43.28 km<sup>2</sup>) and Periyar (37.92 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 19 % of converted forest habitat to the species are represented with Palani (327.44 km<sup>2</sup>), Nilgiris North – Ootacamund (317.60 km<sup>2</sup>), Anamalai (215.99 km<sup>2</sup>) and Nilgiris South – Palghat (79.93 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Elaeocarpus munroi* ecological niche.

#### 4.3.8. Grinnellian Niche of *Elaeocarpus recurvatus* Using Bioclimatic Factors

The MaxEnt model for *Elaeocarpus recurvatus* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.998 (Fig. 4.37). This value indicates excellent model

performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Elaeocarpus recurvatus* (Fig. 4.38). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (50.8%) and Precipitation of Coldest Quarter (10.8%) contributed most to the model. This is followed by Isothermality (7.5%), Precipitation of Driest Month (4.7%) and Mean Diurnal Range (0.6%) (Appendix II). The Elevation also emerged as an important non-bioclimatic variable, contributing 23.3% to model gain, indicating that topographic constraints partly define the niche of this species.

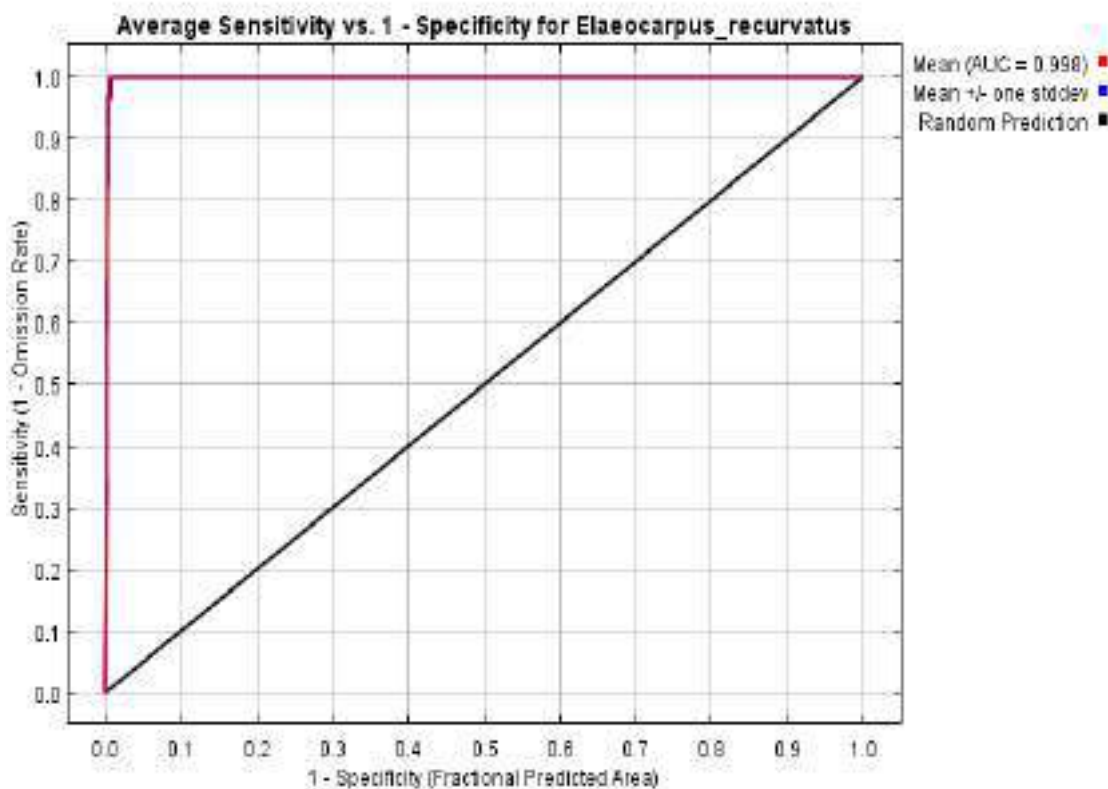


**Fig. 4.37.** Area Under Curve indicating model performance of *Elaeocarpus recurvatus*



**Fig. 4.38. Jackknife test of training gain showing bioclimatic variables of importance**

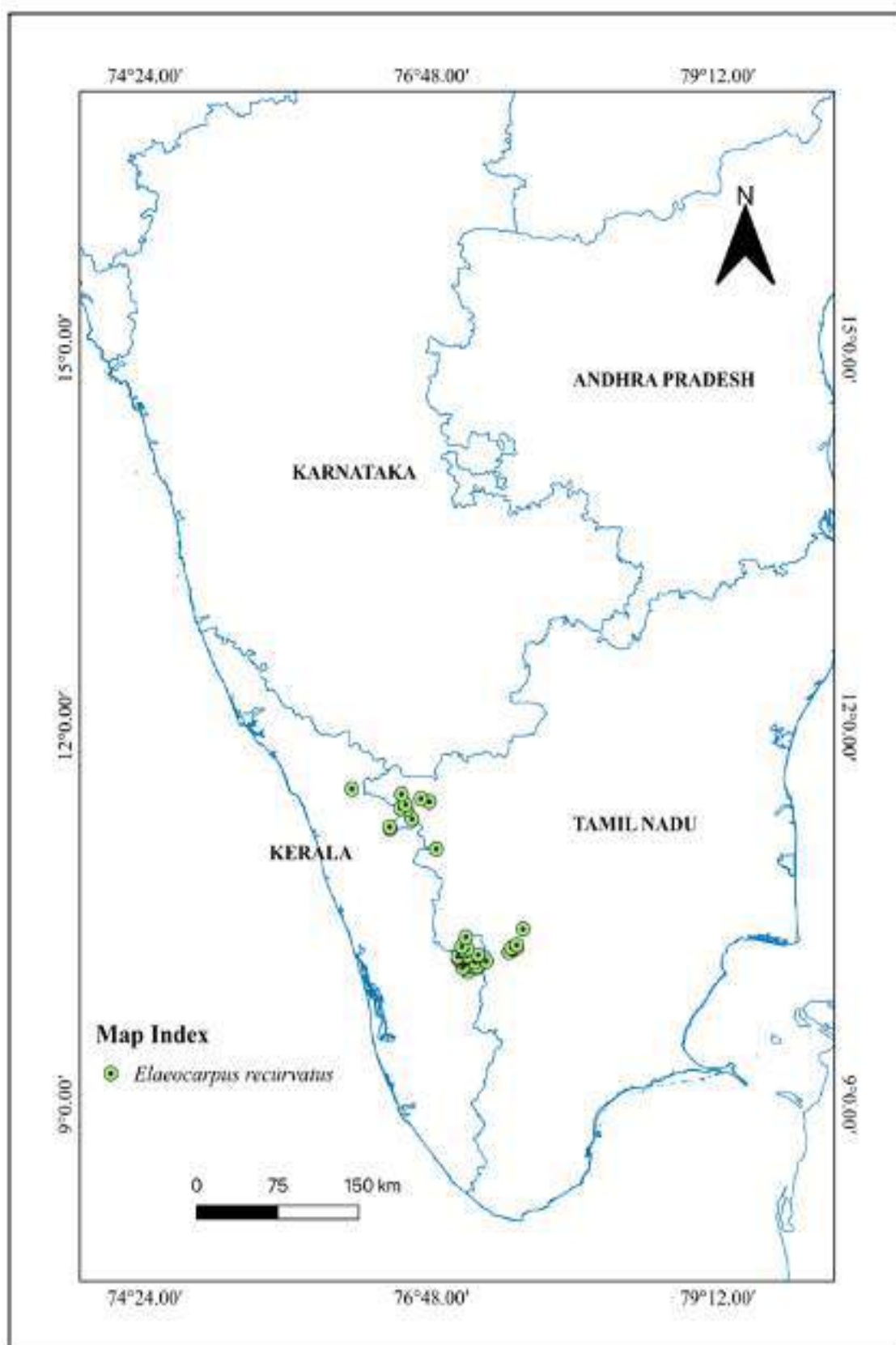


Fig. 4.39. Actual distribution of *Elaeocarpus recurvatus*



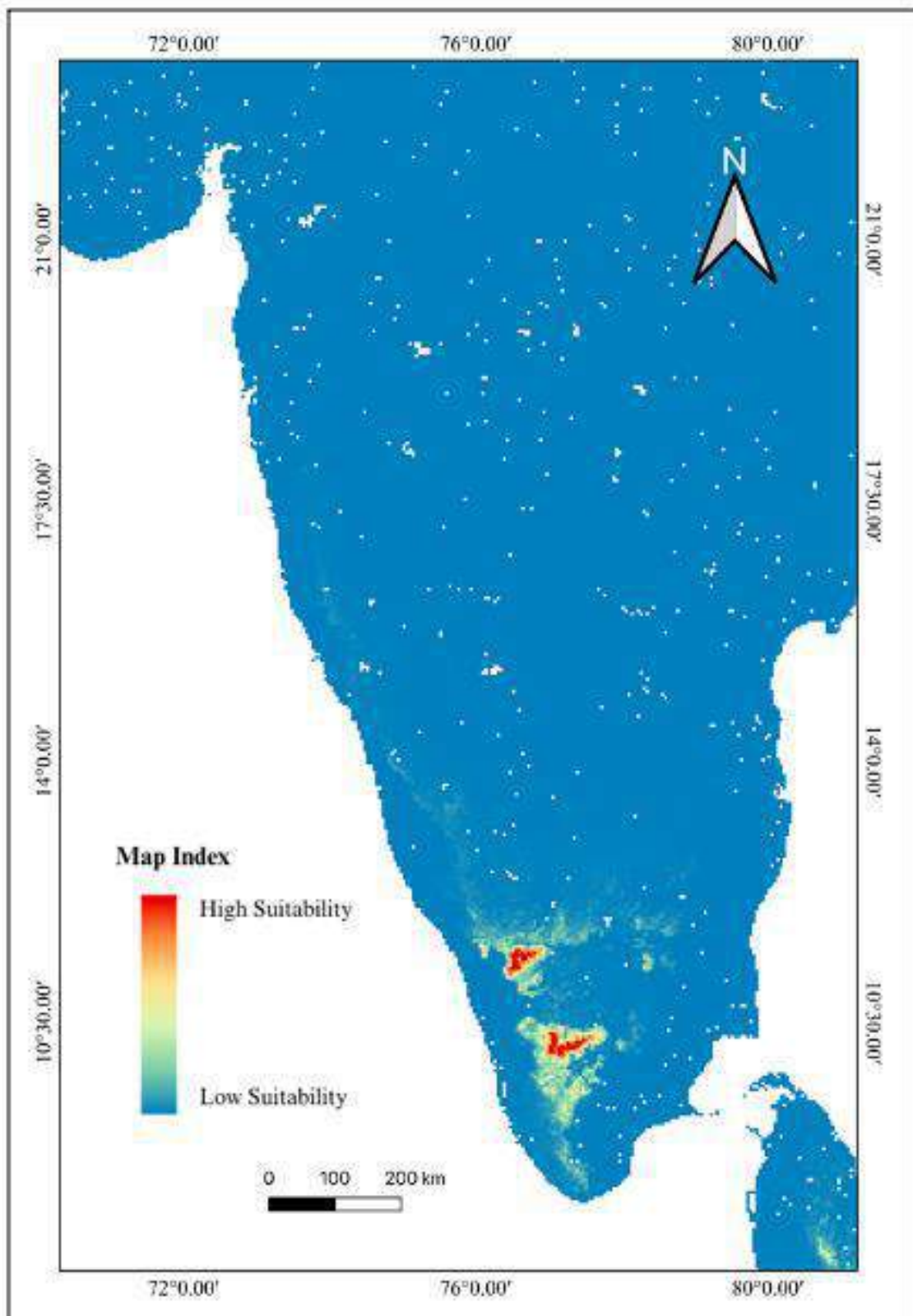


**Fig. 4.40.** Predicted habitat suitability of *Elaeocarpus recurvatus* using MaxEnt model under present climate scenario

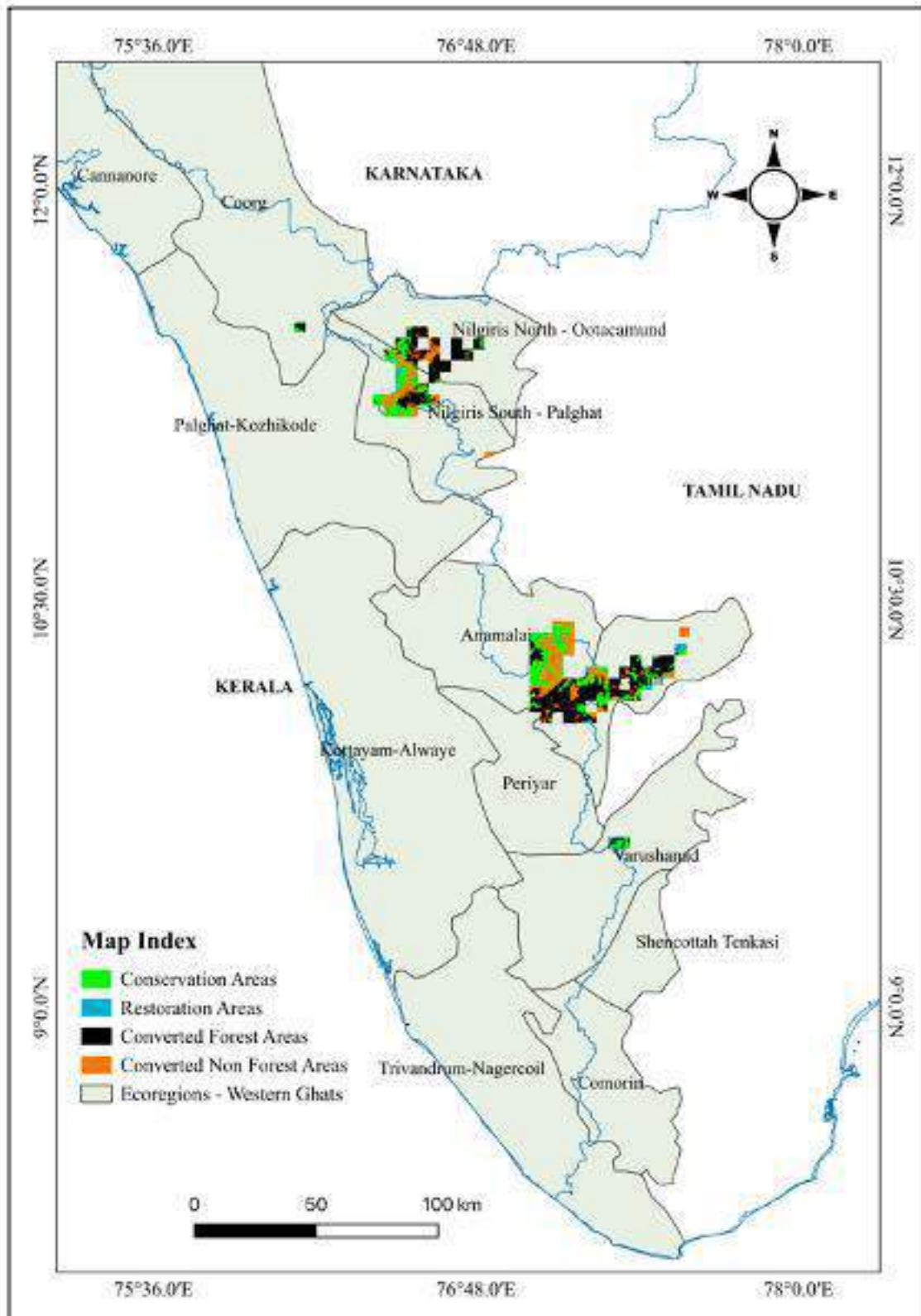


**Fig. 4.41.** Refined predicted area of *Elaeocarpus recurvatus* into potential conservation, restoration and irreversibly lost habitats at ecoregion level

### Eltonian Niche of *Elaeocarpus recurvatus* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Elaeocarpus recurvatus* is currently restricted to 15 subpopulations within the Western Ghats, particularly in parts of Kerala and Tamil Nadu (Fig. 4.39). Under the current climate scenario, the MaxEnt model predicts a total of 1982.53 km<sup>2</sup> of highly suitable habitat for *Elaeocarpus recurvatus* in the Western Ghats (Fig. 4.40). This predicted distribution spans over eight distinct ecoregions. The highest suitability predictions were concentrated in the Palani (622.52 km<sup>2</sup>), Anamalai (583.43 km<sup>2</sup>), Nilgiris South – Palghat (369.52 km<sup>2</sup>), Nilgiris South – Ootacamund (337.93 km<sup>2</sup>) ecoregions (Table 12).

**Table 4.12. Ecoregion wise habitat prediction for *Elaeocarpus recurvatus* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No.      | Ecoregion                   | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|--------------|-----------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1            | Anamalai                    | 583.44                            | 209.41                               | 7.11                                | 160.52                                   | 206.40                                       |
| 2            | Coorg                       | 17.33                             | 6.34                                 | 0.37                                | 10.62                                    | 0.00                                         |
| 4            | Nilgiris South - Ootacamund | 337.93                            | 57.90                                | 1.30                                | 225.54                                   | 53.19                                        |
| 5            | Nilgiris South - Palghat    | 369.53                            | 138.98                               | 12.59                               | 77.91                                    | 140.05                                       |
| 6            | Palani                      | 622.52                            | 146.58                               | 00.00                               | 348.55                                   | 127.40                                       |
| 7            | Periyar                     | 9.64                              | 0.11                                 | 24.63                               | 9.38                                     | 24.48                                        |
| 8            | Varushanad                  | 42.15                             | 18.90                                | 9.77                                | 12.67                                    | 0.81                                         |
| <b>Total</b> |                             | <b>1982.53</b>                    | <b>578.22</b>                        | <b>55.77</b>                        | <b>845.17</b>                            | <b>552.34</b>                                |

The initial modelling of the potential distribution for *Elaeocarpus recurvatus*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 1982.53 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.41). A total of Conservation area spanning 578.22 km<sup>2</sup>, Potential Ecorestoration area of 55.77 km<sup>2</sup>, irreversibly converted forest habitat (845.17 km<sup>2</sup>) and converted non-forested human-dominated areas (552.34 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Anamalai (209.40 km<sup>2</sup>), Palani (146.57 km<sup>2</sup>), Nilgiris South – Palghat (138.98 km<sup>2</sup>), Nilgiris South – Ootacamund (57.90 km<sup>2</sup>) and Varushanad (18.9 km<sup>2</sup>) represent maximum potential conservation areas suitable for *E. recurvatus*. The degraded habitats are also represented by ecoregions such as Periyar (24.63 km<sup>2</sup>), Nilgiris South – Palghat (12.59 km<sup>2</sup>), Varushanad (9.76 km<sup>2</sup>) and Anamalai (7.10 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 16 % of converted forest habitat to the species are represented with Palani (348.54 km<sup>2</sup>), Nilgiris South – Ootacamund (225.53 km<sup>2</sup>), Anamalai (160.51 km<sup>2</sup>) and Nilgiris South – Palghat (77.90 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Elaeocarpus recurvatus* ecological niche.

#### 4.3.9. Grinnellian Niche of *Ficus beddomei* Using Bioclimatic Factors

The MaxEnt model for *Ficus beddomei* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.995 (Fig. 4.42). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Ficus beddomei* (Fig. 4.43). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (44.8%) and Precipitation Coldest Quarter (28.6%) contributed most to the model. This is followed by Isothermality (9.5%),

Precipitation of Wettest Quarter (1.4%) and Precipitation of Driest Quarter (0.8%) (Appendix II). The Elevation also emerged as an important non-bioclimatic variable, contributing 12.5% to model gain, indicating that topographic constraints partly define the niche of this species.



**Fig. 4.42.** Area Under Curve indicating model performance of *Ficus beddomei*

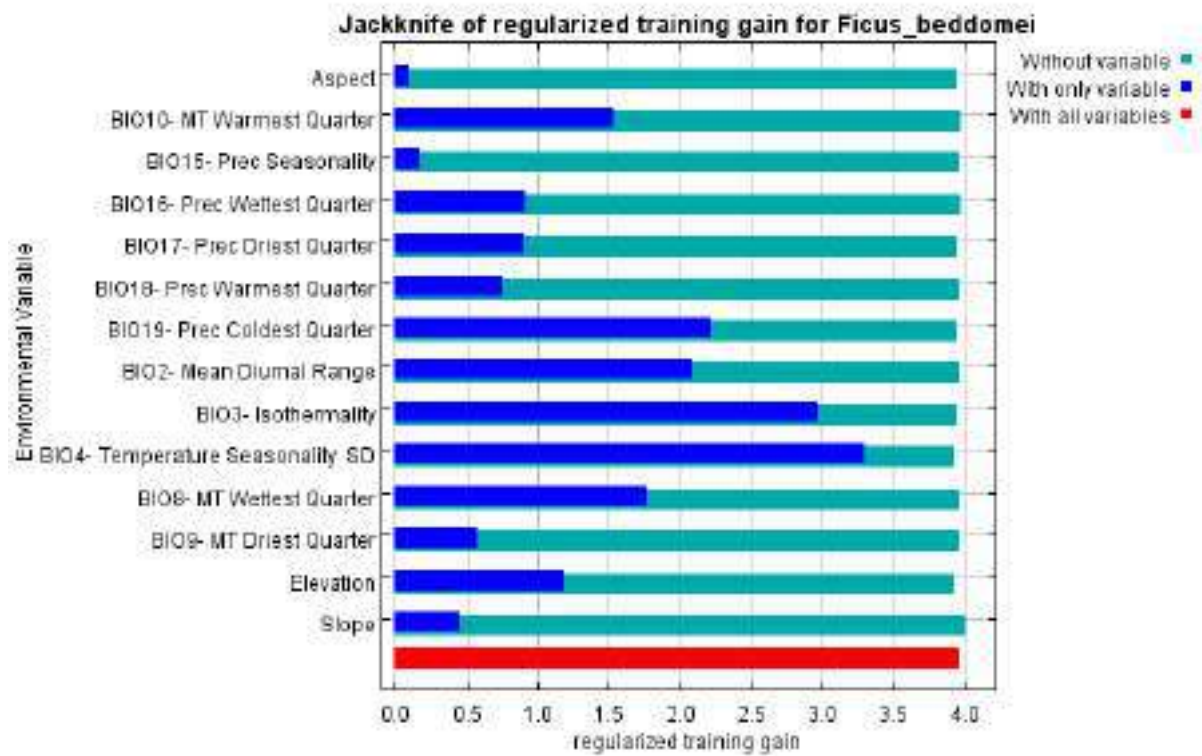


**Fig. 4.43. Jackknife test of training gain showing bioclimatic variables of importance**

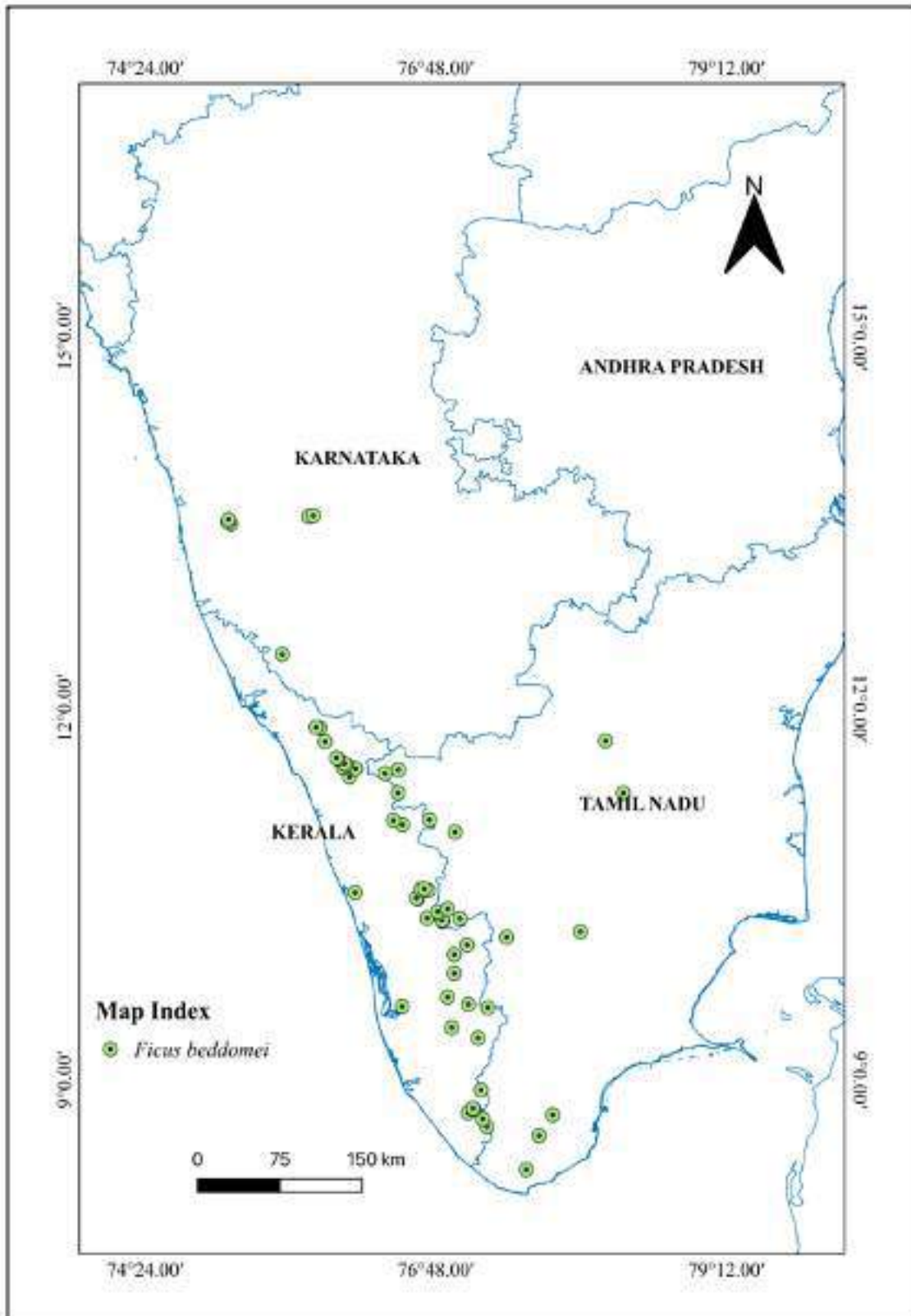


Fig. 4.44. Actual distribution of *Ficus beddomei*



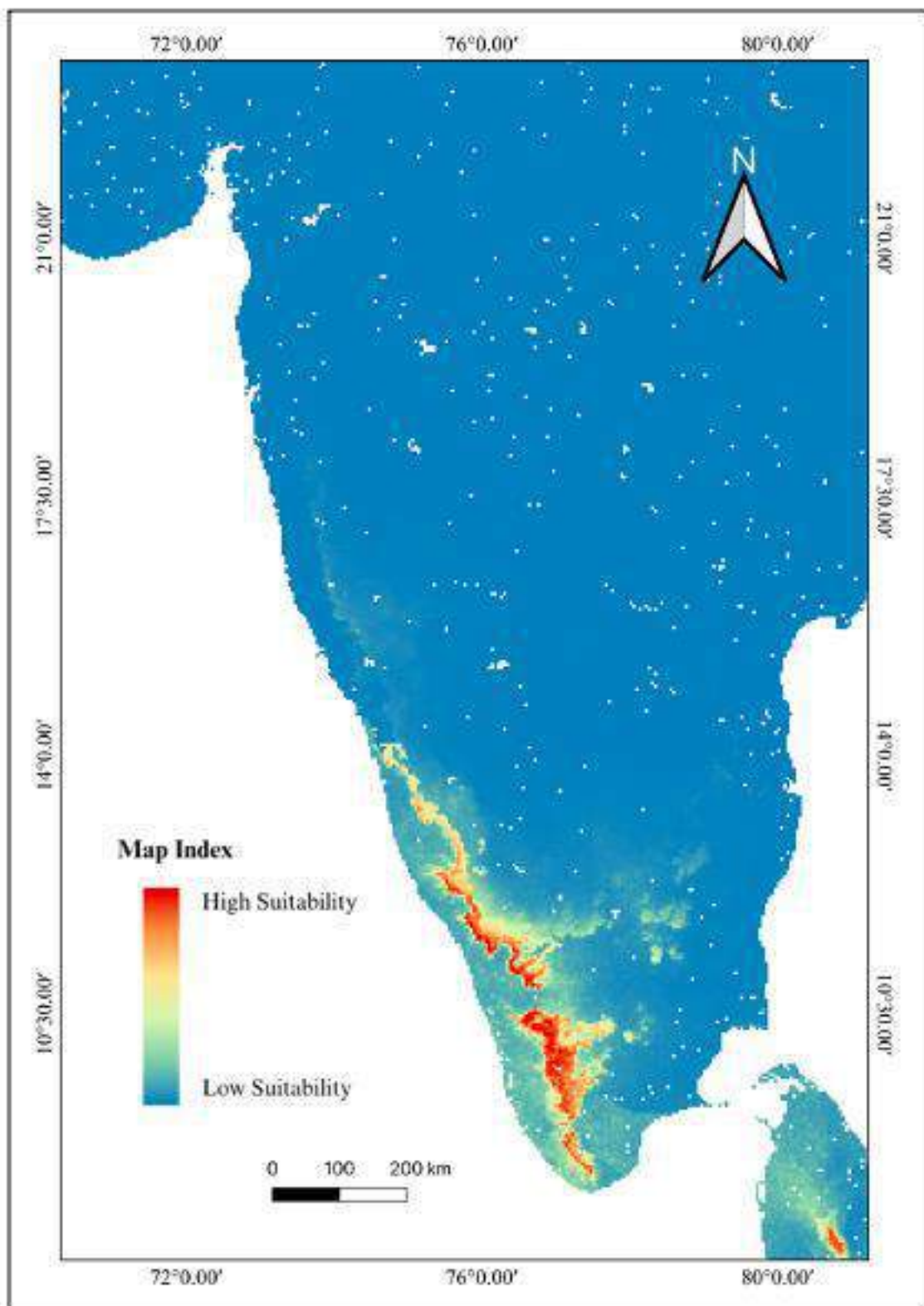


**Fig. 4.45.** Predicted habitat suitability of *Ficus beddomei* using MaxEnt model under present climate scenario

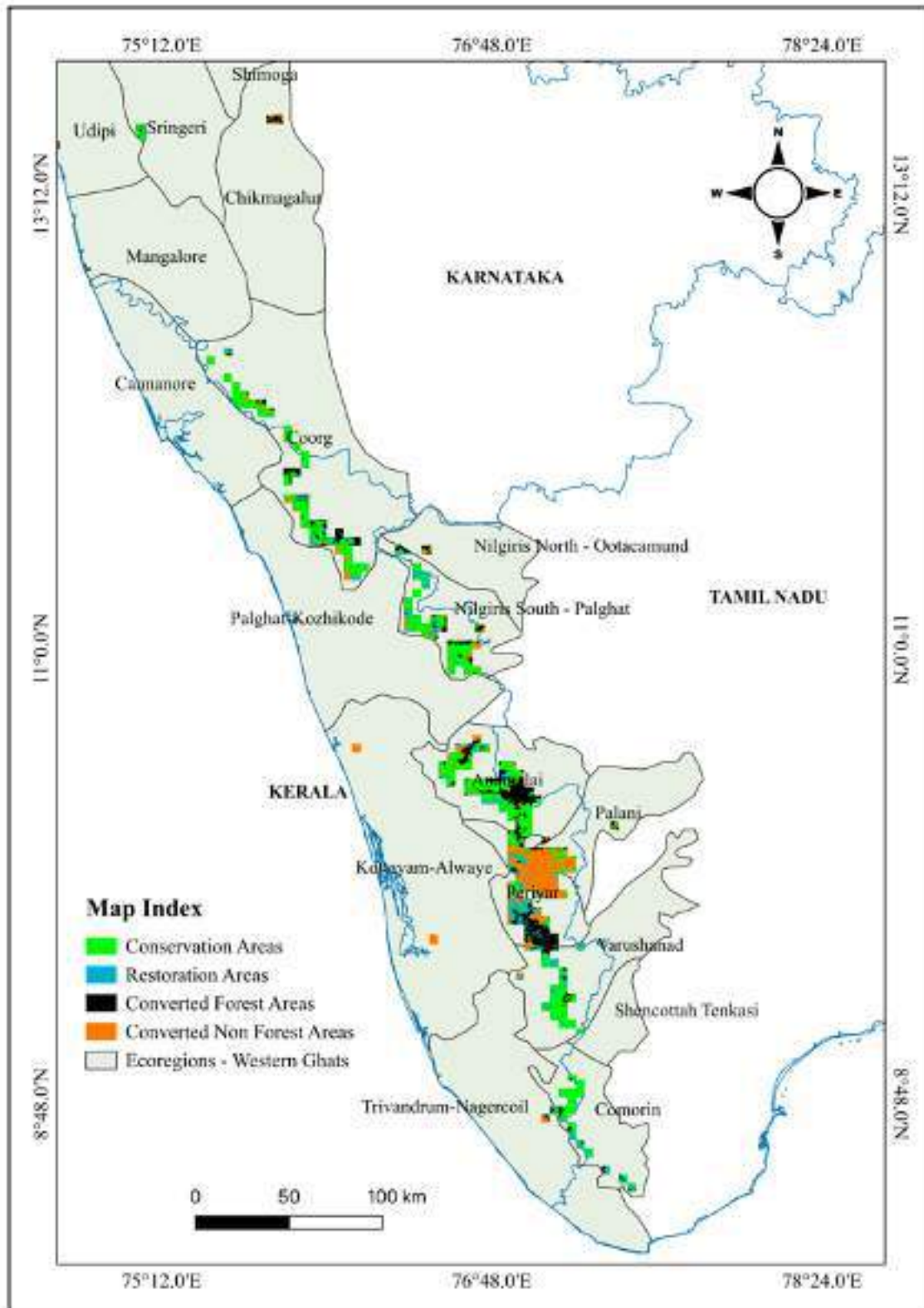


**Fig. 4.46. Refined predicted area of *Ficus beddomei* into potential conservation, restoration and irreversibly lost habitats at ecoregion level**

### Eltonian Niche of *Ficus beddomei* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Ficus beddomei* is currently restricted to 25 subpopulations within the Western Ghats, particularly in parts of Kerala, Tamil Nadu and Karnataka (Fig. 4.44). Under the current climate scenario, the MaxEnt model predicts a total of 5089.89 km<sup>2</sup> of highly suitable habitat for *Ficus beddomei* in the Western Ghats (Table 4.45). This predicted distribution spans over 12 distinct ecoregions. The highest suitability predictions were concentrated in the Periyar (1162.89 km<sup>2</sup>), Anamalai (1125.46 km<sup>2</sup>), Coorg (949.24 km<sup>2</sup>), Nilgiris South – Palghat (687.81 km<sup>2</sup>) and Varushanad (439.77 km<sup>2</sup>) ecoregions (Table 4.13).

**Table 4.13. Ecoregion wise habitat prediction for *Ficus beddomei* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No. | Ecoregion                         | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|---------|-----------------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1       | Anamalai                          | 1125.46                           | 633.04                               | 78.66                               | 323.30                                   | 90.47                                        |
| 2       | Chikmagalur                       | 40.96                             | 2.11                                 | 00.00                               | 25.53                                    | 13.33                                        |
| 3       | Comorin                           | 336.29                            | 222.27                               | 83.28                               | 28.36                                    | 2.38                                         |
| 4       | Coorg                             | 949.25                            | 640.43                               | 70.22                               | 139.64                                   | 98.95                                        |
| 5       | Kottayam -<br>Alwaye              | 44.33                             | 00.00                                | 00.00                               | 00.00                                    | 44.33                                        |
| 6       | Nilgiris<br>North -<br>Ootacamund | 26.04                             | 1.24                                 | 3.19                                | 12.86                                    | 8.76                                         |
| 7       | Nilgiris<br>South -<br>Palghat    | 687.81                            | 412.60                               | 114.80                              | 75.33                                    | 85.08                                        |
| 8       | Palani                            | 201.47                            | 57.18                                | 5.82                                | 18.42                                    | 120.06                                       |

|              |                           |                |                |               |               |                |
|--------------|---------------------------|----------------|----------------|---------------|---------------|----------------|
| 9            | Periyar                   | 1162.89        | 131.06         | 241.31        | 239.02        | 551.50         |
| 10           | Sringeri                  | 43.09          | 32.81          | 4.79          | 5.49          | 0.00           |
| 11           | Trivandrum -<br>Nagercoil | 32.50          | 3.55           | 7.67          | 8.57          | 12.71          |
| 12           | Varushanad                | 439.78         | 284.92         | 95.14         | 44.43         | 15.29          |
| <b>Total</b> |                           | <b>5089.89</b> | <b>2421.21</b> | <b>704.87</b> | <b>920.94</b> | <b>1042.87</b> |

The initial modelling of the potential distribution for *Ficus beddomei*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 5089.89 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.6.). A total of Conservation area spanning 2421.21 km<sup>2</sup>, Potential Ecorestoration area of 704.87 km<sup>2</sup>, irreversibly converted forest habitat (920.94 km<sup>2</sup>) and converted non-forested human-dominated areas (1042.87 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Coorg (640.43 km<sup>2</sup>), Anamalai (633.04 km<sup>2</sup>), Nilgiris South – Palghat (412.60 km<sup>2</sup>), Varushanad (284.92 km<sup>2</sup>), Comorin (222.27 km<sup>2</sup>), Periyar (131.05 km<sup>2</sup>) represent maximum potential conservation areas suitable for *Ficus beddomei*. The degraded habitats are also represented by ecoregions such as Periyar (241.31 km<sup>2</sup>), Nilgiris South – Palghat (114.80 km<sup>2</sup>), Varushanad (95.13 km<sup>2</sup>), Comorin (83.27 km<sup>2</sup>), Anamalai (78.65 km<sup>2</sup>), Coorg (70.22 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 18 % of converted forest habitat to the species are represented with Anamalai (323.29 km<sup>2</sup>), Periyar (239.02 km<sup>2</sup>), Coorg (139.64 km<sup>2</sup>), Nilgiris South – Palghat (75.33 km<sup>2</sup>), Varushanad (44.42 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to ecological niche of *Ficus beddomei*.

#### 4.3.10. Grinnellian Niche of *Garcinia wightii* Using Bioclimatic Factors

The MaxEnt model for *Garcinia wightii* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.997 (Fig. 4.47). This value indicates excellent model performance

according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Garcinia wightii* (Fig. 4.48). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (38.2%) and Precipitation of Coldest Quarter (27.9%) contributed most to the model. This is followed by Precipitation of Driest Quarter (10.9%), Isothermality (3%), Precipitation of Wettest Quarter (2.3%) and Precipitation of Warmest Quarter (2%) (Appendix II). The Slope also emerged as an important non-bioclimatic variable, contributing 13% to model gain, indicating that topographic constraints partly define the niche of this species.

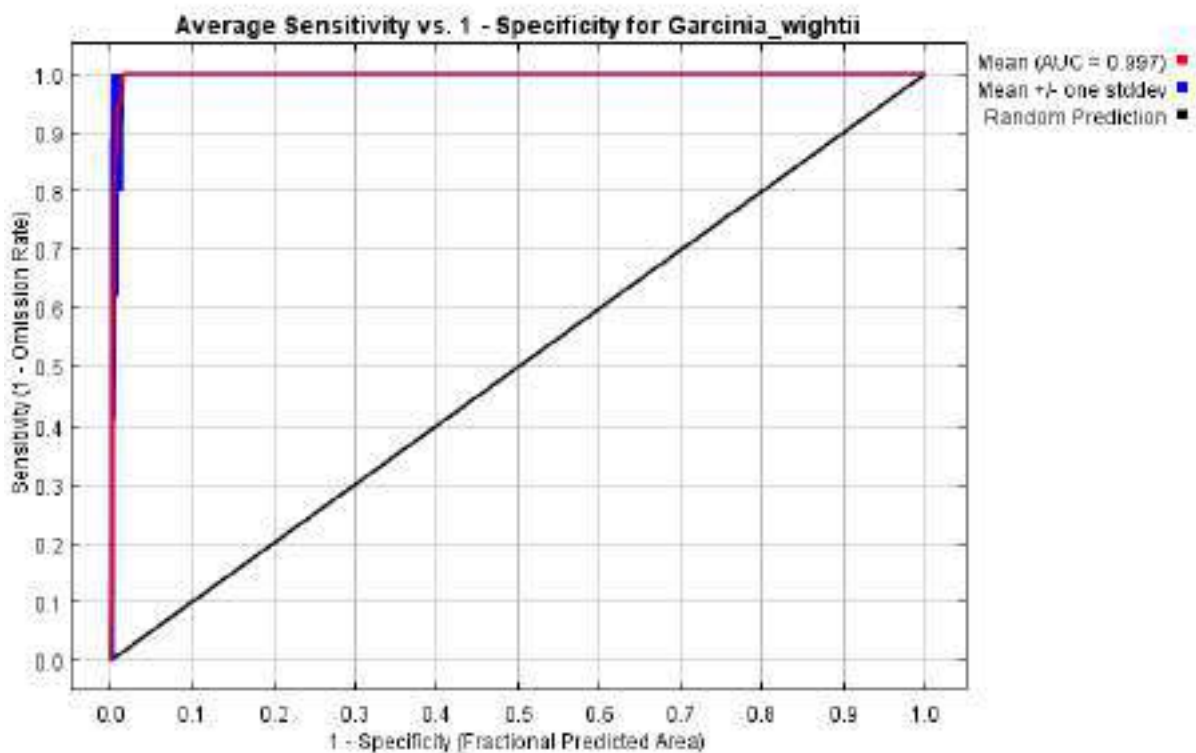


**Fig. 4.47.** Area Under Curve indicating model performance of *Garcinia wightii*

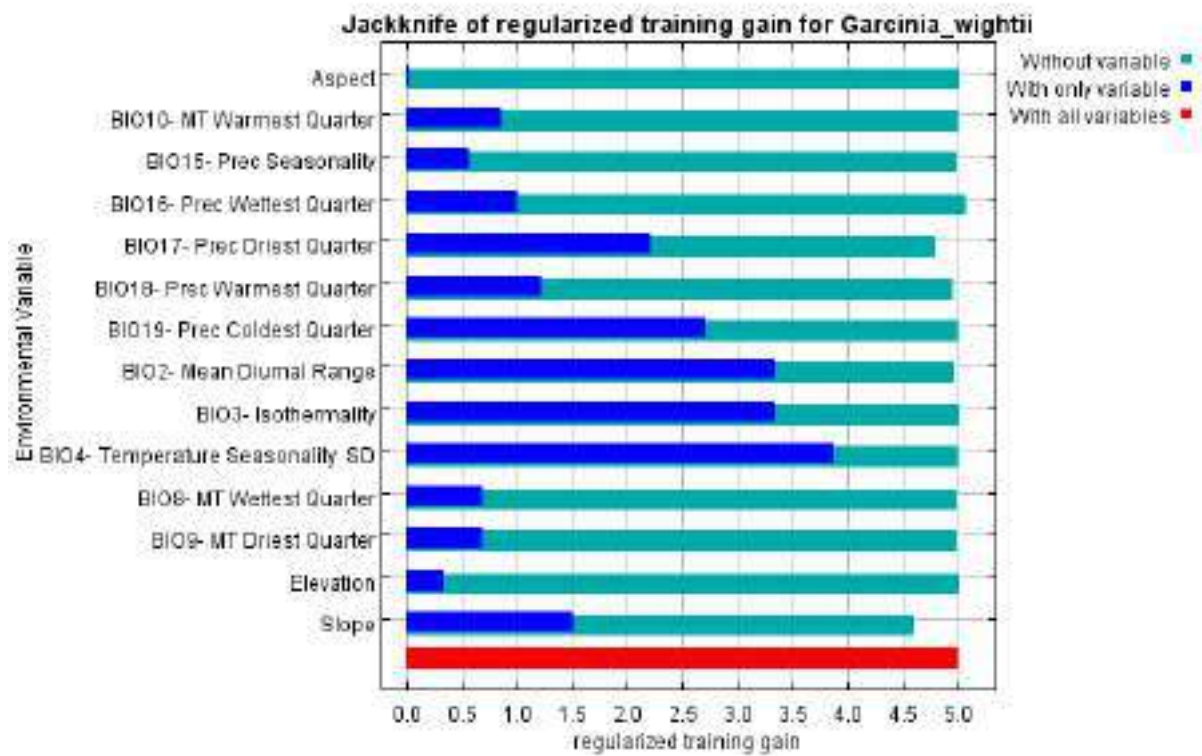


**Fig. 4.48. Jackknife test of training gain showing bioclimatic variables of importance**

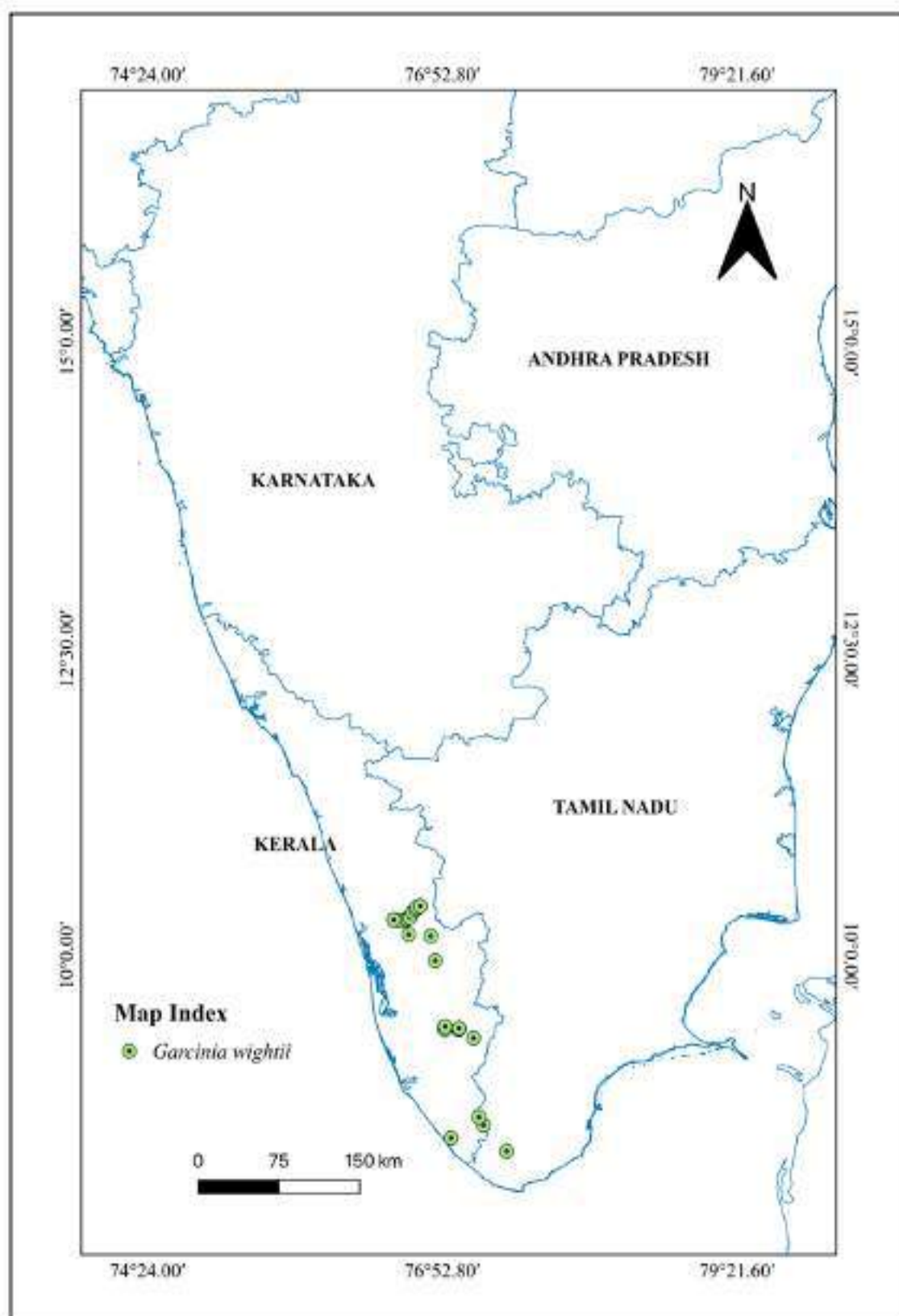


Fig. 4.49. Actual distribution of *Garcinia wightii*



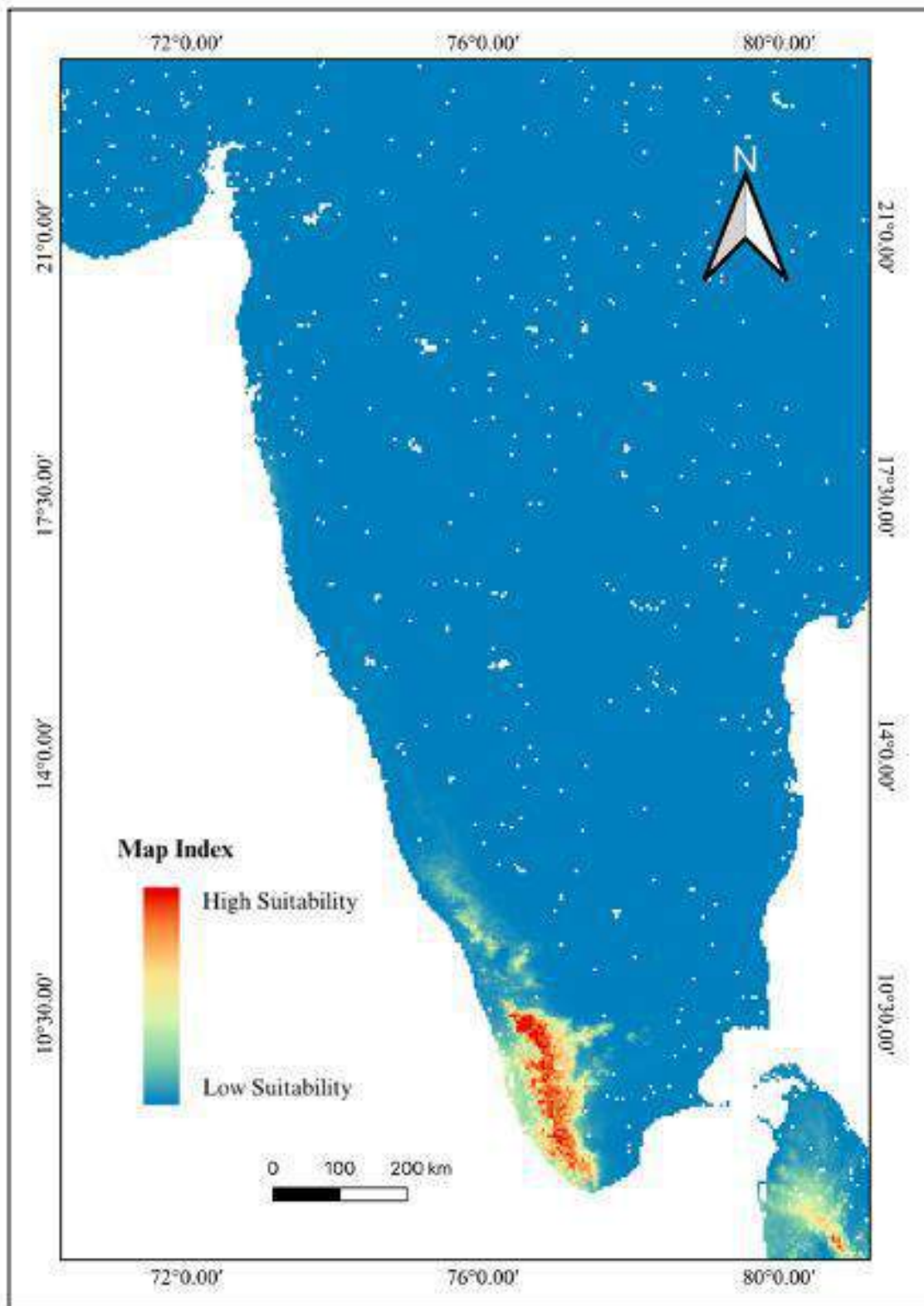


**Fig. 4.50.** Predicted habitat suitability of *Garcinia wightii* using MaxEnt model under present climate scenario

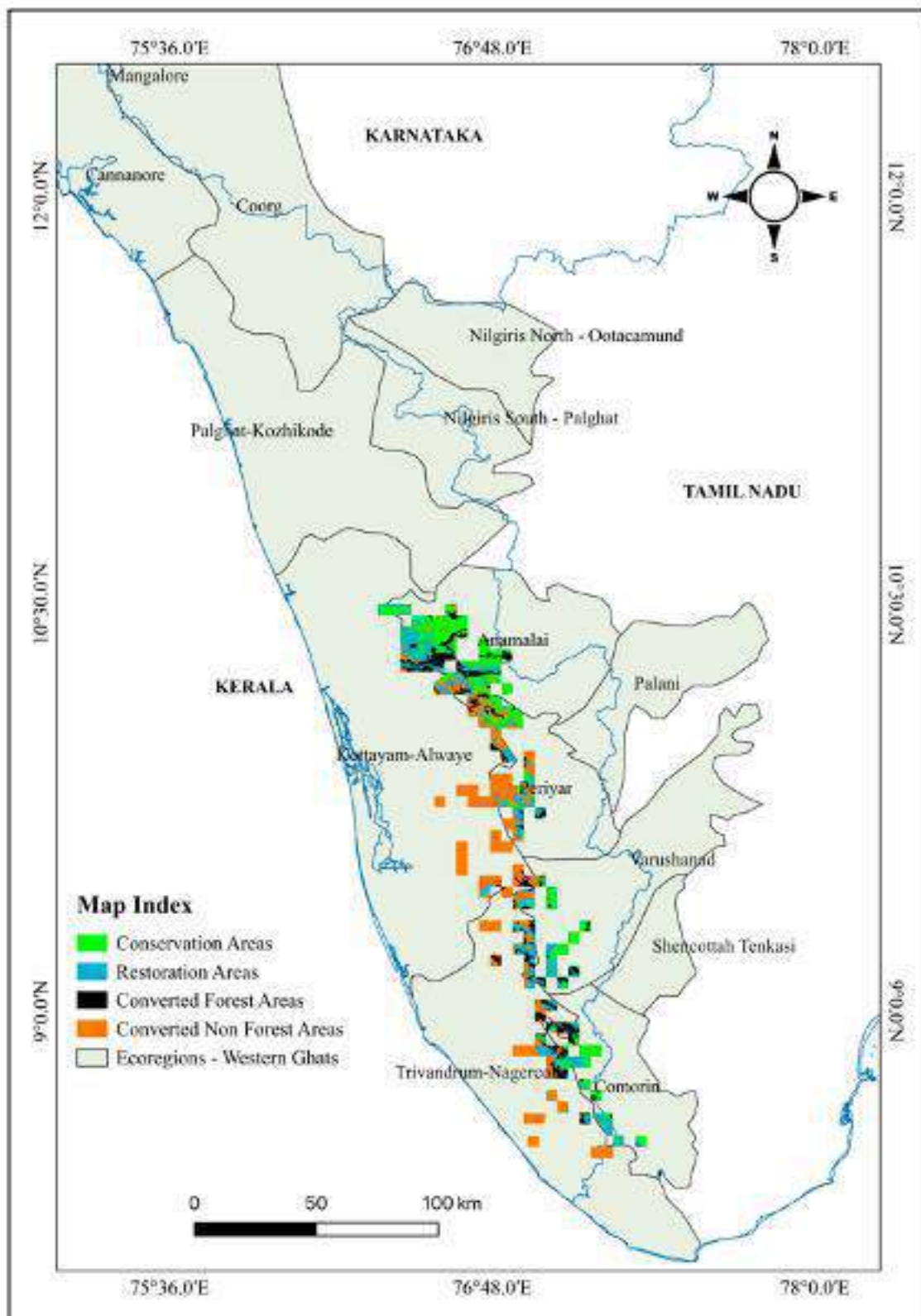


Fig. 4.51. Refined predicted area of *Garcinia wightii* into potential conservation, restoration and irreversibly lost habitats at ecoregion level

### Eltonian Niche of *Garcinia wightii* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Garcinia wightii* is currently restricted to 13 subpopulations within the Western Ghats, particularly in parts of Kerala and Tamil Nadu (Fig. 4.49). Under the current climate scenario, the MaxEnt model predicts a total of 3340.20 km<sup>2</sup> of highly suitable habitat for *Garcinia wightii* in the Western Ghats (Fig. 4.50). This predicted distribution spans over six distinct ecoregions. The highest suitability predictions were concentrated in the Anamalai (799.69%), Trivandrum - Nagercoil (684.68%), Kottayam-Always (681.33%), Periyar (575.70%) ecoregions (Table 4.14).

**Table 4.14. Ecoregion wise habitat prediction for *Garcinia wightii* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No.      | Ecoregion            | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|--------------|----------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1            | Anamalai             | 799.70                            | 403.33                               | 183.25                              | 158.76                                   | 54.36                                        |
| 2            | Comorin              | 276.38                            | 119.68                               | 108.26                              | 42.45                                    | 5.98                                         |
| 3            | Kottayam-Always      | 681.33                            | 38.55                                | 137.20                              | 73.54                                    | 432.04                                       |
| 4            | Periyar              | 575.71                            | 110.02                               | 145.12                              | 49.45                                    | 271.12                                       |
| 5            | Trivandrum-Nagercoil | 684.68                            | 20.44                                | 163.89                              | 142.57                                   | 357.79                                       |
| 6            | Varushanad           | 322.40                            | 121.72                               | 121.50                              | 47.24                                    | 31.95                                        |
| <b>Total</b> |                      | <b>3340.20</b>                    | <b>813.75</b>                        | <b>859.22</b>                       | <b>514.00</b>                            | <b>1153.23</b>                               |

The initial modelling of the potential distribution for *Garcinia wightii*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 3340.20 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct

land-use categories crucial for conservation planning (Fig. 4.51). A total of Conservation area spanning 813.75 km<sup>2</sup>, Potential Ecorestoration area of 859.22 km<sup>2</sup>, irreversibly converted forest habitat (514.00 km<sup>2</sup>) and converted non-forested human-dominated areas (1153.23 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Anamalai (403.33 km<sup>2</sup>), Varushanad (121.71 km<sup>2</sup>), Comorin (119.68 km<sup>2</sup>), Periyar (110.02 km<sup>2</sup>) represent maximum potential conservation areas suitable for *Garcinia wightii*. The degraded habitats are also represented by ecoregions such as Anamalai (183.24 km<sup>2</sup>), Trivandrum- Nagercoil (163.89 km<sup>2</sup>), Periyar (145.11 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 15 % of converted forest habitat to the species are represented with Anamalai (158.75 km<sup>2</sup>), Trivandrum- Nagercoil (142.56 km<sup>2</sup>), Kottayam- Alwaye (73.54 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Garcinia wightii* ecological niche.

#### **4.3.11. Grinnellian Niche of *Goniothalamus wightii* Using Bioclimatic Factors**

The MaxEnt model for *Goniothalamus wightii* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.998 (Fig. 4.52). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Goniothalamus wightii* (Fig. 4.53). Among the 19 bioclimatic variables assessed Precipitation of Coldest Quarter (37.8%) and Precipitation of Driest Month (22.4%) contributed most to the model. This is followed by Temperature Seasonality SD (22.3%), Isothermality (6.9%), Mean Diurnal Range (0.6%) and Precipitation Seasonality (0.4%). The Elevation and Slope also emerged as an important non-bioclimatic variable, contributing 8% and 0.6% respectively to model gain, indicating that topographic constraints partly define the niche of this species.

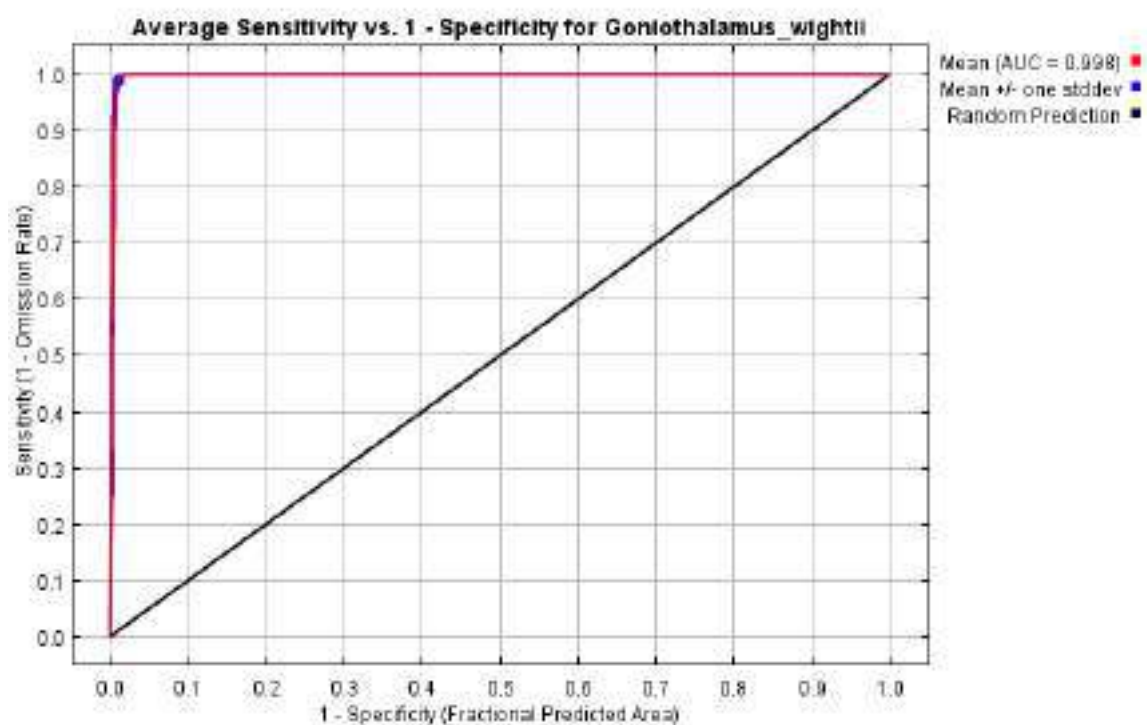


**Fig. 4.52.** Area Under Curve indicating model performance of *Goniothalamus wightii*

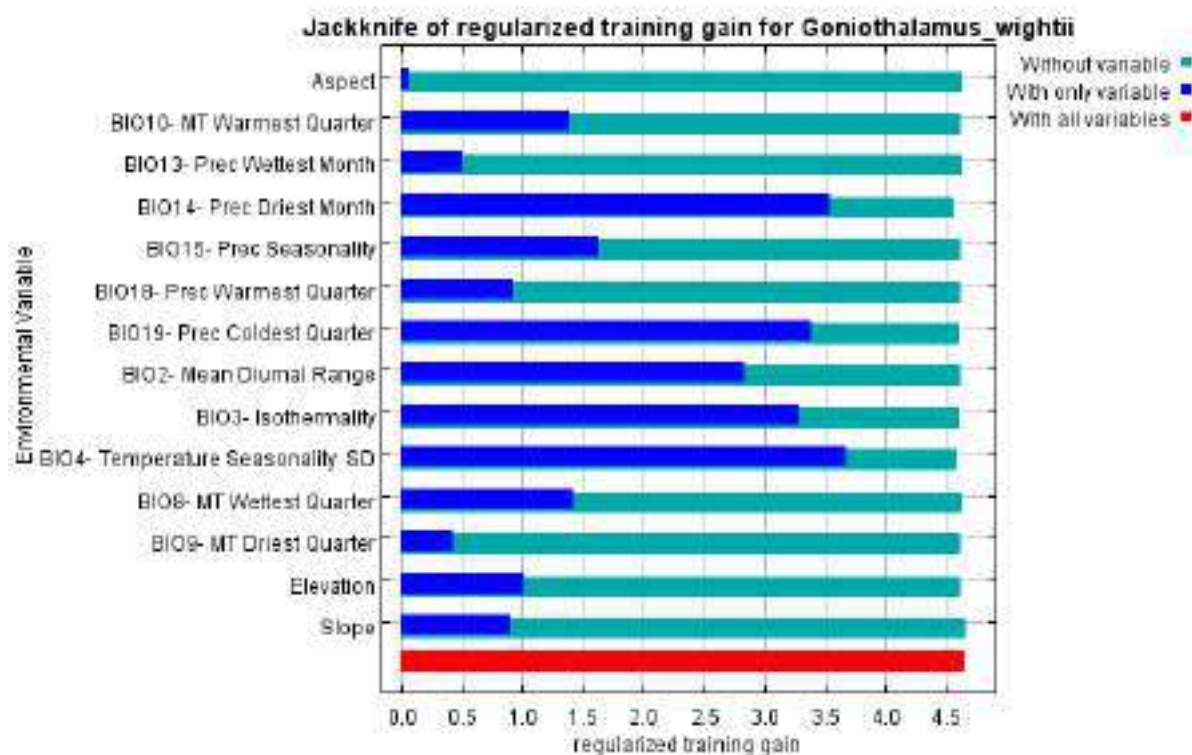


**Fig. 4.53.** Jackknife test of training gain showing bioclimatic variables of importance

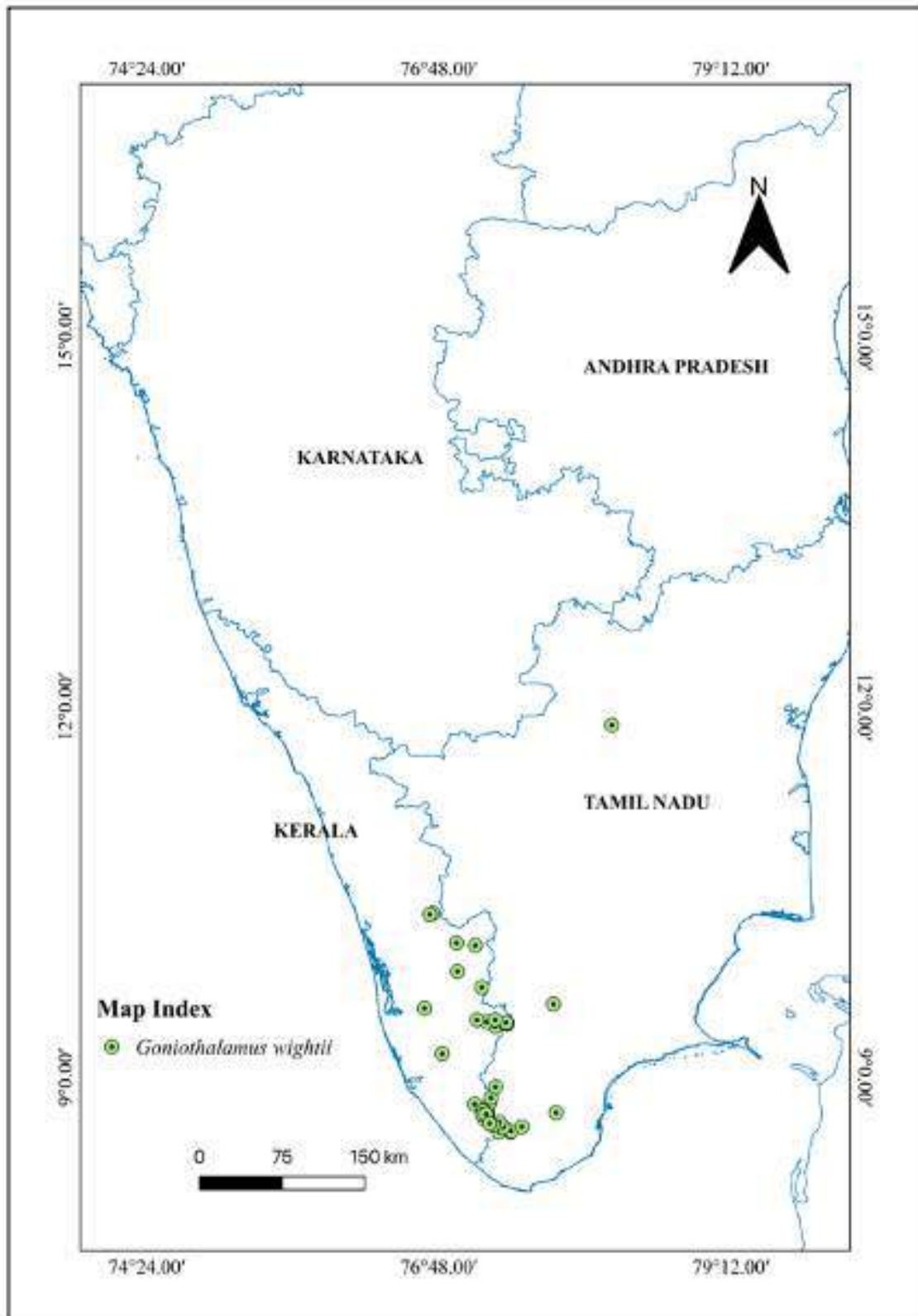


Fig. 4.54. Actual distribution of *Goniothalamus wightii*



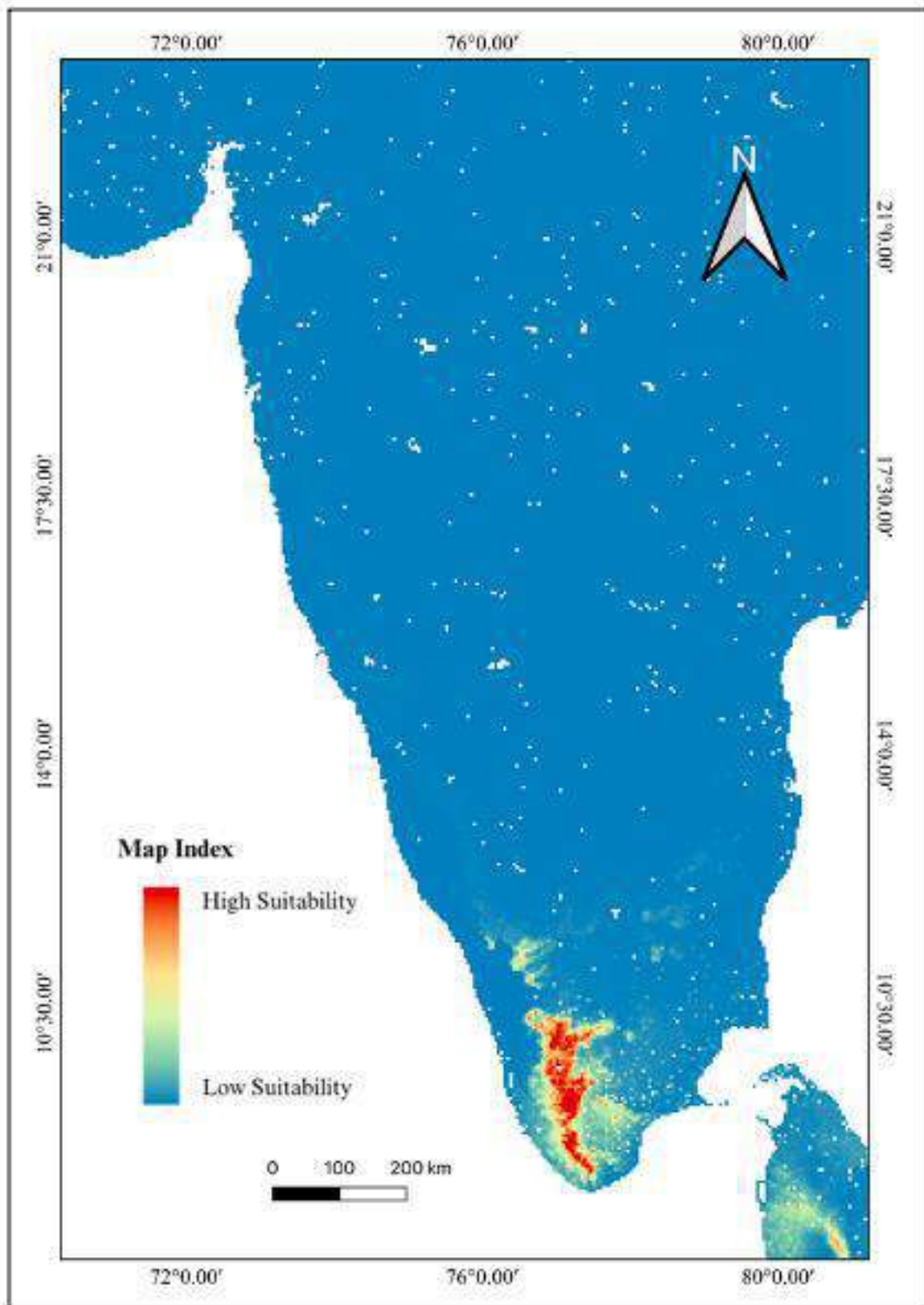


**Fig. 4.55.** Predicted habitat suitability of *Goniothalamus wightii* using MaxEnt model under present climate scenario



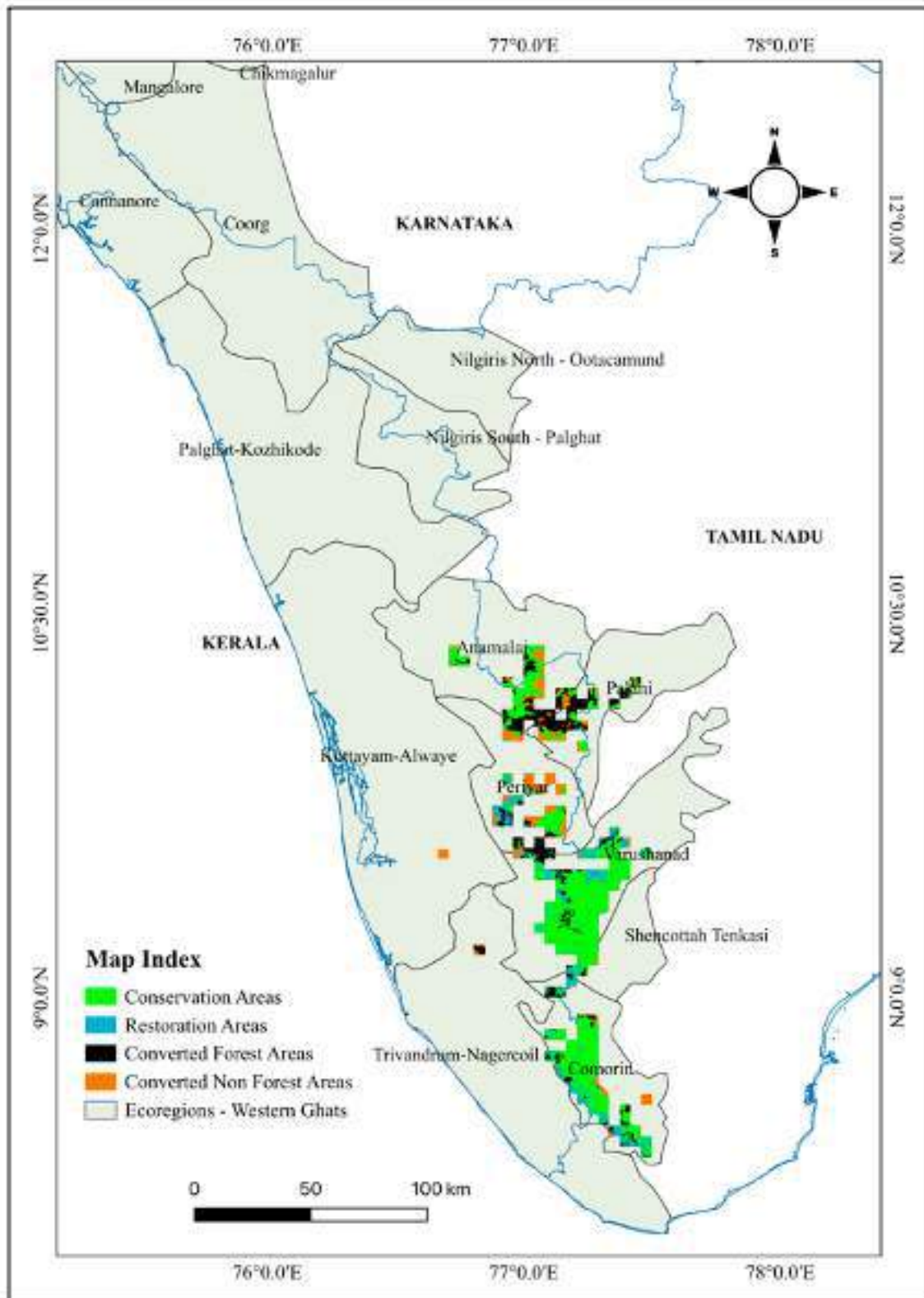


**Fig. 4.56. Refined predicted area of *Goniothalamus wightii* into potential conservation, restoration and irreversibly lost habitats at ecoregion level**

### Eltonian Niche of *Goniothalamus wightii* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Goniothalamus wightii* is currently restricted to 20 subpopulations within the Western Ghats, particularly in parts of Kerala and Tamil Nadu (Fig. 4.54). Under the current climate scenario, the MaxEnt model predicts a total of 3775.68 km<sup>2</sup> of highly suitable habitat for *Goniothalamus wightii* in the Western Ghats (Fig. 4.55). This predicted distribution spans over eight distinct ecoregions. The highest suitability predictions were concentrated in the Varushanad (1261.29 km<sup>2</sup>), Comorin (928.20 km<sup>2</sup>), Periyar (605.55 km<sup>2</sup>), Anamalai (502.95 km<sup>2</sup>) and Palani (350.93 km<sup>2</sup>) ecoregions (Table 4.15).

**Table 4.15. Ecoregion wise habitat prediction for *Goniothalamus wightii* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No.      | Ecoregion                | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|--------------|--------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1            | Anamalai                 | 502.96                            | 254.94                               | 5.99                                | 172.62                                   | 69.42                                        |
| 2            | Comorin                  | 928.21                            | 594.89                               | 192.92                              | 92.05                                    | 48.35                                        |
| 3            | Kottayam-<br>Alwaye      | 18.70                             | 00.00                                | 00.00                               | 00.00                                    | 18.70                                        |
| 4            | Palani                   | 350.93                            | 98.95                                | 4.90                                | 184.37                                   | 62.72                                        |
| 5            | Periyar                  | 605.55                            | 135.78                               | 117.70                              | 155.91                                   | 196.17                                       |
| 6            | Shencottah<br>Tenkasi    | 73.12                             | 47.11                                | 16.19                               | 5.87                                     | 3.95                                         |
| 7            | Trivandrum-<br>Nagercoil | 34.91                             | 3.44                                 | 4.43                                | 20.16                                    | 6.89                                         |
| 8            | Varushanad               | 1261.29                           | 00.00                                | 209.11                              | 85.61                                    | 966.57                                       |
| <b>Total</b> |                          | <b>3775.68</b>                    | <b>1135.11</b>                       | <b>551.23</b>                       | <b>716.58</b>                            | <b>1372.76</b>                               |

The initial modelling of the potential distribution for *Goniothalamus wightii*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 3775.68 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.56). A total of Conservation area spanning 1135.11 km<sup>2</sup>, Potential Ecorestoration area of 551.23 km<sup>2</sup>, and irreversibly converted forest habitat (716.58 km<sup>2</sup>) and converted non-forested human-dominated areas (1372.76 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Comorin (594.89 km<sup>2</sup>), Anamalai (254.93 km<sup>2</sup>), Periyar (135.77 km<sup>2</sup>), Palani (98.95 km<sup>2</sup>), Shencottah Tenkasi (47.10 km<sup>2</sup>) represent maximum potential conservation areas suitable for *Goniothalamus wightii*. The degraded habitats are also represented by ecoregions such as Varushanad (209.10 km<sup>2</sup>), Comorin (192.91 km<sup>2</sup>), Periyar (117.7 km<sup>2</sup>), Shencottah Tenkasi (16.19 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 18 % of converted forest habitat to the species are represented with Palani (184.36 km<sup>2</sup>), Anamalai (172.61 km<sup>2</sup>), Periyar (155.91 km<sup>2</sup>), Comorin (92.04 km<sup>2</sup>), Varushanad (85.61 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Goniothalamus wightii* ecological niche.

#### **4.3.12. Grinnellian Niche of *Humboldtia vahliana* Using Bioclimatic Factors**

The MaxEnt model for *Humboldtia vahliana* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.995 (Fig. 4.57). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Humboldtia vahliana* (Fig. 4.58). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (39.3%) and Precipitation of Coldest Quarter (37%) contributed most to the model. This is followed by Precipitation of Driest Quarter (7.2%), Isothermality (6.7%), Precipitation of Warmest Quarter (1.5%). The

Slope and Elevation also emerged as an important non-bioclimatic variable, contributing 5.4 % and 1.2% respectively to model gain, indicating that topographic constraints partly define the niche of this species.

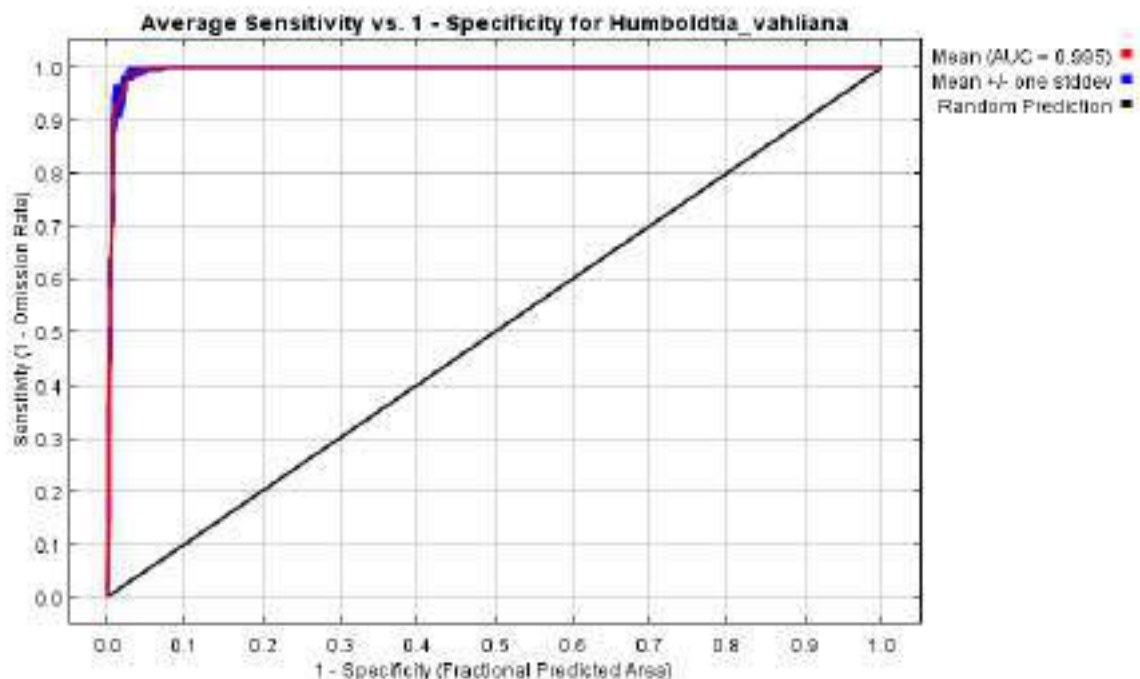


Fig. 4.57. Area Under Curve indicating model performance of *Humboldtia vahlana*

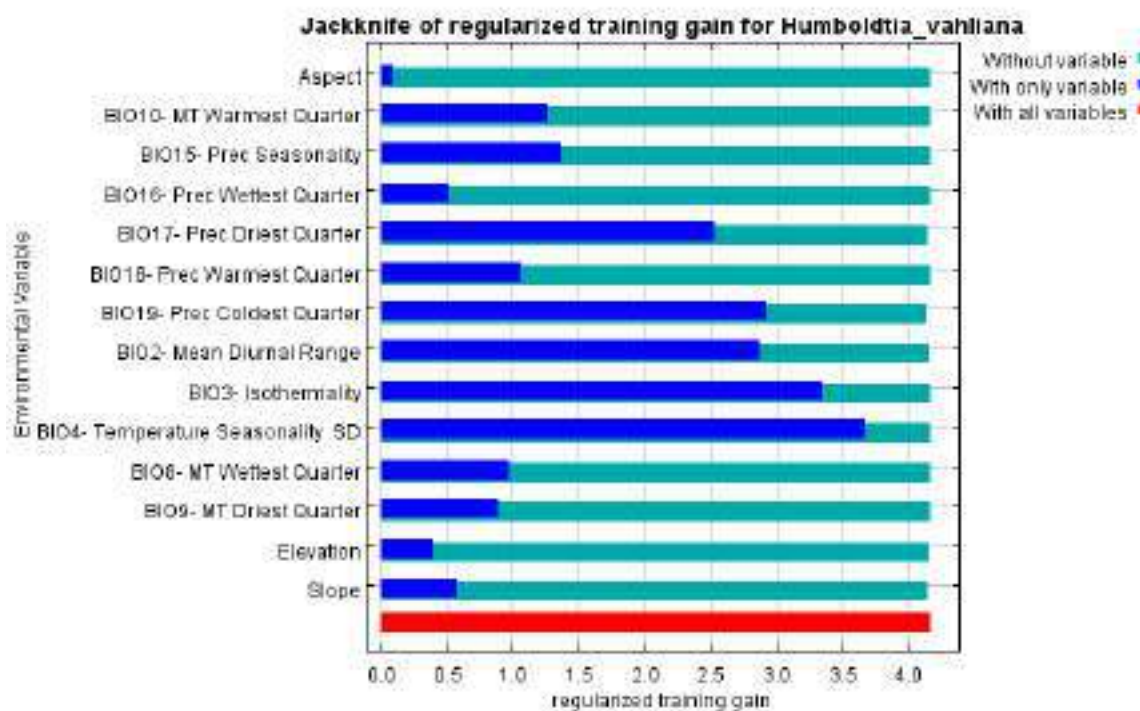


Fig. 4.58. Jackknife test of training gain showing bioclimatic variables of importance

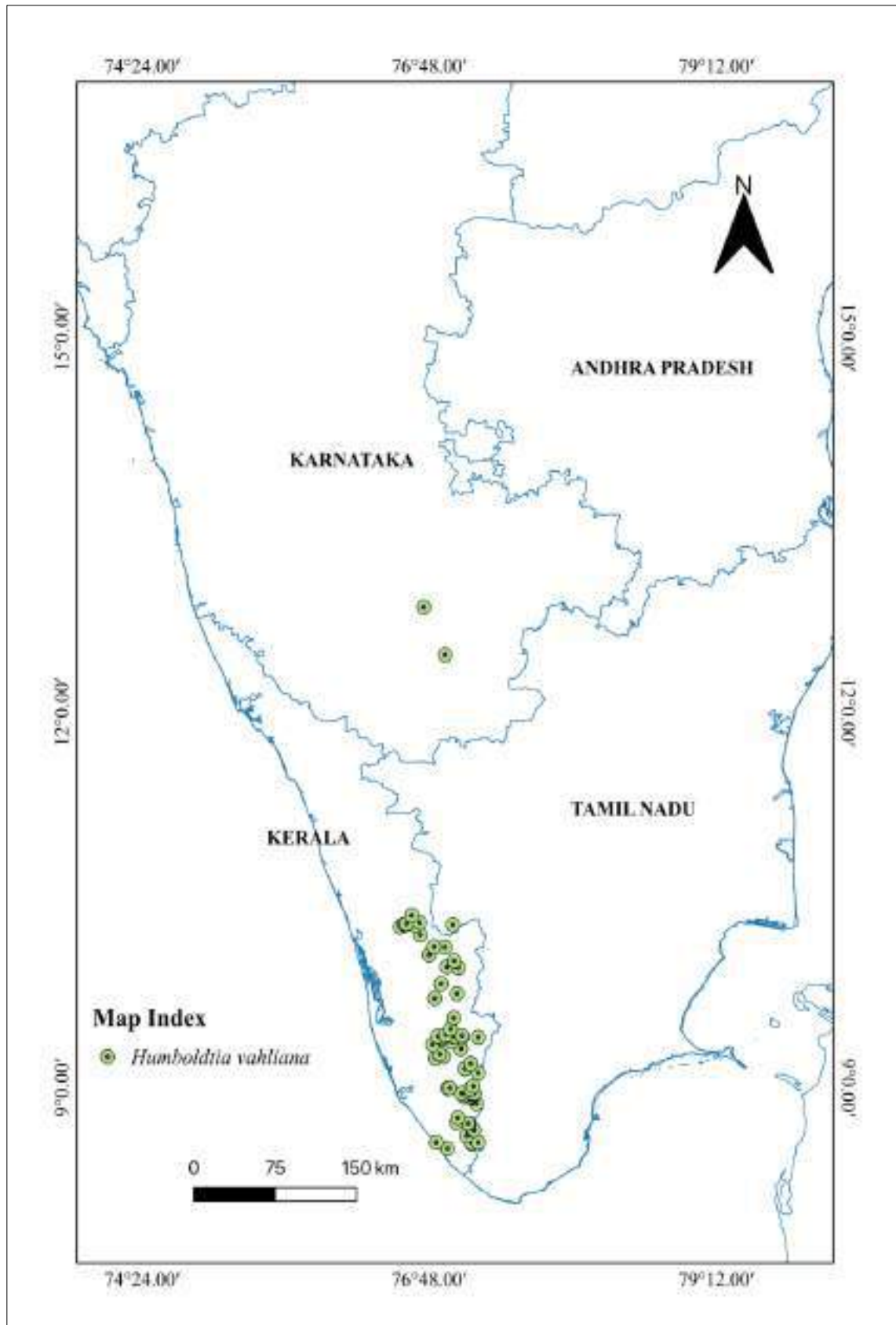


Fig. 4.59. Actual distribution of *Humboldtia vahliana*

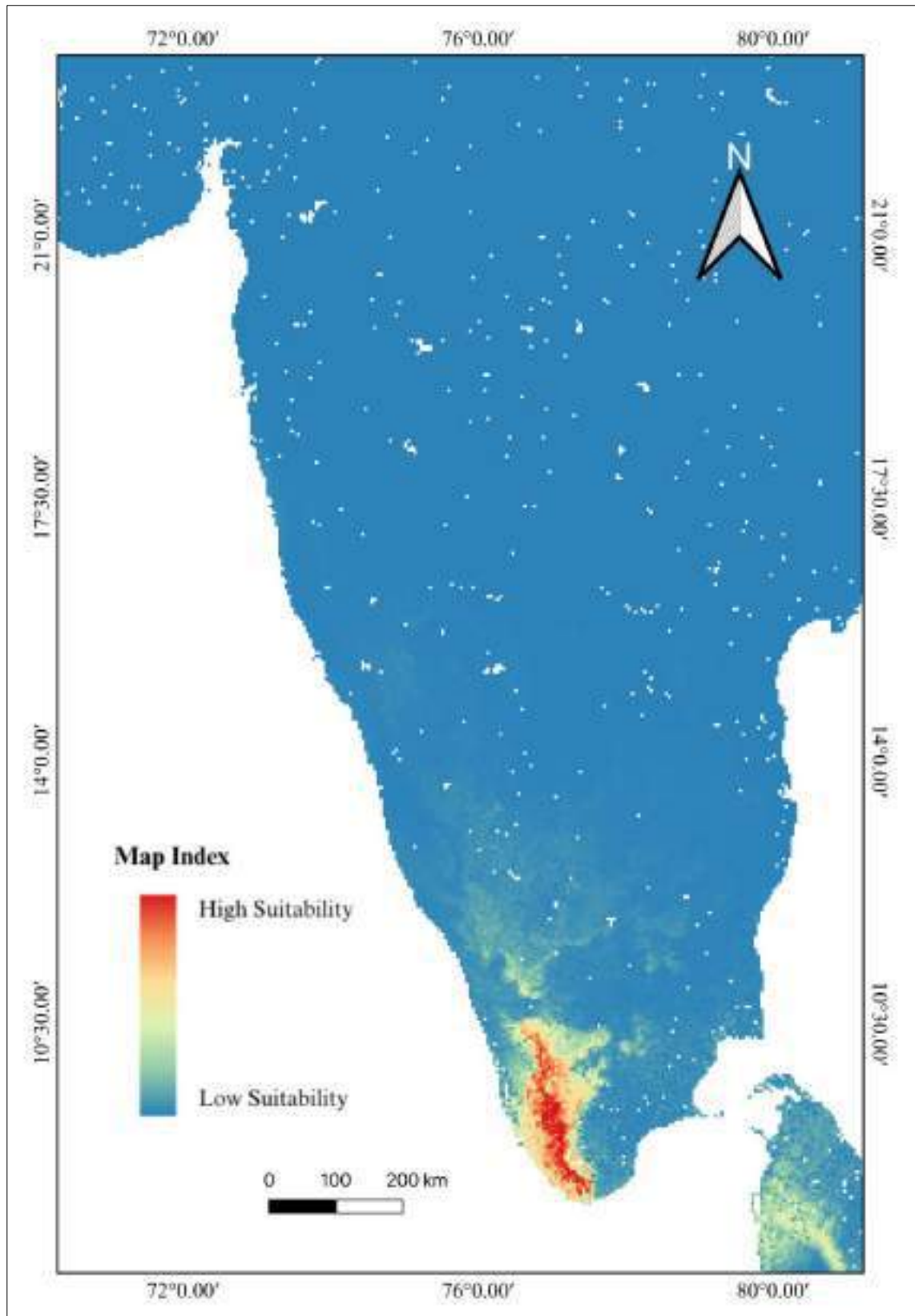


**Fig. 4.60.** Predicted habitat suitability of *Humboldtia vahliana* using MaxEnt model under present climate scenario



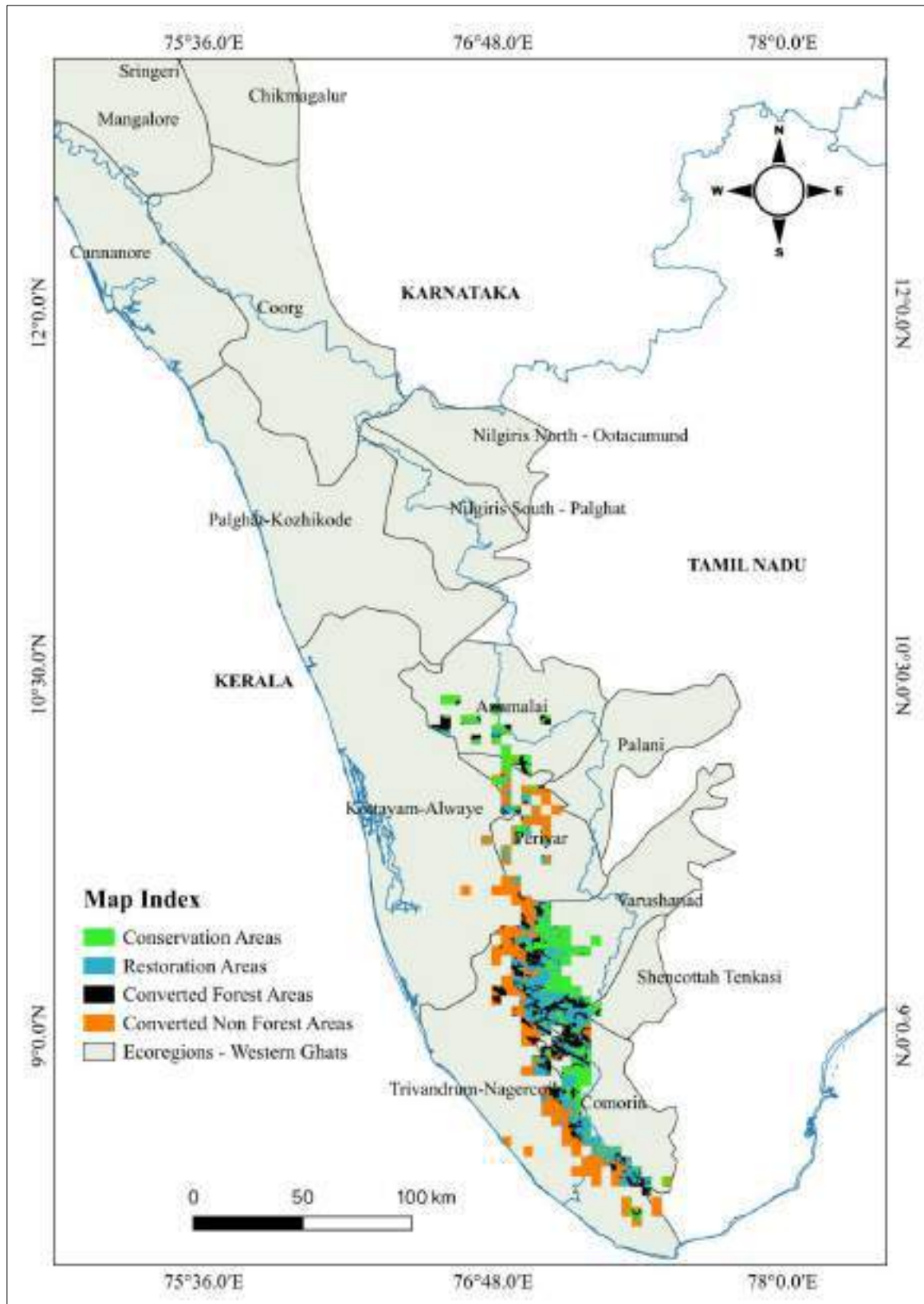


**Fig. 4.61. Refined predicted area of *Humboldtia vahliana* into potential conservation, restoration and irreversibly lost habitats at ecoregion level**



### Eltonian Niche of *Humboldtia vahliana* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Humboldtia vahliana* is currently restricted to 28 subpopulations within the Western Ghats, particularly in parts of Kerala, Tamil Nadu and Karnataka (Fig. 4.59). Under the current climate scenario, the MaxEnt model predicts a total of 4565.31 km<sup>2</sup> of highly suitable habitat for *Humboldtia vahliana* in the Western Ghats (Fig. 4.60). This predicted distribution spans over seven distinct ecoregions. The highest suitability predictions were concentrated in the Trivandrum-Nagercoil (1569.88 km<sup>2</sup>), Varushanad (1101.82 km<sup>2</sup>), Comorin (741.05 km<sup>2</sup>), Periyar (536.30 km<sup>2</sup>) and Anamalai (355.84 km<sup>2</sup>) ecoregions (Table 4.16).

**Table 4.16. Ecoregion wise habitat prediction for *Humboldtia vahliana* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No.      | Ecoregion            | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|--------------|----------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1            | Anamalai             | 355.84                            | 189.85                               | 42.00                               | 103.18                                   | 20.81                                        |
| 2            | Comorin              | 741.06                            | 222.52                               | 297.70                              | 170.17                                   | 50.66                                        |
| 3            | Kottayam-Alwaye      | 221.72                            | 1.82                                 | 25.00                               | 22.92                                    | 171.98                                       |
| 4            | Periyar              | 536.31                            | 86.31                                | 115.80                              | 21.86                                    | 312.34                                       |
| 5            | Shencottah Tenkasi   | 38.68                             | 17.87                                | 14.24                               | 5.82                                     | 0.75                                         |
| 6            | Trivandrum-Nagercoil | 1569.89                           | 46.91                                | 331.07                              | 284.93                                   | 906.98                                       |
| 7            | Varushanad           | 1101.82                           | 449.49                               | 396.38                              | 174.50                                   | 81.45                                        |
| <b>Total</b> |                      | <b>4565.31</b>                    | <b>1014.77</b>                       | <b>1222.18</b>                      | <b>783.39</b>                            | <b>1544.98</b>                               |

The initial modelling of the potential distribution for *Humboldtia vahliana*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 4565.31 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning. A total of Conservation area spanning 1014.77 km<sup>2</sup>, Potential Ecorestoration area of 1222.18 km<sup>2</sup>, and irreversibly converted forest habitat (783.39 km<sup>2</sup>) and converted non-forested human-dominated areas (1544.98 km<sup>2</sup>) (Fig. 4.61). The ecoregions such as Varushanad (449.49 km<sup>2</sup>), Comorin (222.52 km<sup>2</sup>), Anamalai (189.85 km<sup>2</sup>) and Periyar (86.30 km<sup>2</sup>) represent maximum potential conservation areas suitable for *Humboldtia vahliana*. The degraded habitats are also represented by ecoregions such as Varushanad (396.37 km<sup>2</sup>), Trivandrum-Nagercoil (331.07 km<sup>2</sup>), Comorin (297.69 km<sup>2</sup>), Periyar (115.8 km<sup>2</sup>), and Anamalai (41.99 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 17 % of converted forest habitat to the species are represented with Trivandrum-Nagercoil (284.93 km<sup>2</sup>), Varushanad (174.50 km<sup>2</sup>), Comorin (170.17 km<sup>2</sup>), Anamalai (103.18 km<sup>2</sup>) and Kottayam-Alwaye (22.92 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Humboldtia vahliana* ecological niche.

#### **4.3.13. Grinnellian Niche of *Hydnocarpus pentandrus* Using Bioclimatic Factors**

The MaxEnt model for *Hydnocarpus pentandrus* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.993 (Fig. 4.62). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Hydnocarpus pentandrus* (Fig. 4.63). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (68.1%) and Precipitation of Coldest Quarter (8.8%) contributed most to the model. This is followed by Isothermality (8.5%), Precipitation of Wettest Quarter (4.7%) and Precipitation of Warmest Quarter

(2.4%) (Appendix II). The Slope and Aspect also emerged as an important non-bioclimatic variable, contributing 3.6% and 1.1% respectively to model gain, indicating that topographic constraints partly define the niche of this species.

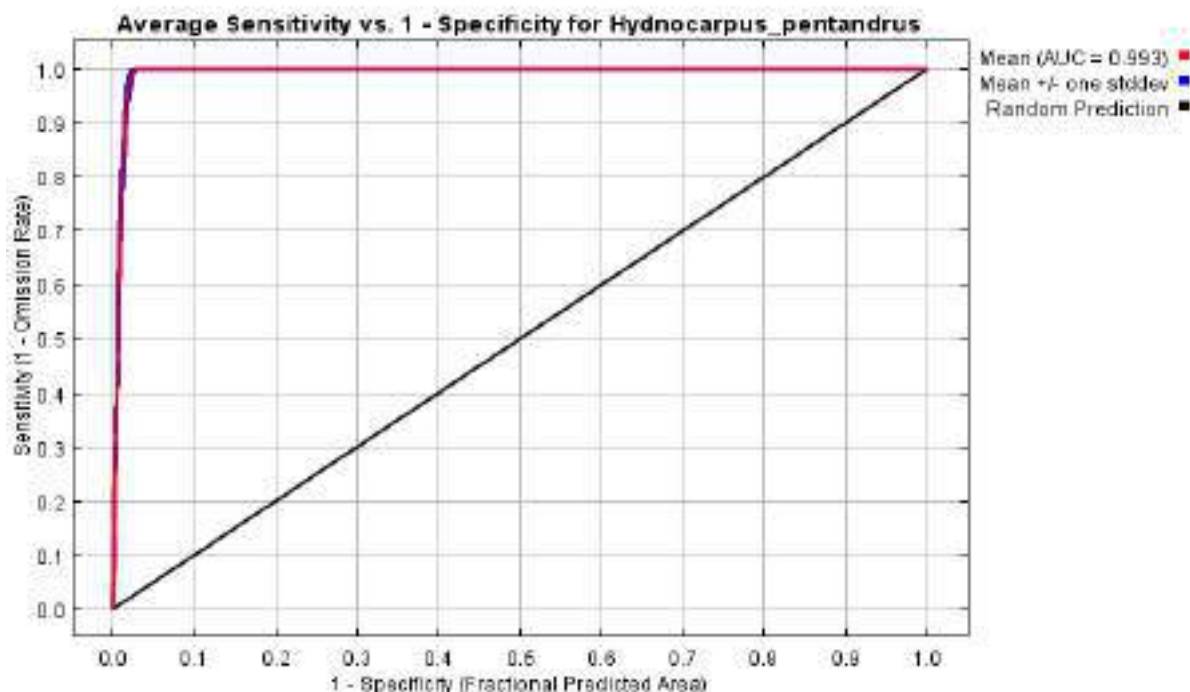


Fig. 4.62. Area Under Curve indicating model performance of *Hydnocarpus pentandrus*



Fig. 4.63. Jackknife test of training gain showing bioclimatic variables of importance

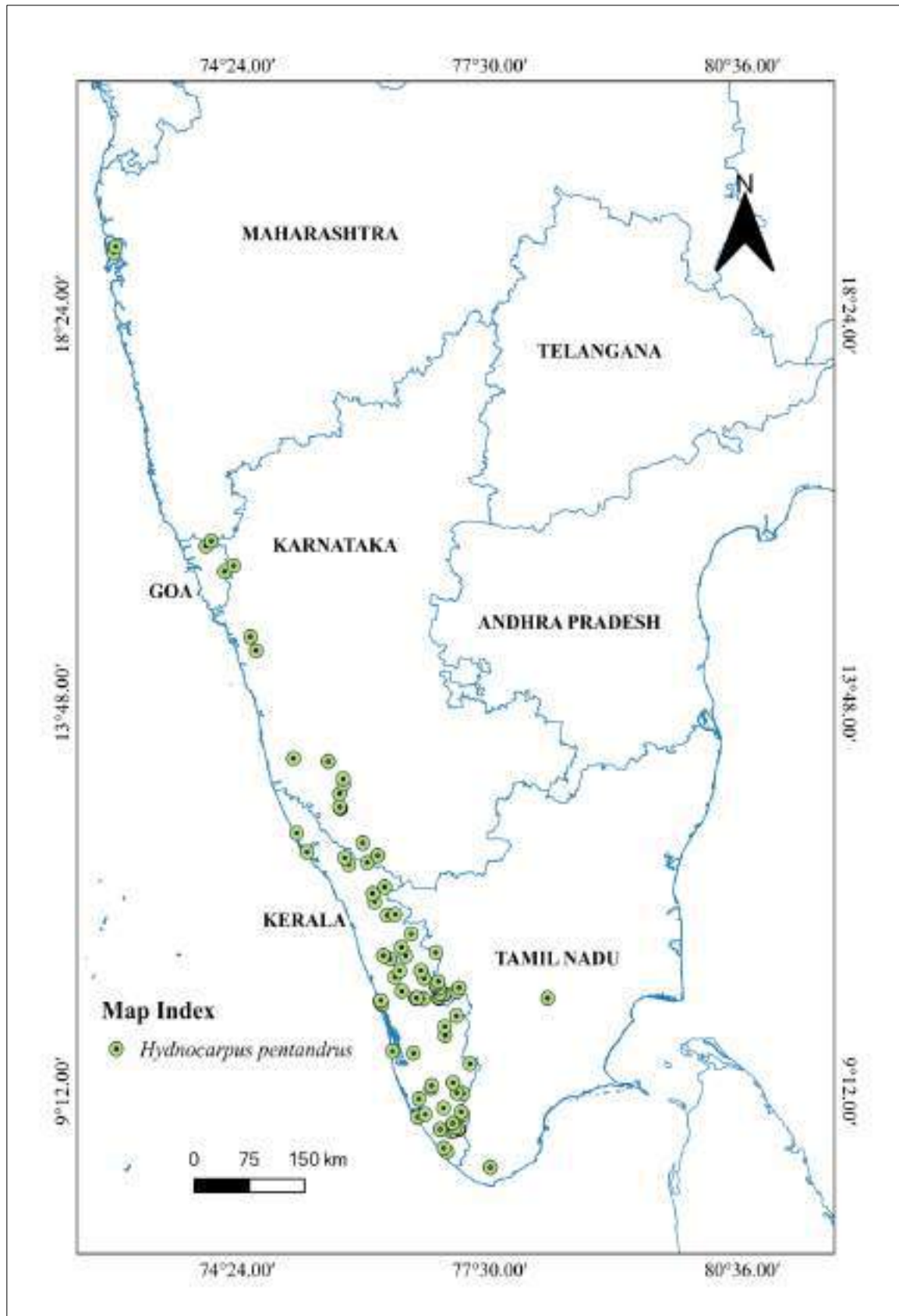


Fig. 4.64. Actual distribution of *Hydnocarpus pentandrus*

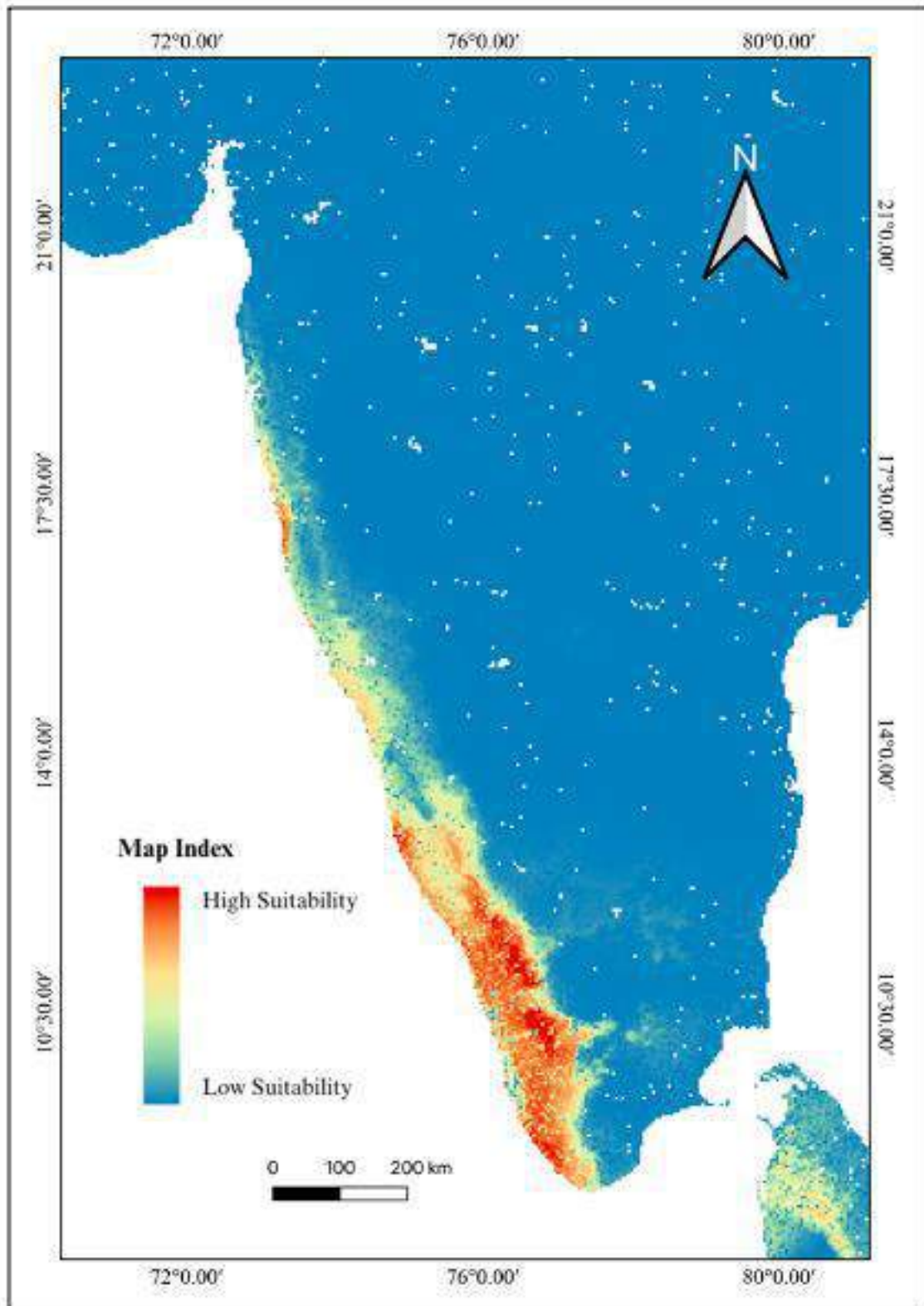


**Fig. 4.65.** Predicted habitat suitability of *Hydnocarpus pentandrus* using MaxEnt model under present climate scenario

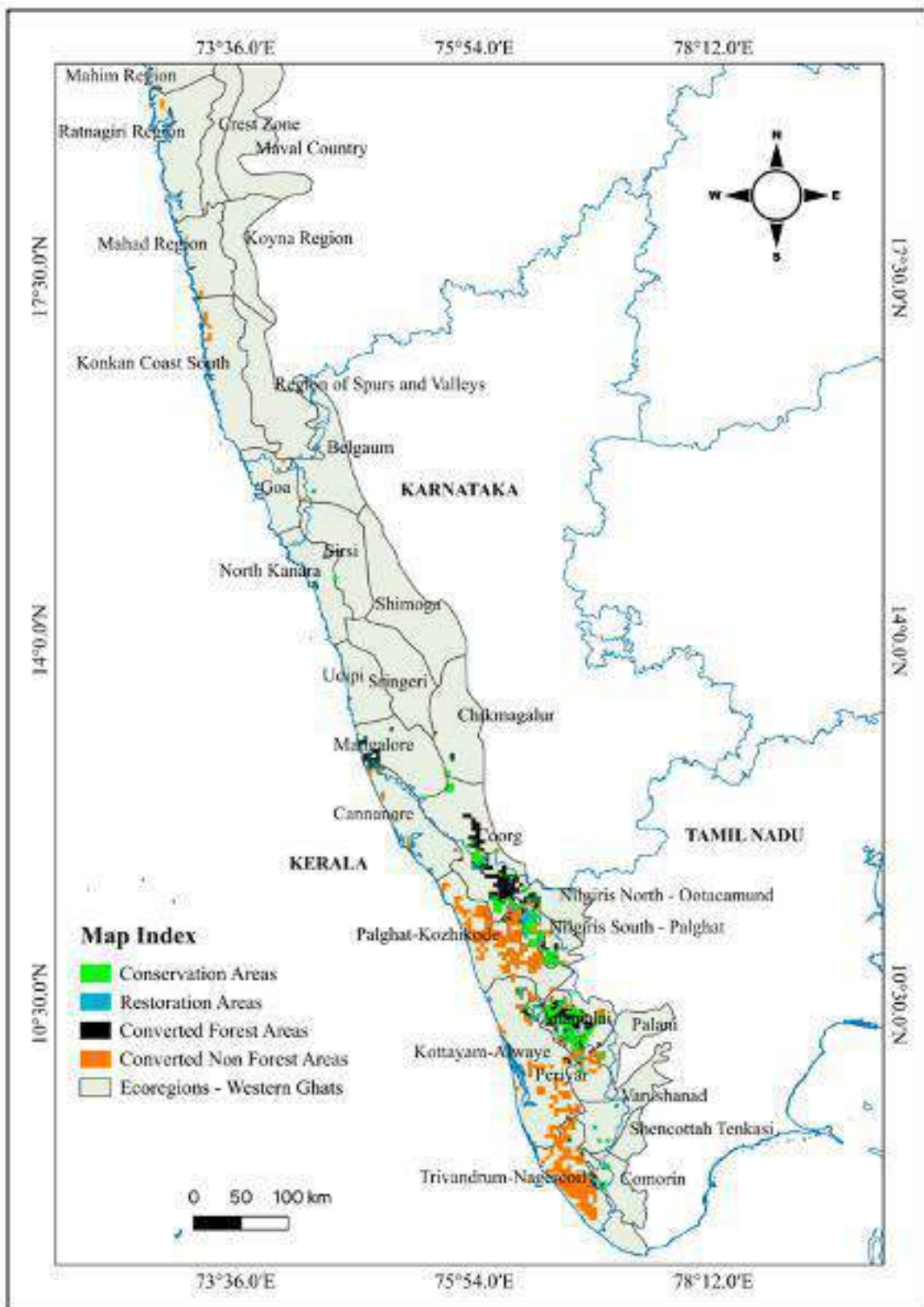


**Fig. 4.66.** Refined predicted area of *Hydnocarpus pentandrus* into potential conservation, restoration and irreversibly lost habitats at ecoregion level



### Eltonian Niche of *Hydnocarpus pentandrus* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Hydnocarpus pentandrus* is currently restricted to 43 subpopulations within the Kerala, Tamil Nadu, Karnataka, Goa, Maharashtra parts of the Western Ghats (Fig. 4.64). Under the current climate scenario, the MaxEnt model predicts a total of 13684.31 km<sup>2</sup> of highly suitable habitat for *Hydnocarpus pentandrus* in the Western Ghats (Fig. 4.65). This predicted distribution spans over 21 distinct ecoregions. The highest suitability predictions were concentrated in the Palghat-Kozhikode (2898.71km<sup>2</sup>), Trivandrum-Nagercoil (2353.03 km<sup>2</sup>), Anamalai (1873.03 km<sup>2</sup>), Coorg (1828.13 km<sup>2</sup>), Kottayam-Alwaye (1546.26 km<sup>2</sup>), Nilgiris South-Palghat (1103.24 km<sup>2</sup>), Periyar (572.55 km<sup>2</sup>), Mangalore (298.08 km<sup>2</sup>), Cannanore (273.92 km<sup>2</sup>), Nilgiris North-Ootacamund (239.97 km<sup>2</sup>) ecoregions (Table 4.17).

**Table 4.17. Ecoregion wise habitat prediction for *Hydnocarpus pentandrus* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No. | Ecoregion          | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|---------|--------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1       | Anamalai           | 1873.03                           | 924.12                               | 171.34                              | 494.37                                   | 283.21                                       |
| 2       | Belgaum            | 39.04                             | 3.05                                 | 13.78                               | 3.23                                     | 18.98                                        |
| 3       | Cannanore          | 273.92                            | 00.00                                | 107.33                              | 32.85                                    | 133.74                                       |
| 4       | Chikmagalur        | 86.08                             | 36.41                                | 10.52                               | 30.64                                    | 8.51                                         |
| 5       | Comorin            | 100.31                            | 55.70                                | 24.61                               | 19.59                                    | 0.41                                         |
| 6       | Coorg              | 1828.13                           | 479.28                               | 192.40                              | 1078.77                                  | 77.68                                        |
| 7       | Goa                | 41.40                             | 0.00                                 | 0.00                                | 0.00                                     | 41.40                                        |
| 8       | Konkan Coast South | 131.88                            | 0.00                                 | 0.00                                | 0.00                                     | 131.88                                       |
| 9       | Kottayam-Alwaye    | 1546.26                           | 39.95                                | 157.59                              | 88.42                                    | 1260.29                                      |
| 10      | Mahad region       | 32.73                             | 0.00                                 | 0.00                                | 0.00                                     | 32.73                                        |



|              |                           |                 |                |                |                |                |
|--------------|---------------------------|-----------------|----------------|----------------|----------------|----------------|
| 11           | Mangalore                 | 298.08          | 3.20           | 118.07         | 176.81         | 0.01           |
| 12           | Nilgiris North-Ootacamund | 239.98          | 58.99          | 46.46          | 102.23         | 32.30          |
| 13           | Nilgiris South-Palghat    | 1103.25         | 597.49         | 187.79         | 124.31         | 193.67         |
| 14           | North Kanara              | 23.24           | 13.10          | 5.37           | 4.76           | 0.00           |
| 15           | Palani                    | 104.81          | 34.70          | 0.84           | 10.00          | 59.27          |
| 16           | Palghat-Kozhikode         | 2898.71         | 43.59          | 162.21         | 65.33          | 2627.58        |
| 17           | Periyar                   | 572.56          | 122.66         | 100.63         | 42.89          | 306.37         |
| 18           | Ratnagiri                 | 40.40           | 0.00           | 0.00           | 0.00           | 40.40          |
| 19           | Sirsi                     | 12.57           | 10.43          | 1.41           | 0.73           | 0.00           |
| 20           | Trivandrum-Nagercoil      | 2353.04         | 13.37          | 106.80         | 82.86          | 2150.01        |
| 21           | Varushanad                | 84.90           | 48.37          | 33.20          | 1.40           | 1.93           |
| <b>Total</b> |                           | <b>13684.31</b> | <b>2484.41</b> | <b>1440.34</b> | <b>2359.20</b> | <b>7400.37</b> |

The initial modelling of the potential distribution for *Hydnocarpus pentandrus*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 13684.31 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.66). A total of Conservation area spanning 2484.41 km<sup>2</sup>, Potential Ecorestoration area of 1440.34 km<sup>2</sup>, irreversibly converted forest habitat (2359.20 km<sup>2</sup>) and converted non-forested human-dominated areas (7400.37 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Anamalai (924.11 km<sup>2</sup>), Nilgiris South-Palghat (597.48 km<sup>2</sup>), Coorg (479.28 km<sup>2</sup>), Periyar (122.66 km<sup>2</sup>), Nilgiris North-Ootacamund (58.98 km<sup>2</sup>), Comorin (55.69 km<sup>2</sup>), Varushanad (48.37 km<sup>2</sup>), Palghat-Kozhikode (43.58 km<sup>2</sup>), Kottayam-Alwaye (39.95 km<sup>2</sup>) represent maximum potential conservation areas suitable for *A. malabarica*. The degraded habitats are also represented by ecoregions such as Coorg (192.4 km<sup>2</sup>), Nilgiris South-Palghat

(187.78 km<sup>2</sup>), Anamalai (171.34 km<sup>2</sup>), Palghat-Kozhikode (162.21 km<sup>2</sup>), Kottayam-Alwaye (157.59 km<sup>2</sup>), Mangalore (118.06 km<sup>2</sup>), Cannanore (107.33 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 17 % of converted forest habitat to the species are represented with Coorg (1078.77 km<sup>2</sup>), Anamalai (494.36 km<sup>2</sup>), Mangalore (176.81 km<sup>2</sup>), Nilgiris South-Palghat (124.31 km<sup>2</sup>), Nilgiris North-Ootacamund (102.23 km<sup>2</sup>), Kottayam-Alwaye (88.42 km<sup>2</sup>), Trivandrum-Nagercoil (82.85 km<sup>2</sup>), Palghat-Kozhikode (65.33 km<sup>2</sup>), Periyar (42.89 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Hydnocarpus pentandrus* ecological niche.

#### **4.3.14. Grinnellian Niche of *Impatiens parasitica* Using Bioclimatic Factors**

The MaxEnt model for *Impatiens parasitica* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.997 (Fig. 4.67). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Impatiens parasitica* (Fig. 4.68). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (43.4%) and Precipitation of Coldest Quarter (26.5%) contributed most to the model. This is followed by Precipitation of Driest Month (4.3%), Precipitation of Wettest Month (3%), Isothermality (1.5%), Precipitation Seasonality (1.4%) (Appendix II). The Elevation and Slope also emerged as an important non-bioclimatic variable, contributing 18% and 1.5 % respectively to model gain, indicating that topographic constraints partly define the niche of this species.

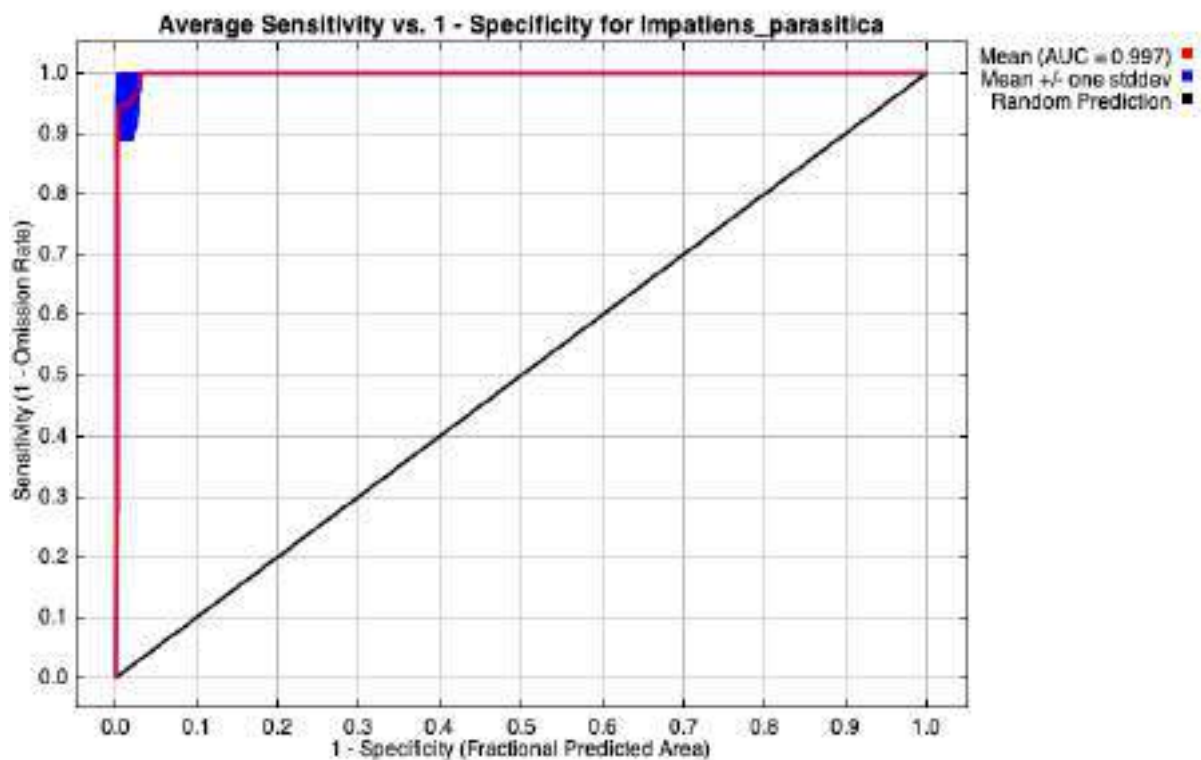


Fig. 4.67. Area Under Curve indicating model performance of *Impatiens parasitica*

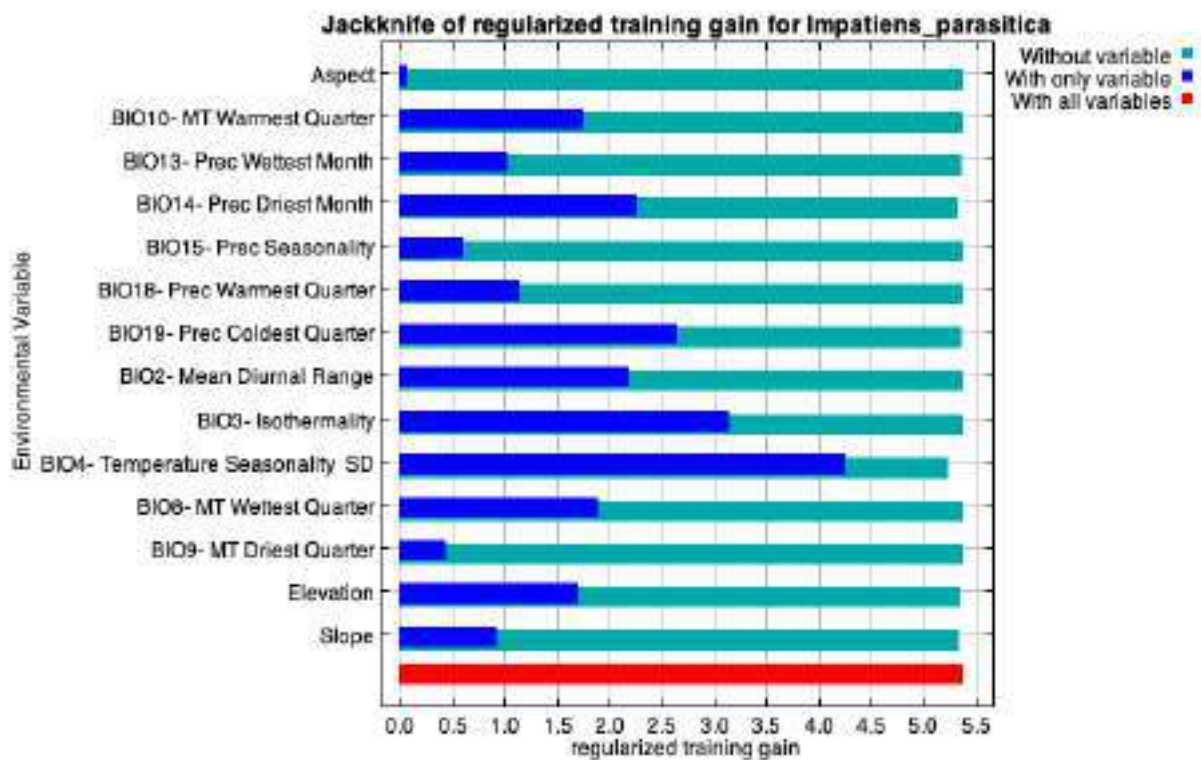


Fig. 4.68. Jackknife test of training gain showing bioclimatic variables of importance

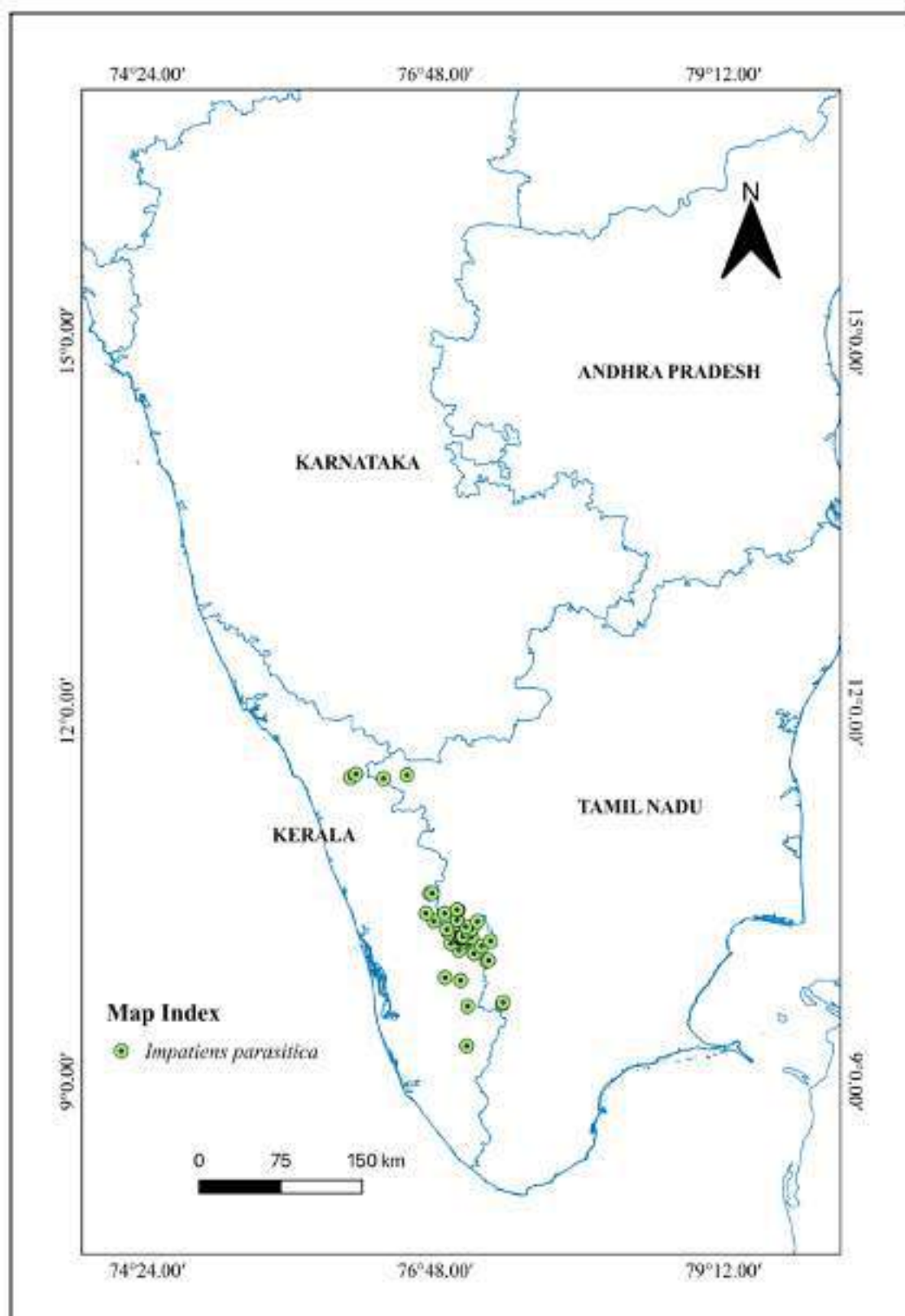


Fig. 4.69. Actual distribution of *Impatiens parasitica*

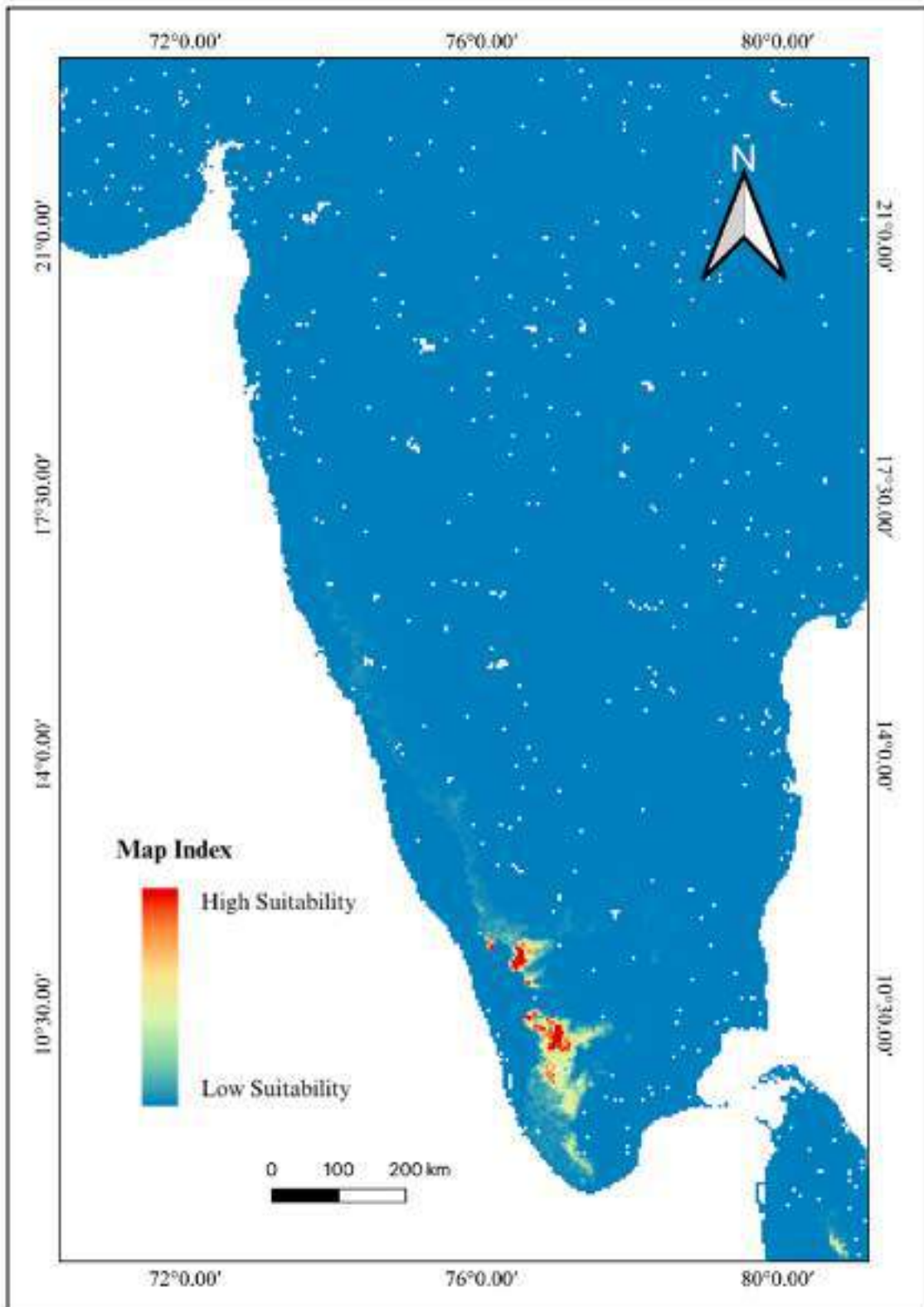


**Fig. 4.70. Predicted habitat suitability of *Impatiens parasitica* using MaxEnt model under present climate scenario**

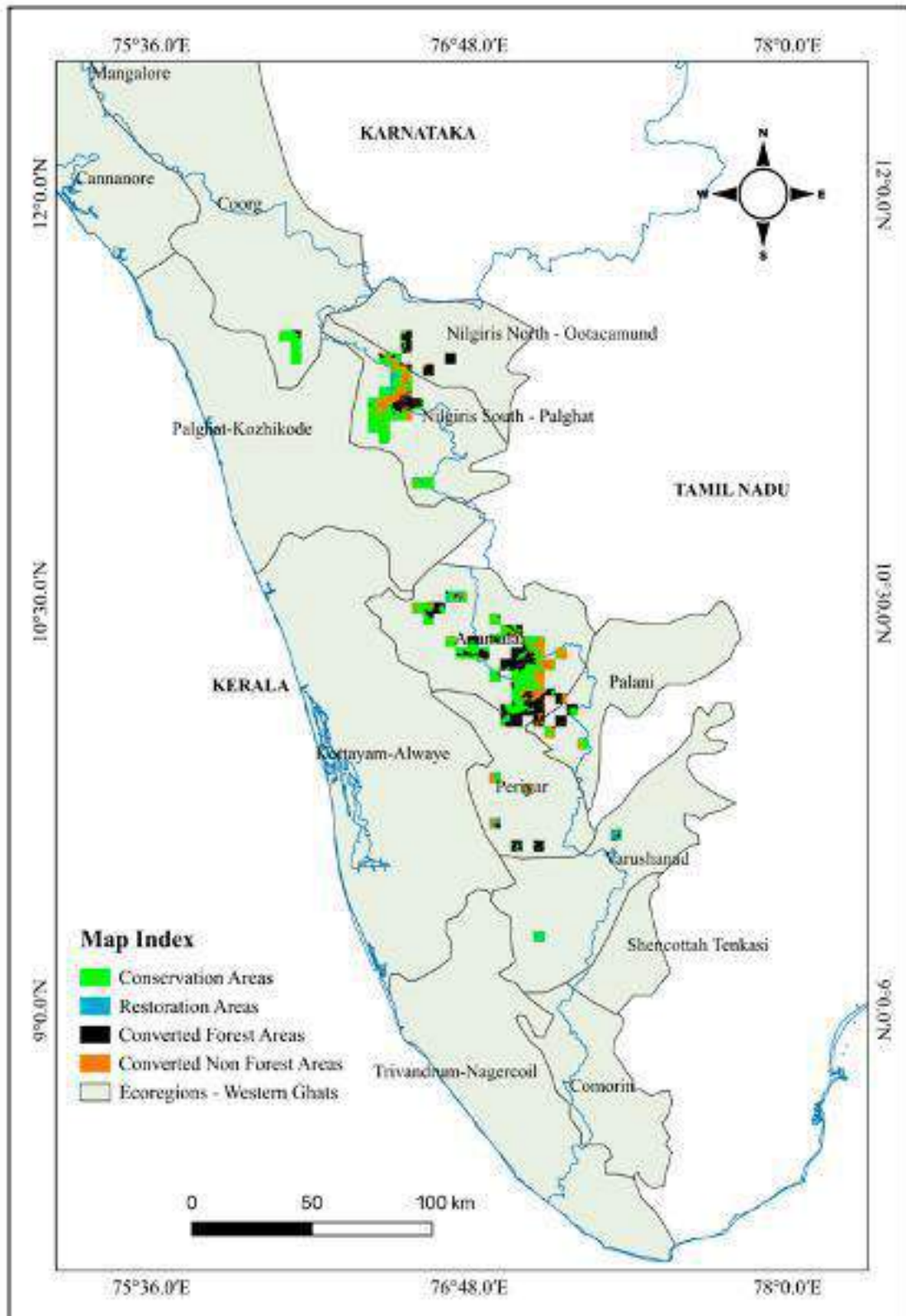


Fig. 4.71. Refined predicted area of *Impatiens parasitica* into potential conservation, restoration and irreversibly lost habitats at ecoregion level

### Eltonian Niche of *Impatiens parasitica* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Impatiens parasitica* is currently restricted to 21 subpopulations within the Western Ghats, particularly in parts of Kerala and Tamil Nadu (Fig. 4.69). Under the current climate scenario, the MaxEnt model predicts a total of 1813.226 km<sup>2</sup> of highly suitable habitat for *Impatiens parasitica* in the Western Ghats (Fig. 4.70). This predicted distribution spans over seven distinct ecoregions. The highest suitability predictions were concentrated in the Anamalai (862.15 km<sup>2</sup>), Nilgiris South – Palghat (468.82 km<sup>2</sup>), Periyar (160.95 km<sup>2</sup>), Palani (98.51 km<sup>2</sup>) ecoregions (Table 4.18).

**Table 4.18. Ecoregion wise habitat prediction for *Impatiens parasitica* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No.      | Ecoregion                         | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|--------------|-----------------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1            | Anamalai                          | 862.15                            | 420.248                              | 21.85                               | 259.13                                   | 160.91                                       |
| 2            | Coorg                             | 83.66                             | 76.86                                | 0                                   | 5.716                                    | 1.084                                        |
| 3            | Nilgiris North<br>-<br>Ootacamund | 98.03                             | 17.32                                | 0.252                               | 74.50                                    | 5.955                                        |
| 4            | Nilgiris South<br>- Palghat       | 468.82                            | 265.25                               | 23.57                               | 58.98                                    | 121.01                                       |
| 5            | Palani                            | 98.51                             | 36.54                                | 1.61                                | 39.35                                    | 21.00                                        |
| 6            | Periyar                           | 160.95                            | 21.92                                | 28.77                               | 81.55                                    | 28.69                                        |
| 7            | Varushanad                        | 41.09                             | 17.57                                | 19.24                               | 3.473                                    | 0.79                                         |
| <b>Total</b> |                                   | <b>1813.226</b>                   | <b>855.726</b>                       | <b>95.32</b>                        | <b>522.718</b>                           | <b>339.462</b>                               |

The initial modelling of the potential distribution for *Impatiens parasitica*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted



area of 1813.226 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.71). A total of Conservation area spanning 855.726 km<sup>2</sup>, Potential Ecorestoration area of 95.32 km<sup>2</sup>, irreversibly converted forest habitat (522.718 km<sup>2</sup>) and converted non-forested human-dominated areas (339.462 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Anamalai (420.24 km<sup>2</sup>), Nilgiris South – Palghat (265.25 km<sup>2</sup>), Periyar (21.92 km<sup>2</sup>), Palani (36.54 km<sup>2</sup>), Nilgiris North – Ootacamund (17.32 km<sup>2</sup>) represent maximum potential conservation areas suitable for *Impatiens parasitica*. The degraded habitats are also represented by ecoregions such as Anamalai (21.85 km<sup>2</sup>), Nilgiris South – Palghat (23.57 km<sup>2</sup>), Palani (1.61 km<sup>2</sup>), Periyar (28.77 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 7 % of converted forest habitat to the species are represented with Periyar (81.55 km<sup>2</sup>), Nilgiris South – Palghat (58.98 km<sup>2</sup>), Anamalai (259.13 km<sup>2</sup>), Varushanad (3.473 km<sup>2</sup>), Palani (39.35 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Impatiens parasitica* ecological niche.

#### **4.3.15. Grinnellian Niche of *Litsea oleoides* Using Bioclimatic Factors**

The MaxEnt model for *Litsea oleoides* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.996 (Fig. 4.72). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Litsea oleoides* (Fig. 4.73). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (49.9%) and Precipitation of Coldest Quarter (18.6%) contributed most to the model. This is followed by Isothermality (9.6%), Precipitation of Driest Quarter (4.2%), Precipitation of Wettest Quarter (0.7%) (Appendix II). The Elevation, Slope and Aspect also emerged as an important non-bioclimatic

variable, contributing 11.8%, 4% and 0.5% respectively to model gain, indicating that topographic constraints partly define the niche of this species.

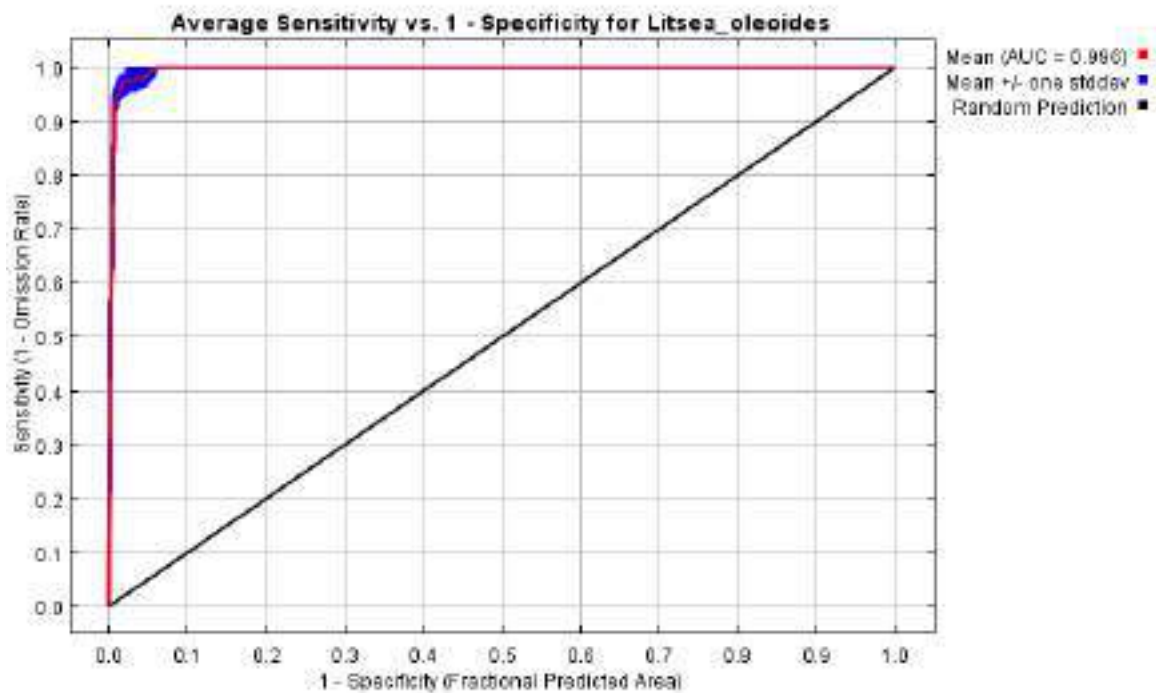


**Fig. 4.72.** Area Under Curve indicating model performance of *Litsea oleoides*



**Fig. 4.73.** Jackknife test of training gain showing bioclimatic variables of importance

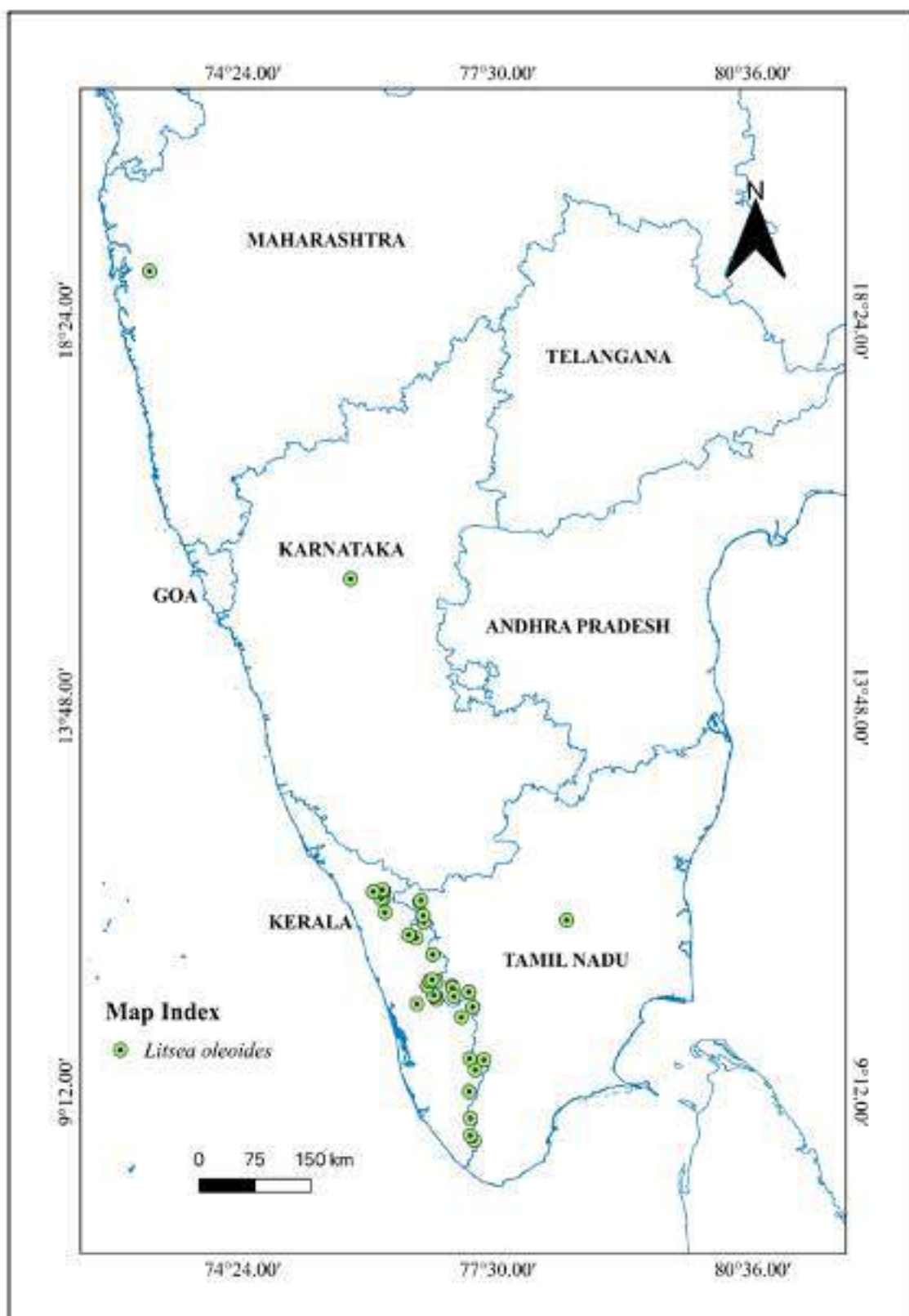


Fig. 4.74. Actual distribution of *Litsea oleoides*

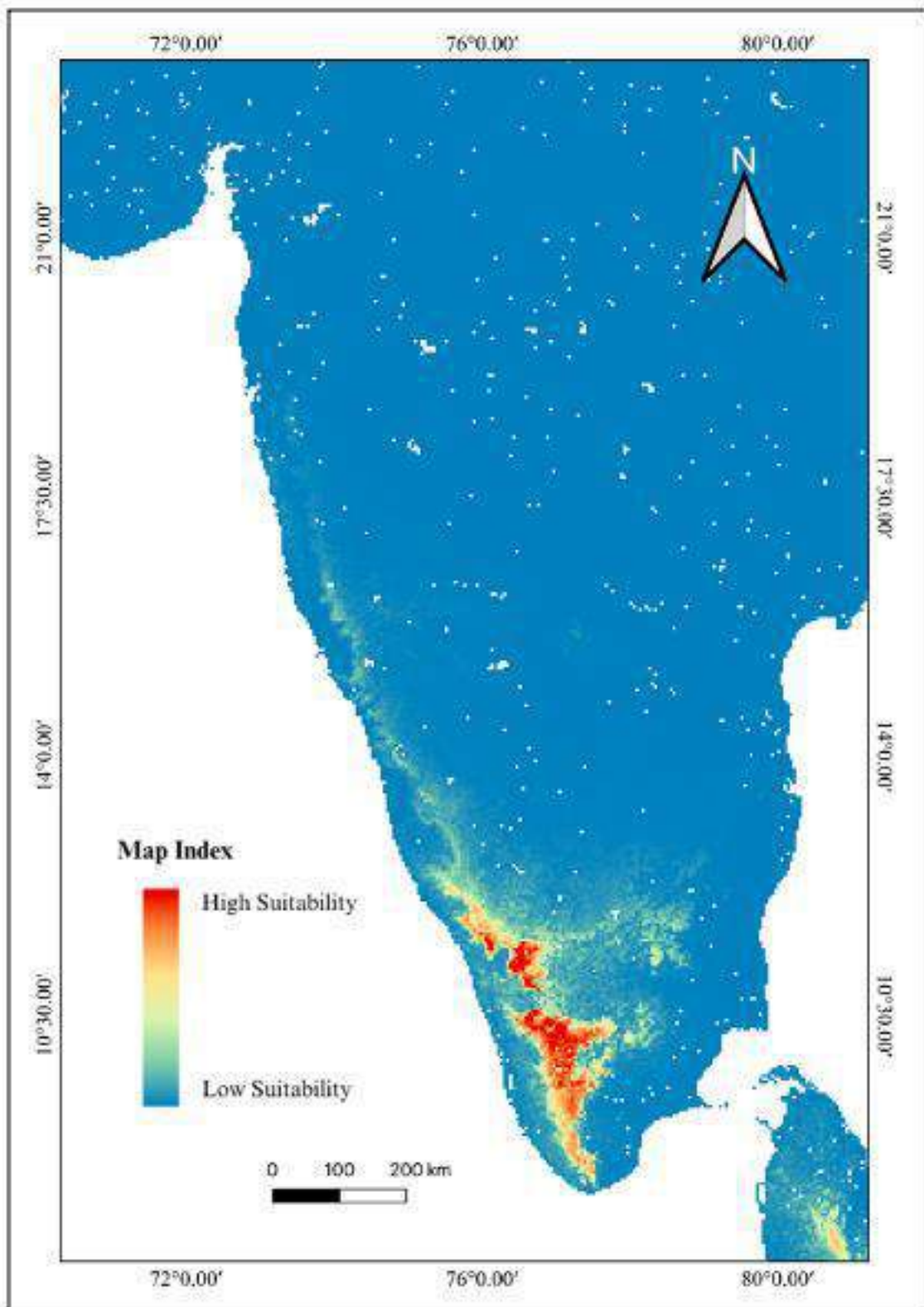


**Fig. 4.75.** Predicted habitat suitability of *Litsea oleoides* using MaxEnt model under present climate scenario

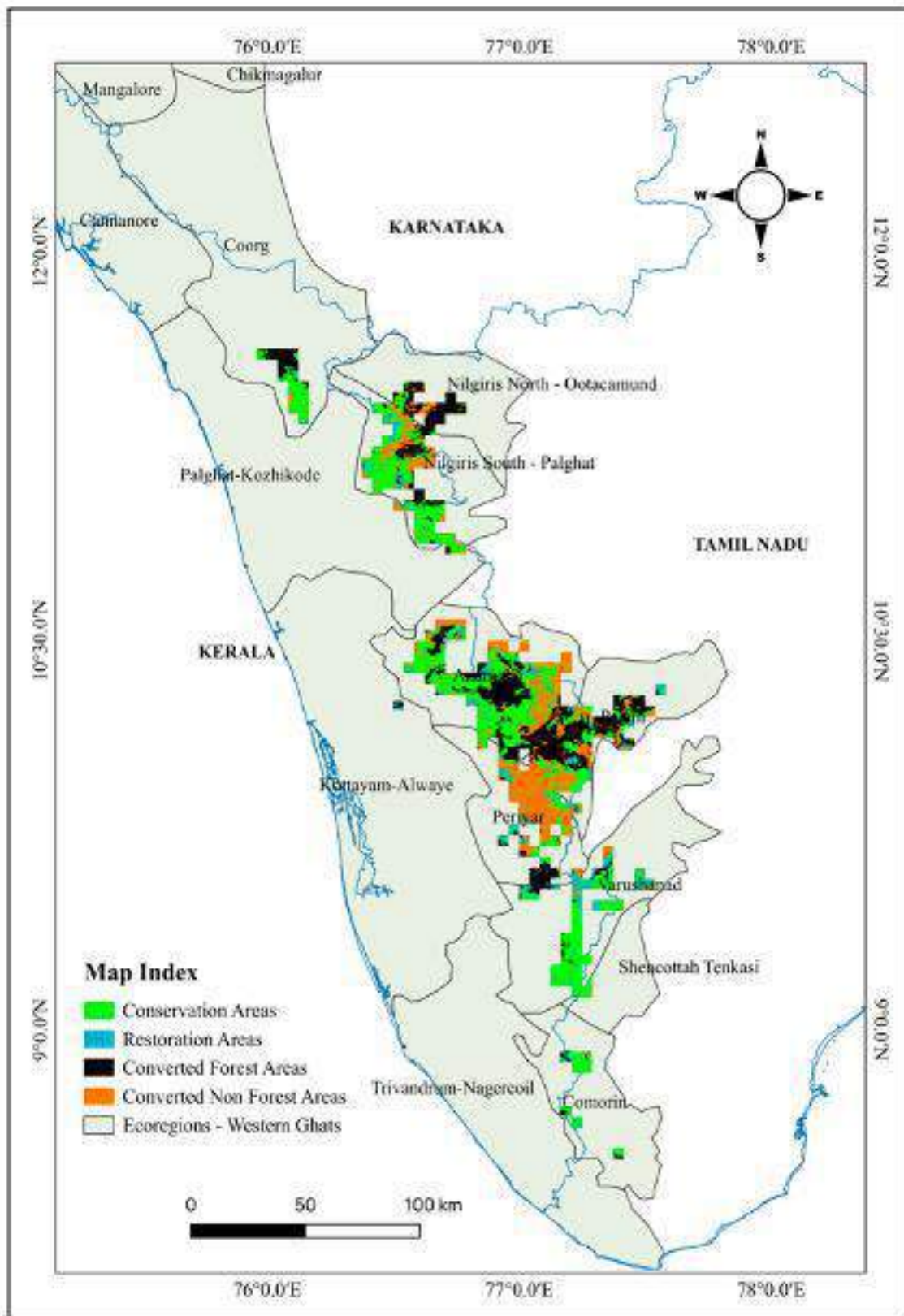


**Fig. 4.76.** Refined predicted area of *Litsea oleoides* into potential conservation, restoration and irreversibly lost habitats at ecoregion level

### Eltonian Niche of *Litsea oleoides* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Litsea oleoides* is currently restricted to 21 subpopulations within the Western Ghats, particularly in Kerala, Tamil Nadu, Karnataka and Maharashtra (Fig. 4.74). Under the current climate scenario, the MaxEnt model predicts a total of 6646.92 km<sup>2</sup> of highly suitable habitat for *Litsea oleoides* in the Western Ghats (Fig. 4.75). This predicted distribution spans over 11 distinct ecoregions. The highest suitability predictions were concentrated in the Anamalai (2039.68 km<sup>2</sup>), Nilgiris South-Palghat (1033.33 km<sup>2</sup>), Palani (1028.16 km<sup>2</sup>), Periyar (918.17 km<sup>2</sup>), Varushanad (739.33 km<sup>2</sup>), Coorg (312.52 km<sup>2</sup>), Nilgiris North-Ootacamund (295.27 km<sup>2</sup>) ecoregions (Table 4.19).

**Table 4.19. Ecoregion wise habitat prediction for *Litsea oleoides* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No. | Ecoregion                     | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|---------|-------------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1       | Anamalai                      | 2039.68                           | 910.58                               | 107.30                              | 557.31                                   | 464.50                                       |
| 2       | Comorin                       | 171.27                            | 121.80                               | 23.15                               | 23.24                                    | 3.08                                         |
| 3       | Coorg                         | 312.53                            | 162.34                               | 18.31                               | 117.87                                   | 14.01                                        |
| 4       | Kottayam-<br>Alwaye           | 17.18                             | 0.00                                 | 8.45                                | 8.73                                     | 0.00                                         |
| 5       | Nilgiris North-<br>Ootacamund | 295.27                            | 33.46                                | 0.25                                | 218.85                                   | 42.71                                        |
| 6       | Nilgiris South-<br>Palghat    | 1033.33                           | 566.54                               | 87.40                               | 158.85                                   | 220.54                                       |
| 7       | Palani                        | 1028.17                           | 264.86                               | 66.15                               | 428.54                                   | 268.61                                       |
| 8       | Palghat-<br>Kozhikode         | 54.71                             | 26.76                                | 4.32                                | 6.80                                     | 16.83                                        |
| 9       | Periyar                       | 918.17                            | 153.80                               | 110.90                              | 155.41                                   | 498.05                                       |



|    |                       |                |                |               |                |                |
|----|-----------------------|----------------|----------------|---------------|----------------|----------------|
| 10 | Shencottah<br>Tenkasi | 37.28          | 31.40          | 2.50          | 0.00           | 3.37           |
| 11 | Varushanad            | 739.33         | 490.12         | 157.94        | 56.82          | 34.45          |
|    | <b>Total</b>          | <b>6646.92</b> | <b>2761.67</b> | <b>586.67</b> | <b>1732.43</b> | <b>1566.15</b> |

The initial modelling of the potential distribution for *Litsea oleoides*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 6646.92 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.76). A total of Conservation area spanning 2761.67 km<sup>2</sup>, Potential Ecorestoration area of 586.67 km<sup>2</sup>, irreversibly converted forest habitat (1732.43 km<sup>2</sup>) and converted non-forested human-dominated areas (1732.43 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Anamalai (910.57 km<sup>2</sup>), Nilgiris South-Palghat (566.54 km<sup>2</sup>), Varushanad (490.12 km<sup>2</sup>), Palani (264.86 km<sup>2</sup>), Coorg (162.33 km<sup>2</sup>), Periyar (153.80 km<sup>2</sup>) and Comorin (121.80 km<sup>2</sup>) represent maximum potential conservation areas suitable for *Litsea oleoides*. The degraded habitats are also represented by ecoregions such as Varushanad (157.94 km<sup>2</sup>), Periyar (110.89 km<sup>2</sup>), Anamalai (107.29 km<sup>2</sup>), Nilgiris South-Palghat (87.40 km<sup>2</sup>), Palani (66.15 km<sup>2</sup>) and Comorin (23.14 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 26 % of converted forest habitat to the species are represented with Anamalai (557.30 km<sup>2</sup>), Palani (428.54 km<sup>2</sup>), Nilgiris North-Ootacamund (218.85 km<sup>2</sup>), Nilgiris South-Palghat (158.84 km<sup>2</sup>), Periyar (155.41 km<sup>2</sup>) and Coorg (117.86 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Litsea oleoides* ecological niche.

#### 4.3.16. Grinnellian Niche of *Medinilla anamalaiana* Using Bioclimatic Factors

The MaxEnt model for *Medinilla anamalaiana* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.995 (Fig. 4.77). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's



strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Medinilla anamalaiana* (Fig. 4.78). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (77.6%) and Mean Diurnal Range (3.9%) contributed most to the model. This is followed by Precipitation of Warmest Quarter (3.3%), Mean Temperature of Warmest Quarter (0.8%), Precipitation of Coldest Quarter (0.5%) (Appendix II). The Slope and Elevation also emerged as an important non-bioclimatic variable, contributing 8.6% and 5.2% respectively to model gain, indicating that topographic constraints partly define the niche of this species.

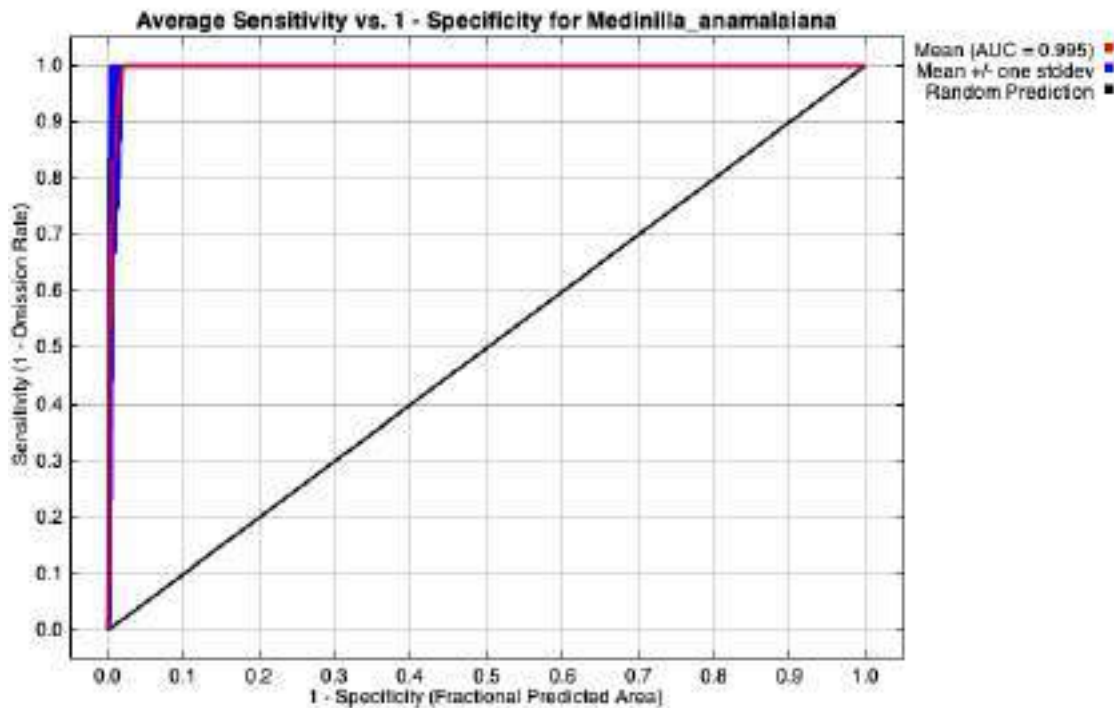


**Fig. 4.77.** Area Under Curve indicating model performance of *Medinilla anamalaiana*

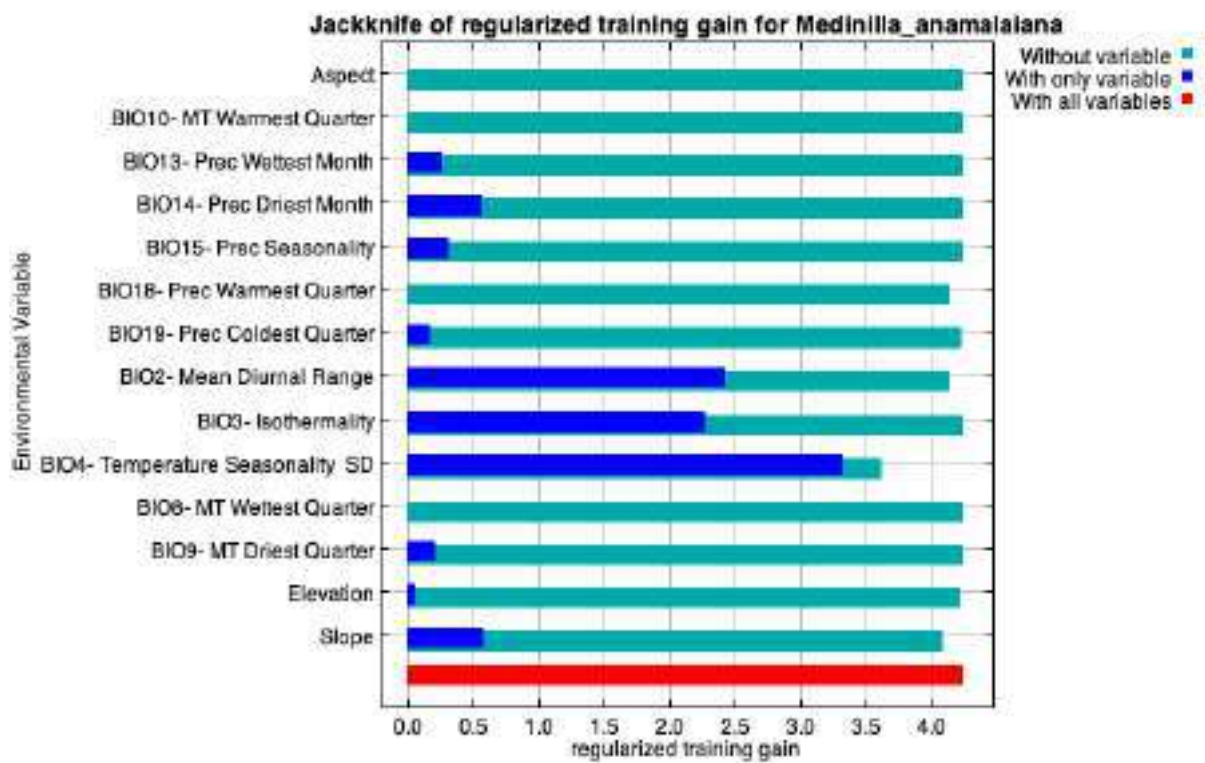


**Fig. 4.78. Jackknife test of training gain showing bioclimatic variables of importance**

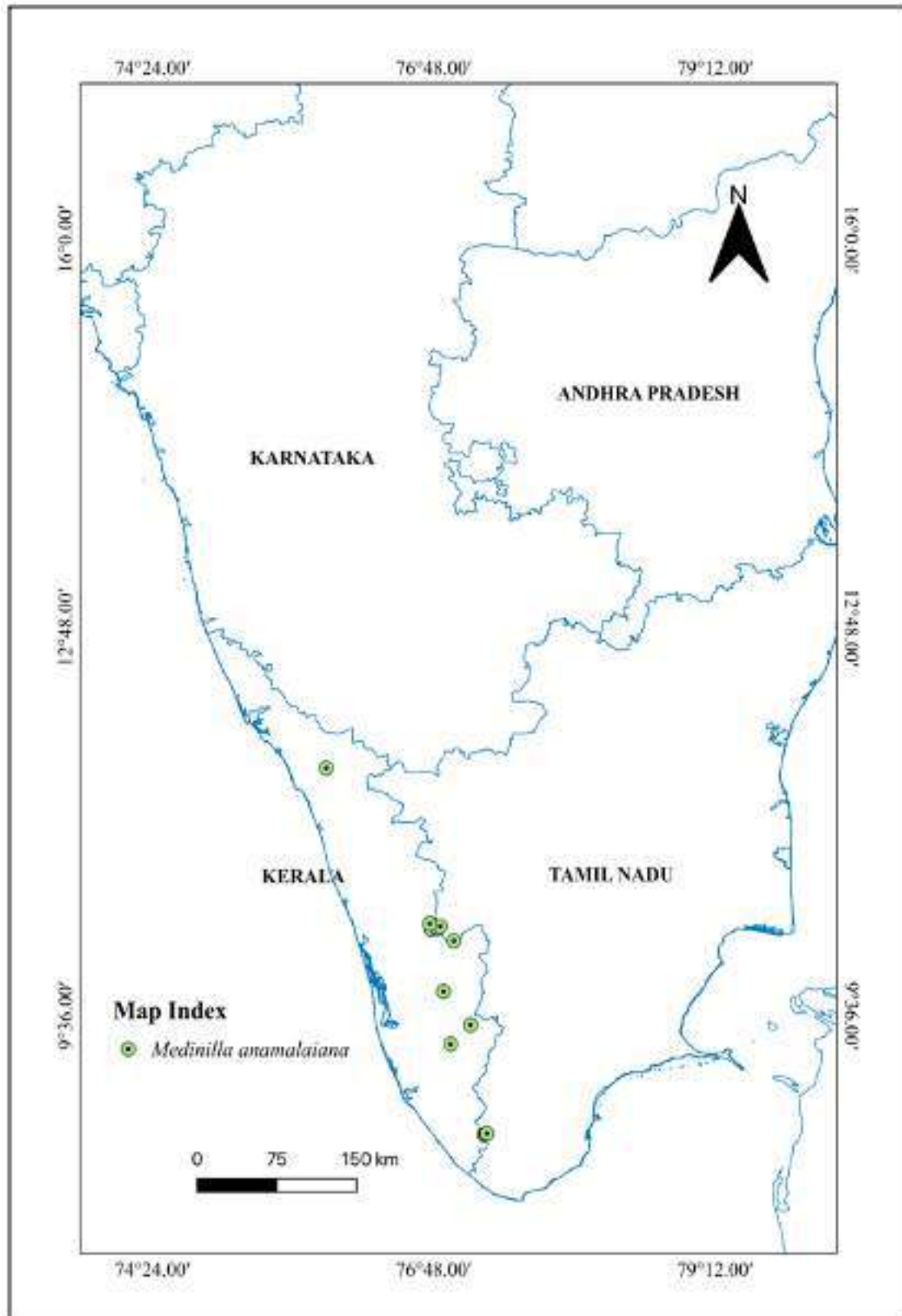


Fig. 4.79. Actual distribution of *Medinilla anamalaiana*

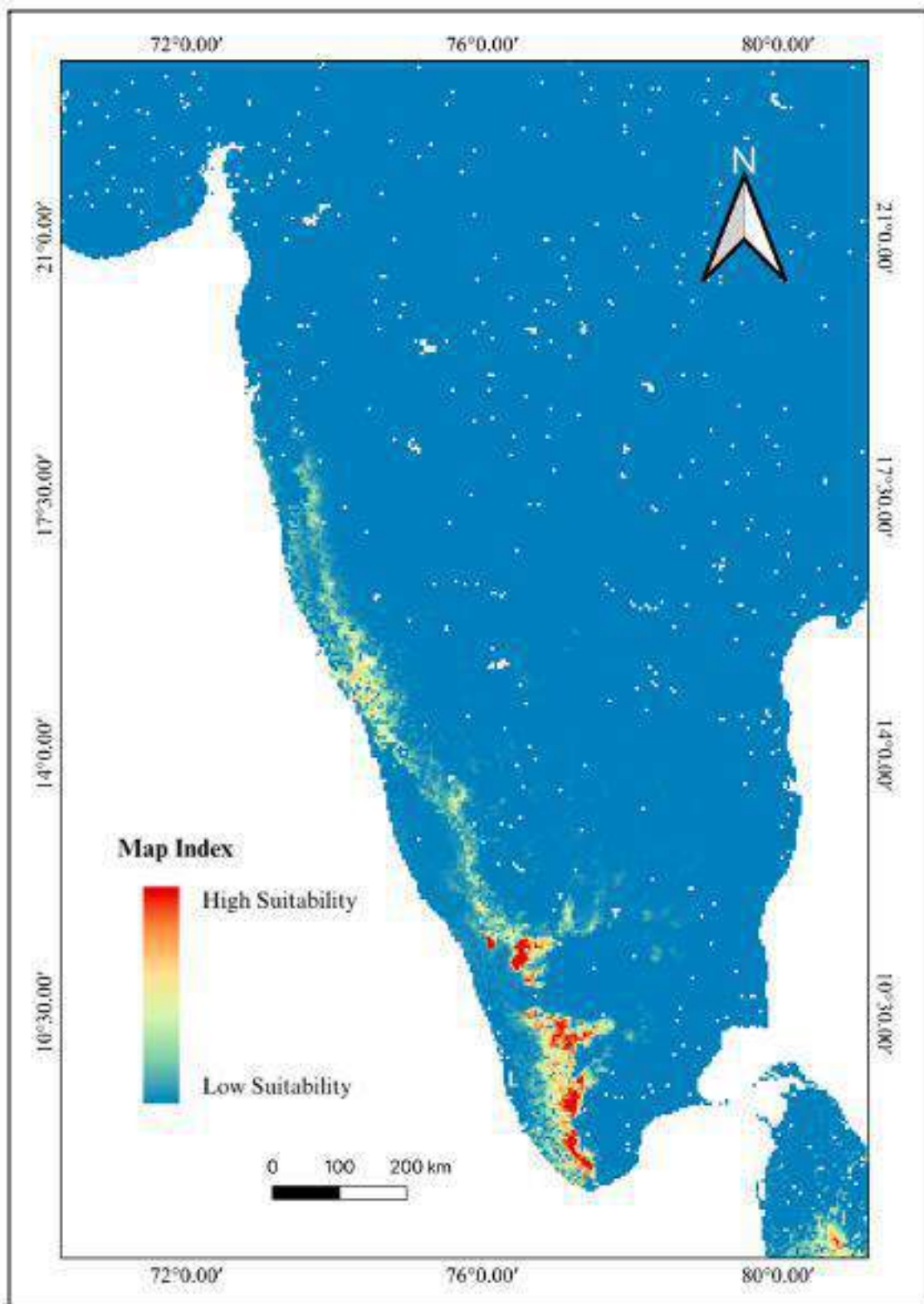


**Fig. 4.80.** Predicted habitat suitability of *Medinilla anamalaiana* using MaxEnt model under present climate scenario

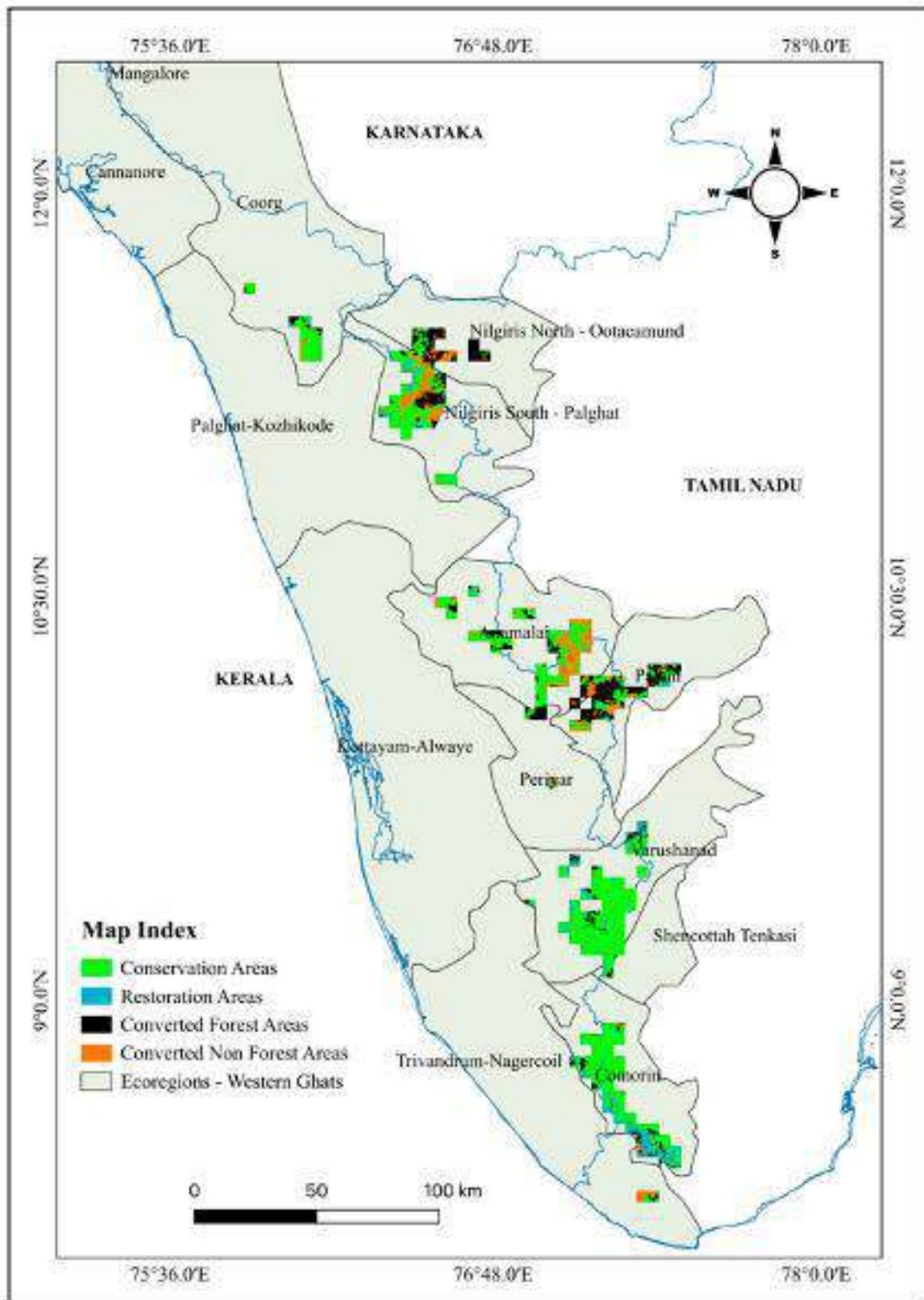


**Fig. 4.81.** Refined predicted area of *Medinilla anamalaiana* into potential conservation, restoration and irreversibly lost habitats at ecoregion level

### Eltonian Niche of *Medinilla anamalaiana* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Medinilla anamalaiana* is currently restricted to eight subpopulations within the Western Ghats, particularly in parts of Kerala and Tamil Nadu (Fig. 4.79). Under the current climate scenario, the MaxEnt model predicts a total of 4020.807 km<sup>2</sup> of highly suitable habitat for *Medinilla anamalaiana* in the Western Ghats (Fig. 4.80). This predicted distribution spans over 10 distinct ecoregions. The highest suitability predictions were concentrated in the Varushanad (877.78 km<sup>2</sup>), Nilgiris South – Palghat (775.86 km<sup>2</sup>), Comorin (758.96 km<sup>2</sup>), Anamalai (719.02 km<sup>2</sup>) ecoregions (Table 4.20).

**Table 4.20. Ecoregion wise habitat prediction for *Medinilla anamalaiana* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No. | Ecoregion                   | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|---------|-----------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1       | Anamalai                    | 719.02                            | 390.59                               | 14.21                               | 109.25                                   | 204.96                                       |
| 2       | Comorin                     | 758.96                            | 524.52                               | 169.98                              | 51.50                                    | 12.95                                        |
| 3       | Coorg                       | 188.56                            | 149.09                               | 6.543                               | 20.23                                    | 12.69                                        |
| 4       | Nilgiris North - Ootacamund | 106.09                            | 22.21                                | 0.37                                | 77.8                                     | 5.703                                        |
| 5       | Nilgiris South - Palghat    | 775.86                            | 366.4                                | 53.57                               | 170.84                                   | 185.04                                       |
| 6       | Palani                      | 434.9                             | 131.4                                | 7.74                                | 230.1                                    | 65.65                                        |
| 7       | Periyar                     | 68.26                             | 12.532                               | 10.28                               | 34.46                                    | 10.97                                        |
| 8       | Shencottah Tenkasi          | 37.56                             | 25.40                                | 5.71                                | 5.046                                    | 1.407                                        |
| 9       | Trivandrum-Nagercoil        | 53.81                             | 16.143                               | 4.45                                | 10.70                                    | 22.50                                        |

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|    |              |                |                |               |               |               |
|----|--------------|----------------|----------------|---------------|---------------|---------------|
| 10 | Varushanad   | 877.78         | 729.36         | 91.75         | 54.73         | 1.92          |
|    | <b>Total</b> | <b>4020.80</b> | <b>2367.66</b> | <b>364.62</b> | <b>764.69</b> | <b>523.82</b> |

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The initial modelling of the potential distribution for *Medinilla anamalaiana*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 4020.80 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.81). A total of Conservation area spanning 2367.66 km<sup>2</sup>, Potential Ecorestoration area of 364.62 km<sup>2</sup>, irreversibly converted forest habitat (764.69 km<sup>2</sup>) and converted non-forested human-dominated areas (523.82 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Varushanad (729.36 km<sup>2</sup>), Comorin (524.52 km<sup>2</sup>), Anamalai (390.59 km<sup>2</sup>), Nilgiris South – Palghat (366.4 km<sup>2</sup>), Coorg (149.09 km<sup>2</sup>) and Palani (131.4 km<sup>2</sup>) represent maximum potential conservation areas suitable for *Medinilla anamalaiana*. The degraded habitats are also represented by ecoregions such as Comorin (169.98 km<sup>2</sup>), Varushanad (91.75 km<sup>2</sup>), Nilgiris South – Palghat (53.57 km<sup>2</sup>), Anamalai (14.21 km<sup>2</sup>) and Periyar (10.28 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 19 % of converted forest habitat to the species are represented with Palani (230.1 km<sup>2</sup>), Nilgiris South – Palghat (170.84 km<sup>2</sup>), Anamalai (109.25 km<sup>2</sup>), Nilgiris North – Ootacamund (77.8 km<sup>2</sup>) and Varushanad (54.73 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Medinilla anamalaiana* ecological niche.

#### 4.3.17. Grinnellian Niche of *Meiogyne pannosa* Using Bioclimatic Factors

The MaxEnt model for *Meiogyne pannosa* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.995 (Fig. 4.82). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.



The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Meiogyne pannosa* (Fig. 4.83). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (54%) and Precipitation of Coldest Quarter (19.6%) contributed most to the model. This is followed by Isothermality (6.6%), Precipitation Seasonality (1.4%), Precipitation of Wettest Quarter (0.9%) and Precipitation of Driest Quarter (0.8%) (Appendix II). The Slope and Elevation also emerged as an important non-bioclimatic variable, contributing 8.1% and 7.3% respectively to model gain, indicating that topographic constraints partly define the niche of this species.

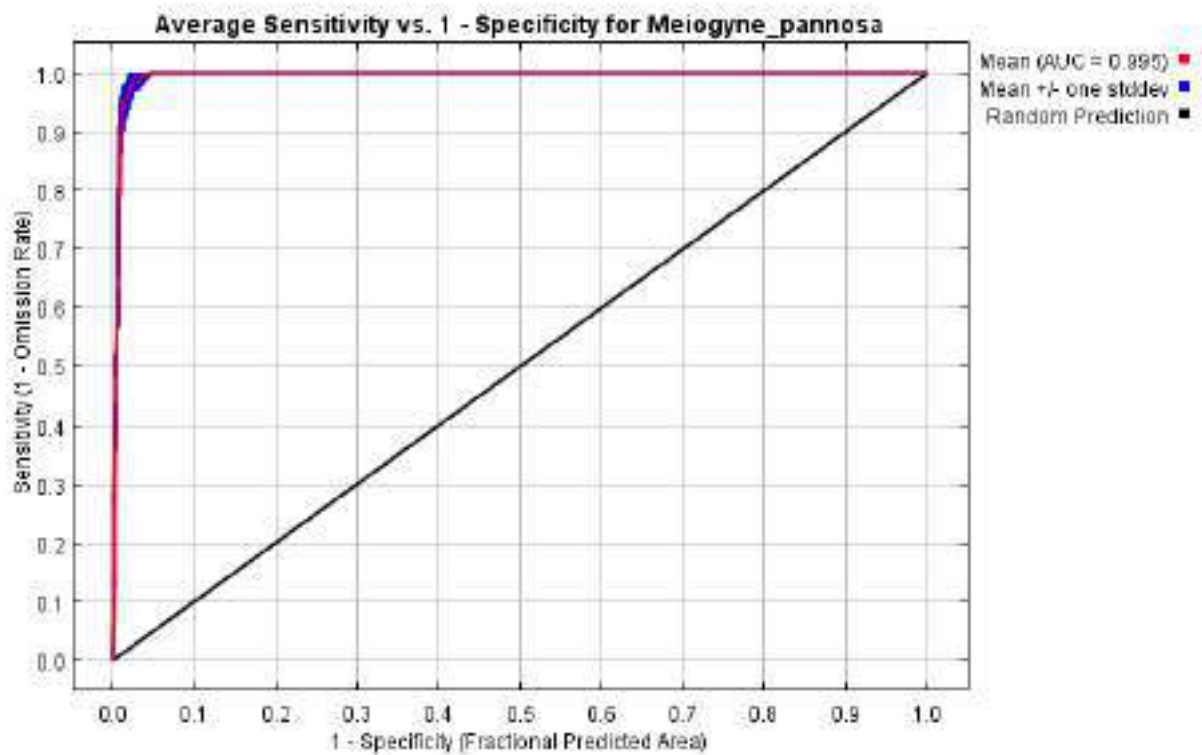


**Fig. 4.82.** Area Under Curve indicating model performance of *Meiogyne pannosa*



**Fig. 4.83. Jackknife test of training gain showing bioclimatic variables of importance**

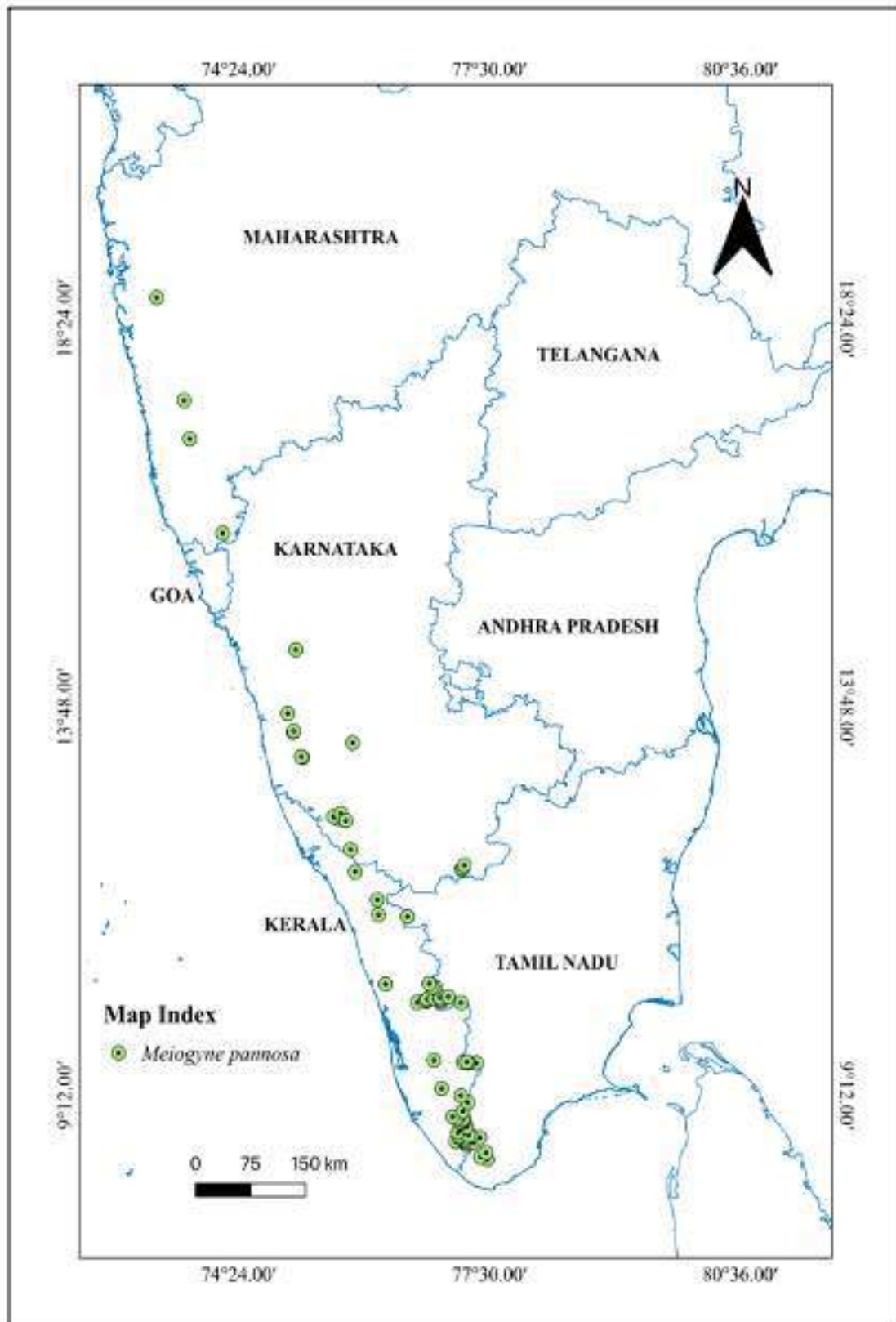


Fig. 4.84. Actual distribution of *Meiogyne pannosa*

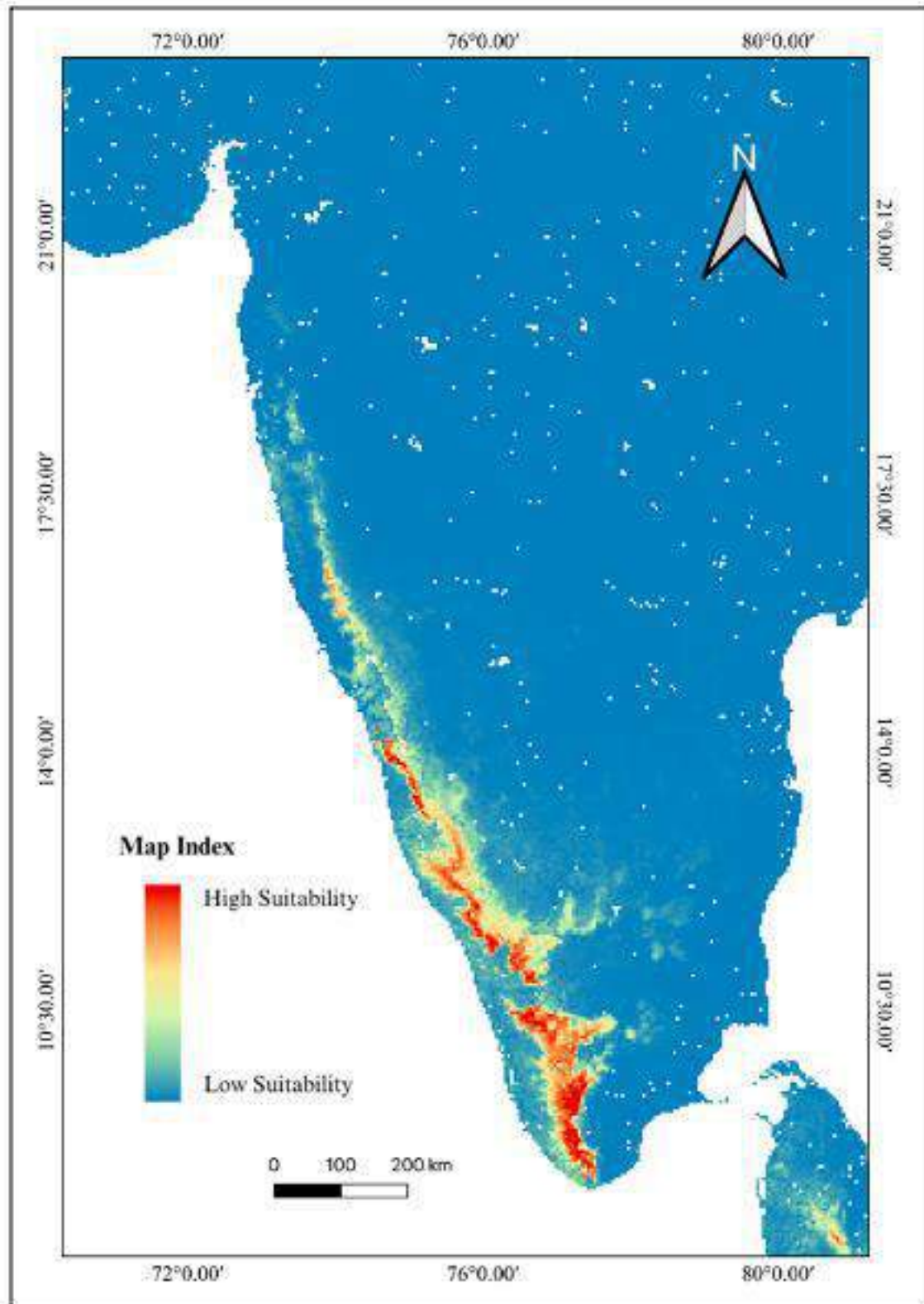


**Fig. 4.85.** Predicted habitat suitability of *Meiogyne pannosa* using MaxEnt model under present climate scenario

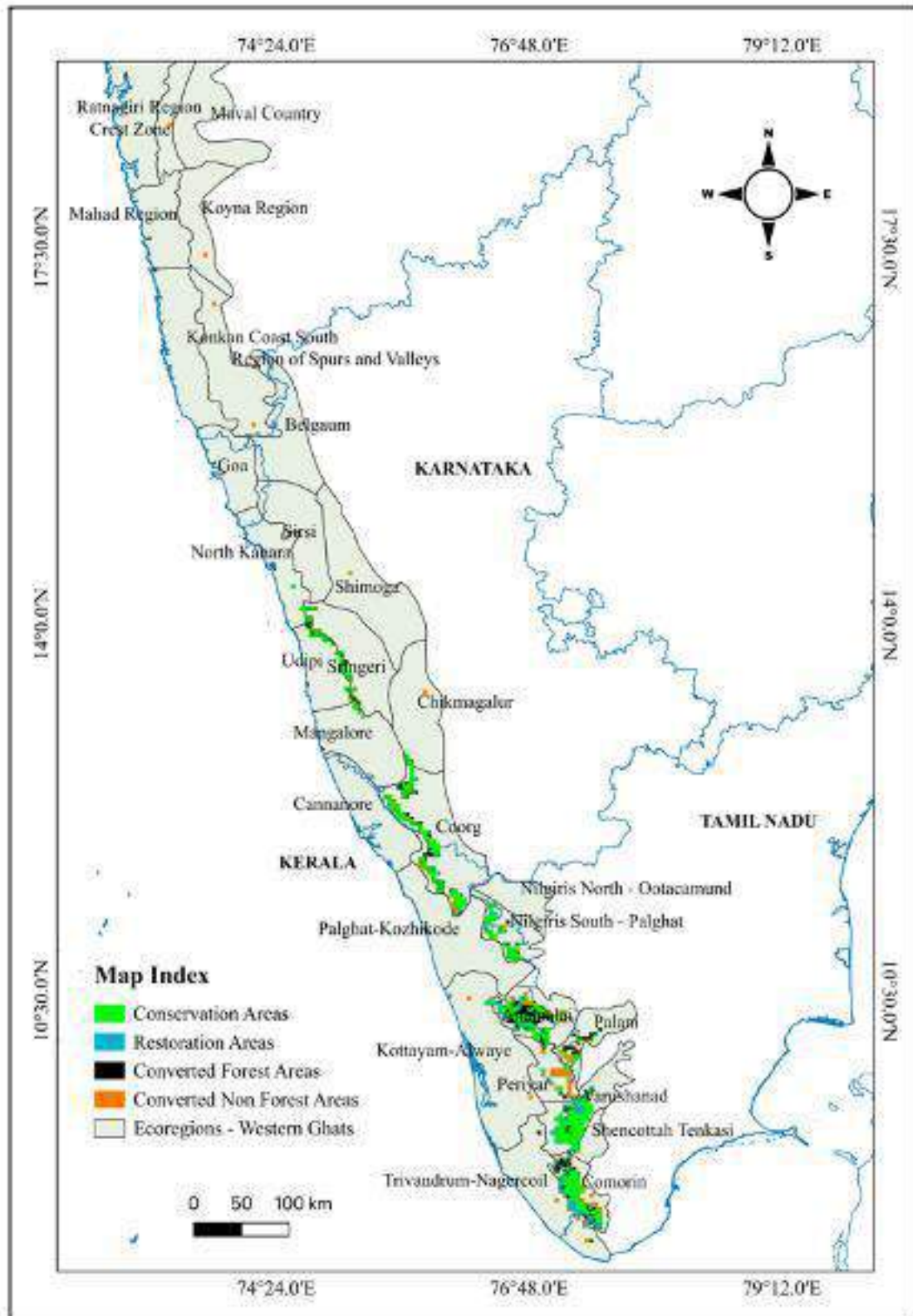


Fig. 4.86. Refined predicted area of *Meiogyne pannosa* into potential conservation, restoration and irreversibly lost habitats at ecoregion level

### Eltonian Niche of *Meiogyne pannosa* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Meiogyne pannosa* is currently restricted to 26 subpopulations within the Kerala, Tamil Nadu, Karnataka, Maharashtra part of the Western Ghats (Fig. 4.84). Under the current climate scenario, the MaxEnt model predicts a total of 9880.81 km<sup>2</sup> of highly suitable habitat for *Meiogyne pannosa* in the Western Ghats (Fig. 4.85). This predicted distribution spans over 19 distinct ecoregions. The highest suitability predictions were concentrated in the Coorg (1852.58 km<sup>2</sup>), Anamalai (1785.01 km<sup>2</sup>), Comorin (1499.16 km<sup>2</sup>), Varushanad (1480 km<sup>2</sup>), Nilgiris South-Palghat (703.97 km<sup>2</sup>), Periyar (566.96 km<sup>2</sup>), Sringeri (478.40 km<sup>2</sup>), Palani (462.20 km<sup>2</sup>) ecoregions (Table 4.21).

**Table 4.21. Ecoregion wise habitat prediction for *Meiogyne pannosa* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No. | Ecoregion                  | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|---------|----------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1       | Anamalai                   | 1785.01                           | 935.86                               | 206.37                              | 413.61                                   | 229.17                                       |
| 2       | Chikmagalur                | 104.87                            | 59.98                                | 5.16                                | 5.25                                     | 34.49                                        |
| 3       | Comorin                    | 1499.16                           | 819.49                               | 331.91                              | 189.00                                   | 158.76                                       |
| 4       | Coorg                      | 1852.58                           | 1206.12                              | 184.68                              | 242.05                                   | 219.74                                       |
| 5       | Crest Zone                 | 19.70                             | 0.00                                 | 0.00                                | 0.00                                     | 19.70                                        |
| 6       | Kottayam-<br>Alwaye        | 65.57                             | 15.71                                | 7.00                                | 0.00                                     | 42.87                                        |
| 7       | Koyna region               | 20.31                             | 0.00                                 | 0.00                                | 0.00                                     | 20.31                                        |
| 8       | Mangalore                  | 84.72                             | 15.71                                | 6.54                                | 8.53                                     | 53.94                                        |
| 9       | Nilgiris South-<br>Palghat | 703.97                            | 479.37                               | 97.24                               | 53.74                                    | 73.63                                        |
| 10      | North Kanara               | 39.67                             | 37.48                                | 0.00                                | 2.19                                     | 0.00                                         |
| 11      | Palani                     | 462.20                            | 156.73                               | 30.13                               | 163.59                                   | 111.77                                       |



|              |                               |                |                |                |                |                |
|--------------|-------------------------------|----------------|----------------|----------------|----------------|----------------|
| 12           | Periyar                       | 566.97         | 122.88         | 92.19          | 42.86          | 309.04         |
| 13           | Region of Spurs<br>and Valley | 40.24          | 0.00           | 0.00           | 0.00           | 40.24          |
| 14           | Shencottah<br>Tenkasi         | 94.66          | 58.54          | 18.81          | 5.87           | 11.44          |
| 15           | Shimoga                       | 21.48          | 5.69           | 0.25           | 0.19           | 15.34          |
| 16           | Sringeri                      | 478.41         | 296.36         | 29.42          | 115.15         | 37.47          |
| 17           | Trivandrum-<br>Nagercoil      | 258.90         | 24.86          | 96.09          | 69.84          | 68.10          |
| 18           | Udipi                         | 302.39         | 221.11         | 24.58          | 50.05          | 6.66           |
| 19           | Varushanad                    | 1480.00        | 1086.24        | 270.94         | 73.88          | 48.93          |
| <b>Total</b> |                               | <b>9880.81</b> | <b>5542.11</b> | <b>1401.31</b> | <b>1435.79</b> | <b>1501.60</b> |

The initial modelling of the potential distribution for *Meiogyne pannosa*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 9880.81 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.86). A total of Conservation area spanning 5542.11 km<sup>2</sup> Potential Ecorestoration area of 1401.31 km<sup>2</sup>, irreversibly converted forest habitat (1435.79 km<sup>2</sup>) and converted non-forested human-dominated areas (1501.60 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Coorg (1206.11 km<sup>2</sup>), Varushanad (1086.24 km<sup>2</sup>), Anamalai (935.86 km<sup>2</sup>), Comorin (819.49 km<sup>2</sup>) and Nilgiris South-Palghat (479.36 km<sup>2</sup>) represent maximum potential conservation areas suitable for *Meiogyne pannosa*. The degraded habitats are also represented by ecoregions such as Comorin (331.90 km<sup>2</sup>), Varushanad (270.94 km<sup>2</sup>), Anamalai (206.37 km<sup>2</sup>), Coorg (184.67 km<sup>2</sup>), Nilgiris South-Palghat (97.23 km<sup>2</sup>) and Trivandrum-Nagercoil (96.09 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 14 % of converted forest habitat to the species are represented with Anamalai (413.61 km<sup>2</sup>), Coorg (242.05 km<sup>2</sup>), Comorin (188.99 km<sup>2</sup>), Palani (163.58 km<sup>2</sup>) and Sringeri (115.15 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales



provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Meiogyne pannosa* ecological niche.

#### **4.3.18. Grinnellian Niche of *Ochna gamblei* Using Bioclimatic Factors**

The MaxEnt model for *Ochna gamblei* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.899 (Fig. 4.87). This value indicates very good model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Ochna gamblei* (Fig. 4.88). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (79.2%) and Precipitation of Warmest Quarter (6%) contributed most to the model. This is followed by Precipitation Seasonality (3.2%), Precipitation of Driest Quarter (3.1%), Isothermality (3%), Mean Temperature of Driest Quarter (1.6%), Mean Diurnal Range (1.3%) (Appendix II). The Elevation also emerged as an important non-bioclimatic variable, contributing 1.1% to model gain, indicating that topographic constraints partly define the niche of this species.

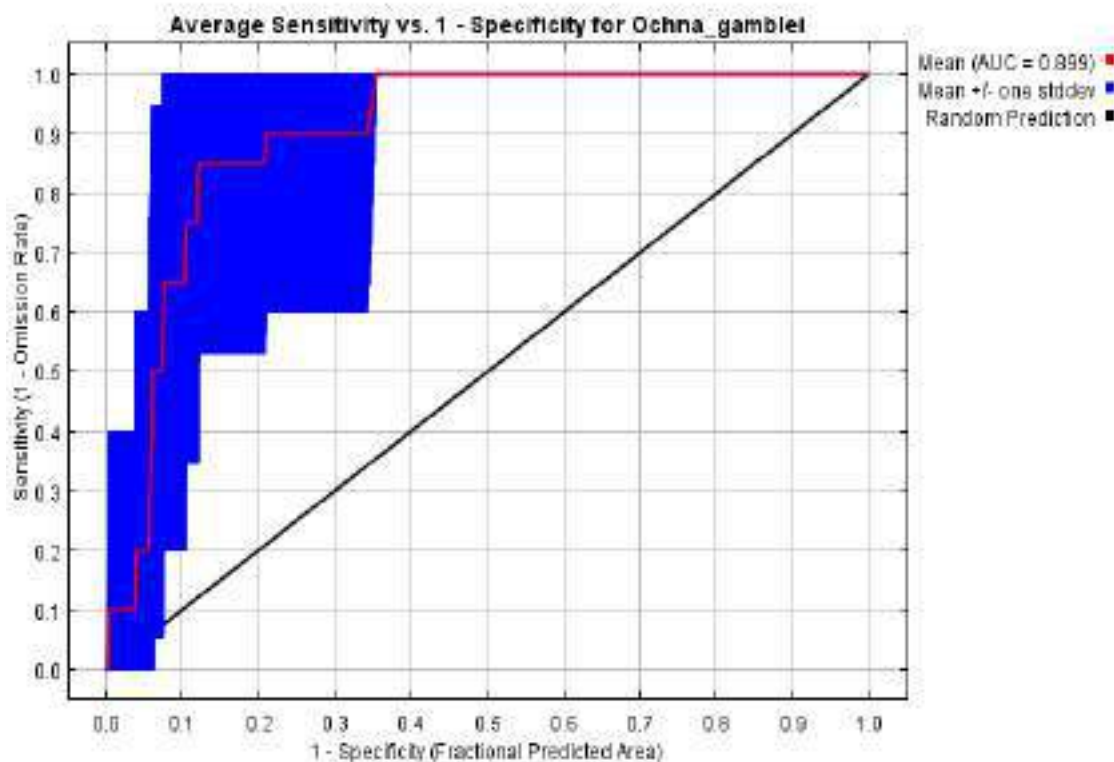


Fig. 4.87. Area Under Curve indicating model performance of *Ochna gamblei*

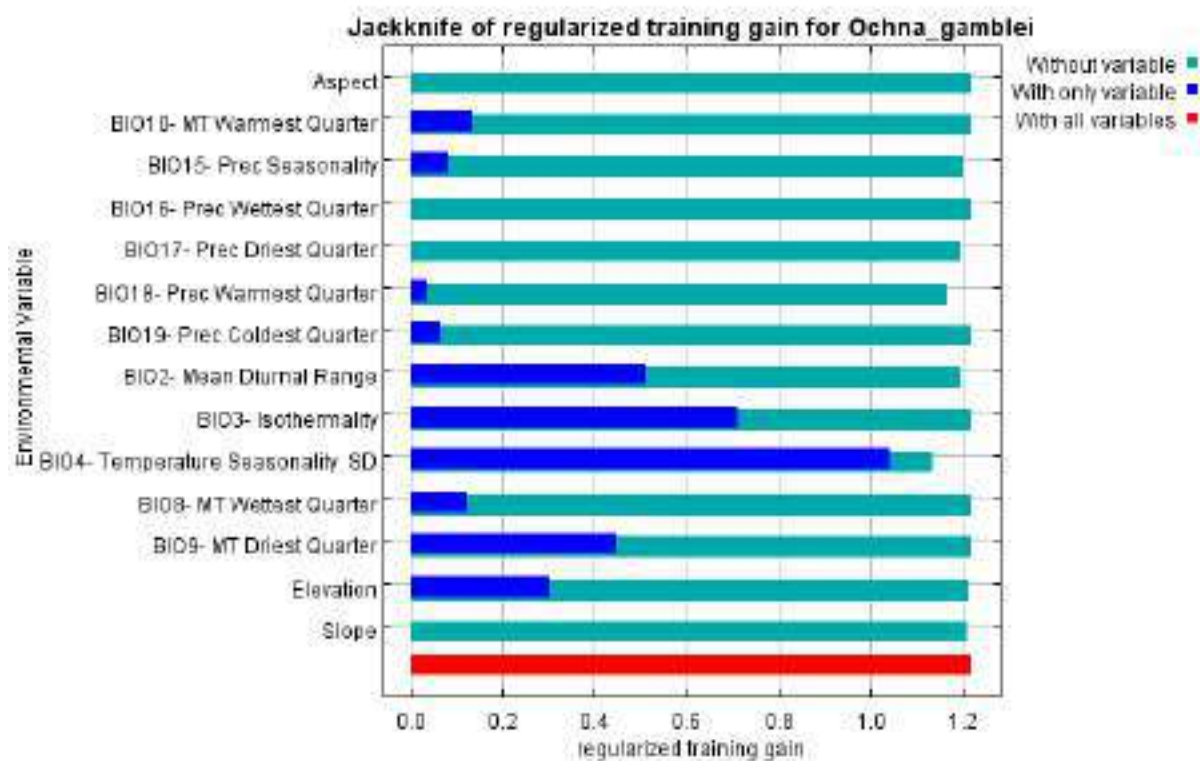


Fig. 4.88. Jackknife test of training gain showing bioclimatic variables of importance

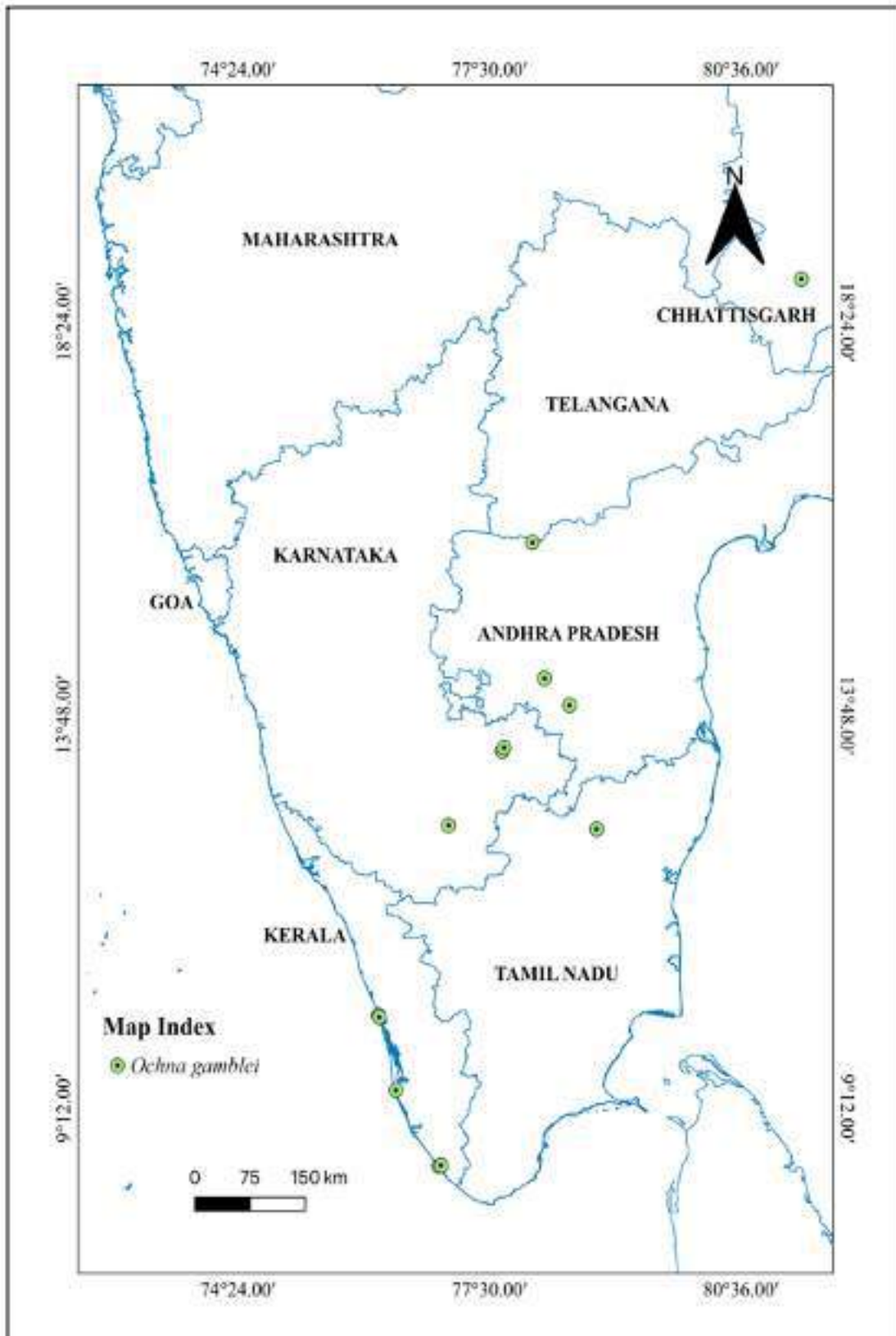


Fig. 4.89. Actual distribution of *Ochna gamblei*

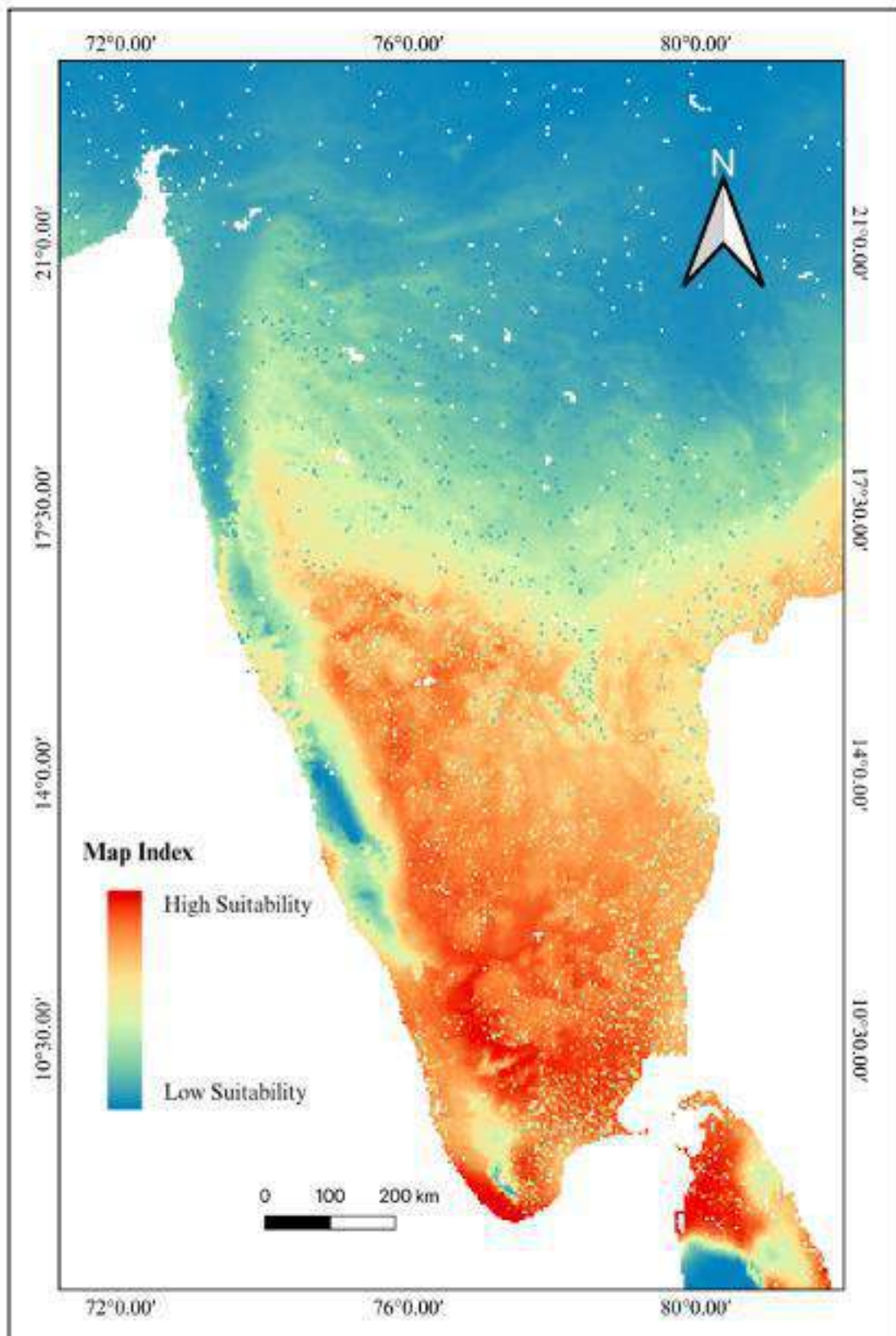


**Fig. 4.90. Predicted habitat suitability of *Ochna gamblei* using MaxEnt model under present climate scenario**

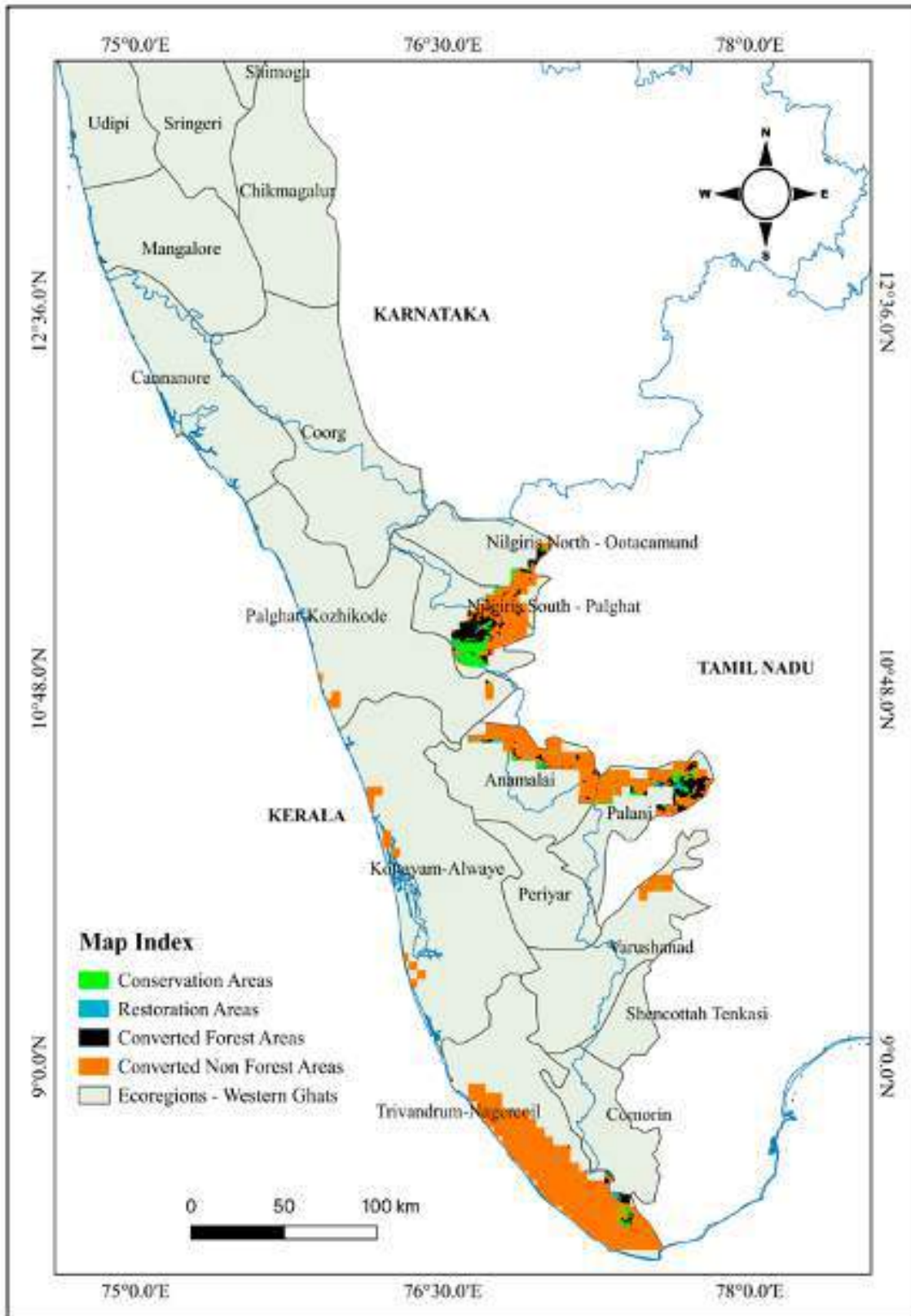


**Fig. 4.91. Refined predicted area of *Ochra gamblei* into potential conservation, restoration and irreversibly lost habitats at ecoregion level**

### Eltonian Niche of *Ochna gamblei* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Ochna gamblei* is currently restricted to 11 subpopulations within the Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Chhattisgarh regions (Fig. 4.89). Under the current climate scenario, the MaxEnt model predicts a total of 6337.25 km<sup>2</sup> of highly suitable habitat for *Ochna gamblei* in the Western Ghats ecoregions (Fig. 4.90). This predicted distribution spans over eight distinct. The highest suitability predictions were concentrated in the Trivandrum-Nagercoil (2703.32 km<sup>2</sup>), Nilgiris South-Palghat (1033.19 km<sup>2</sup>), Anamalai (925.84 km<sup>2</sup>), Palani (920.54 km<sup>2</sup>), Nilgiris North-Ootacamund (297.11 km<sup>2</sup>) ecoregions (Table 4.22).

**Table 4.22. Ecoregion wise habitat prediction for *Ochna gamblei* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No.      | Ecoregion                 | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|--------------|---------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1            | Anamalai                  | 925.85                            | 38.68                                | 19.32                               | 48.44                                    | 819.41                                       |
| 2            | Kottayam-Alwaye           | 197.78                            | 0.00                                 | 0.00                                | 0.00                                     | 197.78                                       |
| 3            | Nilgiris North-Ootacamund | 297.11                            | 24.00                                | 0.00                                | 51.24                                    | 221.87                                       |
| 4            | Nilgiris South-Palghat    | 1033.19                           | 201.61                               | 27.36                               | 255.19                                   | 549.03                                       |
| 5            | Palani                    | 920.54                            | 80.96                                | 30.32                               | 207.13                                   | 602.12                                       |
| 6            | Palghat-Kozhikode         | 106.45                            | 2.45                                 | 0.00                                | 2.54                                     | 101.46                                       |
| 7            | Trivandrum-Nagercoil      | 2703.32                           | 34.68                                | 22.29                               | 50.86                                    | 2595.48                                      |
| 8            | Varushanad                | 153.01                            | 4.33                                 | 0.00                                | 0.00                                     | 148.68                                       |
| <b>Total</b> |                           | <b>6337.25</b>                    | <b>386.71</b>                        | <b>99.29</b>                        | <b>615.40</b>                            | <b>5235.84</b>                               |



The initial modelling of the potential distribution for *Ochna gamblei*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 6337.25 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.91). A total of Conservation area spanning 386.71 km<sup>2</sup>, Potential Ecorestoration area of 99.29 km<sup>2</sup>, irreversibly converted forest habitat (615.40 km<sup>2</sup>) and converted non-forested human-dominated areas (5235.84 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Nilgiris South-Palghat (201.60 km<sup>2</sup>), Palani (80.96 km<sup>2</sup>), Anamalai (38.67 km<sup>2</sup>) and Trivandrum-Nagercoil (34.68 km<sup>2</sup>) represent maximum potential conservation areas suitable for *Ochna gamblei*. The degraded habitats are also represented by ecoregions such as Palani (30.32 km<sup>2</sup>), Nilgiris South-Palghat (27.35 km<sup>2</sup>), Trivandrum-Nagercoil (22.29 km<sup>2</sup>) and Anamalai (19.31 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 10 % of converted forest habitat to the species are represented with Nilgiris South-Palghat (255.19 km<sup>2</sup>), Palani (207.13 km<sup>2</sup>) and Nilgiris North-Ootacamund (51.23 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Ochna gamblei* ecological niche.

#### **4.3.19. Grinnellian Niche of *Prioria pinnata* Using Bioclimatic Factors**

The MaxEnt model for *Prioria pinnata* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.990 (Fig. 4.92). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Prioria pinnata* (Fig. 4.93). Among the 19 bioclimatic variables assessed Precipitation of Coldest Quarter (51.4%) and Temperature Seasonality SD (26.1%) contributed most to the model. This is followed by Isothermality (9.6%), Precipitation of Warmest Quarter (2.2%), Precipitation of Driest Quarter (1.1%), Mean



Diurnal Range (1%) and Precipitation of Wettest Quarter (0.7%) (Appendix II). The Elevation, Aspect, Slope also emerged as an important non-bioclimatic variable, contributing 6%, 0.7% and 0.6% respectively to model gain, indicating that topographic constraints partly define the niche of this species.

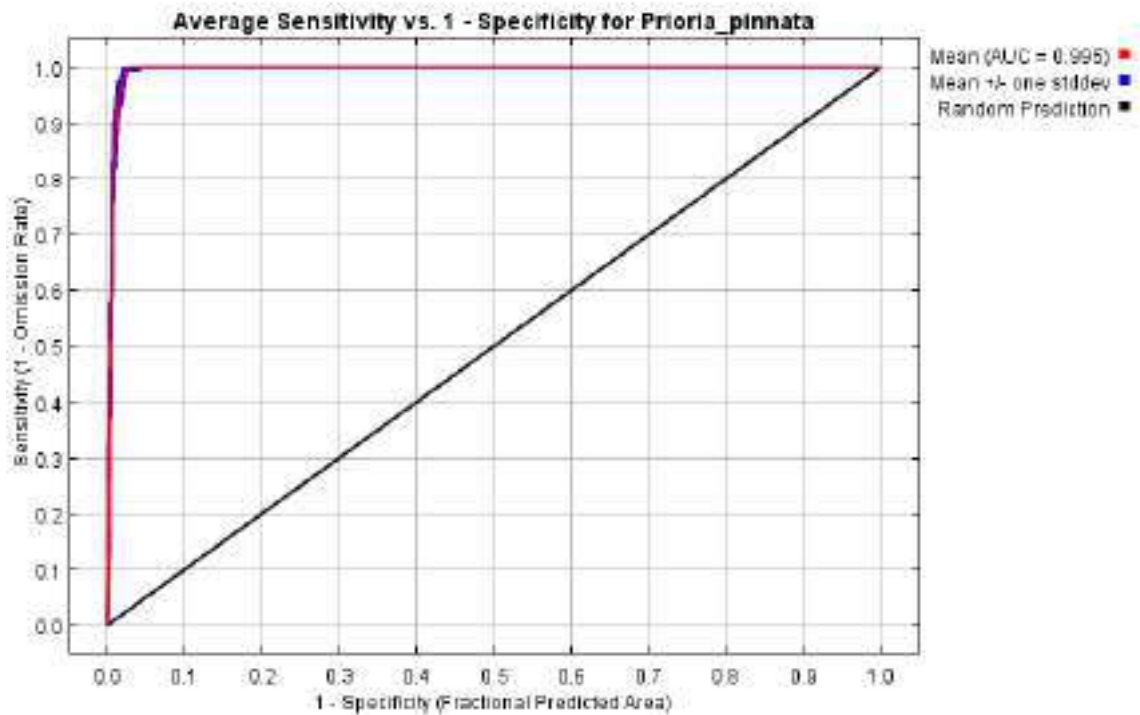


**Fig. 4.92.** Area Under Curve indicating model performance of *Prioria pinnata*

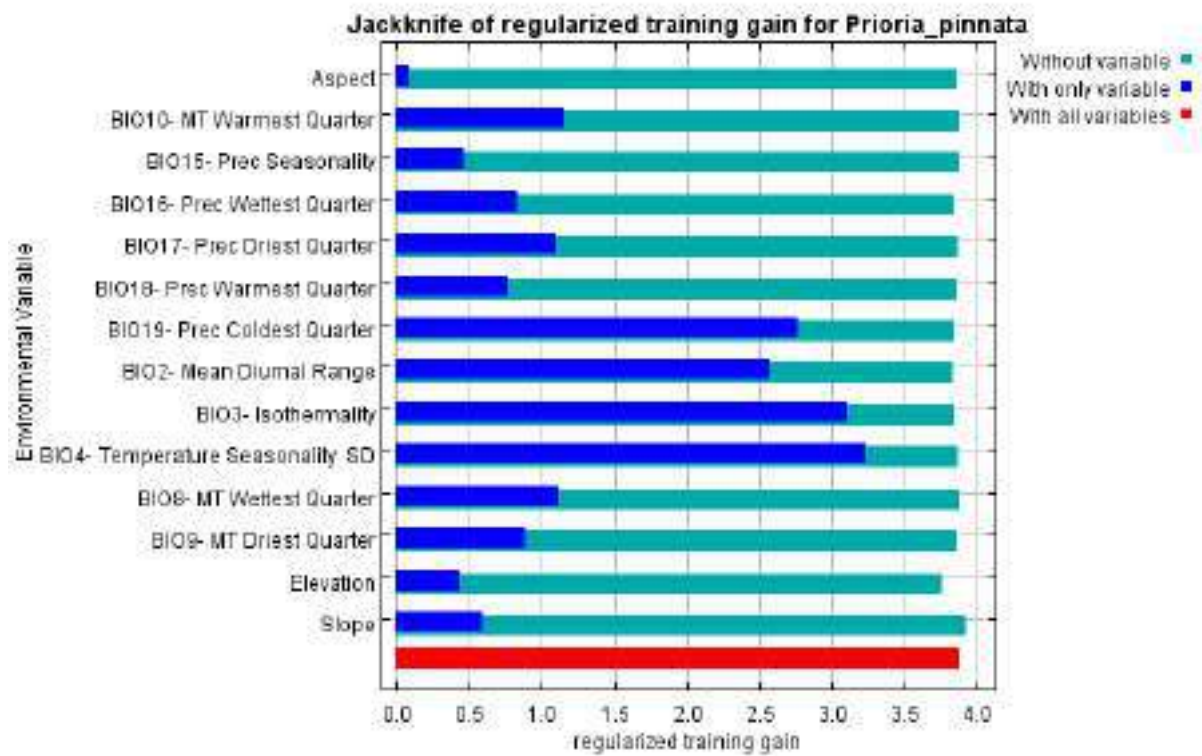


**Fig. 4.93. Jackknife test of training gain showing bioclimatic variables of importance**

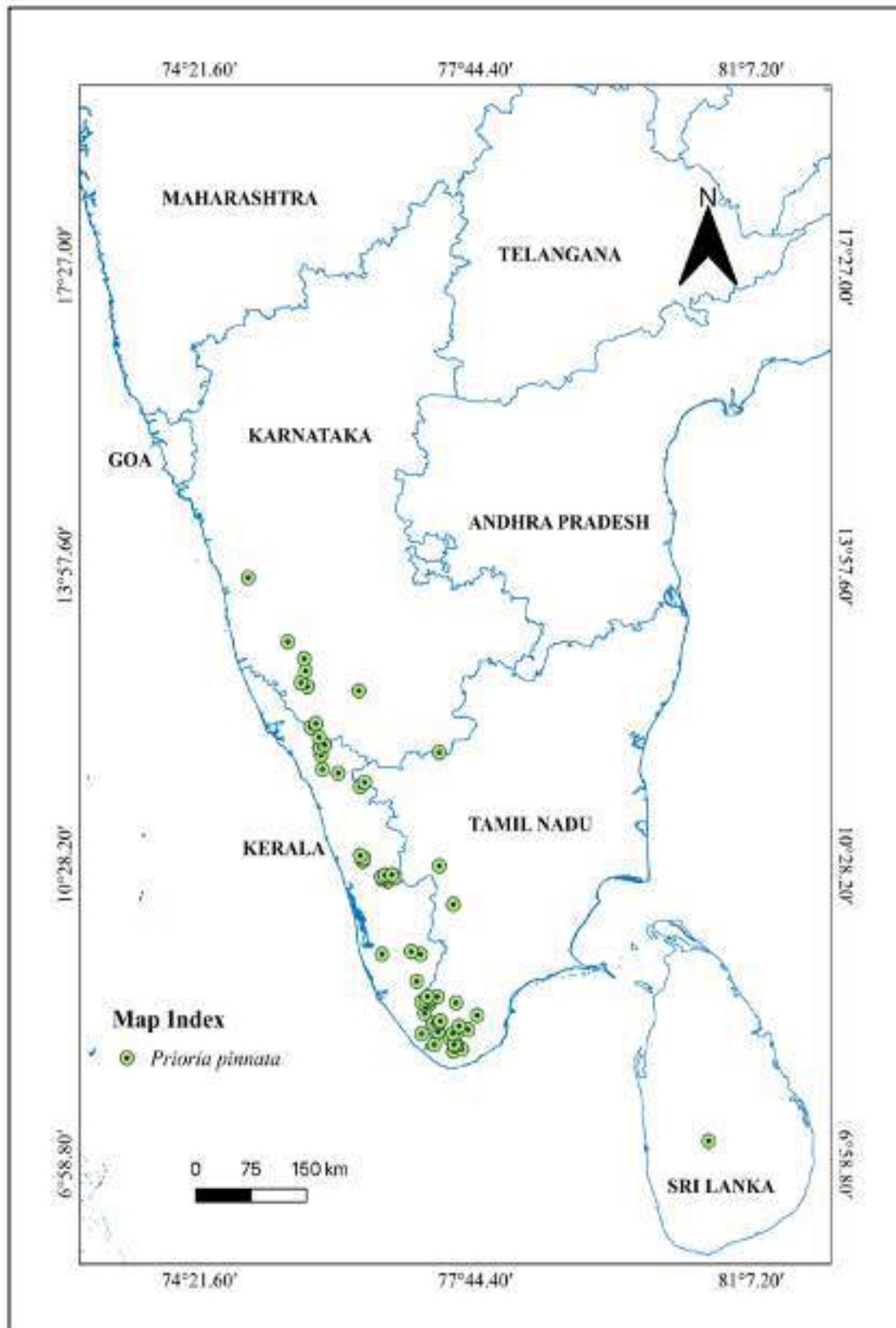


Fig. 4.94. Actual distribution of *Prioria pinnata*

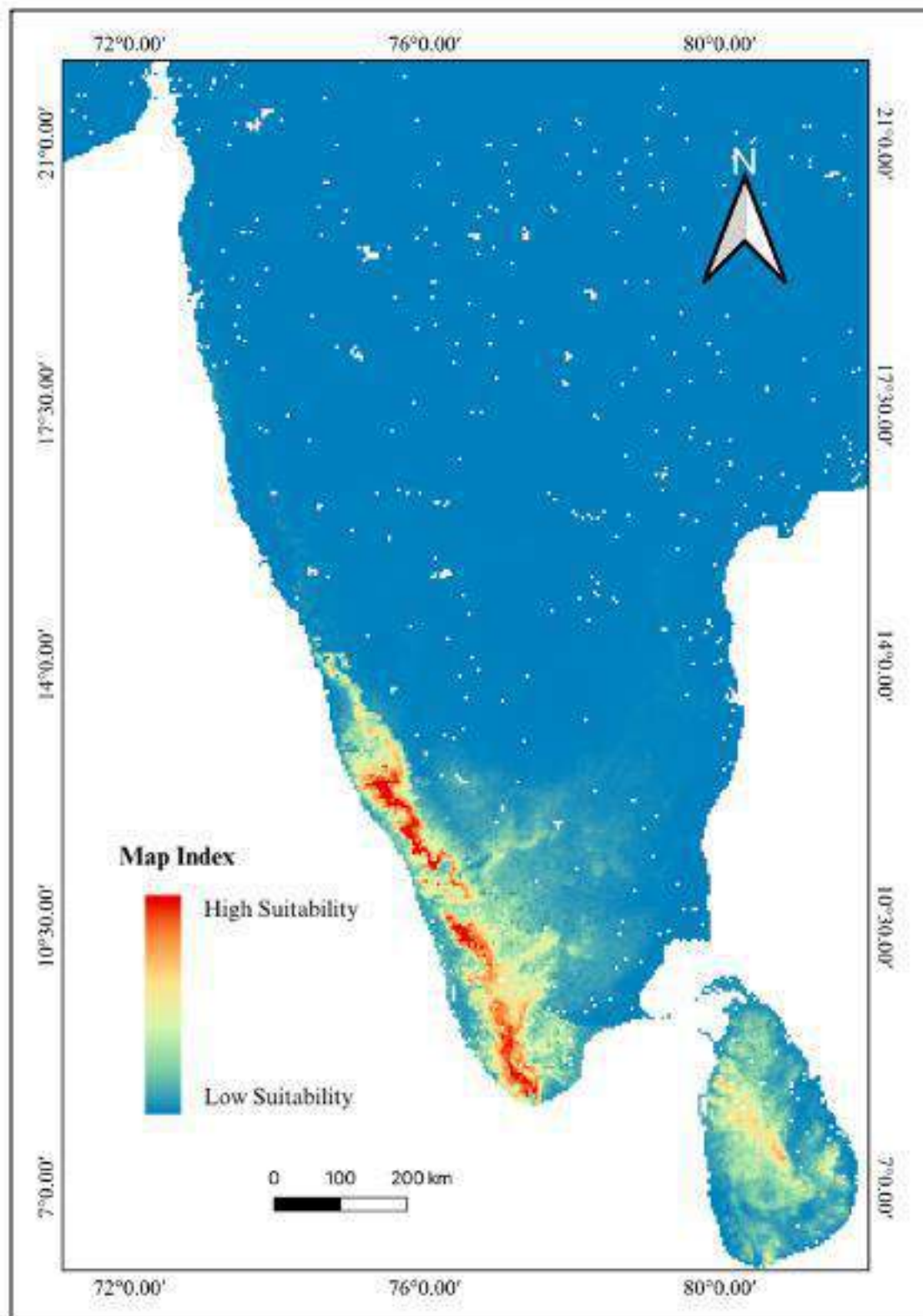


**Fig. 4.95.** Predicted habitat suitability of *Prioria pinnata* using MaxEnt model under present climate scenario

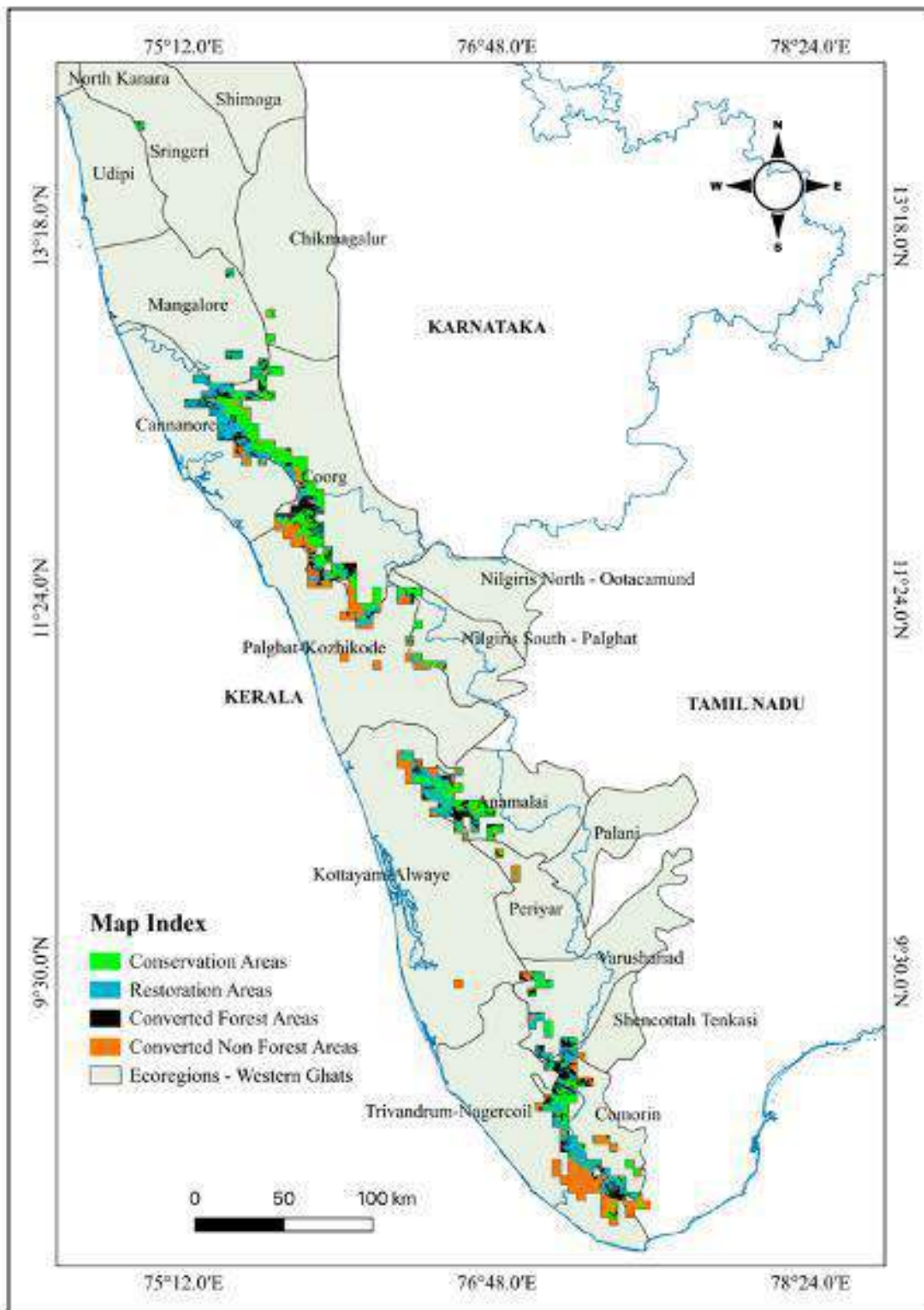


**Fig. 4.96. Refined predicted area of *Prioria pinnata* into potential conservation, restoration and irreversibly lost habitats at ecoregion level**

### Eltonian Niche of *Prioria pinnata* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Prioria pinnata* is currently restricted to 26 subpopulations within the Kerala, Tamil Nadu, Karnataka (India) and Srilanka (Fig. 4.94). Under the current climate scenario, the MaxEnt model predicts a total of 6532.14 km<sup>2</sup> of highly suitable habitat for *Prioria pinnata* in the Western Ghats (Fig. 4.95). This predicted distribution spans over 15 distinct ecoregions. The highest suitability predictions were concentrated in the Coorg (1962.98 km<sup>2</sup>), Comorin (902.21 km<sup>2</sup>), Trivandrum-Nagercoil (808.81 km<sup>2</sup>), Cannanore (692.23 km<sup>2</sup>), Anamalai (642.34 km<sup>2</sup>), Palghat-Kozhikode (402.29 km<sup>2</sup>), Kottayam-Alwaye (376.34 km<sup>2</sup>), Varushanad (308.37 km<sup>2</sup>) ecoregions (Table 4.23).

**Table 4.23. Ecoregion wise habitat prediction for *Prioria pinnata* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No. | Ecoregion                 | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|---------|---------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1       | Anamalai                  | 642.34                            | 274.41                               | 196.44                              | 108.84                                   | 62.65                                        |
| 2       | Cannanore                 | 692.23                            | 128.58                               | 394.36                              | 111.67                                   | 57.63                                        |
| 3       | Chikmagalur               | 40.44                             | 28.45                                | 2.55                                | 1.96                                     | 7.49                                         |
| 4       | Comorin                   | 902.22                            | 260.38                               | 326.59                              | 197.58                                   | 117.67                                       |
| 5       | Coorg                     | 1962.99                           | 1001.16                              | 337.29                              | 344.09                                   | 280.45                                       |
| 6       | Kottayam-Alwaye           | 376.34                            | 47.57                                | 140.01                              | 40.20                                    | 148.56                                       |
| 7       | Mangalore                 | 142.08                            | 40.34                                | 73.11                               | 27.66                                    | 0.98                                         |
| 8       | Nilgiris North-Ootacamund | 34.57                             | 29.32                                | 1.90                                | 3.06                                     | 0.29                                         |
| 9       | Nilgiris South-Palghat    | 109.75                            | 47.58                                | 31.75                               | 3.82                                     | 26.59                                        |
| 10      | Palghat-Kozhikode         | 402.29                            | 15.52                                | 82.07                               | 20.75                                    | 283.96                                       |

|              |                          |                |                |                |                |                |
|--------------|--------------------------|----------------|----------------|----------------|----------------|----------------|
| 11           | Periyar                  | 62.09          | 9.92           | 9.74           | 5.68           | 36.75          |
| 12           | Shencottah<br>Tenkasi    | 28.78          | 6.40           | 11.01          | 1.93           | 9.44           |
| 13           | Sringeri                 | 18.83          | 11.39          | 4.37           | 3.06           | 0.00           |
| 14           | Trivandrum-<br>Nagercoil | 808.81         | 67.74          | 140.85         | 92.92          | 507.31         |
| 15           | Varushanad               | 308.37         | 108.48         | 126.41         | 55.90          | 17.58          |
| <b>Total</b> |                          | <b>6532.14</b> | <b>2077.24</b> | <b>1878.45</b> | <b>1019.12</b> | <b>1557.33</b> |

The initial modelling of the potential distribution for *Prioria pinnata*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 6532.14 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.96). A total of Conservation area spanning 2077.24 km<sup>2</sup>, Potential Ecorestoration area of 1878.45 km<sup>2</sup>, and irreversibly converted forest habitat (1019.12 km<sup>2</sup>) and converted non-forested human-dominated areas (1557.33 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Coorg (1001.16 km<sup>2</sup>), Anamalai (274.41 km<sup>2</sup>), Comorin (260.37 km<sup>2</sup>), Cannanore (128.57 km<sup>2</sup>) and Varushanad (108.48 km<sup>2</sup>) represent maximum potential conservation areas suitable for *Prioria pinnata*. The degraded habitats are also represented by ecoregions such as Cannanore (394.36 km<sup>2</sup>), Coorg (337.28 km<sup>2</sup>), Comorin (326.59 km<sup>2</sup>), Anamalai (196.44 km<sup>2</sup>) and Trivandrum-Nagercoil (140.84 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 54 % of converted forest habitat to the species are represented with Coorg (344.09 km<sup>2</sup>), Comorin (197.58 km<sup>2</sup>), Cannanore (111.67 km<sup>2</sup>), Anamalai (108.84 km<sup>2</sup>) and Trivandrum-Nagercoil (92.91 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Prioria pinnata* ecological niche.



#### 4.3.20. Grinnellian Niche of *Strobilanthes kunthiana* Using Bioclimatic Factors

The MaxEnt model for *Strobilanthes kunthiana* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.997 (Fig. 4.97). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Strobilanthes kunthiana* (Fig. 4.98). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (49.8%) and Precipitation of Coldest Quarter (11.4%) contributed most to the model. This is followed by Isothermality (10.2%), Precipitation of Driest Month (0.8%), Precipitation Seasonality (0.4%), Mean Diurnal Range (0.3%) (Appendix II). The Elevation also emerged as an important non-bioclimatic variable, contributing 26.4% to model gain, indicating that topographic constraints partly define the niche of this species.

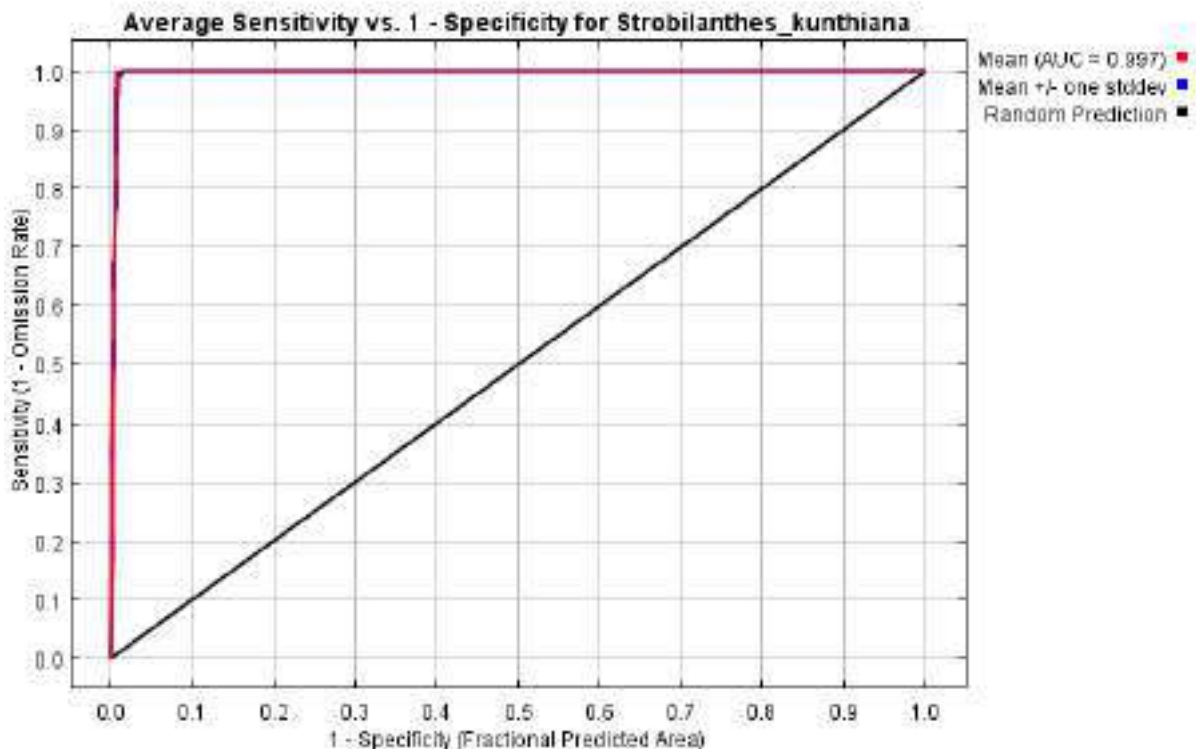


**Fig. 4.97.** Area Under Curve indicating model performance of *Strobilanthes kunthiana*



**Fig. 4.98. Jackknife test of training gain showing bioclimatic variables of importance**

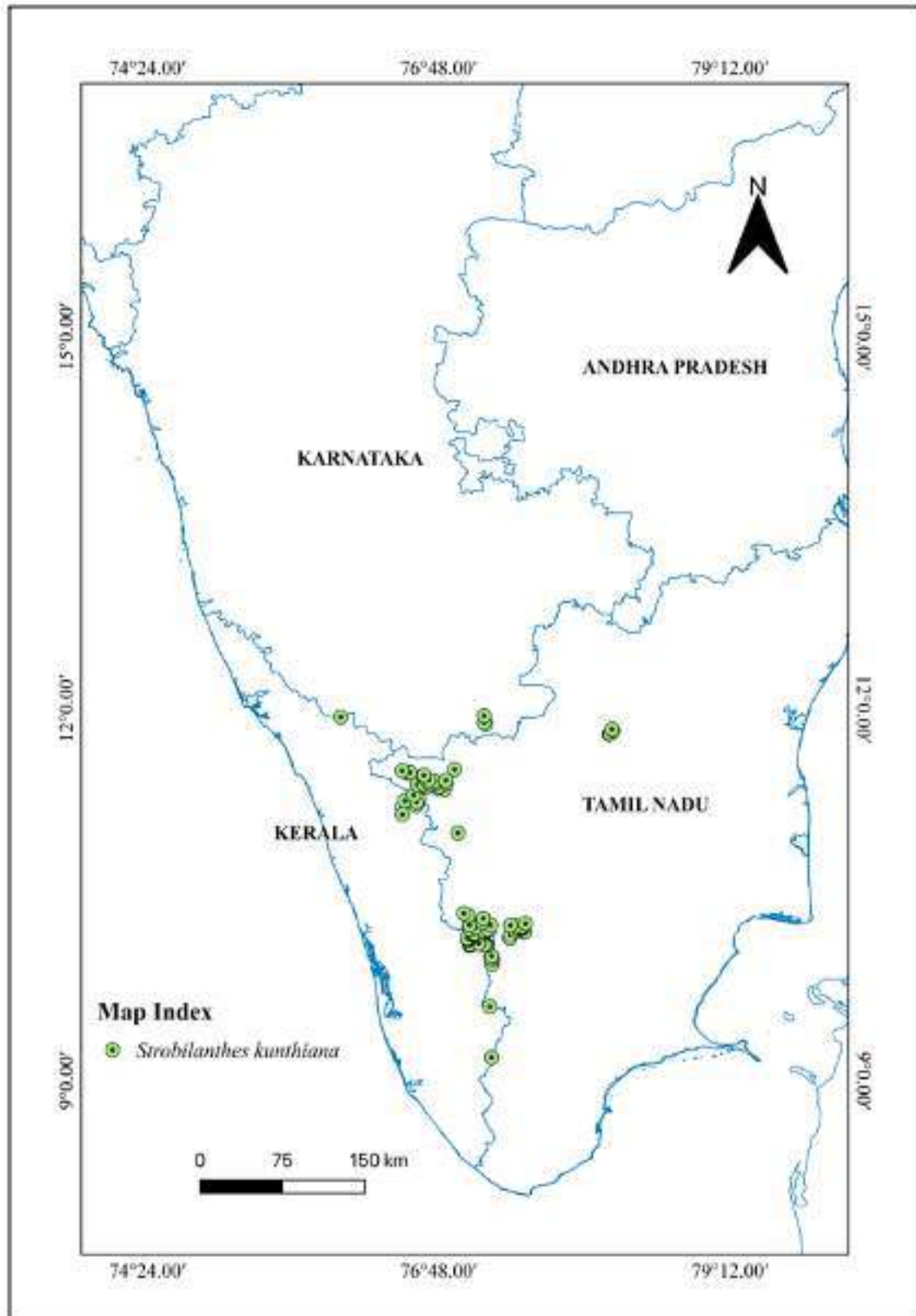


Fig. 4.99. Actual distribution of *Strobilanthes kunthiana*

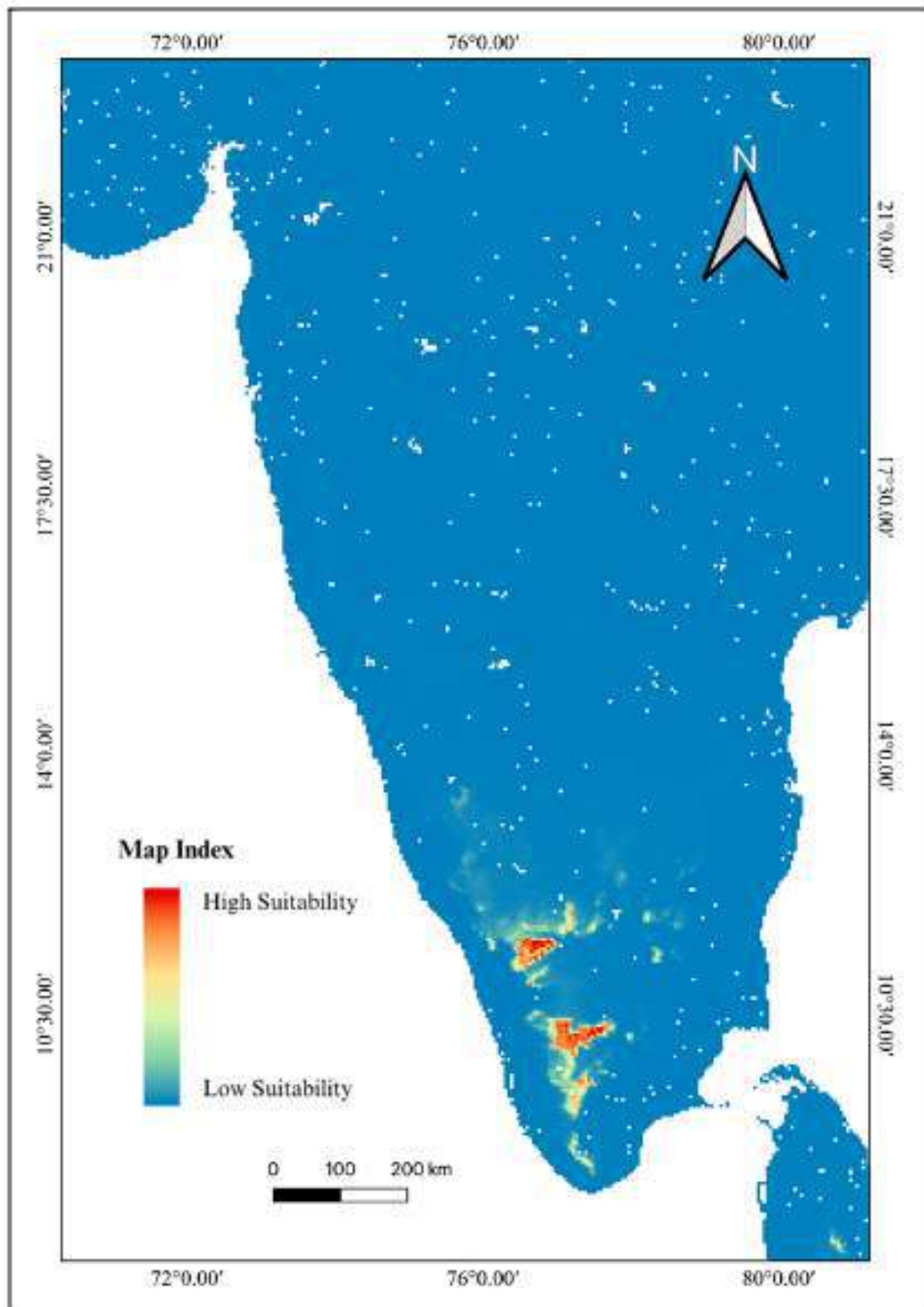


**Fig. 4.100.** Predicted habitat suitability of *Strobilanthes kunthiana* using MaxEnt model under present climate scenario

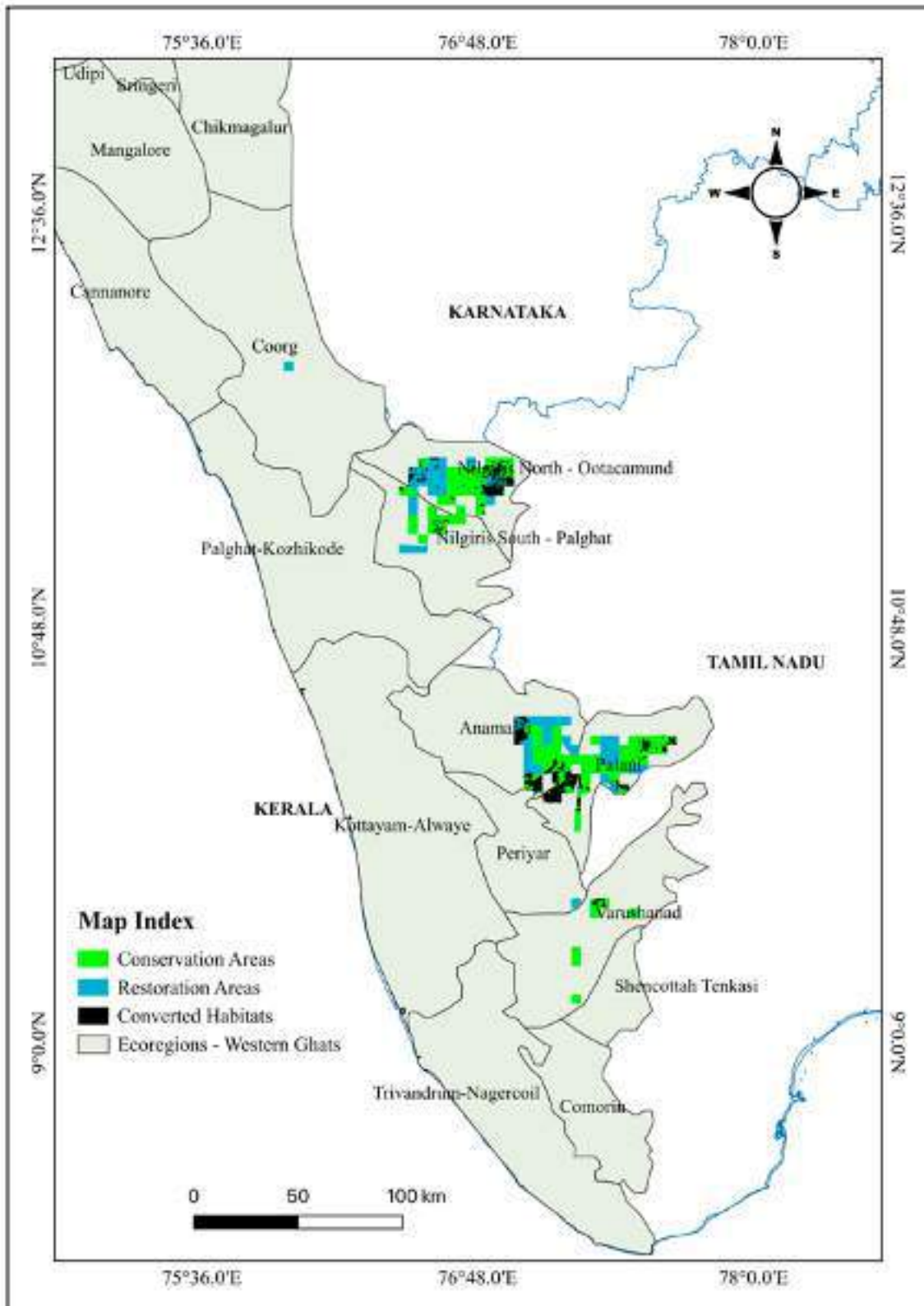


**Fig. 4.101. Refined predicted area of *Strobilanthes kunthiana* into potential conservation, restoration and irreversibly lost habitats at ecoregion level**

### Eltonian Niche of *Strobilanthes kunthiana* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Strobilanthes kunthiana* is currently restricted to 34 subpopulations within the Kerala, Tamil Nadu and Karnataka region (Fig. 4.99). Under the current climate scenario, the MaxEnt model predicts a total of 3132.79 km<sup>2</sup> of highly suitable habitat for *Strobilanthes kunthiana* in the Western Ghats (Fig. 4.100). This predicted distribution spans over seven distinct ecoregions. The highest suitability predictions were concentrated in the Palani (936.00 km<sup>2</sup>), Nilgiri North-Ootacamund (908.02 km<sup>2</sup>), Anamalai (767.958 km<sup>2</sup>), Nilgiris South-Palghat (335.99 km<sup>2</sup>), Varushanad (143.74 km<sup>2</sup>) ecoregions (Table 4.24).

**Table 4.24. Ecoregion wise habitat prediction for *Strobilanthes kunthiana* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No.      | Ecoregion                | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|--------------|--------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1            | Anamalai                 | 767.96                            | 319.42                               | 308.82                              | 143.17                                   | 0.00                                         |
| 2            | Coorg                    | 20.87                             | 0.02                                 | 20.85                               | 0.00                                     | 0.00                                         |
| 3            | Nilgiri North-Ootacamund | 908.03                            | 458.39                               | 313.35                              | 157.35                                   | 0.00                                         |
| 4            | Nilgiris South-Palghat   | 336.00                            | 223.92                               | 94.89                               | 17.30                                    | 0.00                                         |
| 5            | Palani                   | 936.01                            | 550.16                               | 200.45                              | 185.65                                   | 0.00                                         |
| 6            | Periyar                  | 20.18                             | 0.24                                 | 19.95                               | 0.00                                     | 0.00                                         |
| 7            | Varushanad               | 143.74                            | 132.87                               | 0.00                                | 10.87                                    | 0.00                                         |
| <b>Total</b> |                          | <b>3132.79</b>                    | <b>1685.02</b>                       | <b>958.31</b>                       | <b>514.34</b>                            | <b>0.00</b>                                  |

The initial modelling of the potential distribution for *Strobilanthes kunthiana*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted

area of 3132.79 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.101). A total of Conservation area spanning 1685.02 km<sup>2</sup>, Potential Ecorestoration area of 958.31 km<sup>2</sup>, irreversibly converted forest habitat (514.34 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Palani (550.16 km<sup>2</sup>), Nilgiri North-Ootacamund (458.38 km<sup>2</sup>), Anamalai (319.41 km<sup>2</sup>), Nilgiris South-Palghat (223.92 km<sup>2</sup>) and Varushanad (132.86 km<sup>2</sup>) represent maximum potential conservation areas suitable for *Strobilanthes kunthiana*. The degraded habitats are also represented by ecoregions such as Nilgiri North-Ootacamund (313.34 km<sup>2</sup>), Anamalai (308.82 km<sup>2</sup>), Palani (550.16 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 16 % of converted forest habitat to the species are represented with Palani (185.64 km<sup>2</sup>), Nilgiri North-Ootacamund (157.34 km<sup>2</sup>), Anamalai (143.17 km<sup>2</sup>) and Nilgiris South-Palghat (17.29 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Strobilanthes kunthiana* ecological niche.

#### **4.3.21. Grinnellian Niche of *Syzygium densiflorum* Using Bioclimatic Factors**

The MaxEnt model for *Syzygium densiflorum* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.997 (Fig. 4.102). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Syzygium densiflorum* (Fig. 4.103). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (43.2%) and Precipitation of Coldest Quarter (18.9%) contributed most to the model. This is followed by Isothermality (9.3%), Precipitation of Driest Month (9.1%), Precipitation of Wettest Month (1%), Precipitation of Warmest Quarter (0.2%) (Appendix II). The Elevation also emerged as an



important non-bioclimatic variable, contributing 17.6 % to model gain, indicating that topographic constraints partly define the niche of this species.

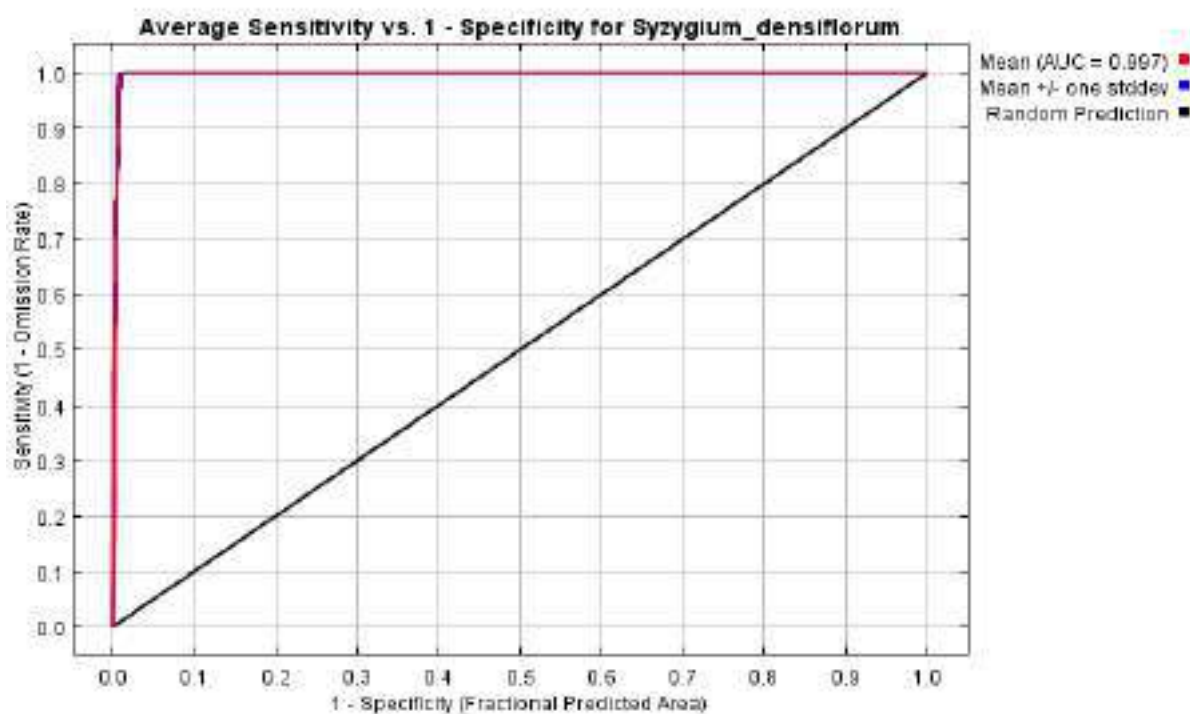


**Fig. 4.102.** Area Under Curve indicating model performance of *Syzygium densiflorum*



**Fig. 4.103.** Jackknife test of training gain showing bioclimatic variables of importance

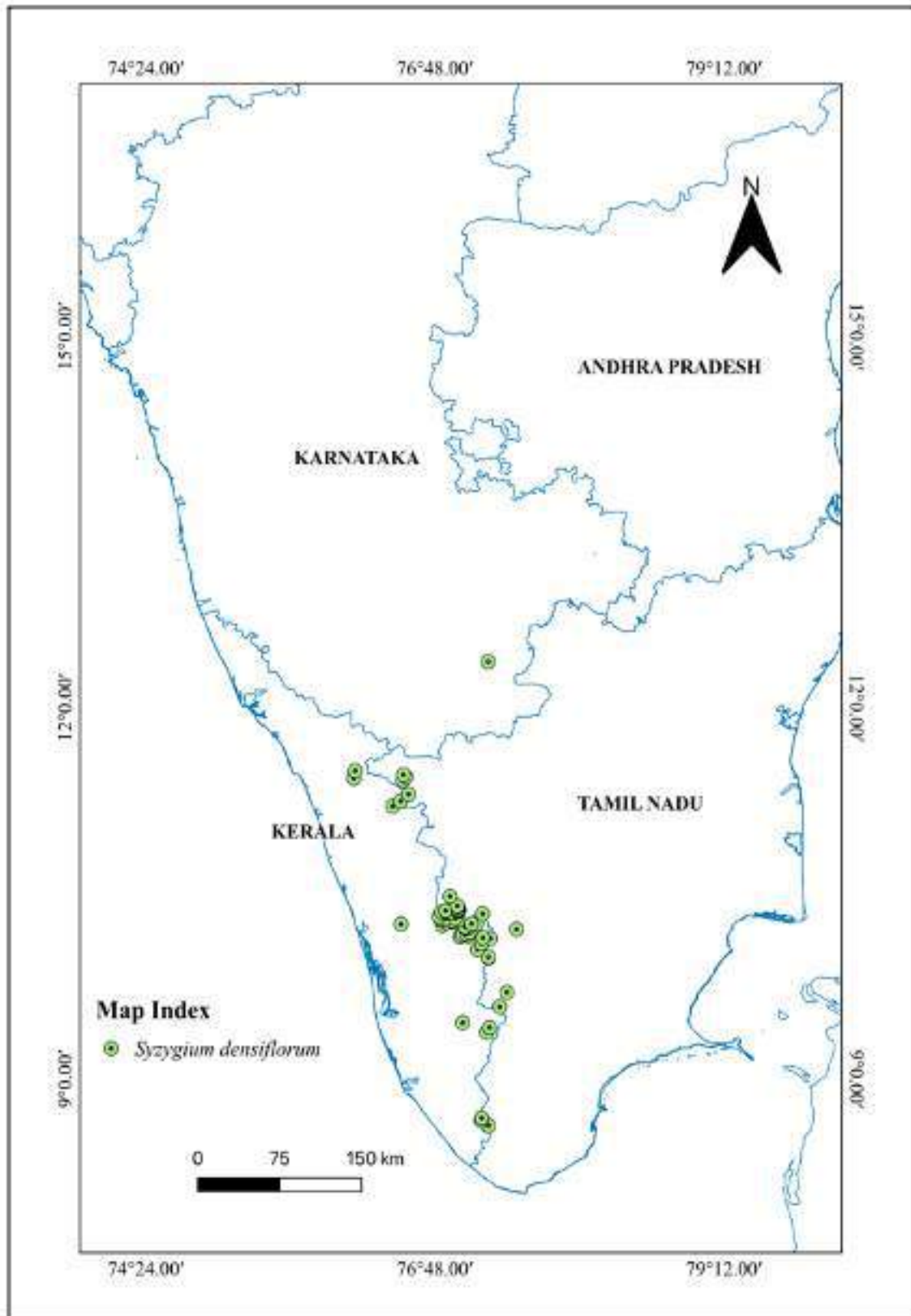


Fig. 4.104. Actual distribution of *Syzygium densiflorum*

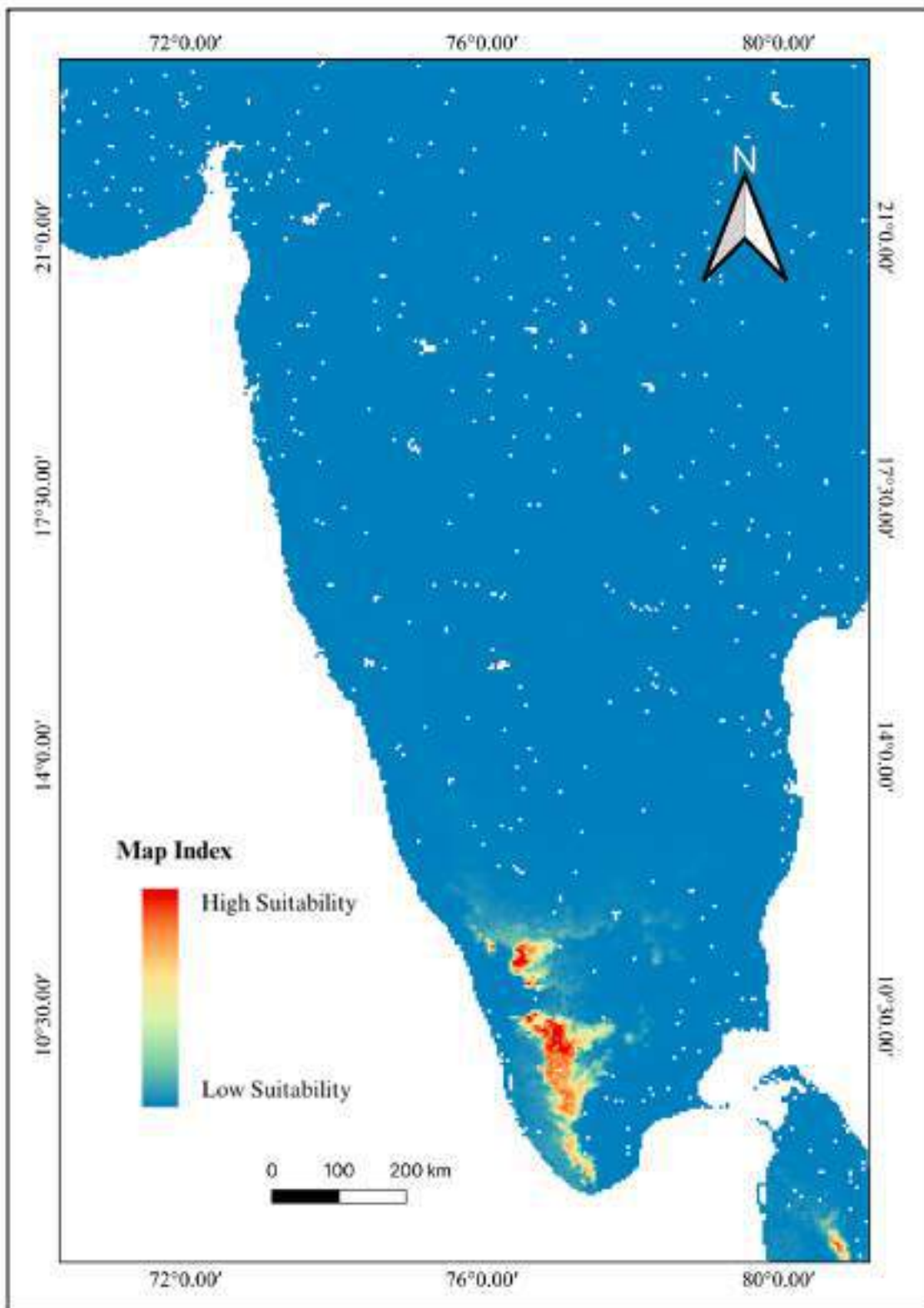


**Fig. 4.105.** Predicted habitat suitability of *Syzygium densiflorum* using MaxEnt model under present climate scenario

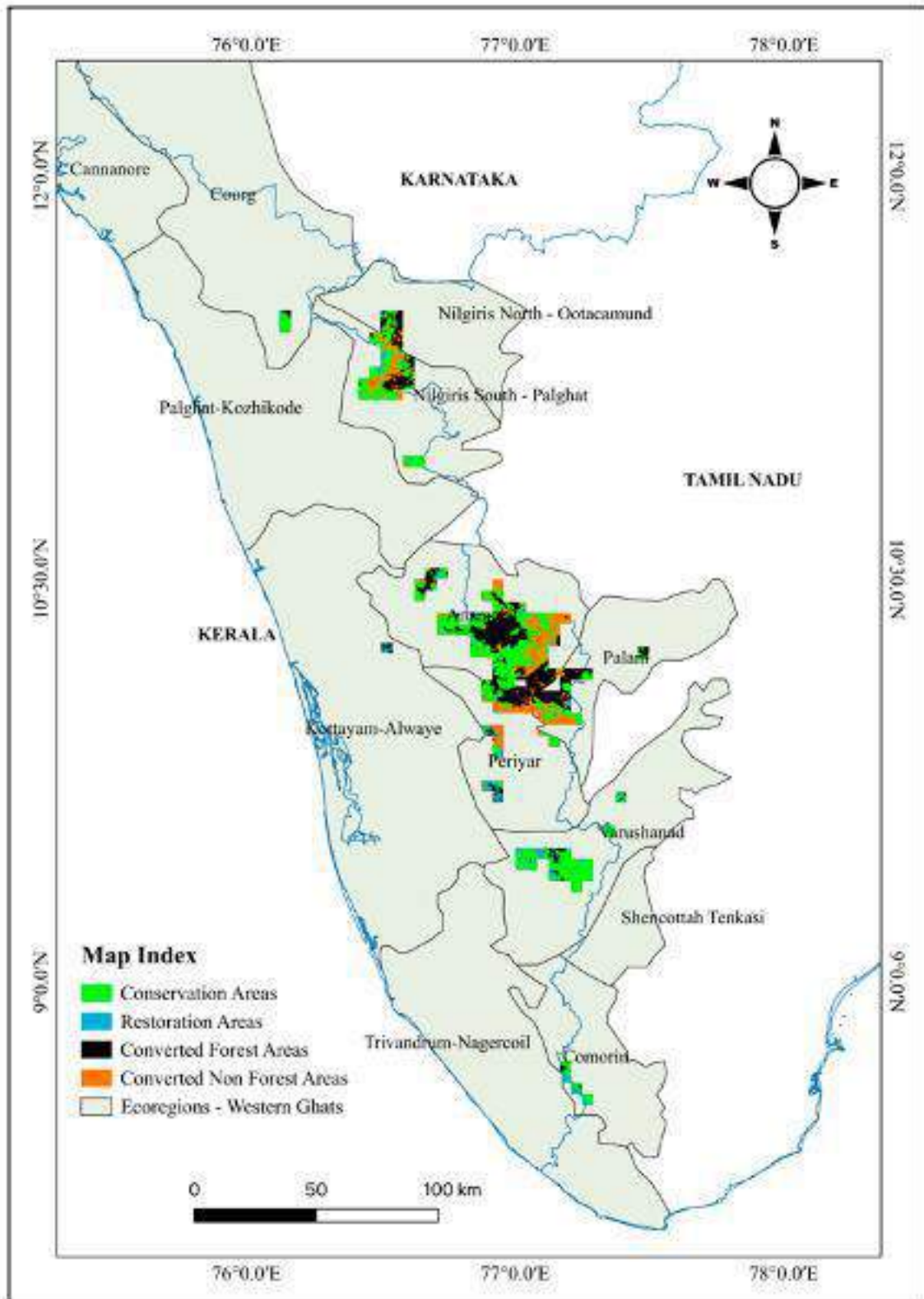


**Fig. 4.106. Refined predicted area of *Syzygium densiflorum* into potential conservation, restoration and irreversibly lost habitats at ecoregion level**

### Eltonian Niche of *Syzygium densiflorum* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Syzygium densiflorum* is currently restricted to 19 subpopulations within the Western Ghats, particularly in parts of Kerala, Tamil Nadu and Karnataka (Fig. 4.104). Under the current climate scenario, the MaxEnt model predicts a total of 3082.38 km<sup>2</sup> of highly suitable habitat for *Syzygium densiflorum* in the Western Ghats (Fig. 4.105). This predicted distribution spans over nine distinct ecoregions. The highest suitability predictions were concentrated in the Anamalai (1487.85 km<sup>2</sup>), Nilgiris South-Palghat (441.77 km<sup>2</sup>), Varushanad (373.08 km<sup>2</sup>), Palani (354.57 km<sup>2</sup>), Periyar (166.53 km<sup>2</sup>), Nilgiris North-Ootacamund (118.47 km<sup>2</sup>) ecoregions (Table 4.25).

**Table 4.25. Ecoregion wise habitat prediction for *Syzygium densiflorum* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No.      | Ecoregion                     | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|--------------|-------------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1            | Anamalai                      | 1487.85                           | 621.73                               | 42.44                               | 500.23                                   | 323.46                                       |
| 2            | Comorin                       | 78.79                             | 38.18                                | 33.95                               | 6.66                                     | 0.00                                         |
| 3            | Coorg                         | 42.06                             | 36.29                                | 0.00                                | 5.77                                     | 0.00                                         |
| 4            | Kottayam-<br>Alwaye           | 19.24                             | 0.45                                 | 9.29                                | 9.49                                     | 0.00                                         |
| 5            | Nilgiris North-<br>Ootacamund | 118.47                            | 38.30                                | 1.17                                | 64.74                                    | 14.26                                        |
| 6            | Nilgiris South-<br>Palghat    | 441.78                            | 219.47                               | 20.66                               | 76.93                                    | 124.72                                       |
| 7            | Palani                        | 354.57                            | 98.22                                | 8.53                                | 148.43                                   | 99.39                                        |
| 8            | Periyar                       | 166.54                            | 35.56                                | 61.44                               | 22.73                                    | 46.80                                        |
| 9            | Varushanad                    | 373.09                            | 275.79                               | 69.64                               | 26.58                                    | 1.08                                         |
| <b>Total</b> |                               | <b>3082.38</b>                    | <b>1363.99</b>                       | <b>247.12</b>                       | <b>861.57</b>                            | <b>609.70</b>                                |

The initial modelling of the potential distribution for *Syzygium densiflorum*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 3082.38 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.106). A total of Conservation area spanning 1363.99 km<sup>2</sup>, Potential Ecorestoration area of 247.12 km<sup>2</sup>, irreversibly converted forest habitat (861.57 km<sup>2</sup>) and converted non-forested human-dominated areas (609.70 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Anamalai (621.72 km<sup>2</sup>), Varushanad (275.79 km<sup>2</sup>), Nilgiris South-Palghat (219.46 km<sup>2</sup>) and Palani (219.46 km<sup>2</sup>) represent maximum potential conservation areas suitable for *Syzygium densiflorum*. The degraded habitats are also represented by ecoregions such as Varushanad (69.63 km<sup>2</sup>), Periyar (61.44 km<sup>2</sup>), Anamalai (42.43 km<sup>2</sup>), Comorin (33.95 km<sup>2</sup>) and Nilgiris South-Palghat (20.65 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 27 % of converted forest habitat to the species are represented with Anamalai (500.22 km<sup>2</sup>), Palani (148.43 km<sup>2</sup>), Nilgiris South-Palghat (76.93 km<sup>2</sup>) and Nilgiris North-Ootacamund (64.74 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Syzygium densiflorum* ecological niche.

#### **4.3.22. Grinnellian Niche of *Syzygium occidentale* Using Bioclimatic Factors**

The MaxEnt model for *Syzygium occidentale* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.998 (Fig. 4.107). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Syzygium occidentale* (Fig. 4.108). Among the 19 bioclimatic variables assessed Precipitation of Coldest Quarter (44.8%) and Temperature



Seasonality SD (28%) contributed most to the model. This is followed by Precipitation of Driest Quarter (6.3%), Precipitation of Warmest Quarter (4.8%), Isothermality (4.2%), Precipitation of Wettest Quarter (3.8%) (Appendix II). The Slope and Elevation also emerged as an important non-bioclimatic variable, contributing 4.5% and 2.3% respectively to model gain, indicating that topographic constraints partly define the niche of this species.

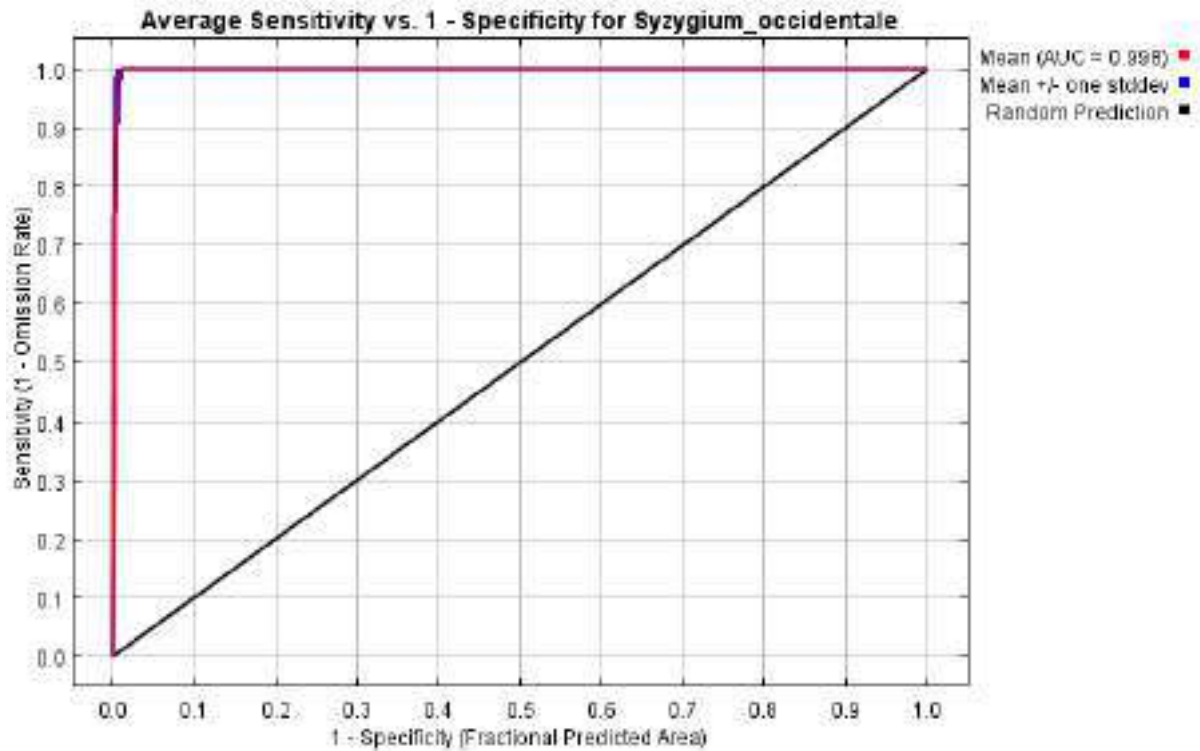


**Fig. 4.107.** Area Under Curve indicating model performance of *Syzygium occidentale*



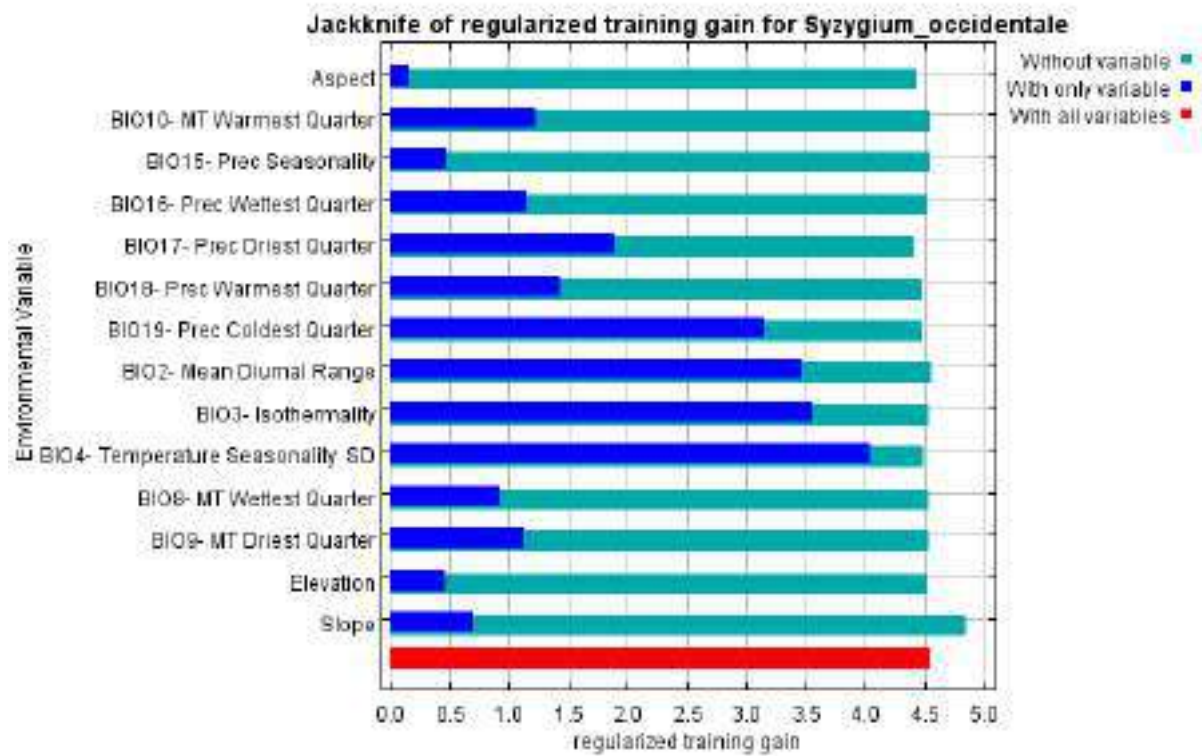


**Fig. 4.108.** Jackknife test of training gain showing bioclimatic variables of importance

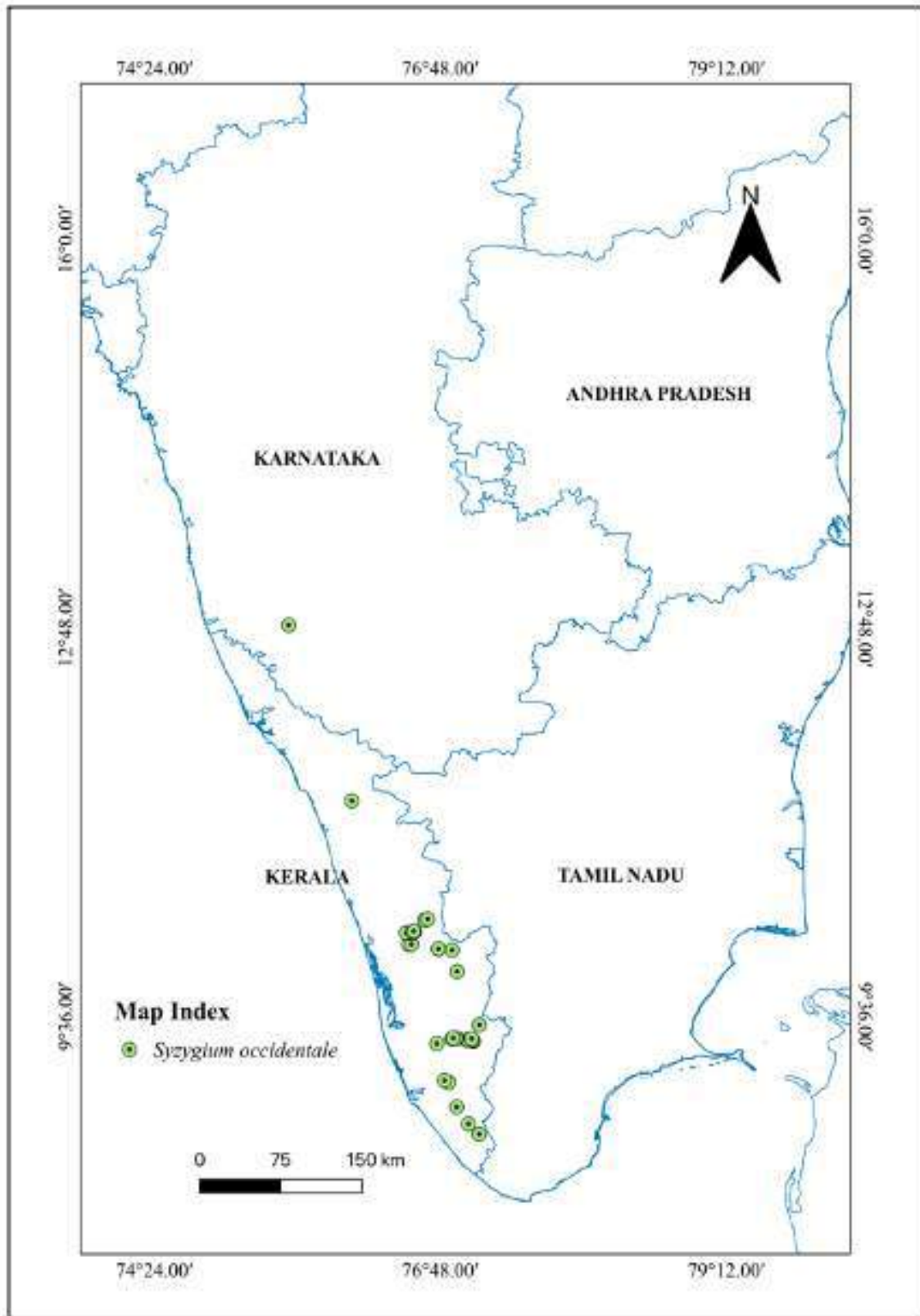


Fig. 4.109. Actual distribution of *Syzygium occidentale*

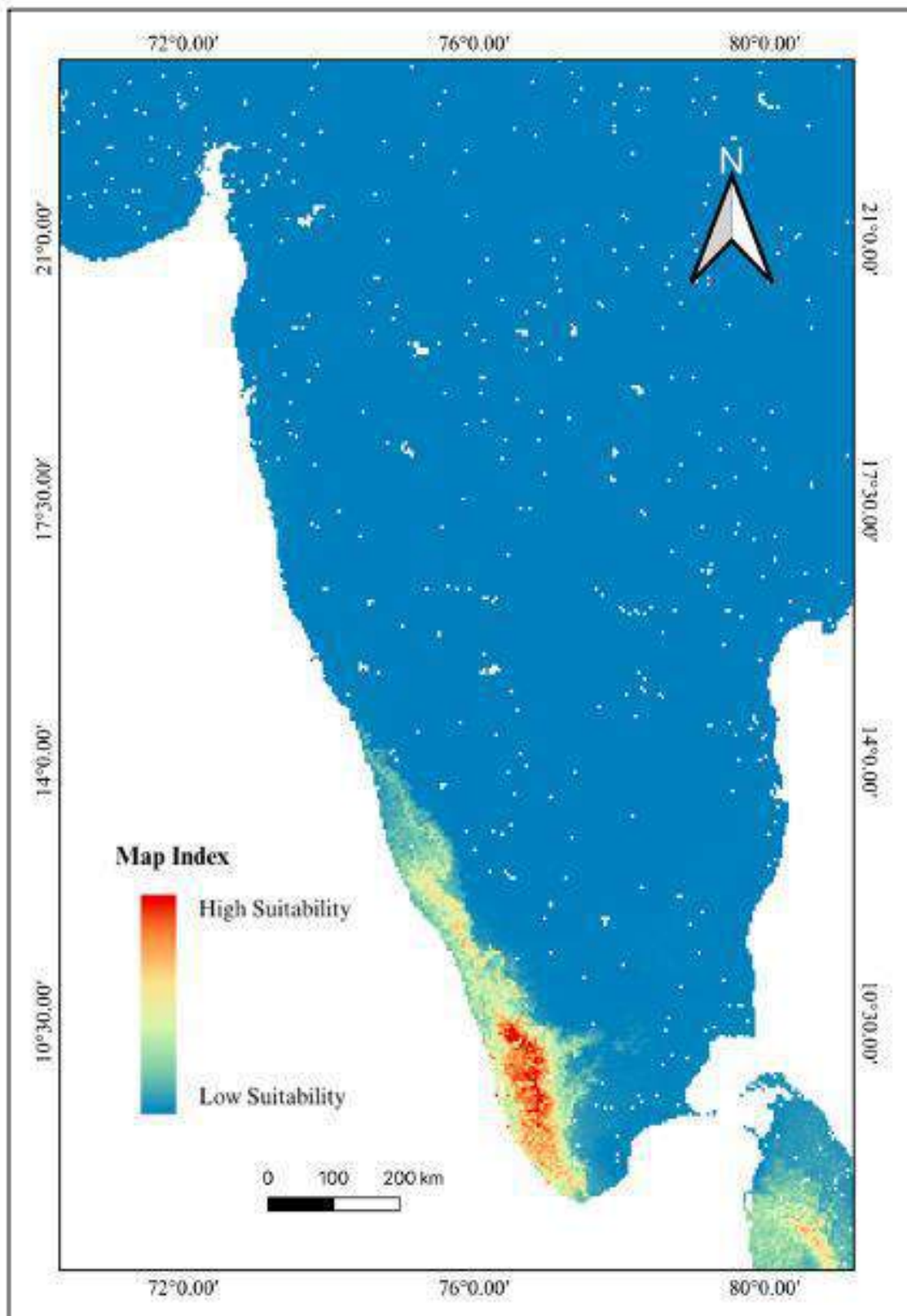


**Fig. 4.110.** Predicted habitat suitability of *Syzygium occidentale* using MaxEnt model under present climate scenario

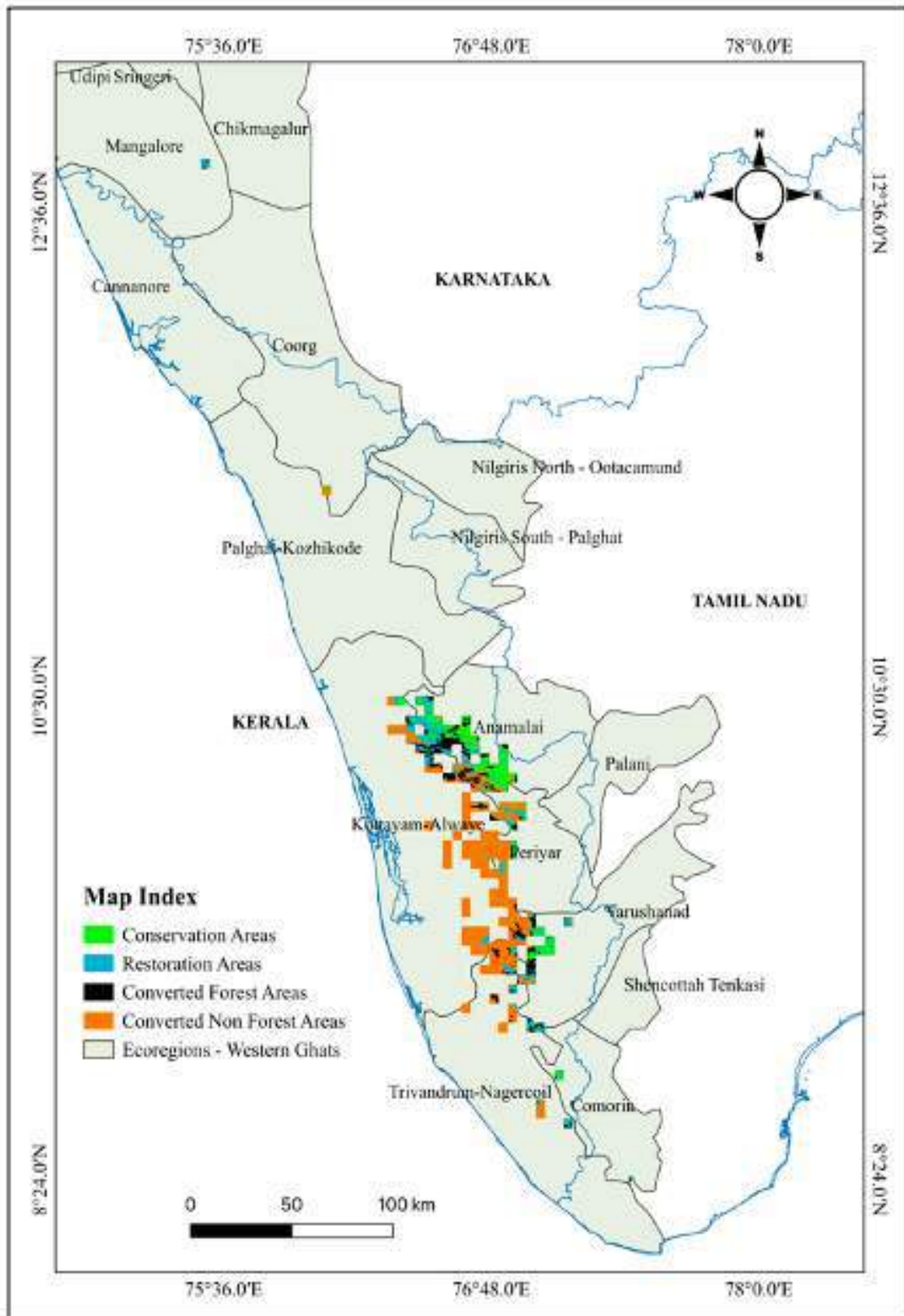


**Fig. 4.111.** Refined predicted area of *Syzygium occidentale* into potential conservation, restoration and irreversibly lost habitats at ecoregion level

### Eltonian Niche of *Syzygium occidentale* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Syzygium occidentale* is currently restricted to 19 subpopulations within the Western Ghats, particularly in parts of Kerala and Karnataka (Fig. 4.109). Under the current climate scenario, the MaxEnt model predicts a total of 3316.34 km<sup>2</sup> of highly suitable habitat for *Syzygium occidentale* in the Western Ghats (Fig. 4.110). This predicted distribution spans over nine distinct ecoregions. The highest suitability predictions were concentrated in the Kottayam-Alwaye (1338.82 km<sup>2</sup>), Anamalai (647.15 km<sup>2</sup>), Periyar (511.93 km<sup>2</sup>), Trivandrum-Nahercoil (453.39 km<sup>2</sup>), Varushanad (291.82 km<sup>2</sup>), Comorin (32.40 km<sup>2</sup>) ecoregions (Table 4.26).

**Table 4.26. Ecoregion wise habitat prediction for *Syzygium occidentale* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No.      | Ecoregion            | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest Area (Km <sup>2</sup> ) |
|--------------|----------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1            | Anamalai             | 647.15                            | 296.87                               | 173.18                              | 129.25                                   | 47.86                                        |
| 2            | Comorin              | 32.41                             | 13.13                                | 14.85                               | 4.42                                     | 0.00                                         |
| 3            | Coorg                | 16.13                             | 4.54                                 | 0.68                                | 0.00                                     | 10.91                                        |
| 4            | Kottayam-Alwaye      | 1338.83                           | 22.99                                | 153.55                              | 126.07                                   | 1036.22                                      |
| 5            | Mangalore            | 20.13                             | 1.70                                 | 15.26                               | 3.16                                     | 0.00                                         |
| 6            | Palghat-Kozhikode    | 4.54                              | 0.00                                 | 0.00                                | 0.00                                     | 4.54                                         |
| 7            | Periyar              | 511.93                            | 76.69                                | 93.93                               | 47.72                                    | 293.59                                       |
| 8            | Trivandrum-Nagercoil | 453.39                            | 4.93                                 | 80.83                               | 55.57                                    | 312.06                                       |
| 9            | Varushanad           | 291.82                            | 84.58                                | 84.47                               | 63.71                                    | 59.07                                        |
| <b>Total</b> |                      | <b>3316.34</b>                    | <b>505.43</b>                        | <b>616.74</b>                       | <b>429.90</b>                            | <b>1764.27</b>                               |

The initial modelling of the potential distribution for *Syzygium occidentale*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 3316.34 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.111). A total of Conservation area spanning 505.43 km<sup>2</sup>, Potential Ecorestoration area of 616. irreversibly converted forest habitat (429.90 km<sup>2</sup>) and converted non-forested human-dominated areas (1764.27 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Anamalai (296.86 km<sup>2</sup>), Varushanad (84.57 km<sup>2</sup>), Periyar (76.69 km<sup>2</sup>), Kottayam-Alwaye (22.98 km<sup>2</sup>) and Comorin (13.13 km<sup>2</sup>) represent maximum potential conservation areas suitable for *Syzygium occidentale*. The degraded habitats are also represented by ecoregions such as Anamalai (173.17 km<sup>2</sup>), Kottayam-Alwaye (153.55 km<sup>2</sup>), Periyar (93.92 km<sup>2</sup>), Varushanad (84.47 km<sup>2</sup>) and Trivandrum-Nagercoil (80.82 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 47 % of converted forest habitat to the species are represented with Anamalai (129.24 km<sup>2</sup>), Kottayam-Alwaye (126.06 km<sup>2</sup>), Varushanad (63.70 km<sup>2</sup>) and Trivandrum-Nagercoil (55.56 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Syzygium occidentale* ecological niche.

#### **4.3.23. Grinnellian Niche of *Syzygium palghatense* Using Bioclimatic Factors**

The MaxEnt model for *Syzygium palghatense* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.864 (Fig. 4.112). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Syzygium palghatense* (Fig. 4.113). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (69%) and Mean Diurnal Range (6.7%) contributed most to the model. This is followed by Precipitation of Driest

Month (1.9%), Precipitation of Warmest Quarter (1.8%), Precipitation of Coldest Quarter (1.6%) (Appendix II). The Slope also emerged as an important non-bioclimatic variable, contributing 13.4% to model gain, indicating that topographic constraints partly define the niche of this species.

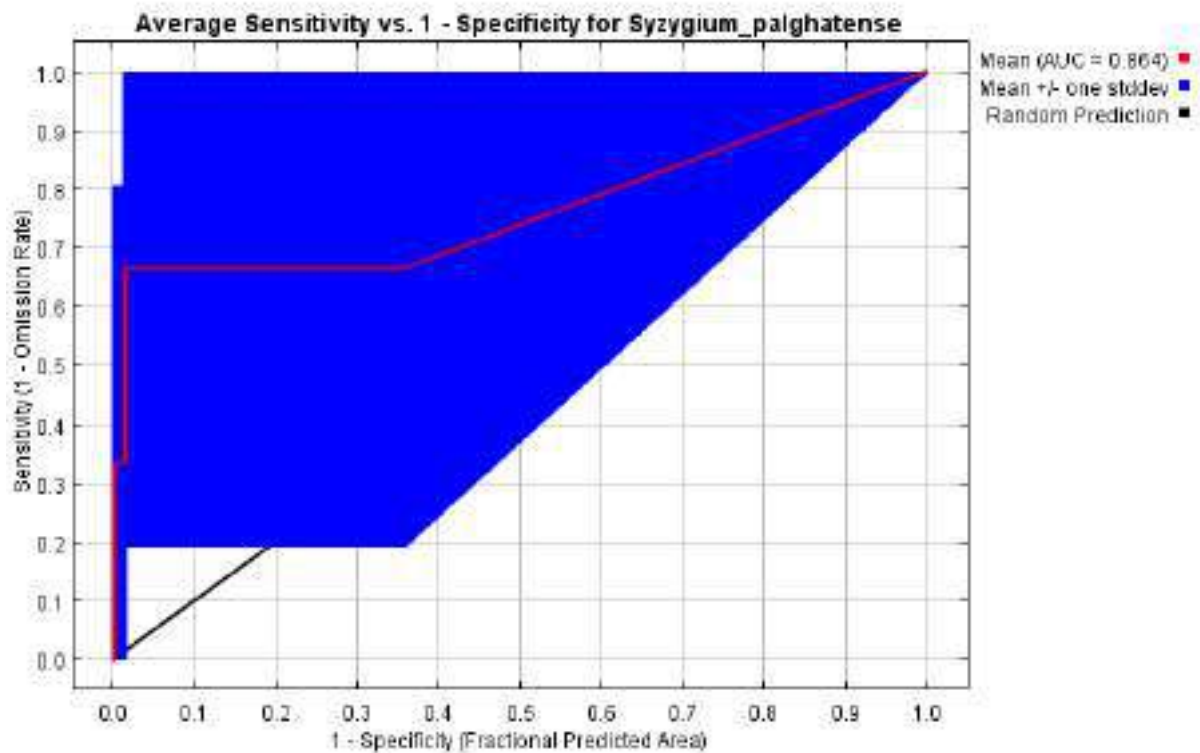


**Fig. 4.112.** Area Under Curve indicating model performance of *Syzygium palghatense*



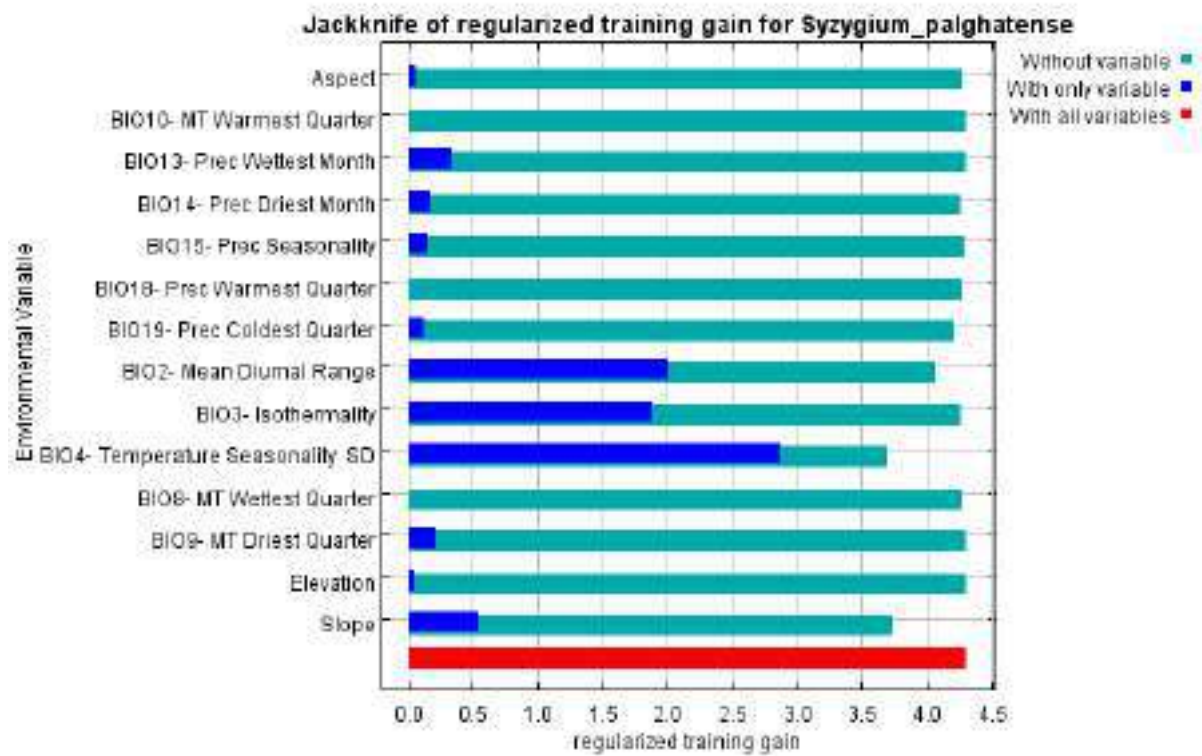


**Fig. 4.113. Jackknife test of training gain showing bioclimatic variables of importance**

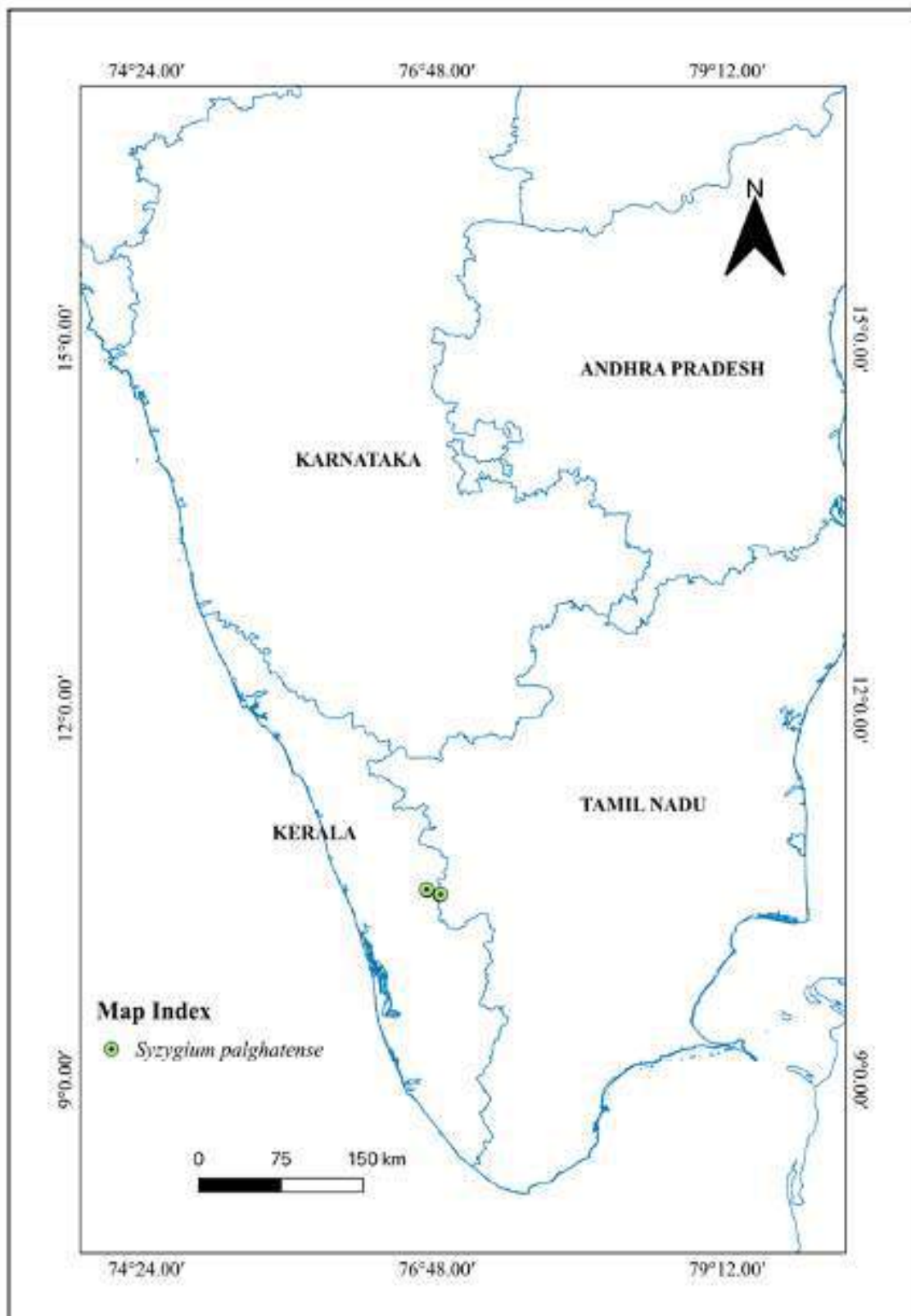


Fig. 4.114. Actual distribution of *Syzygium palghatense*

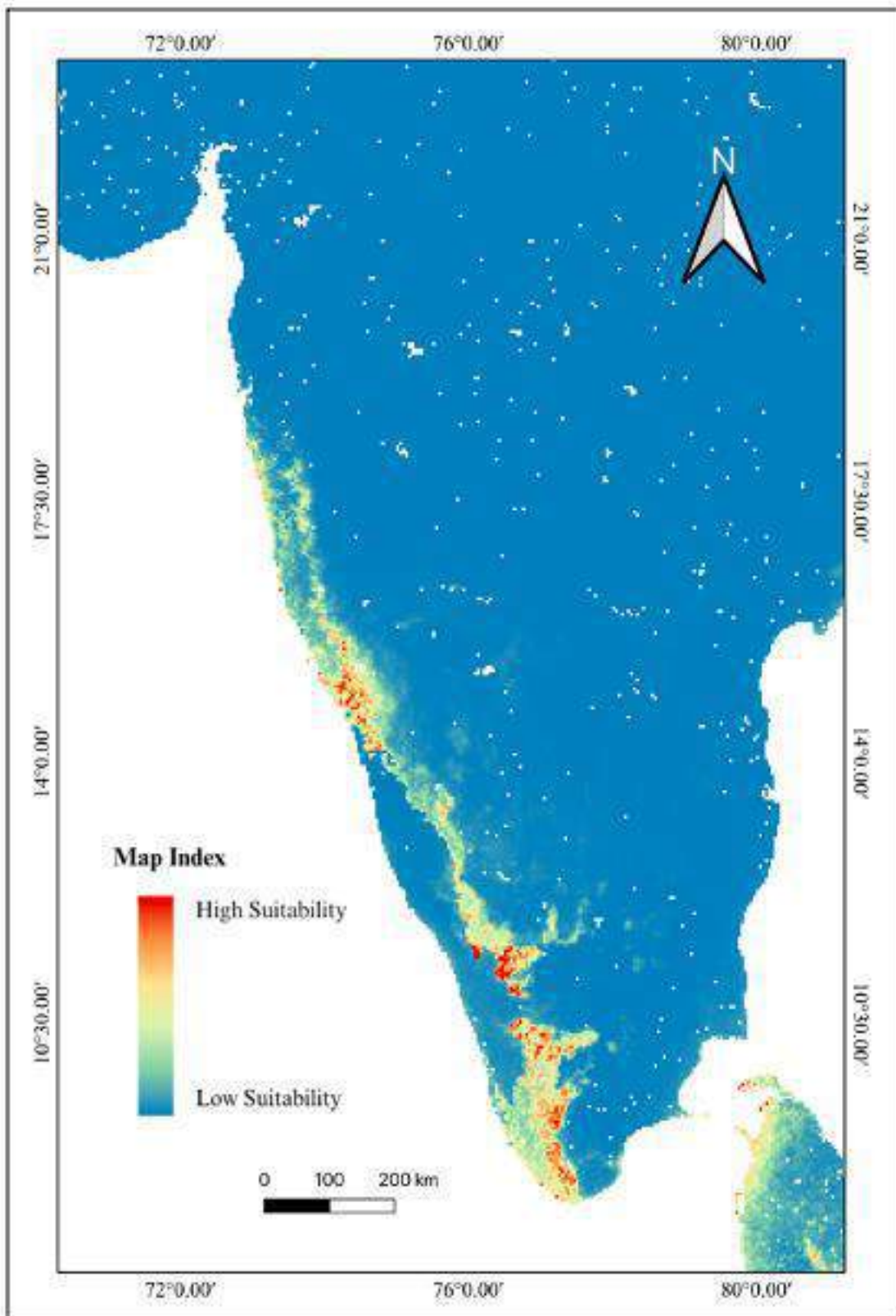


**Fig. 4.115.** Predicted habitat suitability of *Syzygium palghatense* using MaxEnt model under present climate scenario

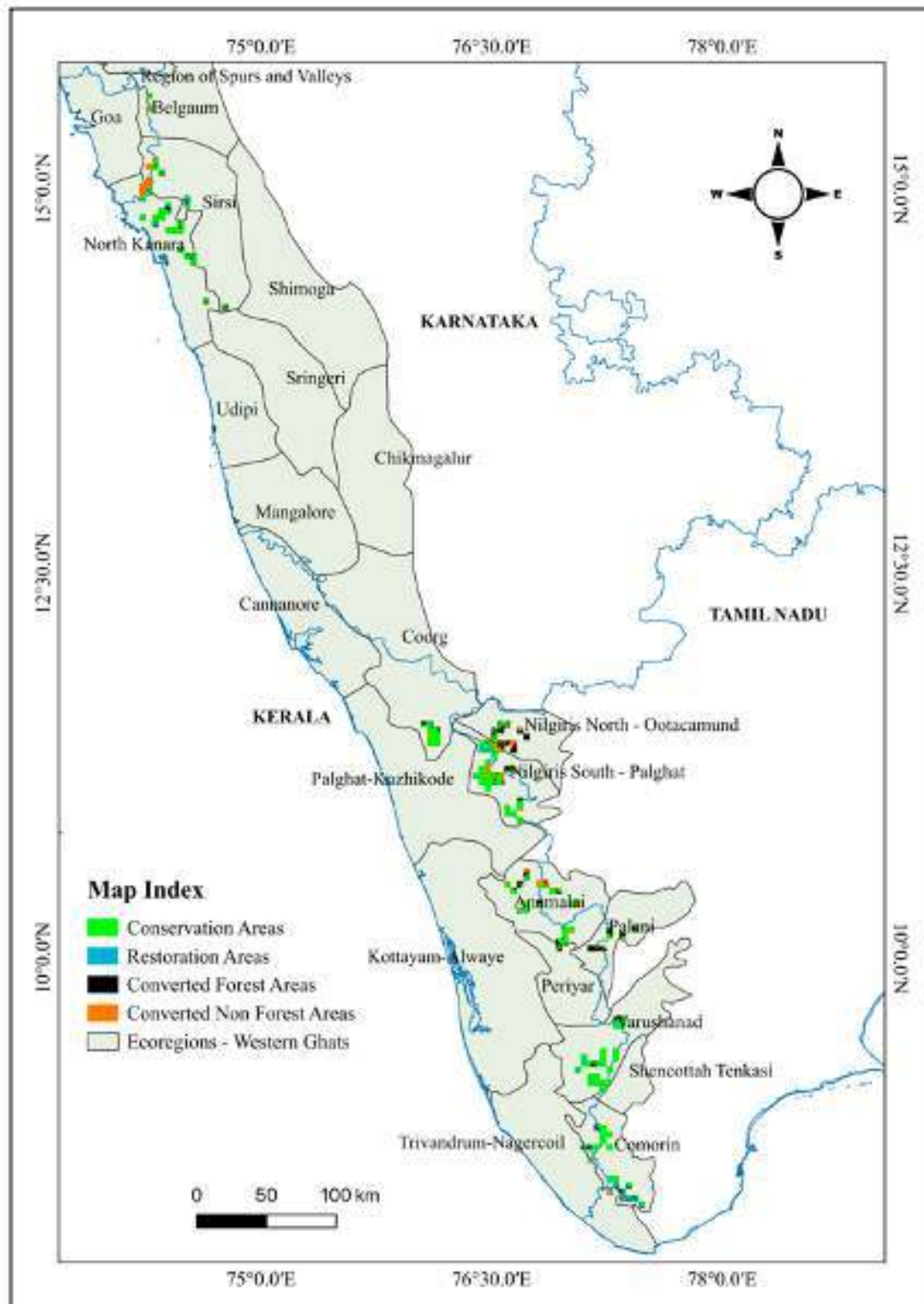


**Fig. 4.116.** Refined predicted area of *Syzygium palghatense* into potential conservation, restoration and irreversibly lost habitats at ecoregion level

### Eltonian Niche of *Syzygium palghatense* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Syzygium palghatense* is currently restricted to two subpopulations within the Western Ghats, Pandaravarai and Nelliampathi restricted to Kerala (Fig. 4.114). Under the current climate scenario, the MaxEnt model predicts a total of 3110.30 km<sup>2</sup> of highly suitable habitat for *Syzygium palghatense* in the Western Ghats (Fig. 4.115). This predicted distribution spans over 13 distinct ecoregions. The highest suitability predictions were concentrated in the Nilgiris South – Palghat (589.95 km<sup>2</sup>), Varushanad (446.63 km<sup>2</sup>), Anamalai (421.73 km<sup>2</sup>), North Kanara (397.11 km<sup>2</sup>), Comorin (377.91 km<sup>2</sup>), Nilgiris North-Ootacamund (243.45 km<sup>2</sup>) ecoregions (Table 27).

**Table 4.27. Ecoregion wise habitat prediction for *Syzygium palghatense* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No. | Ecoregion                  | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|---------|----------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1       | Anamalai                   | 421.73                            | 242.47                               | 20.39                               | 68.79                                    | 90.08                                        |
| 2       | Belgaum                    | 41.15                             | 36.92                                | 0.40                                | 2.70                                     | 1.12                                         |
| 3       | Comorin                    | 377.92                            | 223.35                               | 106.66                              | 39.65                                    | 8.25                                         |
| 4       | Coorg                      | 167.66                            | 131.41                               | 6.55                                | 18.25                                    | 11.45                                        |
| 5       | Nilgiris North -Ootacamund | 243.45                            | 59.30                                | 4.19                                | 133.75                                   | 46.21                                        |
| 6       | Nilgiris South - Palghat   | 589.95                            | 373.45                               | 67.81                               | 42.06                                    | 106.64                                       |
| 7       | North Kanara               | 397.12                            | 245.20                               | 34.46                               | 47.49                                    | 69.96                                        |
| 8       | Palani                     | 146.35                            | 43.40                                | 7.67                                | 81.56                                    | 13.72                                        |
| 9       | Periyar                    | 26.41                             | 10.37                                | 1.67                                | 13.06                                    | 1.32                                         |
| 10      | Shencottah Tenkasi         | 8.94                              | 6.79                                 | 2.15                                | 0.00                                     | 0.00                                         |

|              |                          |                |                |               |               |               |
|--------------|--------------------------|----------------|----------------|---------------|---------------|---------------|
| 11           | Sirsi                    | 200.14         | 92.83          | 19.15         | 25.91         | 62.24         |
| 12           | Trivandrum-<br>Nagercoil | 42.86          | 4.10           | 18.89         | 5.10          | 14.77         |
| 13           | Varushanad               | 446.63         | 377.68         | 44.46         | 23.69         | 0.80          |
| <b>Total</b> |                          | <b>3110.30</b> | <b>1847.28</b> | <b>334.46</b> | <b>501.99</b> | <b>426.57</b> |

The initial modelling of the potential distribution for *Syzygium palghatense*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 3110.30 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.116). A total of Conservation area spanning 1847.28 km<sup>2</sup>, Potential Ecorestoration area of 334.46 km<sup>2</sup>, irreversibly converted forest habitat (501.99 km<sup>2</sup>) and converted non-forested human-dominated areas (426.57 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Varushanad (377.68 km<sup>2</sup>), Nilgiris South – Palghat (373.44 km<sup>2</sup>), North Kanara (245.20 km<sup>2</sup>), Anamalai (242.46 km<sup>2</sup>) and Comorin (223.35 km<sup>2</sup>) represent maximum potential conservation areas suitable for *Syzygium palghatense*. The degraded habitats are also represented by ecoregions such as Comorin (106.65 km<sup>2</sup>), Nilgiris South – Palghat (67.80 km<sup>2</sup>), Varushanad (44.46 km<sup>2</sup>), North Kanara (34.46 km<sup>2</sup>), Anamalai (20.39 km<sup>2</sup>) and Sirsi (19.15 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 16 % of converted forest habitat to the species are represented with Nilgiris North - Ootacamund (133.75 km<sup>2</sup>), Palani (81.55 km<sup>2</sup>), Anamalai (68.79 km<sup>2</sup>) and North Kanara (47.48 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Syzygium palghatense* ecological niche.

#### 4.3.24. Grinnellian Niche of *Syzygium parameswaranii* Using Bioclimatic Factors

The MaxEnt model for *Syzygium parameswaranii* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.999 (Fig. 4.117). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for

ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Syzygium parameswaranii* (Fig. 4.118). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (37.9%) and Precipitation of Driest Month (20.9%) contributed most to the model. This is followed by Precipitation Seasonality (16.8%), MT Warmest Quarter (4.25%), Isothermality (3.7%), Precipitation of Warmest Quarter (1.3%) (Appendix II). The Slope also emerged as an important non-bioclimatic variable, contributing 10.4 % to model gain, indicating that topographic constraints partly define the niche of this species.

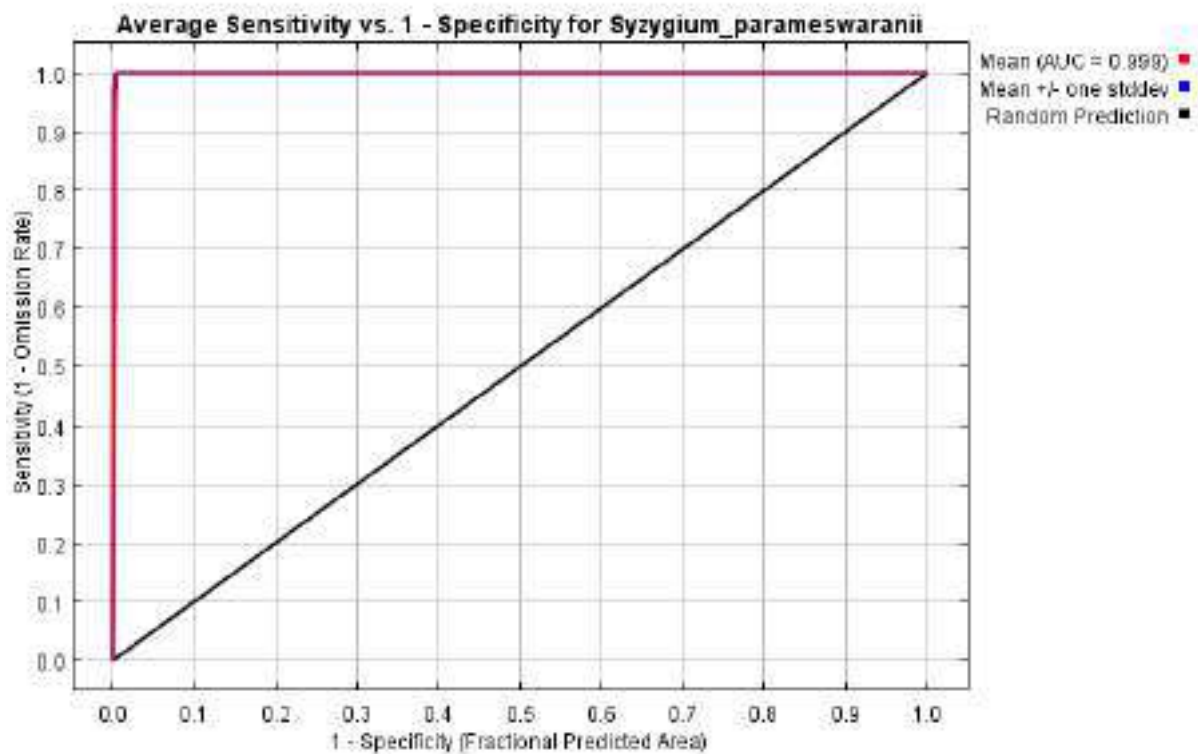


**Fig. 4.117.** Area Under Curve indicating model performance of *Syzygium parameswaranii*





**Fig. 4.118. Jackknife test of training gain showing bioclimatic variables of importance**

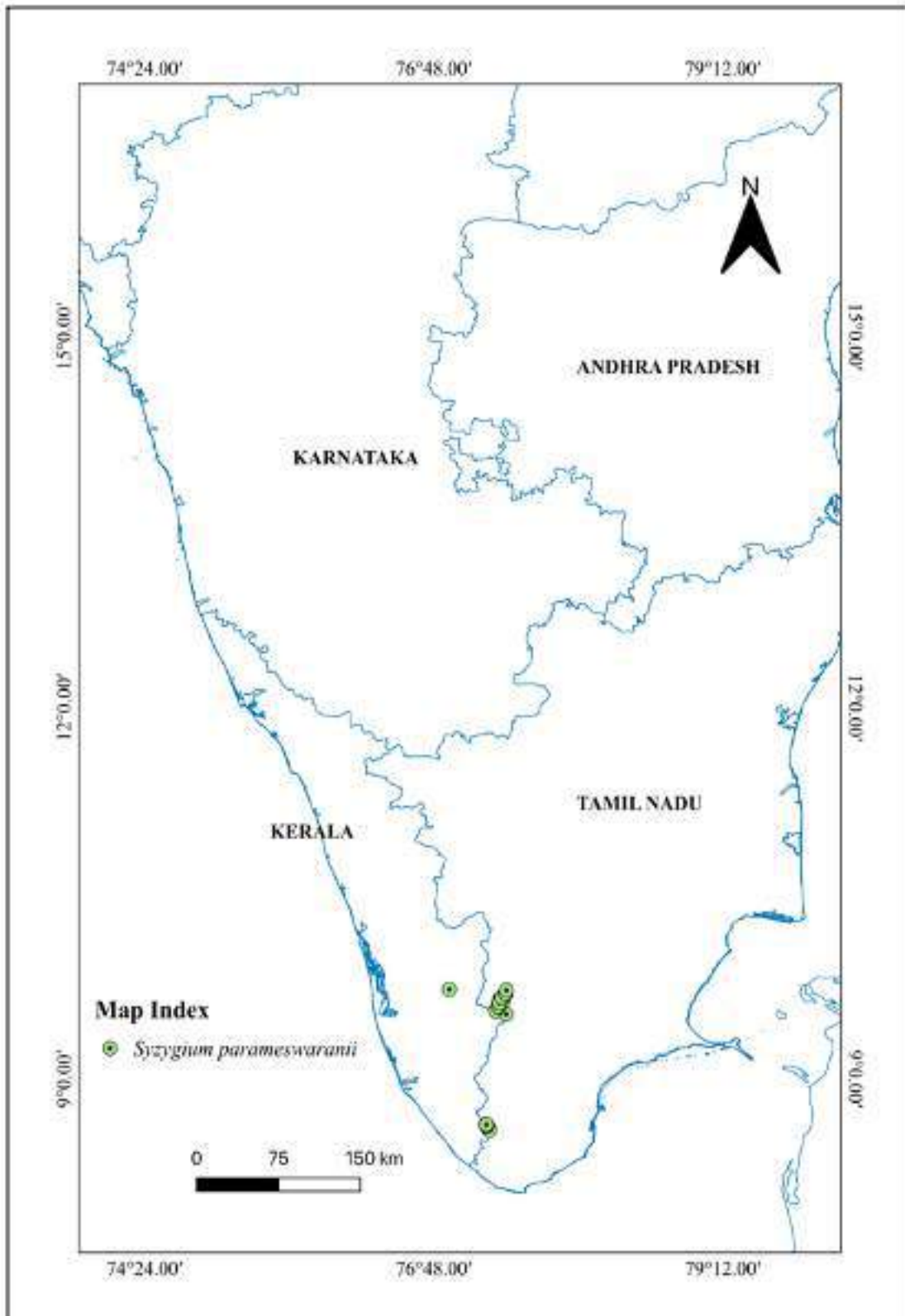


Fig. 4.119. Actual distribution of *Syzygium parameswaranii*

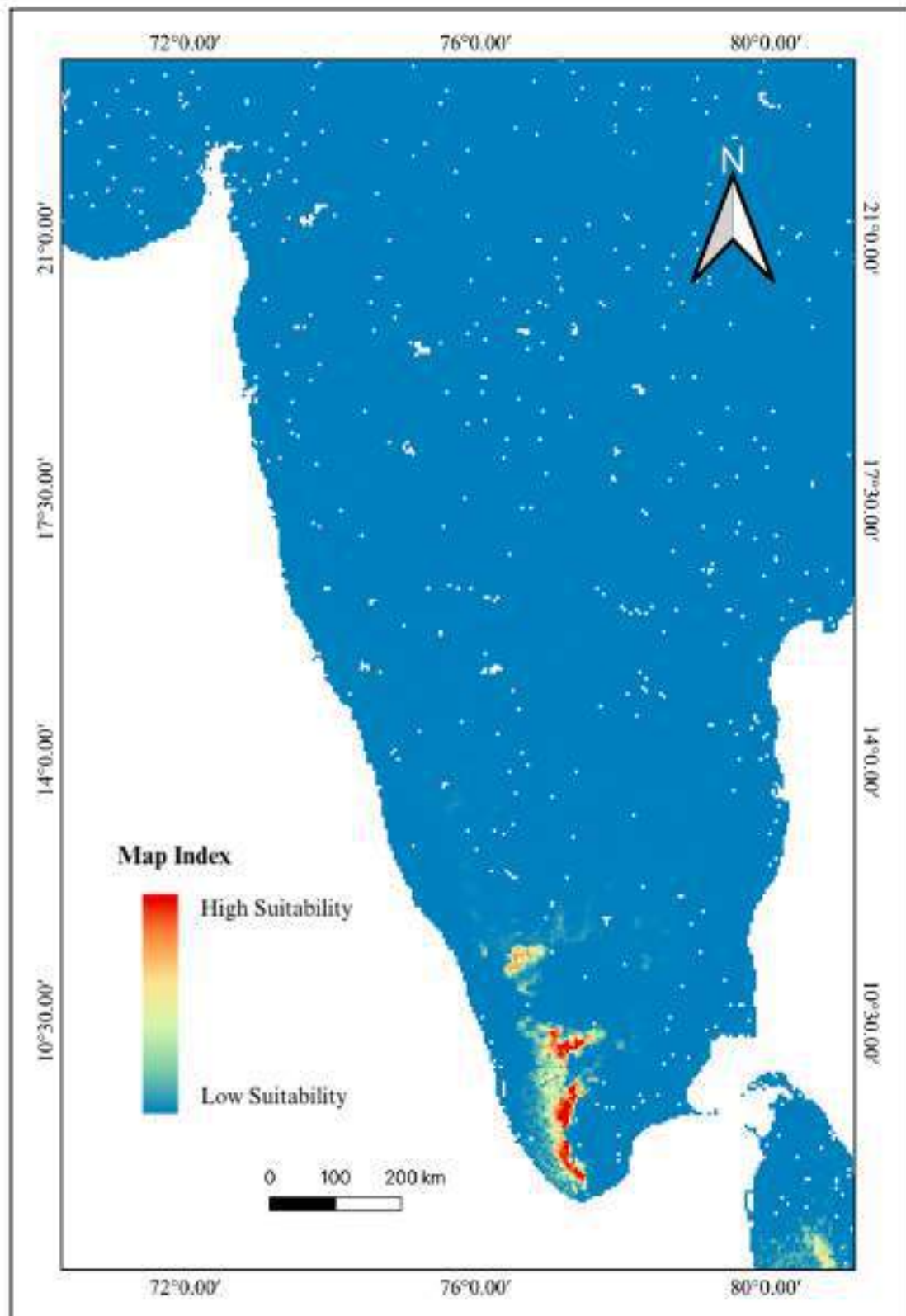


**Fig. 4.120.** Predicted habitat suitability of *Syzygium parameswaranii* using MaxEnt model under present climate scenario

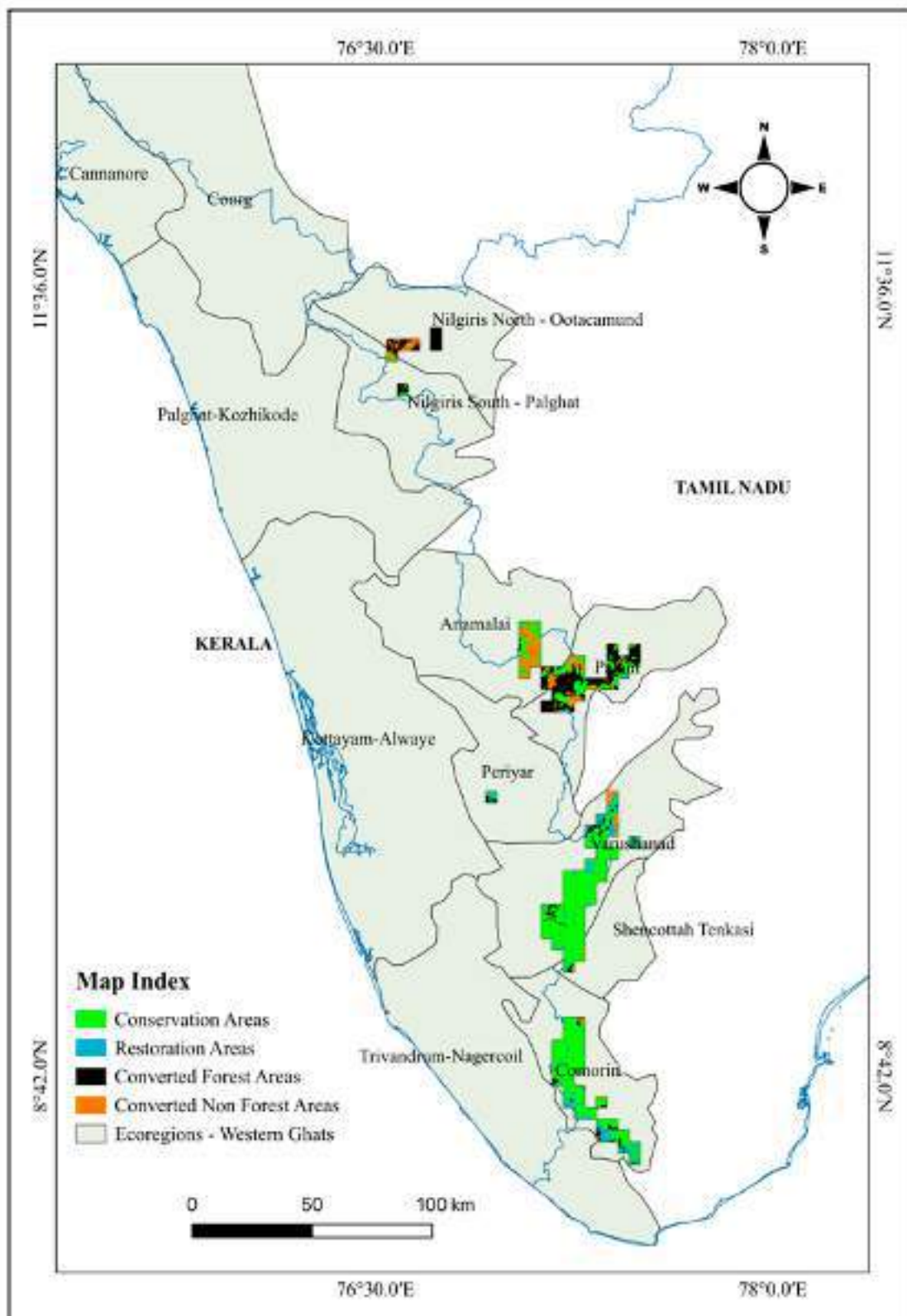


**Fig. 4.121.** Refined predicted area of *Syzygium parmeswaranii* into potential conservation, restoration and irreversibly lost habitats at ecoregion level

### Eltonian Niche of *Syzygium parameswaranii* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Syzygium parameswaranii* is currently restricted to four subpopulations within the Western Ghats, particularly in parts of Kerala and Tamil Nadu (Fig. 4.119). Under the current climate scenario, the MaxEnt model predicts a total of 2407.72 km<sup>2</sup> of highly suitable habitat for *Syzygium parameswaranii* in the Western Ghats (Fig. 4.120). This predicted distribution spans over eight distinct ecoregions. The highest suitability predictions were concentrated in the Varushanad (825.10 km<sup>2</sup>), Comorin (628.40 km<sup>2</sup>), Palani (488.57 km<sup>2</sup>), Anamalai (241.60 km<sup>2</sup>), Nilgiris North-Ootacamund (109.45 km<sup>2</sup>) ecoregions (Table 4.28).

**Table 4.28. Ecoregion wise habitat prediction for *Syzygium parameswaranii* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No.      | Ecoregion                 | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|--------------|---------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1            | Anamalai                  | 241.61                            | 94.15                                | 1.30                                | 29.88                                    | 116.29                                       |
| 2            | Comorin                   | 628.40                            | 475.00                               | 110.52                              | 33.13                                    | 9.75                                         |
| 3            | Nilgiris North-Ootacamund | 109.46                            | 1.91                                 | 0.00                                | 78.66                                    | 28.88                                        |
| 4            | Nilgiris South-Palghat    | 35.96                             | 11.06                                | 0.00                                | 15.45                                    | 9.46                                         |
| 5            | Palani                    | 488.58                            | 138.42                               | 10.14                               | 269.19                                   | 70.83                                        |
| 6            | Periyar                   | 20.82                             | 4.86                                 | 9.40                                | 6.56                                     | 0.00                                         |
| 7            | Shencottah Tenkasi        | 57.79                             | 42.83                                | 6.04                                | 5.07                                     | 3.86                                         |
| 8            | Varushanad                | 825.10                            | 653.56                               | 105.51                              | 39.24                                    | 26.80                                        |
| <b>Total</b> |                           | <b>2407.72</b>                    | <b>1421.78</b>                       | <b>242.90</b>                       | <b>477.16</b>                            | <b>265.88</b>                                |

The initial modelling of the potential distribution for *Syzygium parameswaranii*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 2407.72 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.121). A total of Conservation area spanning 1421.78 km<sup>2</sup>, Potential Ecorestoration area of 242.90 km<sup>2</sup>, irreversibly converted forest habitat (477.16 km<sup>2</sup>) and converted non-forested human-dominated areas (265.88 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Varushanad (653.55 km<sup>2</sup>), Comorin (475.00 km<sup>2</sup>), Palani (138.41 km<sup>2</sup>), Anamalai (94.14 km<sup>2</sup>) and Shencottah Tenkasi (42.82 km<sup>2</sup>) represent maximum potential conservation areas suitable for *Syzygium parameswaranii*. The degraded habitats are also represented by ecoregions such as Comorin (110.51 km<sup>2</sup>), Varushanad (105.50 km<sup>2</sup>), Palani (10.13 km<sup>2</sup>) and Periyar (9.39 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 19 % of converted forest habitat to the species are represented with Palani (269.19 km<sup>2</sup>), Nilgiris North-Ootacamund (78.66 km<sup>2</sup>) and Varushanad (39.23 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Syzygium parameswaranii*, ecological niche.

#### **4.3.25. Grinnellian Niche of *Syzygium sahyadricum* Using Bioclimatic Factors**

The MaxEnt model for *Syzygium sahyadricum* under current climatic conditions exhibited high predictive performance, with an average Area Under the Receiver Operating Characteristic Curve (AUC) of 0.990 (Fig. 4.212). This value indicates excellent model performance according to the classification proposed by Swets (1988), and adapted for ecological niche modelling by Thuiller et al. (2005). The high AUC reflects the model's strong ability to distinguish suitable from unsuitable habitats based on the environmental variables provided.

The Jackknife test of training gain identified the most influential environmental variables shaping the potential distribution of *Syzygium sahyadricum* (Fig. 4.213). Among the 19 bioclimatic variables assessed Temperature Seasonality SD (55.4%) and Precipitation Seasonality (16.2%) contributed most to the model. This is followed by Precipitation of Warmest Quarter (3.2%), Precipitation of Driest Month (1.9%) (Appendix II). The

Elevation and Slope emerged as an important non-bioclimatic variable, contributing 14.9 % and 8.4% respectively to model gain, indicating that topographic constraints partly define the niche of this species.

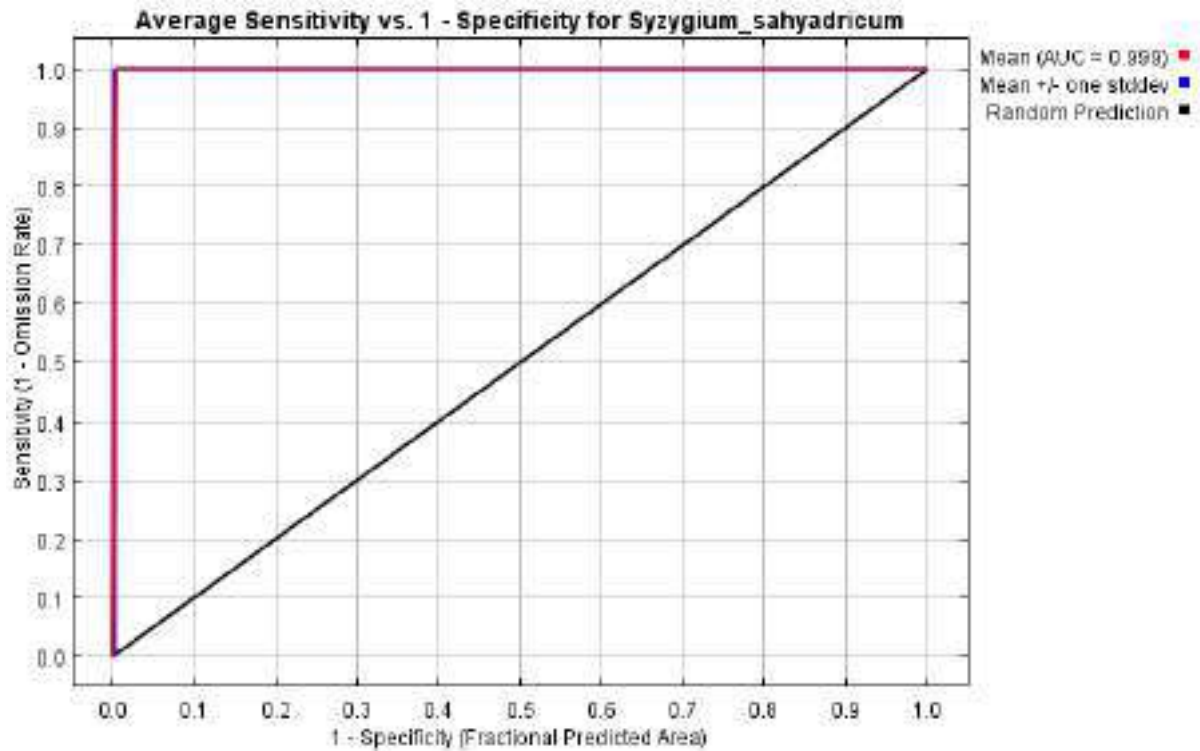


**Fig. 4.122.** Area Under Curve indicating model performance of *Syzygium sahyadricum*



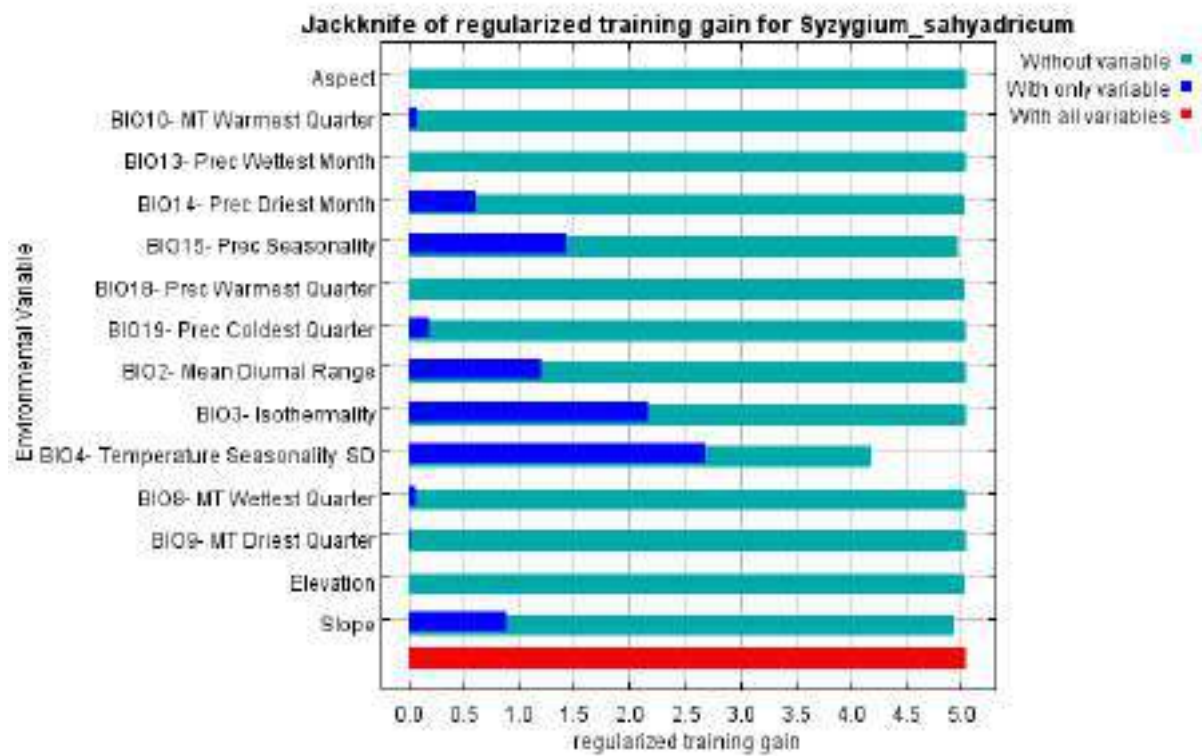


**Fig. 4.123. Jackknife test of training gain showing bioclimatic variables of importance**

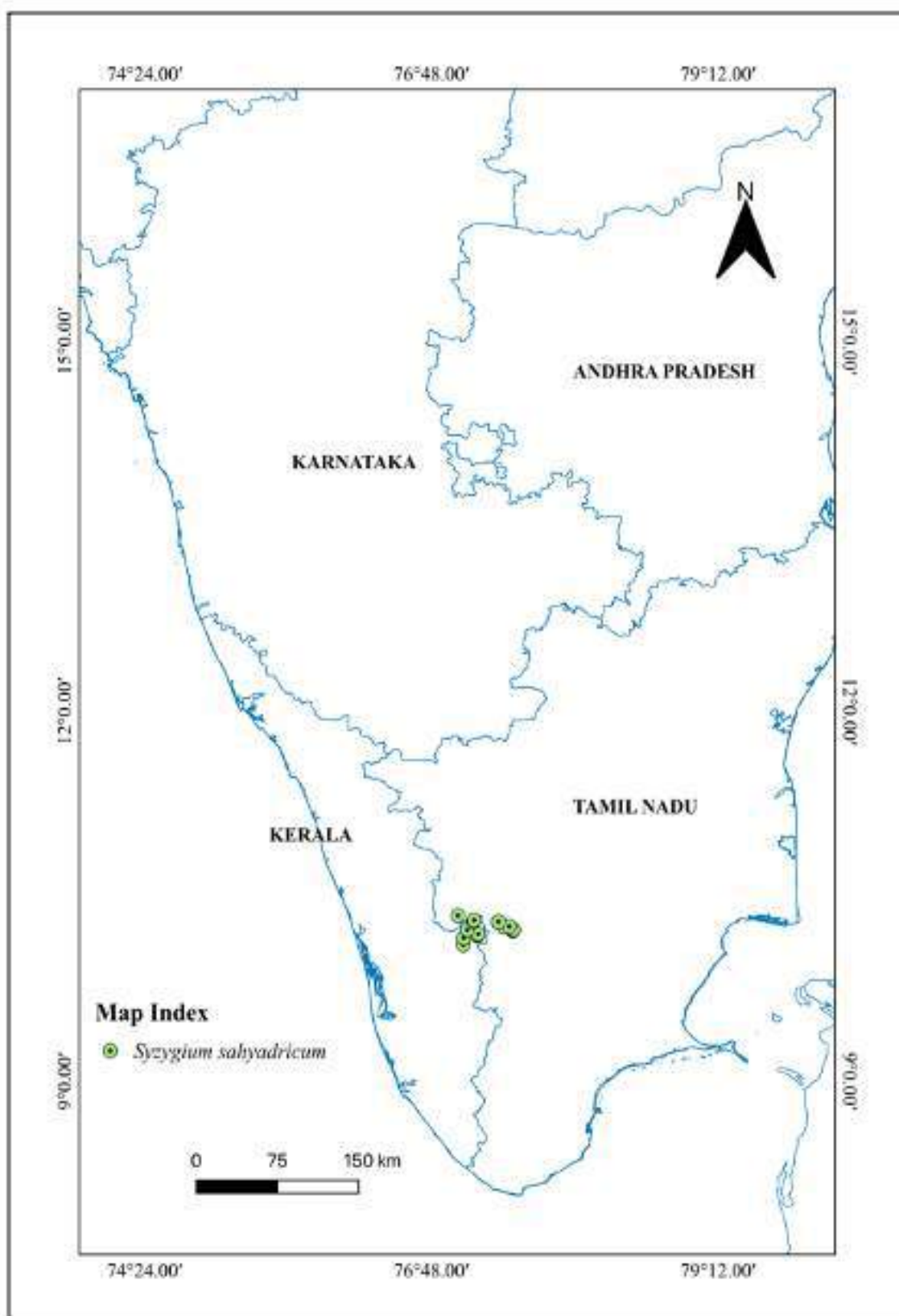


Fig. 4.124. Actual distribution of *Syzygium sahyadricum*

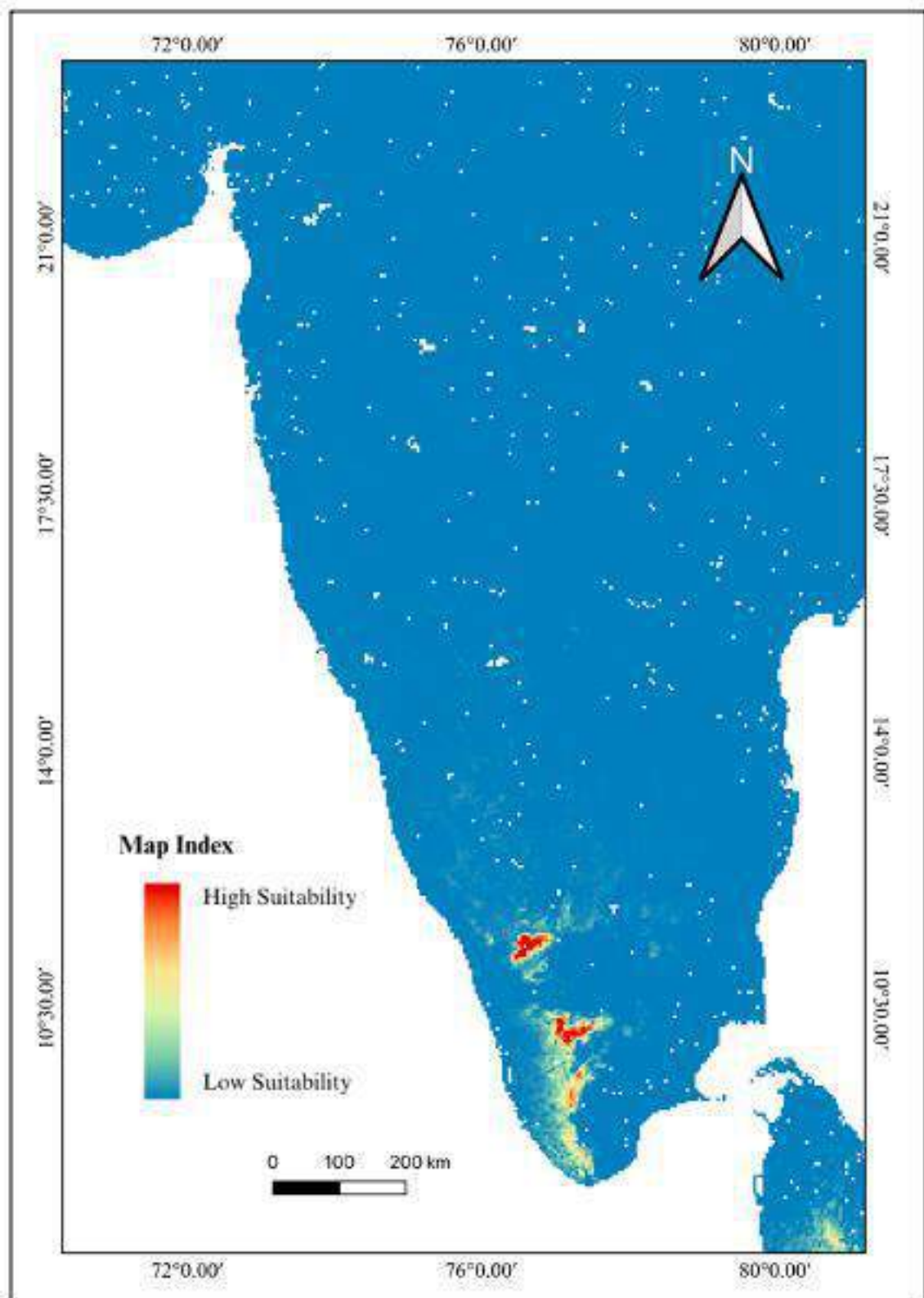


**Fig. 4.125.** Predicted habitat suitability of *Syzygium sahyadricum* using MaxEnt model under present climate scenario

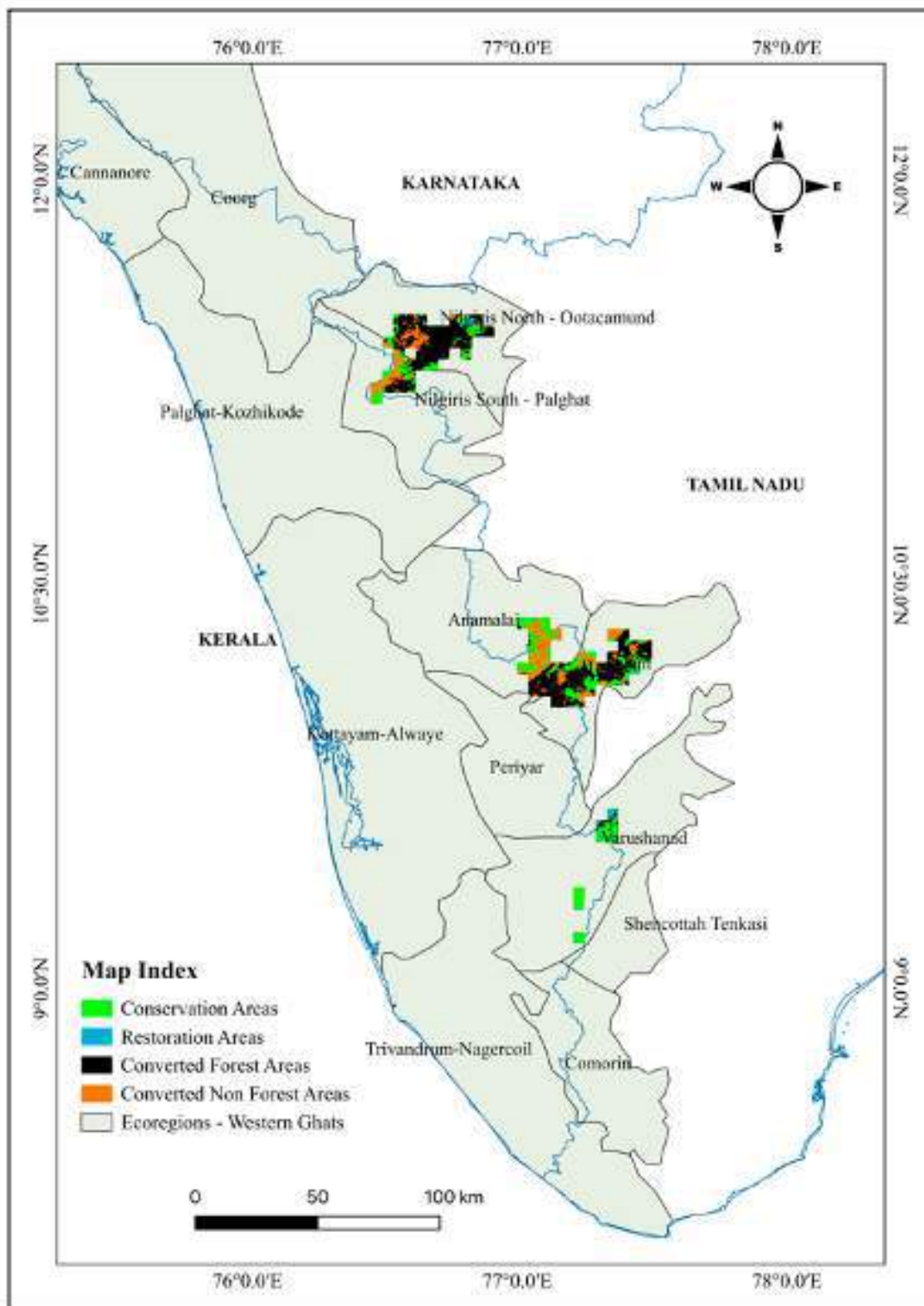


**Fig. 4.126.** Refined predicted area of *Syzygium sahyadricum* into potential conservation, restoration and irreversibly lost habitats at ecoregion level

### Eltonian Niche of *Syzygium Sahyadricum* Using Classified Vegetation Layers Refined to Ecoregion Level

The known distribution of *Syzygium sahyadricum* is currently restricted to 10 subpopulations within the Western Ghats, particularly in parts of Kerala and Tamil Nadu (Fig. 4.124). Under the current climate scenario, the MaxEnt model predicts a total of 2050.18 km<sup>2</sup> of highly suitable habitat for *Syzygium sahyadricum* in the Western Ghats (Fig. 4.125). This predicted distribution spans over five distinct ecoregions. The highest suitability predictions were concentrated in the Palani (637.95 km<sup>2</sup>), Nilgiris North-Ootacamund (587.88 km<sup>2</sup>), Anamalai (407.61 km<sup>2</sup>), Nilgiris South-Palghat (249.79 km<sup>2</sup>) ecoregions (Table 4.29).

**Table 4.29. Ecoregion wise habitat prediction for *Syzygium sahyadricum* showing potential conservation, restoration and irreversibly degraded habitats**

| SL. No.      | Ecoregion                 | Predicted Area (Km <sup>2</sup> ) | Conservation Area (Km <sup>2</sup> ) | Restoration Area (Km <sup>2</sup> ) | Converted Forest Area (Km <sup>2</sup> ) | Converted Non Forest area (Km <sup>2</sup> ) |
|--------------|---------------------------|-----------------------------------|--------------------------------------|-------------------------------------|------------------------------------------|----------------------------------------------|
| 1            | Anamalai                  | 407.62                            | 136.06                               | 2.50                                | 108.64                                   | 160.42                                       |
| 2            | Nilgiris North-Ootacamund | 587.88                            | 78.61                                | 21.70                               | 409.02                                   | 78.54                                        |
| 3            | Nilgiris South-Palghat    | 249.80                            | 80.17                                | 1.00                                | 78.77                                    | 89.86                                        |
| 4            | Palani                    | 637.96                            | 146.58                               | 10.17                               | 366.76                                   | 114.45                                       |
| 5            | Varushanand               | 166.93                            | 117.95                               | 31.30                               | 16.15                                    | 1.53                                         |
| <b>Total</b> |                           | <b>2050.18</b>                    | <b>559.37</b>                        | <b>66.66</b>                        | <b>979.34</b>                            | <b>444.81</b>                                |

The initial modelling of the potential distribution for *Syzygium sahyadricum*, utilizing primarily Grinnellian niche factors (abiotic environmental variables), yielded a predicted area of 2050.18 km<sup>2</sup>. Subsequent refinement of this predicted range, incorporating

vegetation layers (biotic interactions and anthropogenic influences), delineated the area into distinct land-use categories crucial for conservation planning (Fig. 4.126). A total of Conservation area spanning 559.37 km<sup>2</sup>, Potential Ecorestoration area of 66.66 km<sup>2</sup>, and irreversibly converted forest habitat (979.34 km<sup>2</sup>) and converted non-forested human-dominated areas (444.81 km<sup>2</sup>) were enumerated for the species. The ecoregions such as Palani (146.57 km<sup>2</sup>), Anamalai (136.05 km<sup>2</sup>), Varushanand (117.95 km<sup>2</sup>), and Nilgiris South-Palghat (80.17 km<sup>2</sup>) represent maximum potential conservation areas suitable for *Syzygium sahyadricum*. The degraded habitats are also represented by ecoregions such as Varushanand (31.29 km<sup>2</sup>), Nilgiris North-Ootacamund (21.70 km<sup>2</sup>), Palani (10.17 km<sup>2</sup>), and Anamalai (2.49 km<sup>2</sup>). These areas are considered here as potential ecorestoration areas for the species. Among the total 16 % of converted forest habitat to the species are represented with Nilgiris North-Ootacamund (409.02 km<sup>2</sup>), Palani (366.75 km<sup>2</sup>), Anamalai (108.63 km<sup>2</sup>) and Nilgiris South-Palghat (78.76 km<sup>2</sup>). The spatially explicit identification of these land-use categories at both landscape and ecoregional scales provides a critical framework for the development of species-specific conservation strategies and ecosystem restoration interventions tailored to *Syzygium sahyadricum* ecological niche.

#### **4.4. Discussion**

This study employed MaxEnt ecological niche modelling to predict the potential distribution of 25 threatened angiosperm species in the Western Ghats, using Eltonian as well as Grinnellian framework. The high values of Area Under Curve (AUC), (>0.9 for 23 species, >0.8-0.9 for two species) and robust model outputs reflect strong discriminatory power and ecological relevance, indicating that the selected environmental predictors effectively capture the fundamental niche requirements of these species under current climatic conditions (Swets, 1988; Thuiller et al., 2005).

##### **4.4.1. Defining Species Niche with Bioclimatic and Topographic Variables**

The principal component analysis (PCA) revealed that a select group of environmental variables exert the most significant influence on the observed patterns in species distribution (or conservation/ecorestoration area). These key factors, ordered by their contribution to the principal components, include Elevation, Precipitation of the driest quarter, Precipitation of the wettest quarter, Slope, Precipitation of the warmest quarter, and Precipitation of the driest month (Fig. 4.128). These findings suggest that the distribution and establishment of the studied species are primarily governed by a

combination of topographical and seasonal precipitation variables. Elevation and Slope are fundamental physical factors that shape a landscape's microclimate, influencing temperature gradients, soil composition, and water drainage. For instance, steep slopes can lead to rapid runoff, while variations in elevation create distinct microclimates that a species must be adapted to (Yang et al., 2020; John et al., 2024).

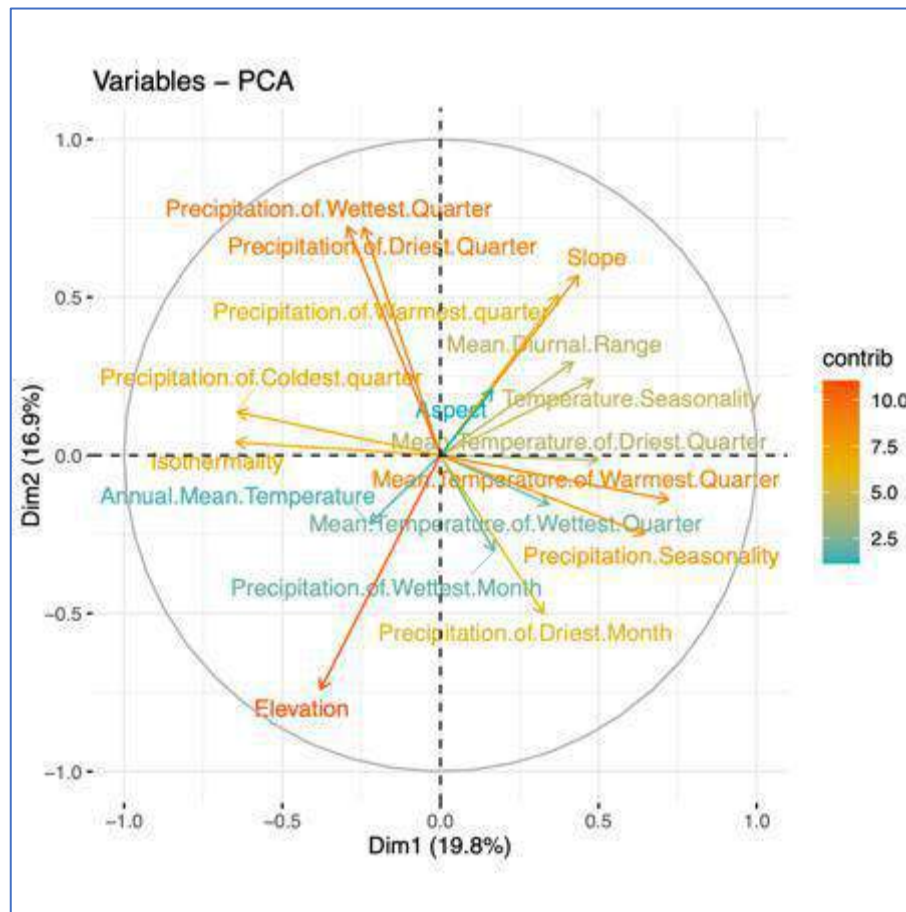


**Fig. 4.127. PCA plot showing significant bioclimatic factors**



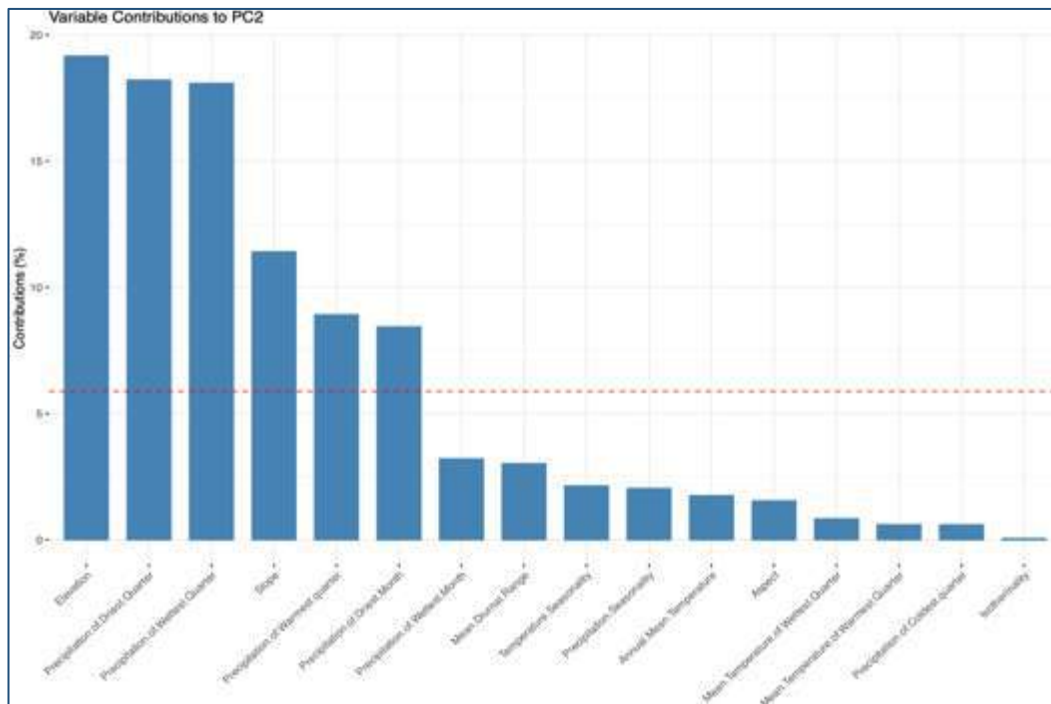


**Fig. 4.128. Most influential variable across the species modelled**

The significant contribution of multiple precipitation metrics, including those for the driest and wettest months and quarters highlights the prime importance of water availability and climatic seasonality. These variables collectively define the water stress conditions a species faces throughout the year, from periods of scarcity to periods of abundance (summer to monsoon). The pronounced influence of these environmental variables suggests that the studied species flourish within highly specific climatic niches in the Western Ghats, primarily defined by the region's characteristic monsoon precipitation patterns. This reliance on seasonal moisture aligns with previous bioclimatic classifications of the Western Ghats by Meher-Homji (2001) and landscape-specific studies like Bachan (2010) on the Anamalai Hills, both of which emphasise the critical role of summer precipitation and the duration of the dry period in delineating distinct bioclimates. Furthermore, the limited number of dry months often observed in montane forests is likely mitigated by the sustained presence of ground-level mist. This phenomenon is itself a product of the complex interplay between climate and topography, where variables like mountain height and proximity to the coast significantly affect the incidence and frequency of cloud cover and mist (Jarvis & Mulligan, 2011). Collectively, the synergistic effect of these topographical and climatic variables creates the unique environmental mosaic that ultimately governs the observed clustering and distribution of species across the landscape. The conservation and restoration efforts to be effective and ensure long-term species

viability, they must be strategically prioritised within areas defined by these precise environmental conditions.

#### 4.4.2. Contribution of Bioclimatic factors for different vegetation groups

The 25 threatened tree species were selected for this study with a multifaceted aim: not only to define the specific Grinnellian (bioclimatic) and Eltonian (vegetation-based) niches of each species, but also to statistically examine if significant bioclimatic and niche differentiation exists across species representing the low elevation, low elevation riparian, medium elevation, and high elevation forest types (Table 4.30).

**Table 4.30. Vegetation sub groups and the corresponding 25 species selected for the study**

| Vegetation Subgroup    | Species                                                                                                                                                                                                                                              |
|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| High Elevation         | <i>Elaeocarpus munroi</i> , <i>Elaeocarpus recurvatus</i> , <i>Impatiens parasitica</i> , <i>Medinilla anamalaiana</i> , <i>Strobilanthes kunthiana</i> , <i>Syzygium densiflorum</i> , <i>Syzygium sahyadricum</i> , <i>Syzygium parameswaranii</i> |
| Medium Elevation       | <i>Aglaia malabarica</i> , <i>Cryptocarya anamalayana</i> , <i>Cryptocarya lawsonii</i> , <i>Ficus beddomei</i> , <i>Goniothalamus wightii</i> , <i>Litsea oleoides</i> , <i>Syzygium palghatense</i>                                                |
| Low Elevation          | <i>Diospyros crumenata</i> , <i>Dipterocarpus indicus</i> , <i>Hydnocarpus pentandrus</i> , <i>Meiogyne pannosa</i> , <i>Ochna gamblei</i> , <i>Prioria pinnata</i>                                                                                  |
| Low elevation Riparian | <i>Aporosa bourdillonii</i> , <i>Garcinia wightii</i> , <i>Humboldtia vahliana</i> , <i>Syzygium occidentale</i>                                                                                                                                     |

**Table 4.31. MANOVA using R for the 25 species grouped under the four vegetation sub groups – bioclimatic variables, slope, aspect and elevation**

| Df             | Pillai | approx F | num Df | den Df | Pr(>F) | Signif. codes |
|----------------|--------|----------|--------|--------|--------|---------------|
| Species groups | 3      | 2.6741   | 2.8958 | 51     | 18     | 0.007932 **   |
| Residuals      | 20     |          |        |        |        |               |

|                |                                                                                                                                                                                    |  |  |  |  |  |
|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|--|--|--|
| Species groups | This is the independent variable, or the factor you're testing. In this case, it's the four categories you created: riparian, low elevation, high elevation, and medium elevation. |  |  |  |  |  |
| Residuals      | This row represents the unexplained variance in the model. The degrees of freedom (Df) here are a part of the calculation.                                                         |  |  |  |  |  |

The Multivariate Analysis of Variance (MANOVA), performed to assess the combined influence of bioclimatic and topographical factors on the 25 endemic species (Table 4.31), yielded a highly significant result ( $\text{Pr}( > F ) = 0.0079$ ). This outcome decisively confirms that the four predefined vegetation subgroups i. high elevation, ii. medium elevation, iii. low elevation, and iv. low elevation riparian possess statistically distinct combined bioclimatic and topographical profiles. This is a crucial finding, as it refutes the null hypothesis of random species distribution and demonstrates that group membership strongly determines the species' overall niche contribution.

Subsequent Univariate ANOVAs precisely identified the key environmental factors responsible for this observed differentiation. The most significant variables driving the separation among the vegetation subgroups are: Precipitation of the Driest Quarter ( $p < 0.001$ ), Elevation ( $p = 0.00097$ ), and Precipitation of the Wettest Quarter ( $p = 0.0051$ ). These results underscore the importance of both altitudinal gradients and seasonal water availability especially at the summer and wet quarters defining the ecological boundaries of these forest formations within the Western Ghats (Table 4.32). This statistical partitioning validates the use of these three factors as the primary environmental determinants of the studied vegetation types.

**Table 4.32. ANOVA of the bioclimatic parameters for the 25 species**

| <b>Bioclimatic Variable</b>         | <b>F value</b> | <b>P-value (Pr(&gt;F))</b> | <b>Significance</b>      |
|-------------------------------------|----------------|----------------------------|--------------------------|
| Precipitation of Driest Quarter     | 38.354         | 0.00000000175              | Highly Significant (***) |
| Elevation                           | 8.1442         | 0.00097                    | Highly Significant (***) |
| Precipitation of Wettest Quarter    | 5.7823         | 0.0051                     | Highly Significant (**)  |
| Annual Mean Temperature             | 2.7878         | 0.067                      | Not Significant (.)      |
| Temperature Seasonality             | 2.069          | 0.1365                     | Not Significant          |
| Precipitation of Coldest Quarter    | 1.9502         | 0.1541                     | Not Significant          |
| Precipitation Seasonality           | 1.6143         | 0.2176                     | Not Significant          |
| Aspect                              | 1.5224         | 0.2394                     | Not Significant          |
| Slope                               | 1.4687         | 0.2532                     | Not Significant          |
| Mean Diurnal Range                  | 1.3433         | 0.2886                     | Not Significant          |
| Precipitation of Driest Month       | 1.1565         | 0.3509                     | Not Significant          |
| Precipitation of Wettest Month      | 0.6617         | 0.5853                     | Not Significant          |
| Precipitation of Warmest Quarter    | 0.6697         | 0.5805                     | Not Significant          |
| Mean Temperature of Wettest Quarter | 0.792          | 0.5126                     | Not Significant          |
| Mean Temperature of Warmest Quarter | 0.6908         | 0.5683                     | Not Significant          |
| Mean Temperature of Driest Quarter  | 0.3793         | 0.7689                     | Not Significant          |
| Isothermality                       | 0.4528         | 0.7182                     | Not Significant          |

The influence of key bioclimatic factors, such as the Precipitation of the Driest Quarter and the Precipitation of the Wettest Quarter, in delineating the bioclimate of the four vegetation groups is a significant finding. This aligns with the work of Meher-Homji (1982), who indicated the importance of dry months, calculated as a function of precipitation and temperature ( $P > 2T$ ), in delineating dry to moist, evergreen, and wet evergreen forest formations. The present study confirms a combination of these three factors, Precipitation of the Wettest Quarter, Precipitation of the Driest Quarter, and Elevation, as the most important bioclimatic parameters defining these vegetation subgroups. This confirmation is particularly valuable as it statistically refines the ecological understanding of riparian systems. While Bachan (2010) and Bachan et al. (2022) argued that distinct bioclimatic factors govern riparian vegetation, distinguishing it from contiguous low-elevation evergreen forests, the current study provides quantitative support. Our results, by highlighting the Precipitation of the Wettest Quarter and Precipitation of the Driest Quarter as key differentiating factors, directly strengthen and refine the contention that low-elevation riparian vegetation occupies a uniquely defined bioclimatic niche.

Further supporting this, the Jackknife tests of variable importance revealed that precipitation-related variables, particularly Annual Precipitation (BIO12) and Precipitation of the Wettest Quarter (BIO16), along with Elevation, were the most influential across all modeled species. While these results align with previous research underscoring the general primacy of water availability and elevational gradients in shaping the distributions of Western Ghats endemics (Das et al., 2006; Page & Shanker, 2020), the current study offers a crucial refinement. By statistically confirming the significance of both the Precipitation of the Driest Quarter and the Precipitation of the Wettest Quarter in defining vegetation subgroups, this research moves beyond the focus on annual precipitation and wet months alone. This establishes that the seasonal extremes of water availability not just total rainfall are the critical bioclimatic determinants, providing a more precise ecological understanding of the niche boundaries for these threatened species.

#### **4.4.3. Integration of Niche Concepts and Model Refinement**

The ecological niche modelling presented in this study effectively illustrates the fundamental–realised niche continuum by integrating both Grinnellian and Eltonian perspectives. The initial MaxEnt-based predictions successfully identified climatically suitable areas, thus delineating the Grinnellian niche space of the selected threatened taxa. These results corroborate earlier findings that climatic and topographical factors act as primary filters shaping species' broad-scale distributions (Peterson et al., 2011). The recent literatures stresses integrating biotic interactions, social factors, and anthropogenic influences into ENM frameworks to improve realism and predictive power (Lawrence et al., 2023; Feng et al., 2024; Abdelwahed et al., 2025).

However, when Eltonian filters specifically, classified vegetation layers representing biotic interactions were incorporated, the models revealed substantial refinements. This indicates that local habitat suitability is not merely constrained by the abiotic envelope but is significantly mediated by ground-level ecological associations and habitat structure. The predicted areas demonstrated that taxa with narrow climatic tolerances (stenoecious taxa) exhibited high niche specificity, aligning with their restricted distribution in the Western Ghats. In contrast, relatively wide-ranging taxa, while showing broader predicted distributions, experienced a noticeable contraction in predicted suitable area once the Eltonian filters were applied. This emphasises a key methodological finding: correlative models, while powerful in delineating potential habitats, tend to overpredict in the absence of biotic considerations (Araújo & Luoto, 2007; Wisz et al., 2013).

The successful integration of vegetation classification layers substantially reduced commission errors and improved the ecological realism of the predictions by directly accounting for habitat structure and interspecific associations (Seoane et al., 2003; Franklin, 2010; Suárez-Seoane et al., 2017). This methodology highlights a crucial advance in conservation modelling, providing actionable maps that reflect the true realised niche space. The ecological realism of species distribution models (SDMs), particularly in topographically complex tropical montane landscapes, is significantly enhanced by incorporating non-bioclimatic topographic predictors, such as slope and aspect. While broad climatic variables define the fundamental niche at a macro-scale, fine-scale topographic variables are essential for capturing the realised niche by modelling species' responses to local environmental filtering (Guisan & Zimmermann, 2000).

To accurately delineate a species' habitat, the imperative is to move beyond purely climatic models and integrate Eltonian niche elements, a necessity frequently overlooked by conventional SDM methodologies (Rotenberry et al., 2006; de Araújo et al., 2014). Our study addresses this by strategically using classified vegetation layers (Devika & Bachan, 2023, 2024; Bachan & Devika, 2025; Devika & Bachan, 2025), which proved effective in refining the original distribution prediction. This approach, similar to those that integrate land use and land cover (LULC) analysis (Iralu et al., 2024), functions as a streamlined, indirect method of ground truthing that effectively incorporates critical Eltonian factors like habitat structure and interspecific associations into the spatial modelling framework. Climate change scenarios and paleoecological data integration enhance understanding of species' range shift and vulnerability (Roy et al., 2022; Babanezhad & Alireza, 2024; Passos et al., 2024; Belfiore et al., 2024; Rivadenira et al., 2025).

The practical utility of these refined model outputs offers a significant advantage for conservation planning. The integration of model predictions with readily available remote sensing resources, such as Google Earth superimposition, can substantially reduce the extensive field efforts typically required for habitat assessment (Benham et al., 2011). This increased prediction accuracy is facilitated by the continuous availability of high-resolution satellite imagery and advanced downscaling techniques for environmental parameters (Adhikari et al., 2012). This advanced spatial modelling allowed for the critical disaggregation of predicted habitats into three distinct, actionable categories: intact primary forests (Conservation Area), degraded forests retaining high suitability (Potential Ecorestoration Area), and irreversibly converted habitat. This distinction significantly enhances the applicability of niche models for actionable conservation planning.

The results support the hypothesis that most threatened angiosperms of the Western Ghats exhibit a narrow niche breadth, confirming their status as habitat specialists with a strong dependence on specific climatic and elevational conditions. This inherent ecological specificity directly increases their vulnerability to anthropogenic pressures and climate change, carrying direct implications for Red List assessments specifically for refining EOO and AOO estimates and anticipating future range contractions (Rodríguez et al., 2011; IUCN Standards and Petitions Committee, 2022). Furthermore, the identification of Potential Ecorestoration Areas presents a unique opportunity to bridge restoration ecology and species recovery planning. These zones, by retaining climatic and topographic suitability, are ideal for prioritizing native species restoration and habitat connectivity

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initiatives, which will ultimately mitigate extinction risk and enhance long-term population resilience.

#### **4.4.4. Prioritizing Ecoregions: Zones of Protection, Recovery, and Mitigation**

##### **(i) Conservation Area**

The Principal Component Analysis (PCA) revealed that the spatial distribution of predicted conservation areas is not uniform across all species, but is significantly driven by a specific set of ecoregions. The analysis of variable contributions indicates that a core group of ecoregions collectively defines the primary conservation patterns within the study area. The ecoregions exhibiting the most significant contributions to the major principal components (PC1 and PC2) are crucial for capturing the extant primary forest habitats. Specifically, PC1 is strongly influenced by the northern and central regions, including Belgaum, Coorg, Goa, North Kanara, Sirsi, Siringeri, and Region of Spurs and Valley. Conversely, PC2 is defined by a broader, more continuous range extending across the central and southern Western Ghats, encompassing Belgaum, Cannanore, Chikmagalur, Comorin, Coorg, Goa, Kottayam-Alwaye, Mangalore, Nilgiris North-Ootacamund, Palani, Palghat-Kozhikode, Sirsi, Trivandrum-Nagercoil, and Udipi.

These findings collectively suggest that conservation efforts are most effectively captured and prioritised within these specific ecoregions. Their high contribution implies that they possess the unique combination of bioclimatic, topographical, and vegetation-composition factors critical for maintaining the remaining primary forest habitat of the threatened species. Therefore, targeted conservation and management strategies should focus on these identified ecoregions to maximise impact on the overall conservation landscape of the Western Ghats.

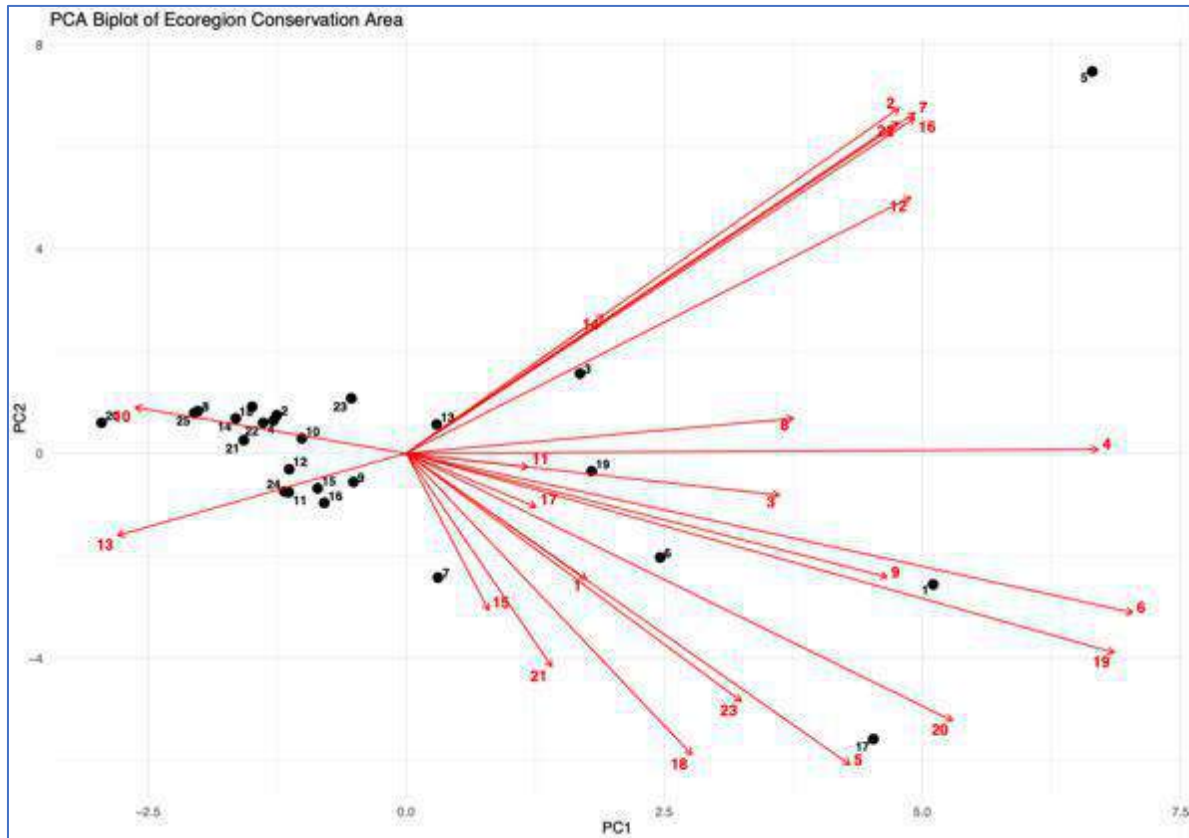


**Fig. 4.129. Relationship between the species and ecoregion with respect to conservation area**

The relationships between species distribution (points) and ecoregional variables (vectors) in the ordination space are interpreted based on angular separation and vector magnitude. A strong positive association (high proportional conservation area within an ecoregion) is indicated when a species point projects closely along the same direction as the ecoregion vector, with proximity to the vector's terminus signifying greater strength. Conversely, a negative association (low proportional conservation area) occurs when the species point lies in the opposite direction ( $180^\circ$ ), while orthogonality ( $90^\circ$ ) indicates negligible correlation or no strong association between the species' conservation status and that particular ecoregion (Fig. 4.129).

The ecoregions identified as having the strongest positive association are ecologically critical. Their high contribution implies they harbor unique combinations of bioclimatic, topographical (elevation, slope, aspect), and vegetation-composition factors essential for predicting the conservation success of the studied species. These areas likely function as key habitats, biodiversity hotspots, or centers of endemism, consistent with the model's predictions. Therefore, to maximise the impact on the overall conservation landscape of

the Western Ghats, targeted management strategies must prioritise these rigorously identified ecoregions.

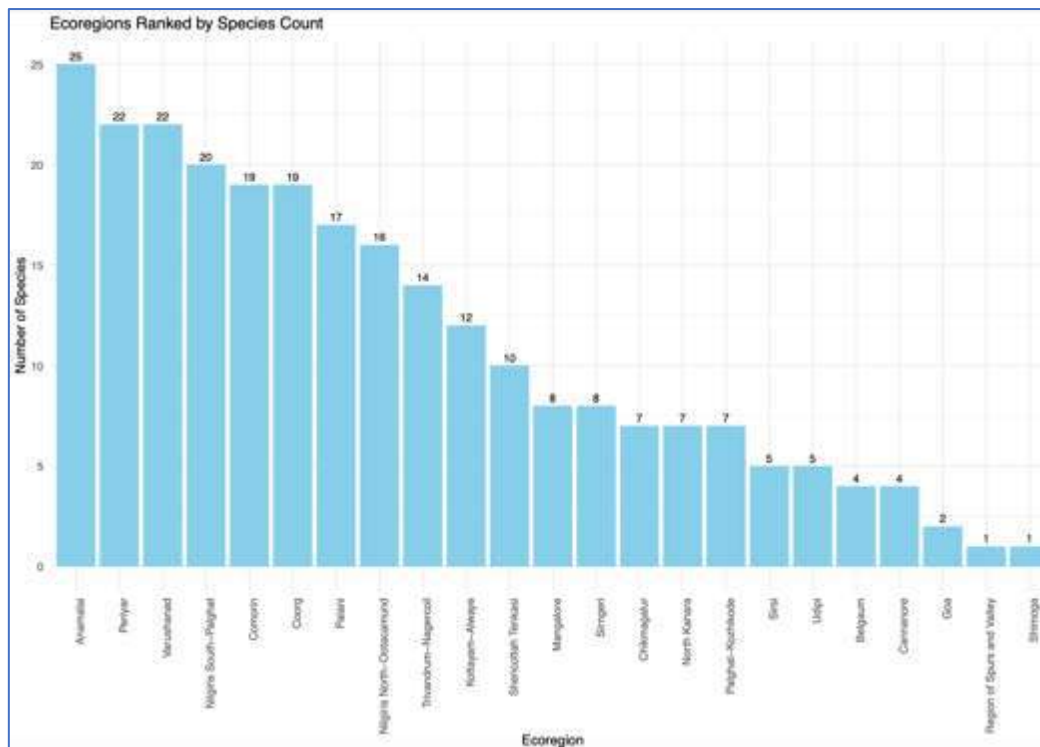


**Fig. 4.130. Conservation Area: Species count contribution by ecoregion**

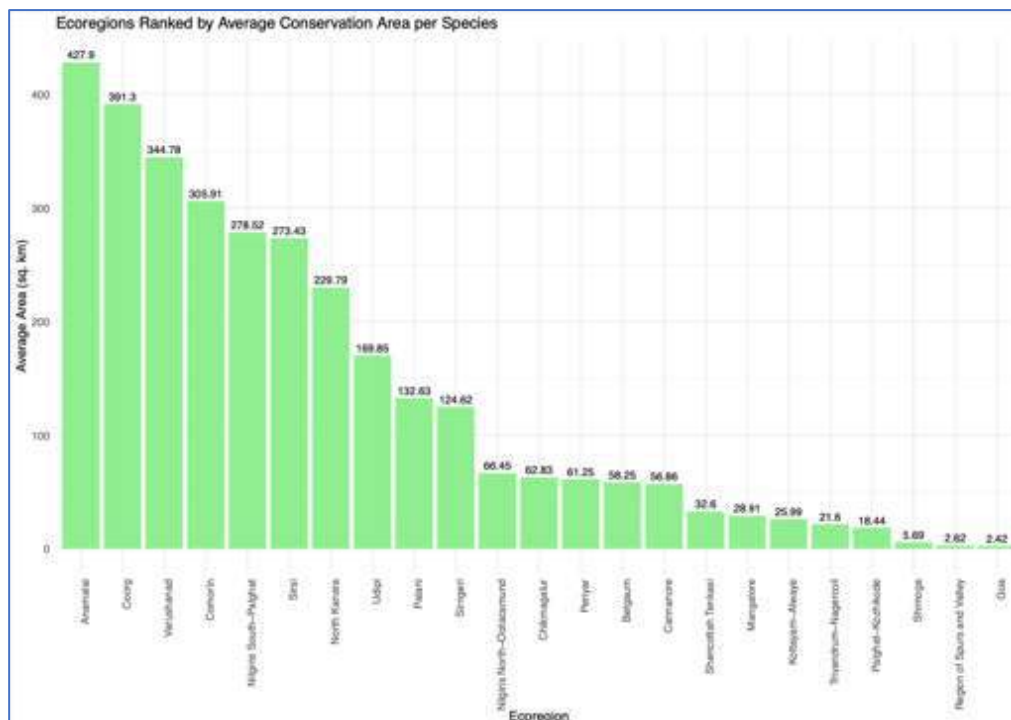


**Fig. 4.131. Conservation Area: Average habitat area per species by ecoregion**

The results of this analysis reveal that while all ecoregions contribute to overall biodiversity, selected few are disproportionately significant for the conservation of the studied threatened species. The Anamalai, Varushanad, and Periyar ecoregions emerge as crucial biodiversity hotspots, boasting the highest numbers of species with predicted suitable habitats. This concentration strongly suggests that these regions possess a unique and favorable combination of environmental conditions, including specific vegetation compositions and climatic niches, that support a high degree of species richness. Furthermore, in evaluating the efficiency of the conservation area, the Anamalai, Coorg, and Varushanad ecoregions provide the largest average area per species. This finding is particularly important for landscape-level conservation, as it indicates that these regions not only support numerous species but also offer expansive, continuous habitats that are essential for long-term population viability and genetic health.

The observation that conservation value is concentrated in a limited number of priority ecoregions is highly consistent with global conservation science. Myers et al. (2000) introduced the concept of biodiversity hotspots precisely on the principle that safeguarding a small number of biologically rich and highly threatened regions yields disproportionate conservation benefits. Similarly, Hoekstra et al. (2005) argued that ecoregion-level prioritization is essential for addressing the biodiversity crisis, as it identifies areas with the highest threat intensity coupled with unique biological assemblages. The identification of Anamalai, Varushanad, and Periyar as focal ecoregions in this study provides empirical support for such prioritization, reinforcing the necessity of adopting tiered conservation strategies that concentrate resources on areas with maximum ecological return.

In the context of the Western Ghats, a UNESCO World Heritage Site and one of the world's eight "hottest hotspots" of biological diversity (UNESCO, 2012; Das et al., 2006) these findings underscore the urgent need to align conservation and restoration initiatives with the identified high-value ecoregions. Conservation strategies that integrate ecological niche modelling with vegetation-layer classification offer a more refined understanding of species–environment relationships, enabling data-driven site prioritization (Guisan & Thuiller, 2005; Franklin, 2010). By targeting restoration in regions with proven high ecological potential, management can maximise biodiversity recovery and ecosystem resilience, while simultaneously buffering against ongoing threats such as deforestation, land-use change, and climate-induced habitat shifts (Ramesh et al., 1997; Ravindranath et al., 2011).

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## (ii) Ecorestoration Area

The analysis of modelled ecorestoration areas, which are degraded habitats with restoration potential, reveals a strategic blueprint for ecological recovery. The data, derived from a comprehensive niche modelling framework incorporating both Grinnellian (bioclimatic, slope, aspect, elevation) and Eltonian (species composition based on classified vegetation) factors, highlights several ecoregions as top priorities. The prioritised table indicates that Cannanore, Comorin, and Varushanad possess the highest average conservation area per species. This finding is critical because it signifies that restoration efforts in these ecoregions would not be focused on small, isolated patches but on larger, more contiguous areas. The data also points to Anamalai, Periyar, and Nilgiris South-Palghat as key biodiversity hotspots with the highest number of species that could benefit from restoration. This suggests that a targeted approach here could have the greatest impact on overall species richness.

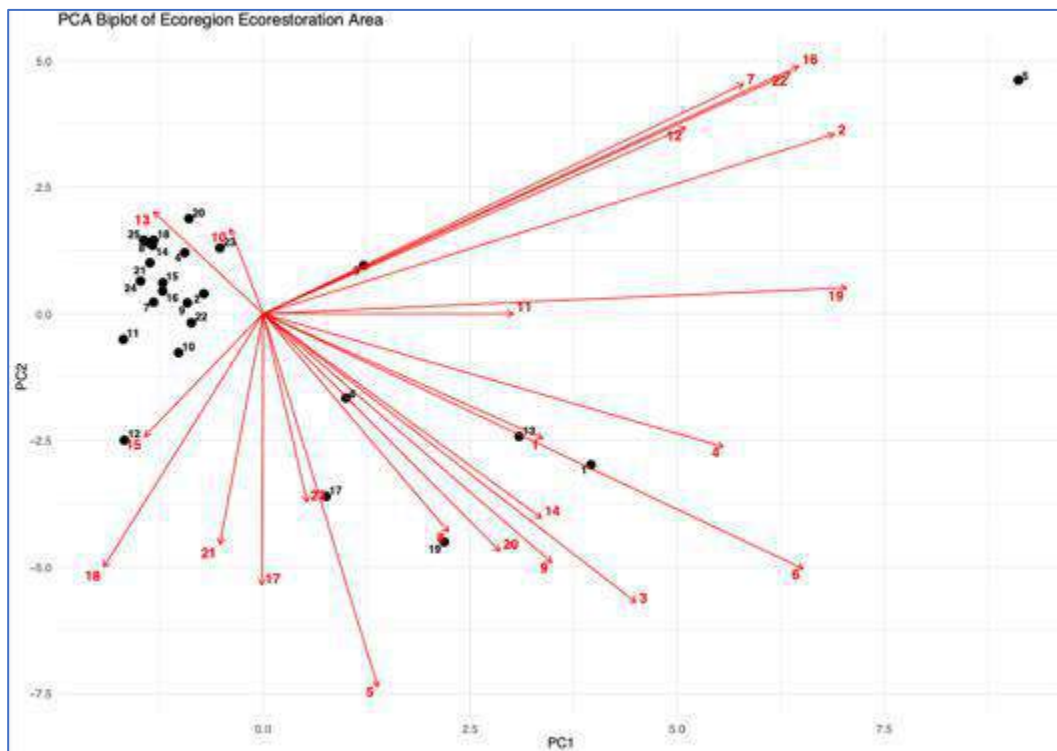


**Fig. 4.132. Ordination of species and ecoregions by potential ecorestoration area**

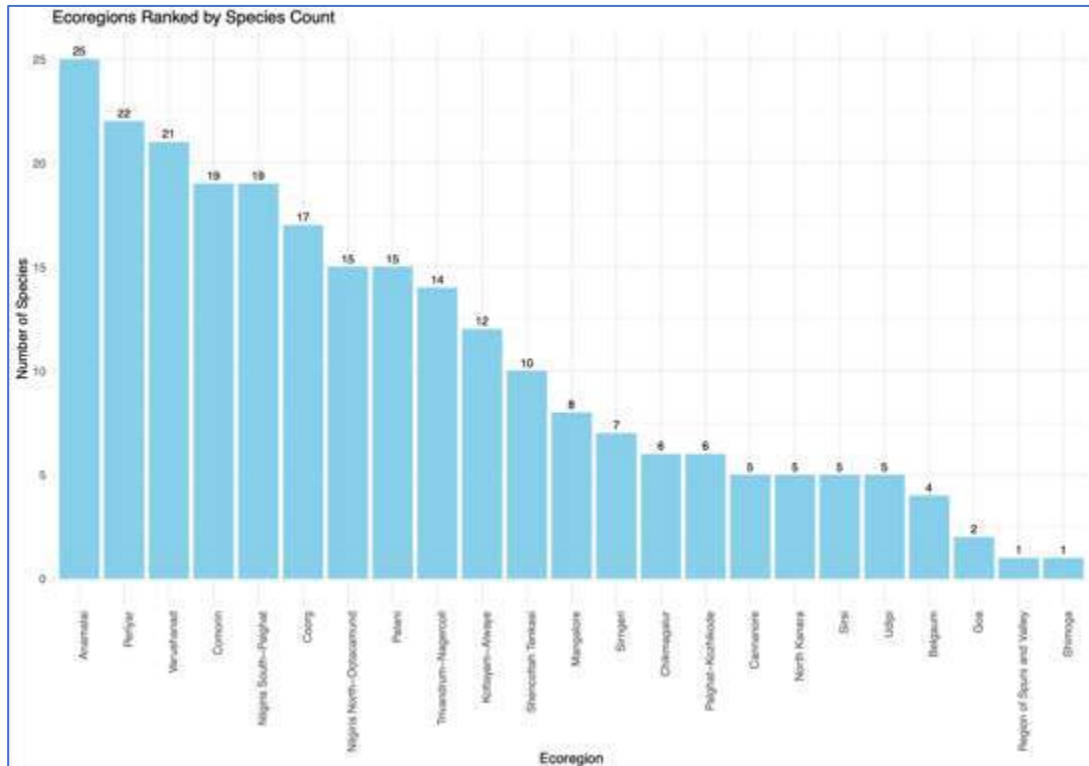


**Fig. 4.133. Ecoregional contribution by species richness in potential ecorestoration area**

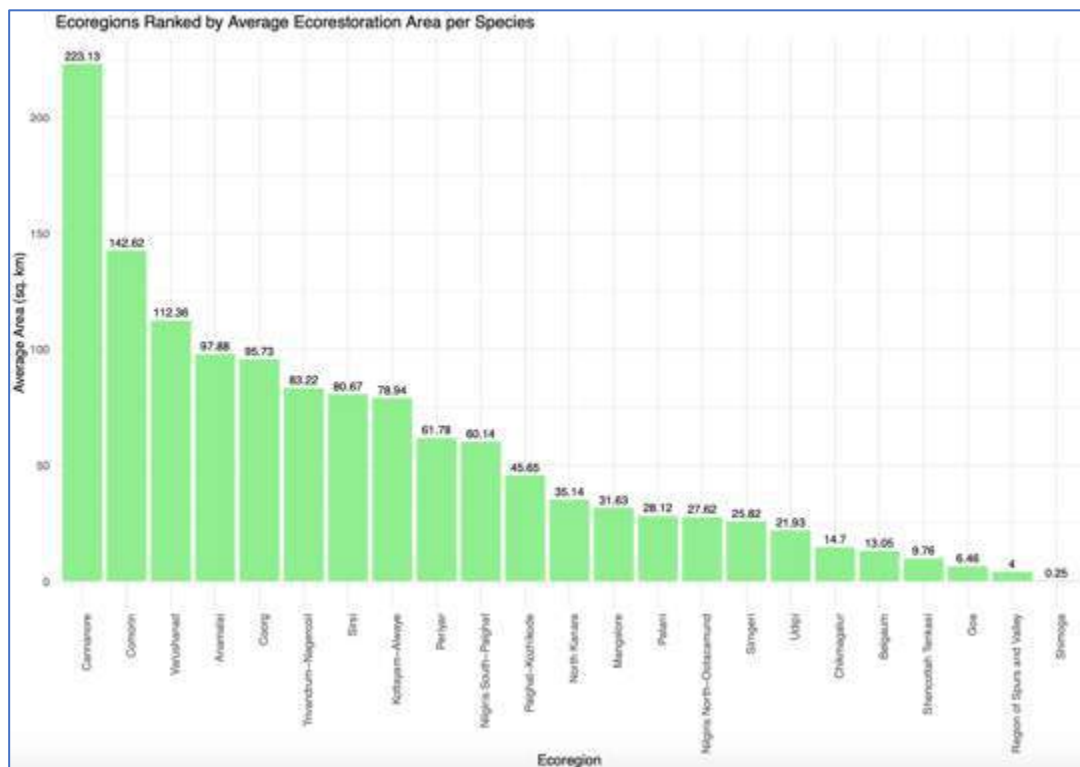


**Fig. 4.134. Ecoregional contribution by average habitat area in potential ecorestoration area**

The findings of this study provide a compelling argument for a targeted, data-driven approach to ecological restoration in degraded forest landscapes. The concentration of high-value ecorestoration areas in a few key regions validates the principle of strategic conservation planning, which is essential given the limited resources available for large-scale recovery projects. The identification of regions like Cannanore, Comorin, and Varushanad, with their high average restoration area, is particularly significant. This directly addresses the negative impacts of habitat fragmentation, a primary driver of biodiversity loss. As Fahrig (2003) argues, habitat loss and fragmentation have distinct effects on biodiversity, with the negative consequences of fragmentation being most severe in landscapes with a low amount of total habitat. Therefore, focusing restoration on larger, more contiguous degraded patches offers the best chance of reversing fragmentation and ensuring the long-term viability of species populations.

Furthermore, the integrated niche modelling approach used in this study, which combined both Grinnellian (abiotic) and Eltonian (biotic) factors, provides a robust scientific basis for prioritizing these areas (Bachan & Devika, 2025; Devika & Bachan, 2025). This methodology is in line with the work of Peterson et al. (2011), who demonstrated the enhanced predictive power of models that incorporate both abiotic conditions and biotic interactions. The findings suggest that these identified ecoregions not only retain the suitable physical environment for species but also harbor the foundational biological components (vegetation layers) that would make restoration successful. By targeting these specific ecoregions, restoration efforts can be maximised for both species richness and habitat connectivity, providing a scientifically sound framework for future conservation and ecological recovery initiatives.

The above findings provide a strategic implementation plan for recent policy initiatives, such as the Ecological Restoration Policy set by the state of Kerala in 2021. The precise spatial delineation of Potential Ecorestoration Areas allows the Protected Area (PA) network and Reserved Forests across all Western Ghats states to move beyond general afforestation and focus specifically on threatened species habitat recovery. This approach directly supports the national commitments under the Kunming-Montreal Global Biodiversity Framework (GBF), particularly its targets related to ecological restoration (Target 2) and the halting of species extinction (Target 4). By concentrating resources on



identified high-potential areas, the Forest Departments can maximise biodiversity recovery and contribute effectively to the larger goals of the UN Decade on Ecosystem Restoration, transforming policy intent into verifiable, scientifically grounded ecological success.

### (iii) Converted Area

The analysis of irreversibly converted habitat areas reveals a critical strategic insight into the impact of anthropogenic activities on species viability. The data, derived from a comprehensive niche modelling framework incorporating Grinnellian (bioclimatic, slope, aspect, elevation) and Eltonian (species composition based on classified vegetation) factors, highlights several ecoregions with the most significant habitat loss. The table indicates that Anamalai, Palani, Coorg, and Nilgiris North-Ootacamund possess the highest average converted area per species.

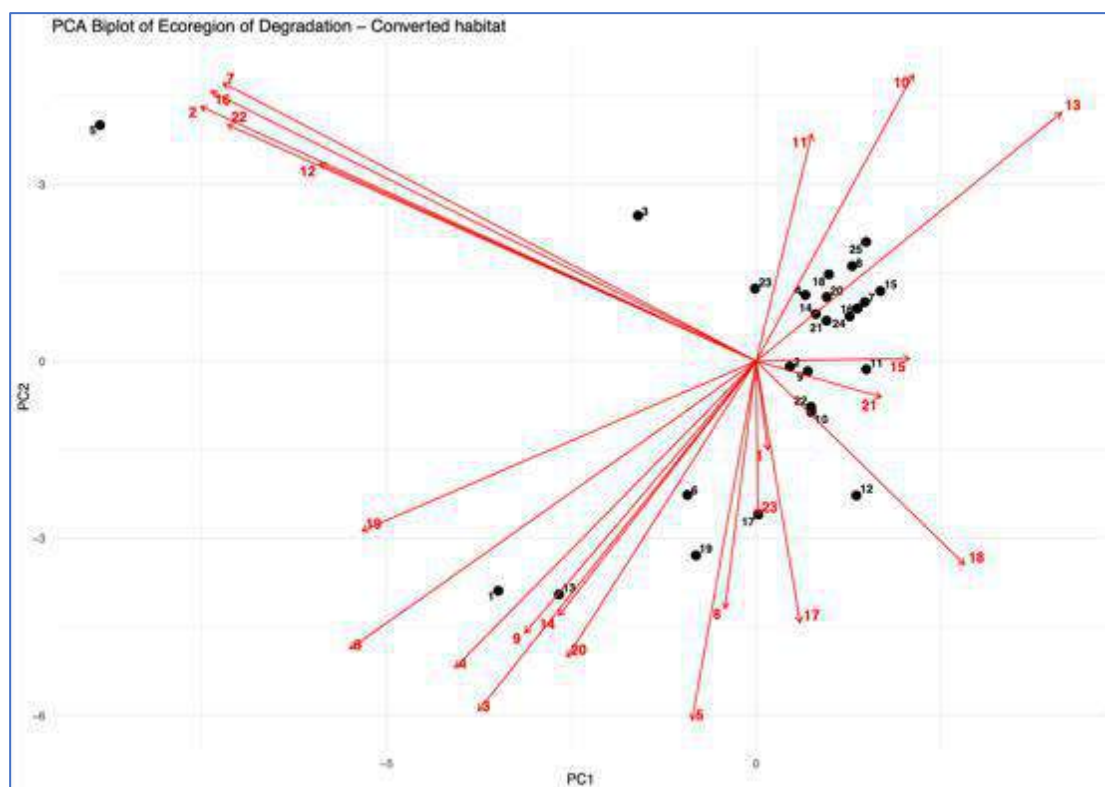


**Fig. 4.135. Ordination of species and ecoregions by irreversibly converted habitat area**

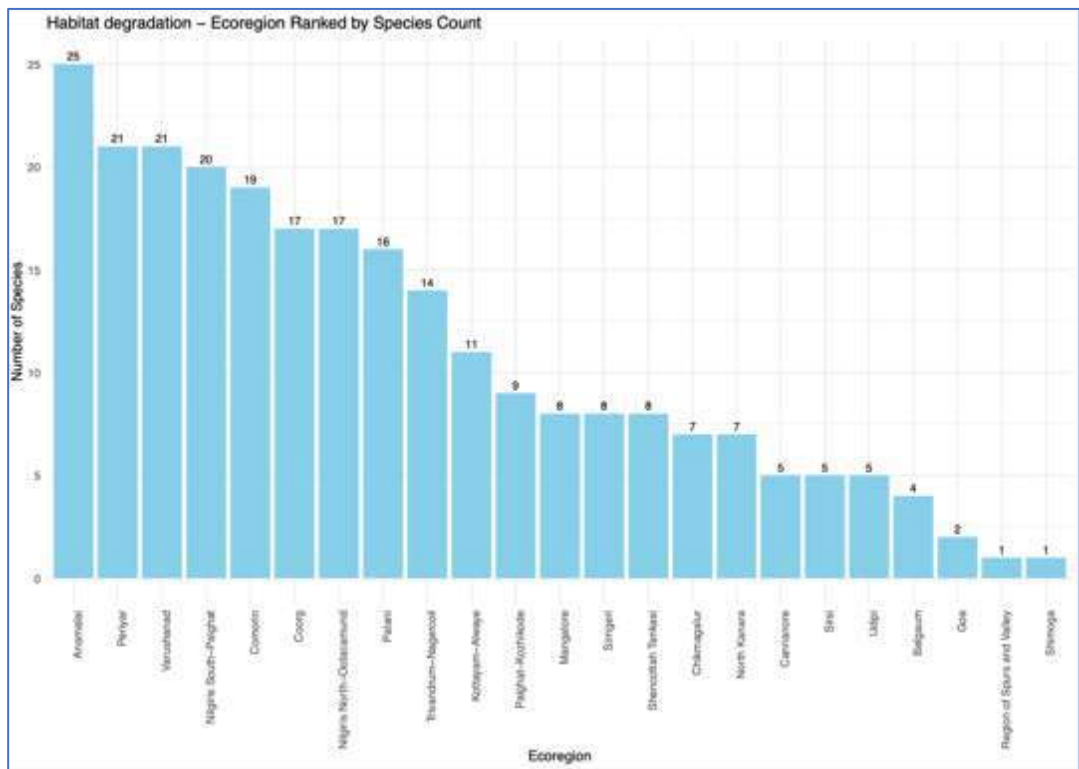


**Fig. 4.136. Ecoregional Contribution by Species Richness in Irreversibly Converted Habitat**

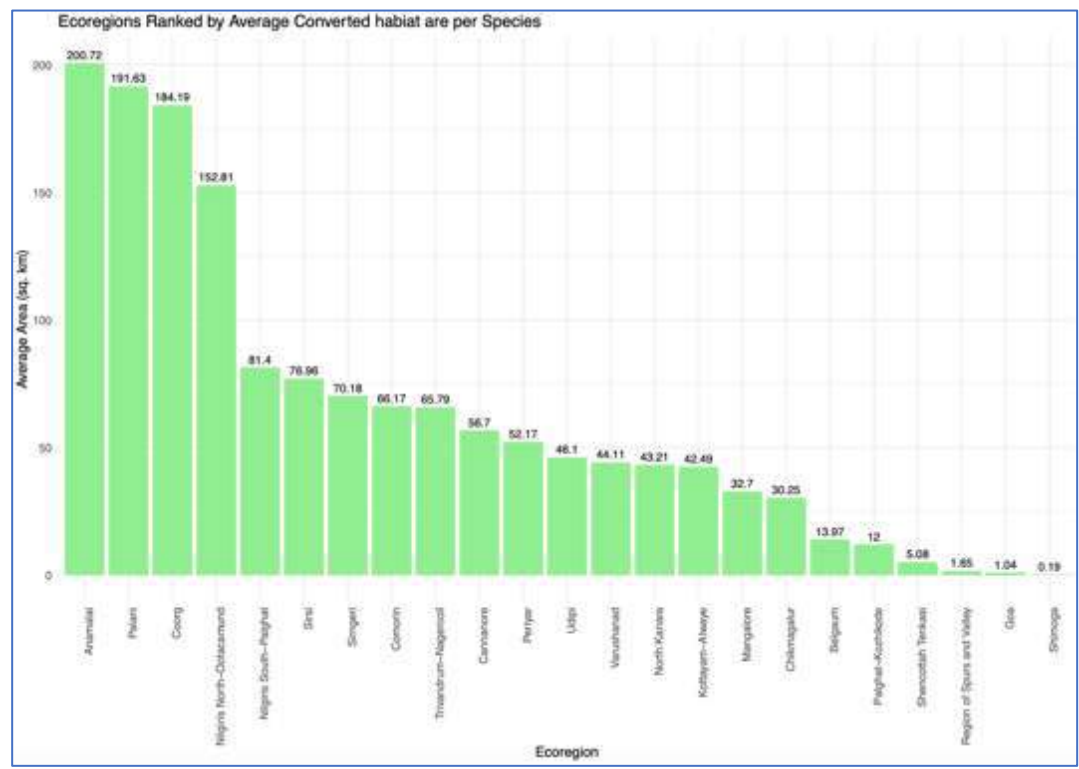


**Fig. 4.137. Ecoregional contribution by average habitat loss per species**

**Impact of Irreversible Habitat Loss and Mitigation Strategy**

The analysis of irreversibly converted habitat areas yields a critical strategic insight: while several ecoregions function as biodiversity hotspots, they have concurrently suffered the largest and most concentrated habitat destruction. This is evident in the fact that Anamalai, Periyar, Nilgiris South-Palghat, and Comorin stand out with the highest number of species impacted by this conversion. This suggests that these regions, while rich in endemic flora, are also under the most acute threat from irreversible habitat loss, placing a large number of species at risk. The findings thus provide a compelling argument for a targeted, data-driven approach to mitigate the impacts of permanent habitat loss in fragmented landscapes. The concentration of high-value converted areas in a few key ecoregions validates the principle that anthropogenic pressures are not uniformly distributed but are highly localised, demanding a focused conservation response. The identification of regions like Anamalai, Palani, Coorg, and Nilgiris North-Ootacamund, with their high average converted area per species, is particularly significant. This directly addresses a core challenge in conservation: prioritizing action where the threat is most severe. As Haddad et al. (2015) demonstrated, habitat fragmentation and loss reduce biodiversity and ecosystem function globally; the current study provides a finer-scale view of this process, pinpointing specific ecoregions where the effects of irreversible loss are most pronounced on a per-species basis.

Furthermore, the integrated niche modelling approach used here, combining both Grinnellian and Eltonian factors provides a robust scientific basis for these conclusions. This methodology aligns with Peterson et al. (2011), who confirmed the enhanced predictive power of models that incorporate both abiotic conditions and biotic interactions. The findings suggest that these high-loss ecoregions, while possessing the suitable environmental niches for a large number of species, are simultaneously facing the most severe and permanent threats. By highlighting these specific areas, this research provides a scientifically sound framework for prioritizing critical conservation efforts, such as land acquisition, policy implementation, and the establishment of new protected areas, which are essential to safeguard the most vulnerable species and their remaining habitats.

The precise spatial data generated by this study offers an immediate and practical framework for transforming administrative and privately held lands into functional conservation assets, directly supporting the restoration objectives of the Western Ghats.

The identification of Potential Ecorestoration Areas within degraded forest landscapes holds significant implications for Forest Administrative Regions. Specifically, there is high potential for converting failed or unproductive monoculture plantation areas (e.g., Teak, *Acacia*) back into natural forest ecosystems. The method of integrated niche modelling, profiling and prediction of niche specific area along with the niche profile serving as a reference ecosystem for Ecorestoration has been identified as an NbS ensuring EbA and SDGs (Bachan & Devika, 2021, 2025). This process, moving beyond simple afforestation to threatened species habitat recovery, directly aligns with and provides a scientifically defensible foundation for the Ecological Restoration Policy recently set forth by the state of Kerala. The study's ability to identify specific, refined sites within various ecoregions and administrative areas provides the necessary spatial specificity to guide on-the-ground practical interventions, ensuring limited resources are deployed where climatic and ecological suitability for recovery is highest.

Beyond public forest lands, the findings present a compelling opportunity for private parties to contribute meaningfully to biodiversity conservation. Private entities, particularly large-scale tea plantations and other agricultural ventures operating in higher altitudes, can leverage this study's data to establish conservation refugia. By designating and actively restoring sections of their land based on the identified bioclimatic and topographical suitability for threatened high-elevation species, they can turn corporate social responsibility (CSR) initiatives into impactful conservation measures. Similarly, private plantations at lower elevations must prioritise the conservation and restoration of their riparian areas. The study's detailed inputs on the bioclimatic distinctiveness of low-elevation and riparian habitats provide the blueprint for creating effective buffer zones and corridors that safeguard unique species and enhance water security across the landscape. By applying the study's precise spatial and ecological data, both government agencies and private stakeholders can shift from generic greening efforts to targeted, ecologically effective restoration that maximises the recovery potential for the Western Ghats' most vulnerable endemic species.

#### **4.5. Summary**

This study provides a comprehensive and data-driven framework for prioritizing conservation efforts in the Western Ghats, utilizing an integrated approach to habitat suitability assessment for 25 threatened and endemic species. By combining Grinnellian

(bioclimatic and topographical) and Eltonian (vegetation-based) niche factors, the research successfully moved beyond correlative predictions to map the realised niche space, offering an ecologically realistic understanding of species distribution. The analysis robustly identified the most significant environmental variables shaping species distribution, Elevation, Precipitation of the Driest Quarter, and Precipitation of the Wettest Quarter and statistical validation confirmed that these three factors are the primary drivers leading to a significant bioclimatic delineation among the major vegetation formations, including montane, riparian, and coastal forests. This provides a crucial refinement to existing classifications by confirming that seasonal moisture extremes and altitudinal gradients govern the ecological separation of these critical habitats.

The analysis delineated three distinct, action-oriented conservation priorities across the ecoregions. For intact primary forests, regions like The Anamalai, Varushanad, and Periyar are crucial for protection. Potential Ecorestoration Areas (degraded but restorable habitats) point to Cannanore, Comorin, and Varushanad as top priorities for active ecological recovery, offering contiguous degraded patches that maximise the potential for reversing fragmentation. Conversely, the assessment of irreversibly converted habitats highlighted Anamalai, Palani, Coorg and Nilgiris as having suffered the most severe and concentrated destruction, necessitating urgent policy intervention. This research underscores that conservation requires a multi-faceted strategy tailored to the specific ecological status of each ecoregion.

This study offers a powerful strategic implementation plan for recent policy initiatives, such as the Ecological Restoration Policy of Kerala (2021). The precise spatial delineation allows Forest Departments and private stakeholders to focus their efforts from converting failed monoculture plantations to establishing conservation refugia in areas with the highest potential for threatened species habitat recovery as an NbS, thereby aligning national actions with global goals like the Kunming-Montreal Global Biodiversity Framework (GBF). By integrating both niche factors and management categories, conservation efforts are rendered more effective, efficient, and scientifically robust.



# Chapter 5

Species Composition and Niche Profile to Elucidate The  
Eltonian Niche Factors

## **Chapter 5**

### **Species Composition and Niche Profile to Elucidate the Eltonian Niche Factors**

#### **5.1. Introduction**

Understanding the ecological niche of a species extends beyond its abiotic tolerances (Grinnellian niche) to encompass its interactions within the biotic community and with anthropogenic influences collectively termed the Eltonian niche (Soberón, 2007; Hutchinson, 1957). The Eltonian niche therefore focuses on the biotic determinants of a species' existence its trophic interactions, resource use, competition, and mutualistic relationships (Chase & Leibold, 2003). These interactions, particularly the patterns of co-occurrence, competition, and facilitation, are critical for delineating the realised niche and for informing conservation interventions for threatened taxa. In the context of the highly diverse and human-impacted tropical mountain landscape Western Ghats, evaluating the Eltonian niche becomes indispensable for designing species recovery and habitat restoration strategies.

In species-level conservation, particularly of threatened taxa, examining the Eltonian niche offers insights into how community composition, species associations, and functional guilds influence persistence or decline. While abiotic (Grinnellian) factors such as climate, topography, and soil define the fundamental niche space, biotic associations determine the realised niche, the conditions under which species actually survive and reproduce (Pulliam, 2000). For many tropical forest species, survival is dependent on ecological networks such as pollination, seed dispersal, facilitation, and mycorrhizal associations (Blüthgen & Klein, 2011; Keddy, 2021). The disruption of these interactions through deforestation, fragmentation, and biotic homogenization alters community composition and hence constrains the Eltonian niche, ultimately threatening species persistence even in climatically suitable habitats (Bascompte & Jordano, 2007; Bregman et al., 2015; Stewart et al., 2015).

Phytosociological sampling is a fundamental ecological method to characterise vegetation structure, species composition, and interspecific relationships within plant communities (Braun-Blanquet, 1932; Mueller-Dombois & Ellenberg, 1974). Through systematic plot-based sampling, parameters such as species density, frequency, dominance, and the



resulting Importance Value Index (IVI) are calculated to assess the ecological amplitude and community role of each species (Curtis & McIntosh, 1951; Mueller-Dombois & Ellenberg, 1974; Pascal, 1988; Bachan, 2010). These metrics not only provide insight into the competitive status of threatened species but also help in identifying key associated species, habitat specificity, and potential ecological facilitators or competitors (Parthasarathy, 1999; Reddy et al., 2007).

Several studies in the Western Ghats have successfully employed phytosociological analyses to understand forest composition and the niche dynamics of rare and threatened plants. Bachan (2010) riparian vegetation types in the Chalakudy river basin and brought classification for riparian vegetation types for the southern Western Ghats region using species composition (Bachan et al., 2022). Parthasarathy (1999) assessed species dominance and regeneration in tropical evergreen forests of the southern Western Ghats, providing baseline ecological profiles for conservation. Similarly, studies by Bhat (1992) and Pascal and Pelissier (1996) have demonstrated the utility of community-level data to delineate the habitat preferences and interspecific associations of endemic tree species. Such approaches are increasingly important in the conservation of narrowly distributed and ecologically specialised species that face pressures from habitat fragmentation, invasive species, and changing disturbance regimes (Nayar & Sastry, 1990; Aravind et al., 2010).

This chapter presents the results of systematic phytosociological surveys conducted across the known habitats of 25 selected threatened angiosperm species in the Western Ghats. By analysing species composition, structure, and the IVI of each focal species within its native habitat, this chapter aims to elucidate the Eltonian niche factors biotic interactions and community context that shape their current distribution and persistence. These insights serve as an essential complement to the abiotic niche modelling detailed in the previous chapter and provide a foundation for formulating site-specific conservation and restoration strategies.

The ecological niche is a foundational concept in ecology, defining how a species interacts with its environment and other organisms. While early definitions focused on the Grinnellian niche, which emphasises physical and environmental variables, subsequent scholarship introduced the Eltonian niche, centered on biotic interactions and community roles. Together, these two concepts define a species' fundamental (potential)

and realised (actual) niche. However, a significant gap remains in empirically delineating the Eltonian niche, as existing methods often rely on broad-scale environmental data and fail to capture the fine-scale relationships that govern species distribution. This study addresses this gap by investigating the Eltonian niche of 25 endemic and threatened angiosperm species in the Western Ghats. We propose that a comprehensive understanding of these species' ecological requirements requires a detailed, community-level analysis. Our methodology moves beyond theoretical concepts to provide an empirical, data-driven framework for understanding the fine-scale relationships that govern species distribution, proving that species associations, rather than just broad environmental gradients, are a primary driver of ecological partitioning. To achieve this, the study employs robust multivariate statistical techniques to analyse phytosociological data from 126 plots. We utilise Cluster Analysis with Bray-Curtis dissimilarity to quantitatively group plots into distinct communities based on species composition. Null Hypothesis (H<sub>0</sub>) was there is no significant difference in species composition across the various habitats of the 25 selected threatened and endemic species. All plots belong to a single, uniform community, and there is no evidence of fine-scale ecological partitioning (Eltonian niche) driven by species associations.

## **5.2. Methodology**

To elucidate the Eltonian niche factors influencing the distribution and niche of 25 selected threatened angiosperm species in the Western Ghats, phytosociological sampling was conducted across their known and predicted habitats. Sites were chosen based on herbarium records, field reconnaissance, and habitat suitability outputs from ecological niche models developed in Chapter 4.

### **5.2.1. Sampling Design, Identification of Sampling Sites and Collection of Data**

The species composition are the indicators of a particular vegetation and the degradation factors. Phytosociological sampling was carried out for the analysis of habitat, species associates, community structure and the dominant species among the community. Given the autecological nature of the study and the restricted distribution of many focal species, systematic sampling was not feasible. Instead, species focused systematic sampling has been adopted where the sampling locations identified for the selected species through the field visits (Fig. 5.5 – 5.18) in reported forest regions (Hauilier & Carpentier, 1998). The habitat of the selected species was sampled with a plot size of 0.1 ha (31.62 x 31.62 m)

square plots since the study focus on the evergreen forest area (MoEFCC, 2014) (Fig. 5.3 & 5.4). A minimum of three plots were ensured for each selected species if there are multiple subpopulations. In the case of *Strobilanthes kunthiana*, 3 x 3 m plot were taken hence it is a shrub. Whereas in the case of epiphytes, *Impatiens parasitica* and *Medinilla anamalaiana* 0.1 ha plot of their host trees were taken (Fig. 5.1). The sample plots were laid out using the cross staff fixed at the corner of the plot, which can be used to set the right angle to the square plot. Plots were demarcated using a cross staff to ensure accurate 90° corners and spatial consistency. Total number of individual species and all the mature trees above 30 cm GBH (Girth at Breast Height) were recorded. Trees coming along the border line with more than one third inside has been included in the plot data. The total culms of bamboo and reeds were counted as a single unit and multi-stemmed plants were noted as separate individuals. All the individual trees in the plot were identified, measured for GBH and height class. The plots were mapped in graph paper along with their latitude, longitude and altitude using GPS.

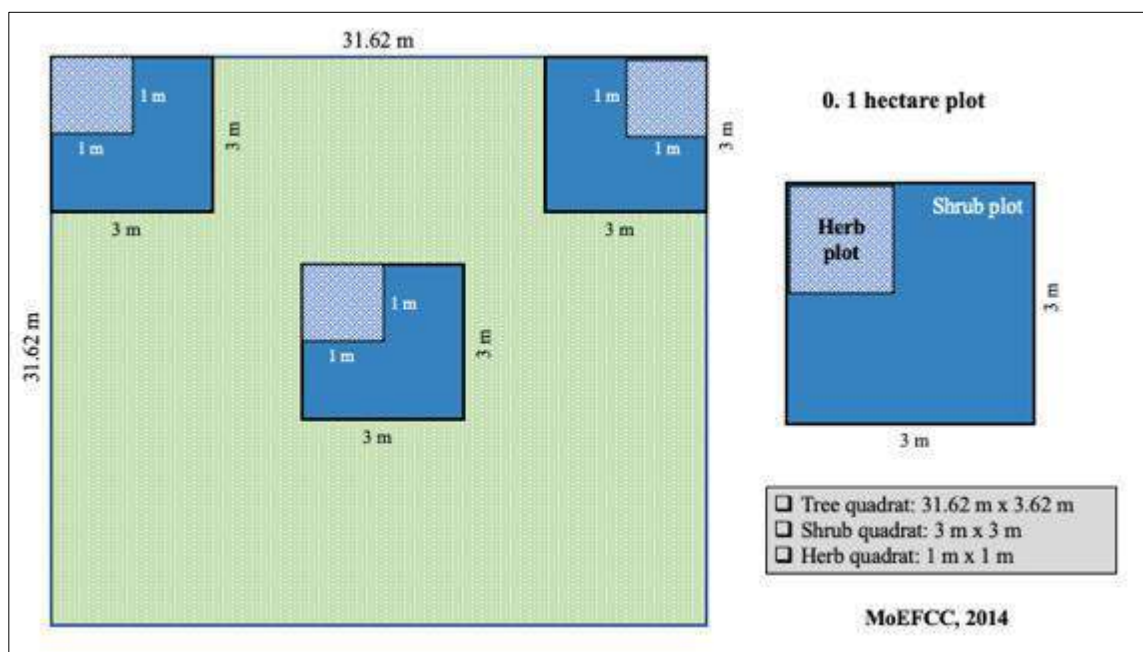


**Fig. 5.1. Quadrat used for phytosociological analysis**

### 5.2.2. Interpreting Floristic Heterogeneity and Ecological Niche

The application of the Bray-Curtis dissimilarity index coupled with hierarchical clustering proved highly effective in partitioning the floristic  $\gamma$ -diversity into ecologically meaningful

units. The choice of the Bray-Curtis metric, which leverages both species presence and abundance (Bray & Curtis, 1957), was critical, as it provided a more nuanced representation of  $\beta$ -diversity compared to binary presence/absence metrics. The resulting distance matrix effectively quantified the magnitude of species turnover between the 126 sampling plots, confirming significant compositional heterogeneity across the study landscape.

|                                 |   |                                                                                                 |
|---------------------------------|---|-------------------------------------------------------------------------------------------------|
| 1. Density (D)                  | = | $\frac{\text{Total number of individual of species}}{\text{Total number of quadrats studied}}$  |
| 2. Frequency (F)                | = | $\frac{\text{Total number of quadrats of occurrence}}{\text{Total number of quadrats studied}}$ |
| 3. Basal area (BA)              | = | $\frac{GBH^2}{4\Pi}$                                                                            |
| 4. Relative Frequency (RF)      | = | $\frac{\text{Frequency of the species}}{\text{Total frequency of all the species}} \times 100$  |
| 5. Relative Density (RD)        | = | $\frac{\text{Density of the species}}{\text{Total density of all the species}} \times 100$      |
| 6. Relative Basal Area (RBA)    | = | $\frac{\text{Basal area of species}}{\text{Total basal area of all species}} \times 100$        |
| 7. Importance Value Index (IVI) | = | $RF + RD + RBA$                                                                                 |

**Fig. 5.2. Phytosociological and statistical formulations used in the study**

The decision to impose a stringent clustering threshold (0.8–1.0) for the delineation of major community associations ensured that the identified clusters represent truly distinct and spatially non-random assemblages (Magurran, 2004; Kent, 2012). This high dissimilarity threshold minimises the risk of grouping ecologically distinct communities,

providing strong statistical support for the resulting classification. The distinct floristic associations are therefore interpreted as representing communities structured by strong, differential environmental filters or historical contingencies (e.g., disturbance, dispersal limitation), rather than continuous ecological gradients.

### **5.2.3. Vertical Structure and Ecological Dominance: The IVI and Height Class Analysis**

The structural characterization of the identified clusters, based on Importance Value Index (IVI) and the five height classes (VST to ET), provides the necessary foundation for interpreting functional relationships within each community.

#### **IVI as a Measure of Realised Ecological Success**

By consolidating relative density, frequency, and basal area into the IVI, the analysis moved beyond simple abundance measures to quantify a species' holistic ecological dominance (Daubenmire, 1949) (Fig. 5.2). Species with high IVI within a cluster are not merely common; they are structurally significant, occupy a large proportion of the available space (high Basal Area), and are widely dispersed (high Frequency). For example, a species exhibiting a high IVI likely represents a foundation species or a dominant competitive force that fundamentally shapes the resource landscape and microenvironment for subordinate species within that particular floristic association.

#### **Height Classes and Vertical Niche Partitioning**

The stratification of trees into height classes provided an empirical assessment of vertical niche partitioning and the structural maturity of the community. The relative abundance of species in the Emergent Tree (ET) and Large Tree (LT) classes within a cluster suggests a high degree of maturity and biomass accumulation, indicative of late-successional dynamics. Conversely, a high proportional representation of Small Tree (ST) and Very Small Tree (VST) species points to ongoing recruitment, gap dynamics, or the dominance of early-successional, shade-intolerant species. These height class distributions are key to understanding the allocation of functional roles along the vertical gradient of the forest.



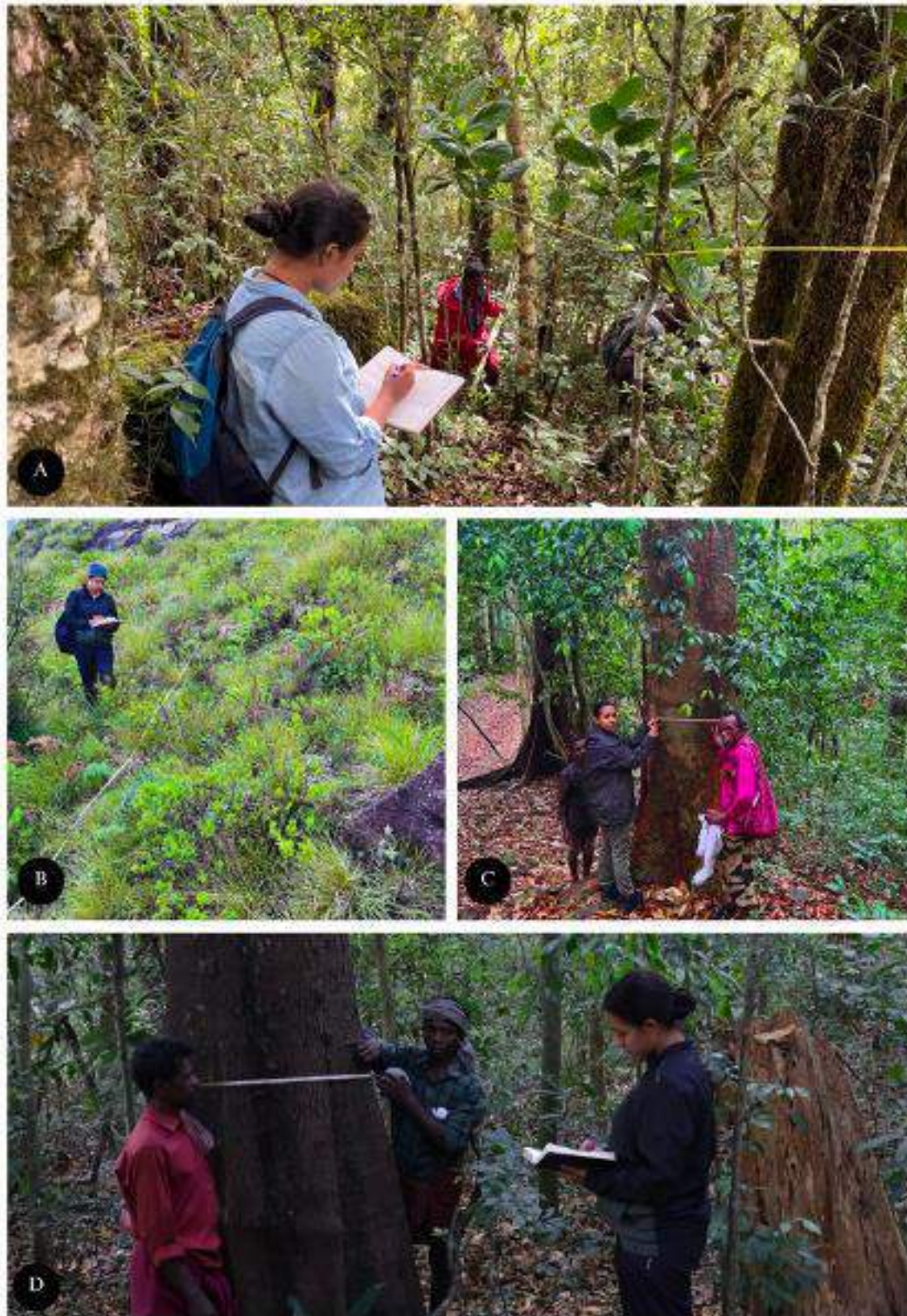


**Fig. 5.3.** Phytosociological sampling at different landscapes – A. Pettimudi; B. Meesapulimala; C. Shendhurney Wildlife Sanctuary; D. Vazhachal Forest



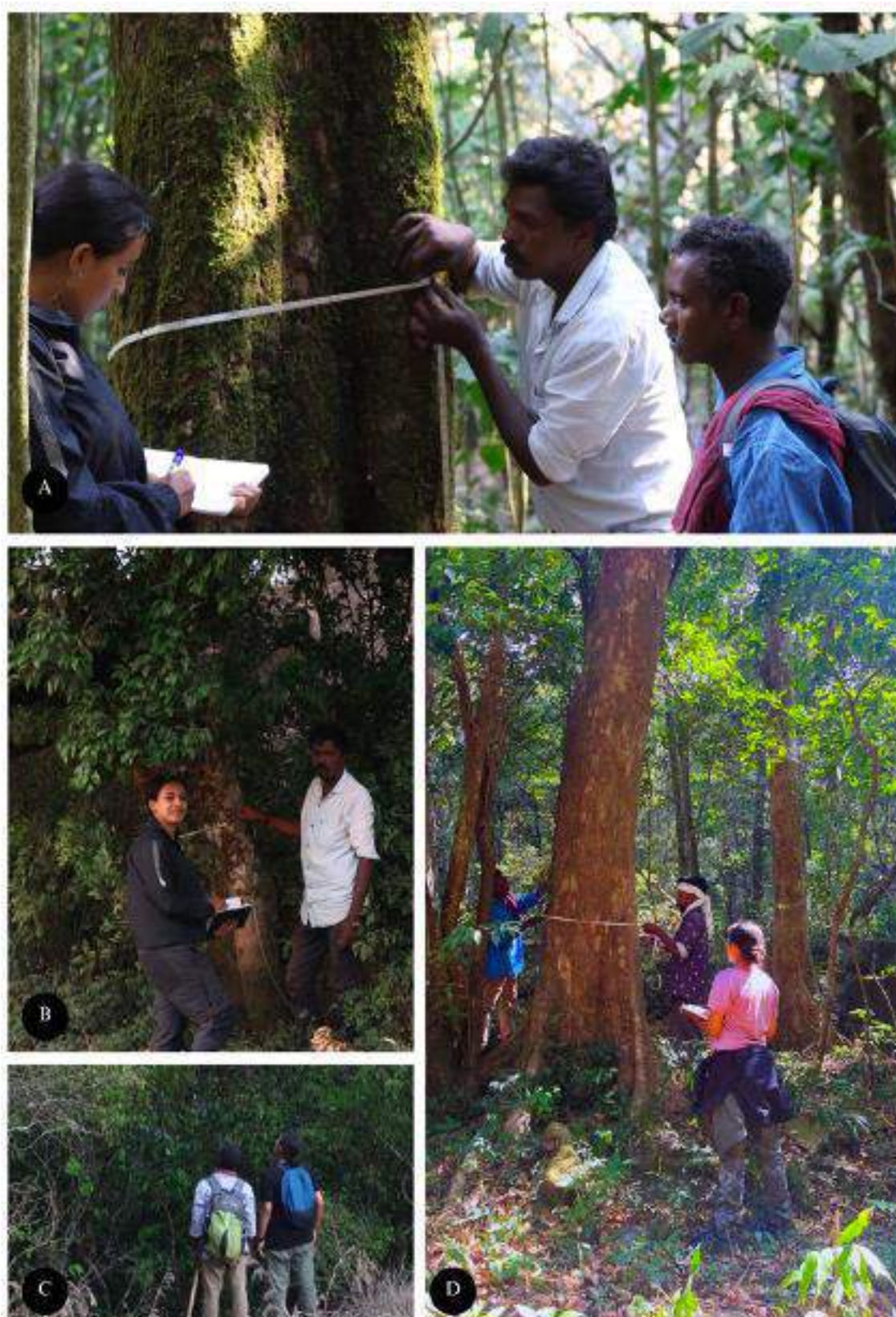


**Fig. 5.4.** Phytosociological sampling at different landscapes: A – C. Nelliampathi, D. Agasthyamala





**Fig. 5.5.** Field work and phytosociological sampling: A – B. Pampadum Shola National Park, C. Anamudi Shola; D – E. Shendhurney Wild Life Sanctuary





**Fig. 5.6.** Field work and phytosociological sampling: A. Agasthyamala peak; B. Pongalapara – Agasthyamala; C-D. Athirumala, E. Near *Syzygium parameswaranii* at Agasthyamala



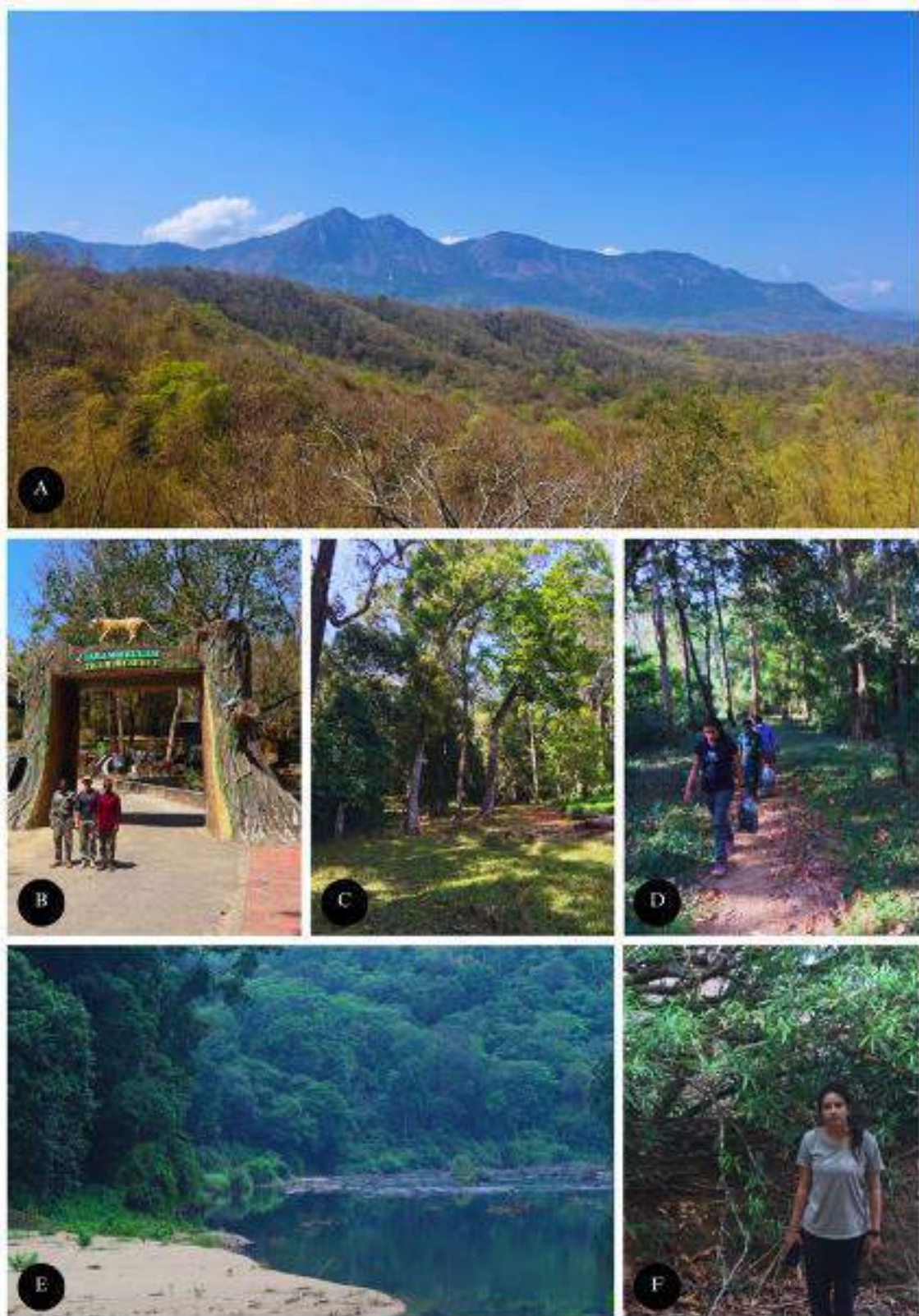


**Fig. 5.7.** Field work and phytosociological sampling: A – B. Parambikulam Tiger Reserve, C – D. Sheikelmudi, E – F. Orukombankutty





**Fig. 5.8.** Field work and phytosociological sampling: A – B. Periyar Tiger Reserve; C. Chinnar Wild Life Sanctuary; D. With the Kadar Community members at Parambikulam Tiger Reserve; E. Anamalai Tiger Reserve





**Fig. 5.9.** Field work and phytosociological sampling: A, E, F. Eravikulam National Park; B. *Syzygium sahyadricum* at Varatukulam – Eravikulam NP; C. Flowering - *Strobilanthes kunthiana* at Varatukulam – Eravikulam NP





**Fig. 5.10.** Field work and phytosociological sampling: A. Anamudi Peak; B. Anamudi base camp; C. Near *Elaeocarpus recurvatus*; D - E. Pettimudi





**Fig. 5.11.** Field work and phytosociological sampling: A. Meesapulimala; B. *Strobilanthes kunthiana* from Meesapulimala; C. *Elaeocarpus recurvatus* at Meesapulimala; *Strobilanthes kunthiana* bloom at Santhanpara Idukki.





**Fig. 5.12.** Field work and phytosociological sampling: A. Engar, Nilambur; B – C. *Hydnocarpus pentandrus*; D. Seeds of *Hydnocarpus pentandrus* collected by the tribal community at Nilambur; E. Teak plantations at Nilambur



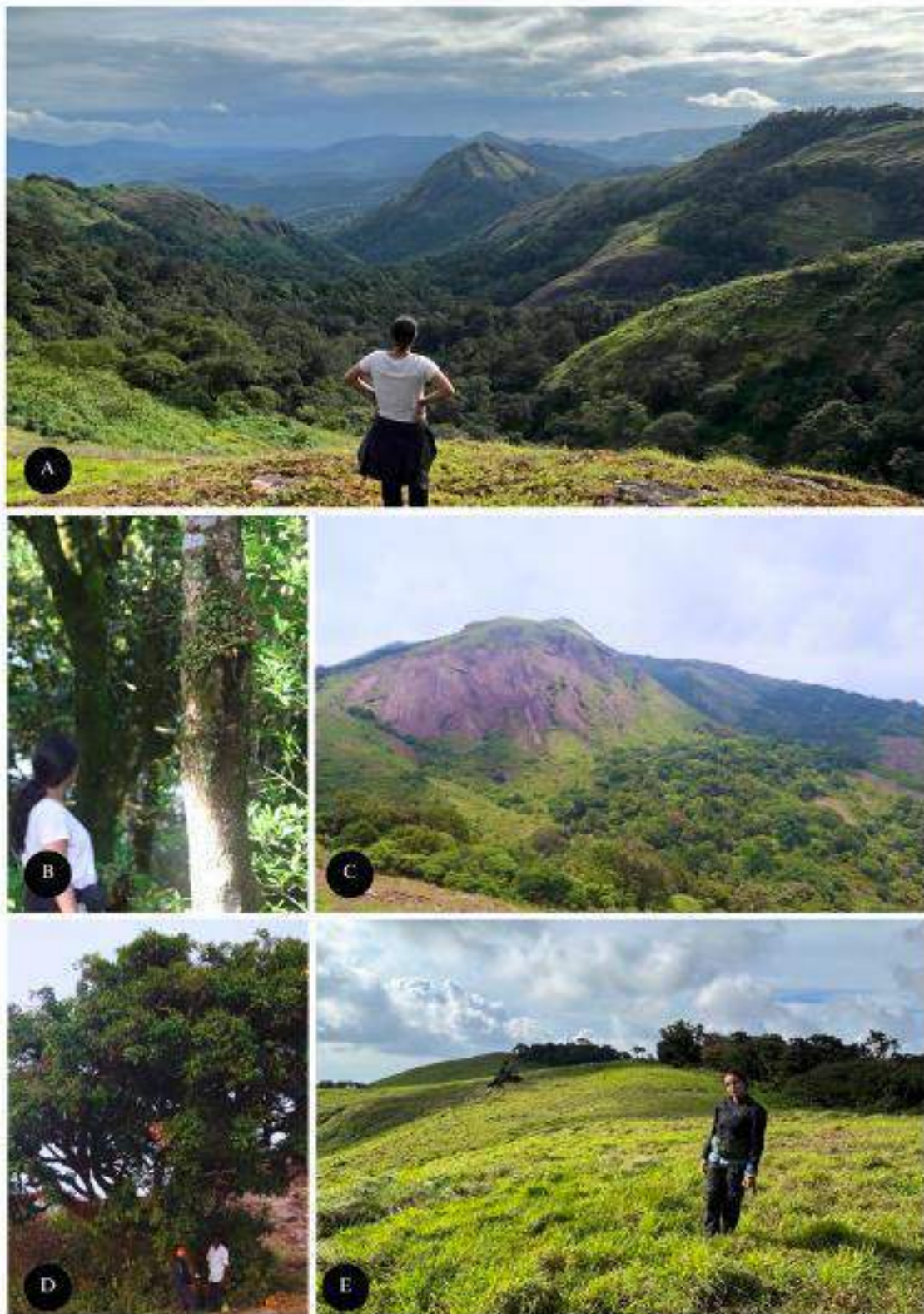


**Fig. 5.13.** Field work and phytosociological sampling: A. Nelliampathi Hills; B. *Impatiens parasitica* at Minnampara; C. Karimala; D. Near *Syzygium palghatense*; E. Padagiri hill top, Nelliampathi





**Fig. 5.14.** Field work and phytosociological sampling: A. 900 Kandi, Wayanad; B. Near *Ficus beddomei* at Vythiri, C. Pookode; D – E. Chembra peak, F. Kurichiyarmala



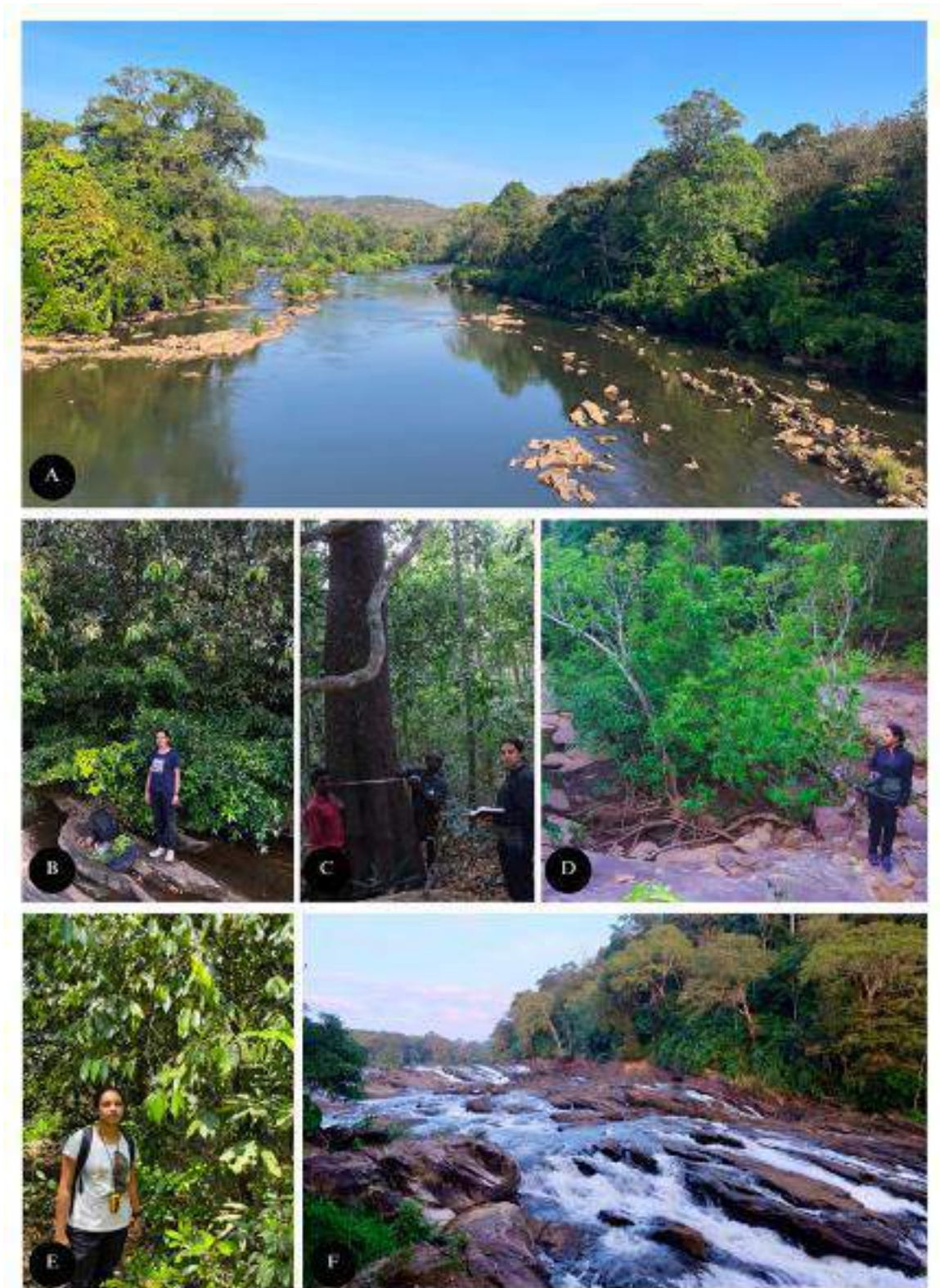


**Fig. 5.15.** Field work and phytosociological sampling: A. Riparian Forest at Vazhachal; B. Near *Garcinia wightii*; C. Near *Diospyros crumenata*; D. Habitat of *Syzygium occidentale*; E. Near *Aporosa bourdillonii*; F. Vazhachal rapids.



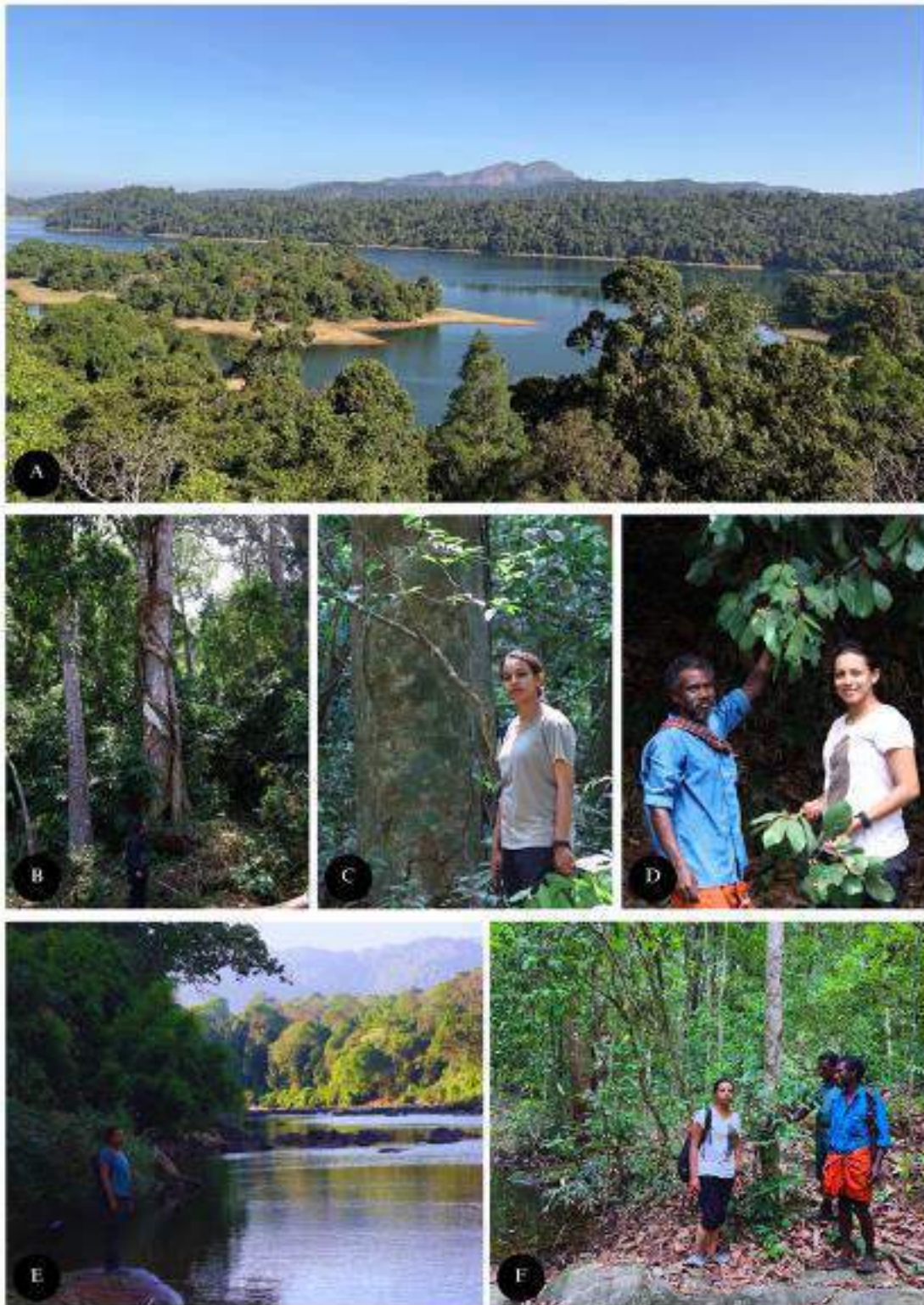


**Fig. 5.16.** Field work and phytosociological sampling: A. Sholayar; B. Near *Ficus beddoemi* at Karanthode; C. Near *Prioria pinnata* at Charpa, D. Near *Cryptocarya anamalayana* at Chandanthode; E. Karanthode - riparian; F. Near *Goniothalamus wightii* at Odangayam





**Fig. 5.17.** Field work and phytosociological sampling: A. Pampa river - Pathanmathitta; B. Vagamon - Kottayam, C. Ponmudi Hills - Thiruvananthapuram; D. Chathurangapara - Idukki; E. Paniyeliporu, Malayattoor - Ernakulam



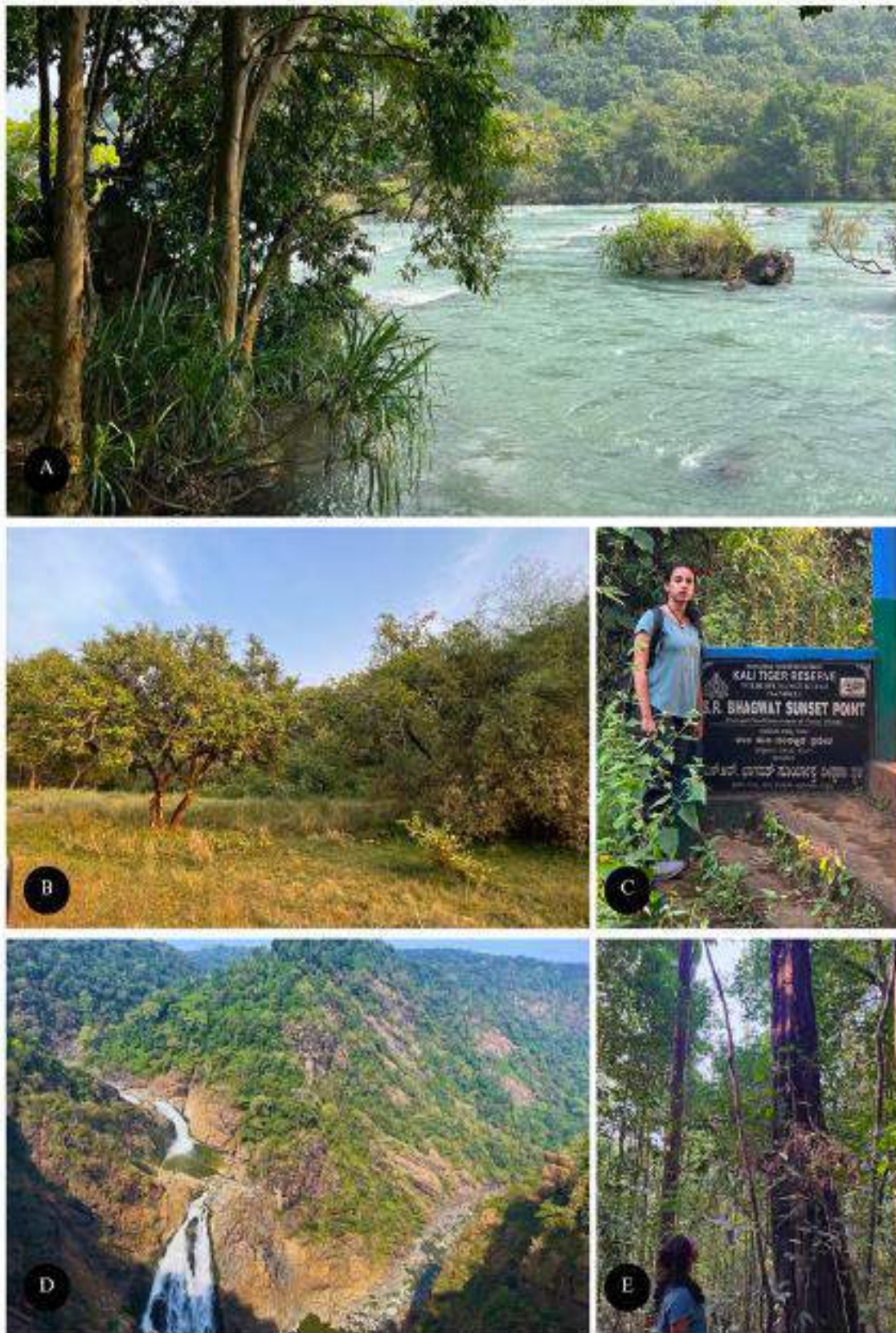


**Fig. 5.18.** Field work and phytosociological sampling: A. Kali River, Karnataka; B – C. Kali Tiger Reserve; D. Magod Falls; E. Dandeli



#### **5.2.4. Niche Profiling: Capturing the Eltonian Niche in a Spatial Context**

The final phase of this ecological analysis employed Niche profiling, a powerful statistical and visualization tool, to move beyond simple community metrics. This technique provides detailed information on species' habitat associations, physical niche, and vertical and spatial distribution with respect to co-occurring species, culminating in a robust two-dimensional habitat model (Devika & Bachan, 2021). The core objective of this modelling step was an intentional shift towards an Eltonian-niche perspective (Devika & Bachan, 2021). While the Grinnellian niche focuses on the abiotic environmental conditions (the habitat template) where a species can persist, the Eltonian niche emphasises the species' realised functional role and impact (the realised interaction space) within the community. Our Niche profile specifically addressed the Eltonian dimension through the following integration of data:

*1. Modelling Functional Position:* The analysis utilised the R program to model each individual species, explicitly integrating its density, basal area, and IVI, and spatially plotting it according to its assigned vertical height class (the five tree layers and other habit forms such as Lian and Epiphytes). This approach is suitable for explaining the Eltonian Niche, as the associations elucidated reflect a comprehensive view of the species' position in the habitat structure.

*2. Visualizing Competitive Success:* The Niche profile spatially maps species' ecological dominance (IVI) to the visual size of the species' canopy, directly correlating a species' realised competitive success and resource utilization, thus illustrating its functional importance.

*3. Capturing Interactions:* By placing species in a shared spatial environment, the profile allows for the direct interpretation of total species interactions (e.g., shading effects, physical proximity, co-occurrence) that define the realised niche in a dynamic ecosystem (Bachan & Devika, 2022).

*4. Integrating Structure and Function:* Unlike purely abundance-based methods, the Niche profile integrates vertical structure with dominance, providing a comprehensive, ecologically realistic spatial map of the community's assembly rules.

Therefore, the spatial distribution of species with respect to others in its habitat is a true reflection of total species interaction and shall be considered a definitive factor explaining the Eltonian Niche. The Niche profile is consequently designated as a reflection of the

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Eltonian Niche, directly addressing the limitations inherent in traditional niche modelling methods (Weber et al., 2017; Devika & Bachan, 2021). Serving as a powerful hypothesis-generating tool, the profile enables a deeper understanding of how the most dominant species occupy and define their functional spaces, reflecting the true ecological role of each taxon within the complex, heterogeneous forest environment.

### **5.3. Results**

The cluster analysis using Bray-Curtis dissimilarity clearly separated ten distinct vegetation compositions : i. Montane Grassland, Montane Shola Forest, ii. Sub-montane Shola Forest (a. Southern and b. Northern guilds), iii. Medium Elevation Sub-montane Wet Evergreen, iv. Medium Elevation Wet Evergreen, v. Low Elevation Evergreen, vi. Very Low Elevation Evergreen Forest, vii. Low Elevation Riparian Evergreen, and viii. Low Elevation Coastal Evergreen (Fig. 5.19). The species associations within these distinct vegetation compositions enumerated in this study are represented by 25 threatened and endemic species, with a species dissimilarity greater than 95–100%. The species associations within these distinct vegetation compositions, as identified in this study (Table 5.1), are represented with species compositions of 25 selected threatened and endemic species, sampled across the Western Ghats with 126 plots comprising 389 associate species (Appendix III). These associations exhibit a high degree of species dissimilarity, with a Bray-Curtis value ranging from 0.95 to 1.0. The specific species that define these unique communities are as follows. The abbreviations for each height class are Emergent Tree (ET), Large Tree (LT), Medium Tree (MT), Small Tree (ST), and Very Small Tree (VST).

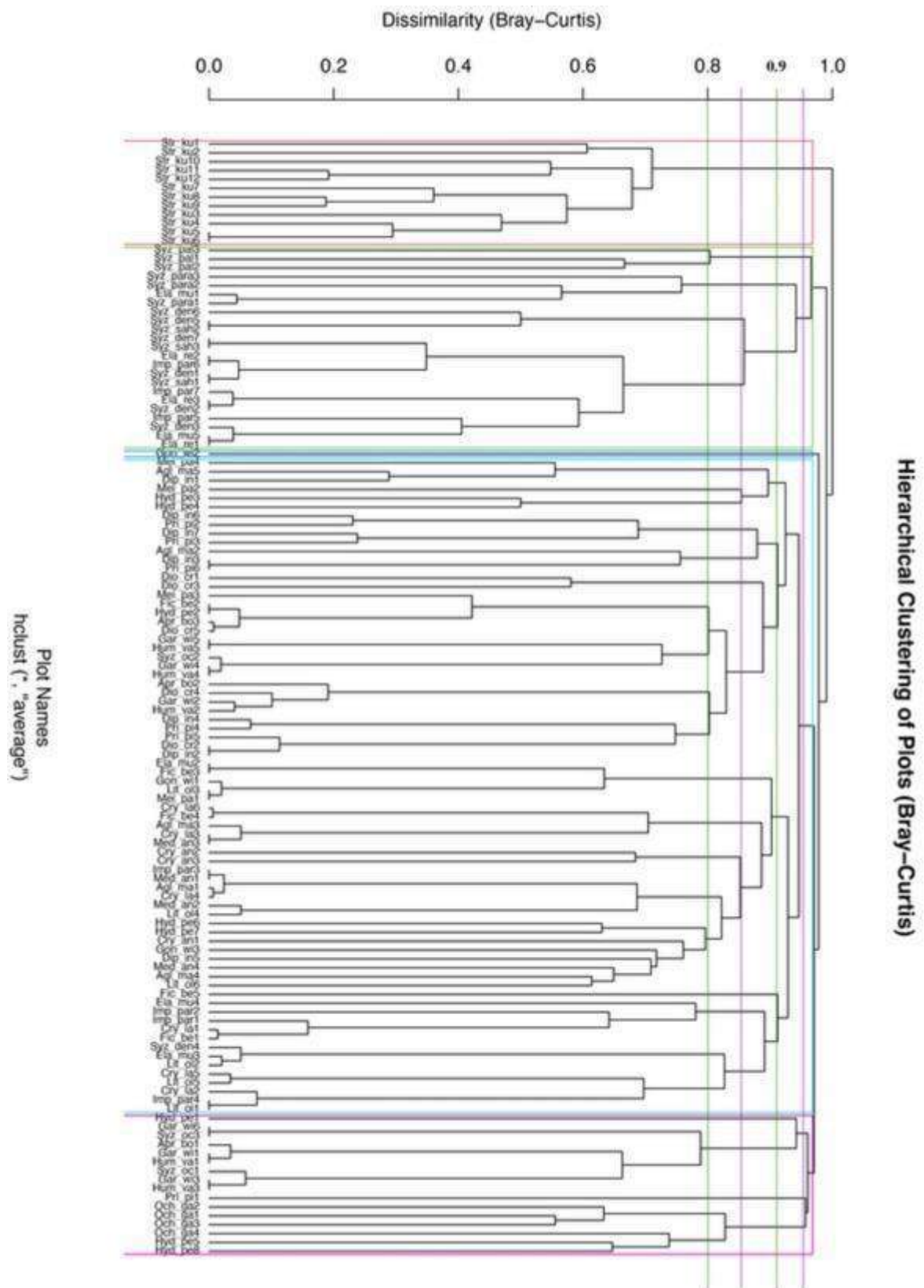


**Fig. 5.19. Bray-Curtis dissimilarity dendrogram of species plots within the Western Ghats**

**Table. 5.1. Community composition of the identified clusters**

| Major Cluster | Vegetation Type                           | Dissimilarity coefficient (%) | Species Composition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|---------------|-------------------------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Cluster 1     | Montane Grass land                        | 100 %                         | <i>Strobilanthes kunthiana</i> , <i>Chrysopogon zeylanicus</i> , <i>Carex brunnea</i> , <i>Crotalaria fysonii</i> , <i>Helichrysum buddlejoides</i> , <i>Pteridium aquilinum</i>                                                                                                                                                                                                                                                                                                                                                                                     |
| Cluster 2     | Montane Shola Forest                      | 98 %                          | <i>Elaeocarpus recurvatus</i> , <i>Cinnamomum macrocarpum</i> , <i>Persea macrantha</i> , <i>Phoebe wightii</i> ; <i>Mastixia arborea</i> ; <i>Syzygium densiflorum</i> , <i>Syzygium sahyadricum</i> , <i>Glochidion nilgriensis</i> , <i>Turpinia cochinchinensis</i> , <i>Rhododendron arboretum</i> , <i>Litsea wightiana</i> , <i>Neolitsea fischeri</i>                                                                                                                                                                                                        |
| Cluster 3     | Sub-montane Shola Forest (Southern Guild) | 97 %                          | <i>Elaeocarpus munroi</i> ; <i>Syzygium parameswaranii</i> , <i>Vernonia travancorica</i> , <i>Cinnamomum wightii</i> , <i>Memecylon talboltianum</i> , <i>Litsea wightiana</i> , <i>Fagraea ceilanica</i> , <i>Symplocos racemose</i> , <i>Glochidion nilgriensis</i> , <i>Litsea ligustrina</i> , <i>Syzygium sasadharanii</i> , <i>Sterculia villosa</i> , <i>Garcinia gummi-gutta</i> ; <i>Ligustrum robustum</i> , <i>Leptonychia caudata</i> , <i>Orophea erythrocarpa</i> ; <i>Ochlandra sp</i> , <i>Glycosmis angustifolia</i> , <i>Glycosmis macrocarpa</i> |

|           |                                                               |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-----------|---------------------------------------------------------------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Cluster 4 | Sub-montane<br>Shola Forest<br>(Northern<br>Guild)            | 98 % | <i>Heritiera papilio</i> , <i>Ficus talbotii</i><br><i>Cassine albens</i> ; <i>Syzygium palghatense</i> ,<br><i>Eugenia indica</i> , <i>Cinnamomum</i><br><i>sulphuratum</i> , <i>Beilschmiedia wightii</i> ,<br><i>Litsea wightiana</i> , <i>Symplocos</i><br><i>cochinchinensis</i> , <i>Phoebe wightii</i> , <i>Litsea</i><br><i>stocksii</i> , <i>Bridelia retusa</i> ; <i>Mallotus</i><br><i>tetracoccus</i> , <i>Ligustrum perrottetii</i> ,<br><i>Clausena indica</i> , <i>Epiprinus</i><br><i>mallotiformis</i> , <i>Cordia monoica</i> ; <i>Maesa</i><br><i>indica</i> , <i>Capparis moonii</i> |
| Cluster 5 | Medium<br>Elevation Sub<br>Montane Wet<br>Evergreen<br>Forest | 96 % | <i>Heritiera papilio</i> , <i>Syzygium gardneri</i> ,<br><i>Ficus beddomei</i> ; <i>Holigarna grahamii</i> ,<br><i>Litsea oleoides</i> , <i>Persea macrantha</i> ,<br><i>Dimocarpus longan</i> , <i>Elaeocarpus</i><br><i>munroi</i> , <i>Litsea stocksii</i> , <i>Phoebe</i><br><i>lanceolata</i>                                                                                                                                                                                                                                                                                                       |
| Cluster 6 | Medium<br>Elevation Wet<br>Evergreen<br>Forest                | 97 % | <i>Cullenia exarillata</i> , <i>Macaranga peltata</i> ,<br><i>Elaeocarpus tuberculatus</i> , <i>Melicope</i><br><i>lunu-ankenda</i> , <i>Calophyllum polyanthum</i> ,<br><i>Dipterocarpus indicus</i> , <i>Holigarna</i><br><i>grahamii</i> , <i>Ficus beddomei</i> , <i>Hopea</i><br><i>parviflora</i> ; <i>Palaquium ellipticum</i> ,<br><i>Persea macrantha</i> , <i>Myristica beddoemi</i> ,<br><i>Cryptocarya lawsonii</i> , <i>Mesua ferrea</i> ,                                                                                                                                                  |

|            |                                                  |      |                                                                                                                                                                                                                                                                                                                                                                                        |
|------------|--------------------------------------------------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Cluster 7  | Low Elevation<br>Evergreen<br>Forest             | 88 % | <i>Tetrameles nudiflora</i> , <i>Macaranga peltate</i> , <i>Lophopetalum wightianum</i> , <i>Alstonia scholaris</i> , <i>Hopea parviflora</i> , <i>Terminalia bellirica</i> , <i>Calophyllum polyanthum</i> , <i>Dipterocarpus indicus</i> , <i>Ficus beddomei</i> ; <i>Vateria indica</i> , <i>Chukrasia tabularis</i> , <i>Diospyros crumenata</i> , <i>Lagerstroemia macrocarpa</i> |
| Cluster 8  | Very Low<br>Elevation<br>Evergreen<br>Forest     | 84 % | <i>Dipterocarpus indicus</i> , <i>Tetrameles nudiflora</i> , <i>Prioria pinnata</i> , <i>Hopea parviflora</i> , <i>Terminalia bellarica</i> , <i>Mesua ferea</i> , <i>Syzygium gardneri</i> ; <i>Hydnocarpus pentandrus</i> , <i>Lagerstroemia macrocarpa</i> , <i>Vepris bilocularis</i> , <i>Aglaia barberi</i> , <i>Knema attenuata</i> , <i>Diospyros sylvatica</i>                |
| Cluster 9  | Low Elevation<br>Riparian<br>Evergreen<br>Forest | 98 % | <i>Hopea parviflora</i> , <i>Calophyllum calaba</i> , <i>Vateria indica</i> , <i>Elaeocarpus tuberculatus</i> ; <i>Syzygium occidentale</i> , <i>Hopea ponga</i> , <i>Terminalia arjuna</i> , <i>Holigarna grahamii</i> , <i>Ochreinauclea missionis</i> , <i>Neolamarckia cadamba</i>                                                                                                 |
| Cluster 10 | Low Elevation<br>Coastal<br>Evergreen            | 98%  | <i>Hopea parviflora</i> , <i>Ficus benghalensis</i> , <i>Prioria pinnata</i> , <i>Vateria indica</i> ; <i>Albizia odoratissima</i> , <i>Tetrameles nudiflora</i> , <i>Lophopetalum wightianum</i> , <i>Artocarpus hirsutus</i> , <i>Holigarna arnottiana</i>                                                                                                                           |



### i. Montane Grassland

The Montane Grassland association represents a highly specialised, non-forested biome found at the highest elevations between 1800 – 2600 m, characterised by a dominant herbaceous and graminoid layer. The extreme dissimilarity of this cluster from all others is defined by the absence of significant tree cover and the dominance of species adapted to high wind, frost, high-intensity sunlight.

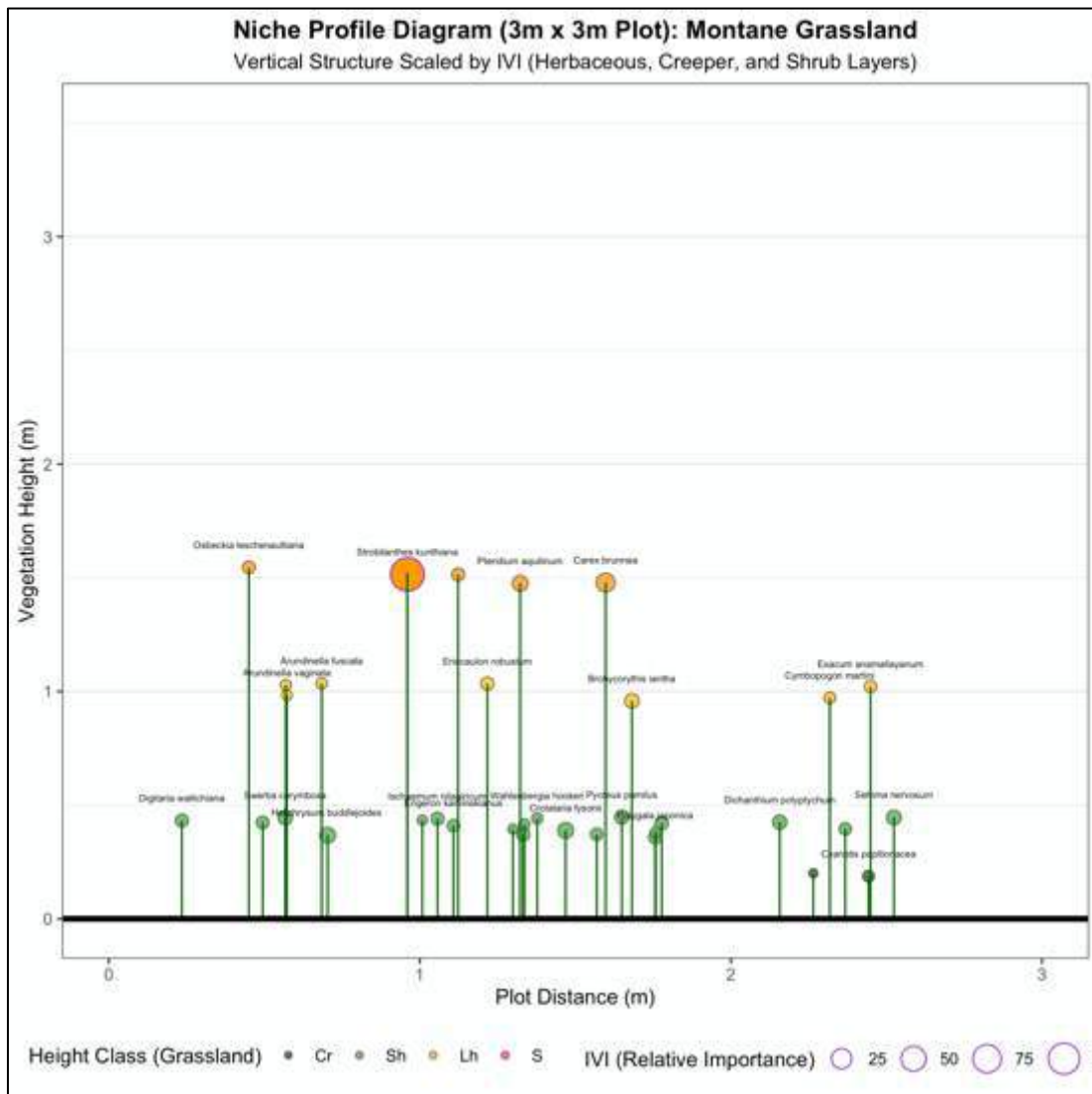


**Fig. 5.20. Niche profile of Montane Grassland**

The community structure is defined almost entirely by specialised graminoids and low-growing shrubs. Dominant grass species, which serve as the primary structural and biomass components, include *Chrysopogon zeylanicus*, *Carex brunnea*, *Sehima nervosum*, and *Dichanthium polytychum*. These species form the foundation of the grazing niche and play a critical Eltonian niche role in stabilizing the thin montane topsoil. The forb layer

includes specialised herbs such as *Crotalaria fysonii*, *Helichrysum buddlejoides*, and *Hypericum mysorense*. A key structural component of this association is the presence of the mass-flowering *Strobilanthes kunthiana*, which, while technically a shrub, dominates the landscape periodically, defining a unique pulse-fruiting and flowering event that impacts the entire associated faunal guild. Other characteristic associates include the fern *Pteridium aquilinum* and various species of *Eriocaulon* and *Anaphalis*. The Eltonian niche of this Montane Grassland is that of a specialised, climatically-determined ecosystem where functional traits are geared towards stress tolerance rather than light competition. The entire structure is fundamentally driven by the focal species in the study, *Strobilanthes kunthiana*, which dictates the local phenology and resource availability for a vast number of associated insects and herbivores. The structural and compositional uniqueness of this association provide a niche for the targeted species, *Strobilanthes kunthiana* in the study (Fig. 5.20).

## **ii. Montane Shola Forest**

The Montane Shola Forest is characterised by a high-density, multi-layered canopy structure typical of high-elevation, moist environments, exhibiting significant species dissimilarity from other forest types. The upper canopy is defined by emergent and large tree dominant members of the Lauraceae, Myrtaceae and Elaeocarpaceae families, including *Elaeocarpus recurvatus*, *Cinnamomum macrocarpum*, *Persea macrantha*, and *Mastixia arborea*, which serve as the primary interceptors of cloud moisture. Even though they are emergent and large tree they will grow stunted only up to 20-25m height due to extreme wind and mist. The canopy (MT) is the most species-rich layer, featuring a high concentration of Myrtaceae species such as *Syzygium densiflorum* and *Syzygium sahyadricum*, alongside *Rhododendron arboretum*, *Litsea wightiana*, and the endemic species *Elaeocarpus munori*. This mid-story concentration of microphyllous evergreens defines a specialised functional guild adapted to cold, cloud-influenced montane conditions. The lower stratum is structurally important due to the presence of the endemic reed bamboo, *Ochlandra sp*, and specialised shrubs like *Elaeagnus kologa* and *Rhodomyrtus tomentosa* around the shola boundaries. The structural and compositional uniqueness of this association provide a niche for the targeted species such as *Elaeocarpus recurvatus*, *Syzygium densiflorum*, *Syzygium sahyadricum* and *Elaeocarpus munori* in the study (Fig. 5.21).

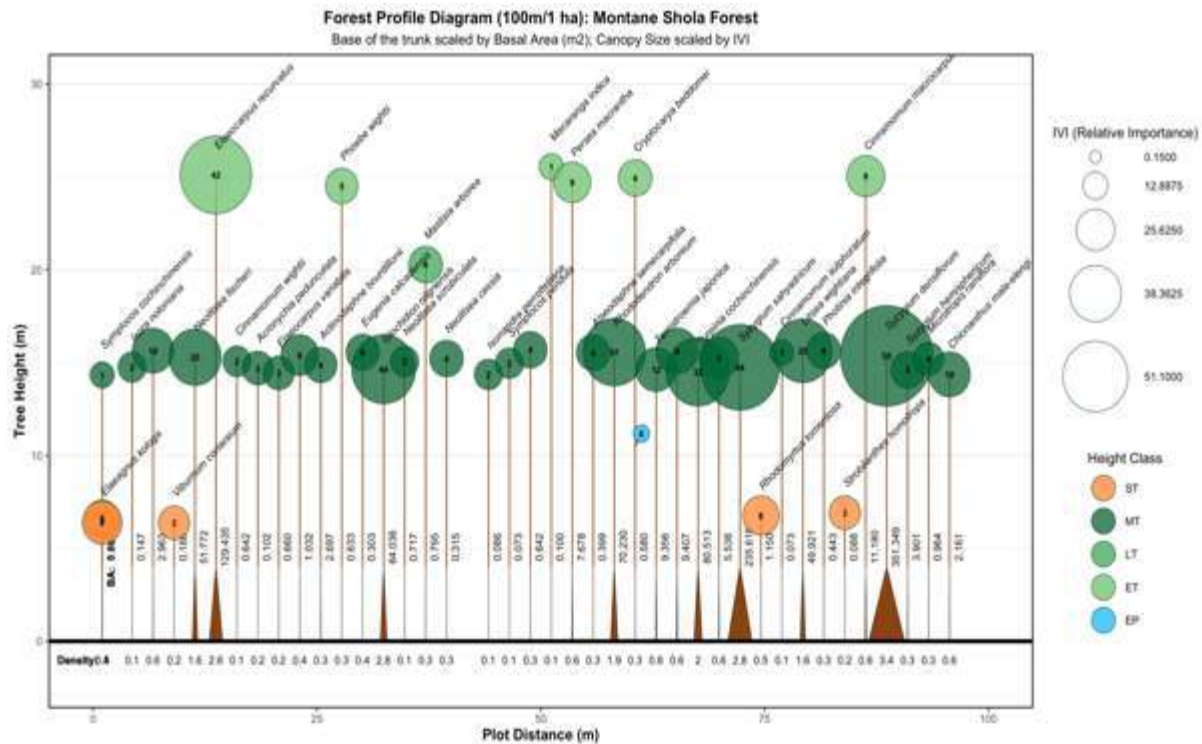


**Fig. 5.21. Niche profile of Montane Shola Forest**

### iii. Sub-montane Shola Forest (Southern Guild)

The Sub-montane Shola Forest (Southern Guild) represents a distinctive transitional vegetation type occurring along the mid-elevation slopes of the Western Ghats, where elements of both evergreen and montane floras intermix. This assemblage is characterised by the co-occurrence of canopy dominants and shade-tolerant understorey taxa, forming a structurally complex community indicative of intermediate successional stages between medium-elevation wet evergreen and higher-elevation shola forests. The upper canopy is dominated by *Elaeocarpus munroi*, a characteristic sub-montane evergreen tree contributing to canopy continuity and microclimatic regulation. The mid-canopy layer is diverse, comprising *Syzygium parameswaranii*, *Vernonia travancorica*, *Cinnamomum wightii*, *Memecylon talbotianum*, *Litsea wightiana*, *Fagraea ceilanica*, *Symplocos racemosa*, *Glochidion nilgiriensis*, *Litsea ligustrina*, *Syzygium sasadharanii*, *Sterculia villosa*, and *Garcinia gummi-gutta*. These taxa reflect both Lauraceae and Myrtaceae dominance, typical of moisture-rich, shaded mid-elevation forests, and indicate strong ecological specialization for mesic conditions. The sub-canopy and shrub layers include *Ligustrum robustum*, *Leptonychia caudata*, and *Orophea erythrocarpa*, which contribute

to vertical stratification and regeneration potential within canopy gaps. The ground and understorey layers especially along the margins are dominated by clumps of *Ochlandra* species and small shrubs such as *Glycosmis angustifolia* and *Glycosmis macrocarpa*, representing important components of the forest's microhabitat structure and resource heterogeneity. The presence of *Ochlandra* spp. further signifies the guild's ecological continuity with streamside and sub-montane wet evergreen systems (Fig. 5.22).

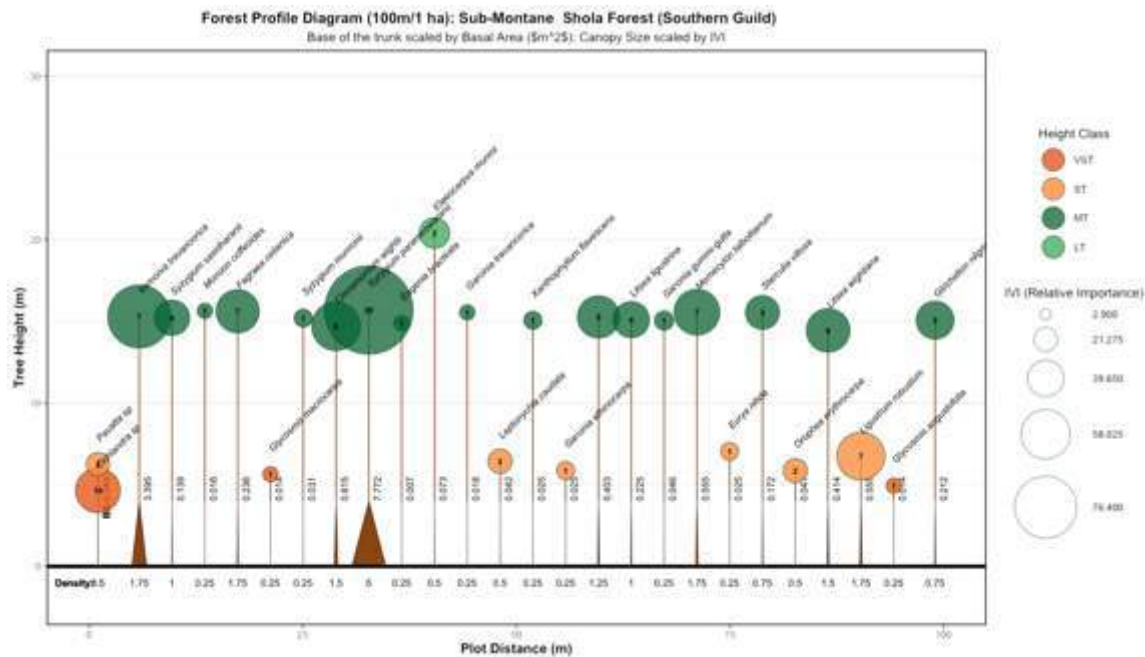


**Fig. 5.22. Structural profile of Sub-montane Shola Forest (Southern Guild)**

The focal species, *Syzygium parameswaranii*, an endemic and threatened tree confined to the southern Western Ghats, which shares a significant niche within this guild. Its association with diverse associated taxa suggests strong biotic dependence such as shared pollinators and dispersers, that define the Eltonian niche of this vegetation type. The persistence of this guild relies on intact canopy architecture, faunal linkages, and microclimatic stability, highlighting the ecological significance of mid-elevation refugia for endemic tree assemblages in the Western Ghats.

#### **iv. Sub-montane Shola Forest (Northern Guild)**

The Sub-montane Shola Forest (Northern Guild) represents a structurally complex vegetation type occurring along the northern mid-elevational slopes of the Western Ghats, typically between the lower montane and sub-montane wet evergreen formations. This community reflects a mosaic of floristic elements that bridge the composition of medium-

elevation evergreen forests and upper montane sholas, shaped by topographic heterogeneity, persistent moisture, and diffuse light conditions. The emergent stratum is defined by *Heritiera papilio* and *Ficus talbotii*, two large canopy species that contribute to vertical continuity, canopy shade, and microhabitat diversification.

The large-tree layer is represented primarily by *Cassine albens*, while the mid-canopy is species-rich and ecologically significant, comprising *Syzygium palghatense*, *Eugenia indica*, *Cinnamomum sulphuratum*, *Beilschmiedia wightii*, *Litsea wightiana*, *Symplocos cochinchinensis*, *Phoebe wightii*, *Litsea stocksii*, and *Bridelia retusa*. This assemblage displays a strong dominance of Lauraceae and Myrtaceae elements, characteristic of humid, shaded forest interiors with high dependence on animal-mediated pollination and seed dispersal. Such composition suggests a community structured by mutualistic networks and microclimatic stability. The sub-canopy and shrub strata are marked by *Mallotus tetracoccus*, *Ligustrum perrottetii*, *Clausena indica*, *Epiprinus mallotiformis*, and *Cordia monoica*, indicating early-successional or light-gap components that sustain regeneration dynamics following localised disturbances. The ground and understorey layers include *Maesa indica* and *Capparis moonii*, complemented by the woody climber *Derris brevipes*, which contributes to canopy connectivity and supports arboreal fauna (Fig. 5.23).

The focal species *Syzygium palghatense*, an endemic and threatened taxon confined to the northern sectors of the Western Ghats, serves as a structural and functional keystone within this guild. Its co-occurrence with Lauraceae and Euphorbiaceae taxa underscores niche complementarity and biotic dependency patterns typical of Eltonian frameworks. The persistence of this guild thus reflects intricate ecological interactions among canopy dominants, mid-story associates, and understorey flora, maintaining the stability and resilience of sub-montane forest ecosystems under the unique climatic and biogeographic conditions of the northern Western Ghats.

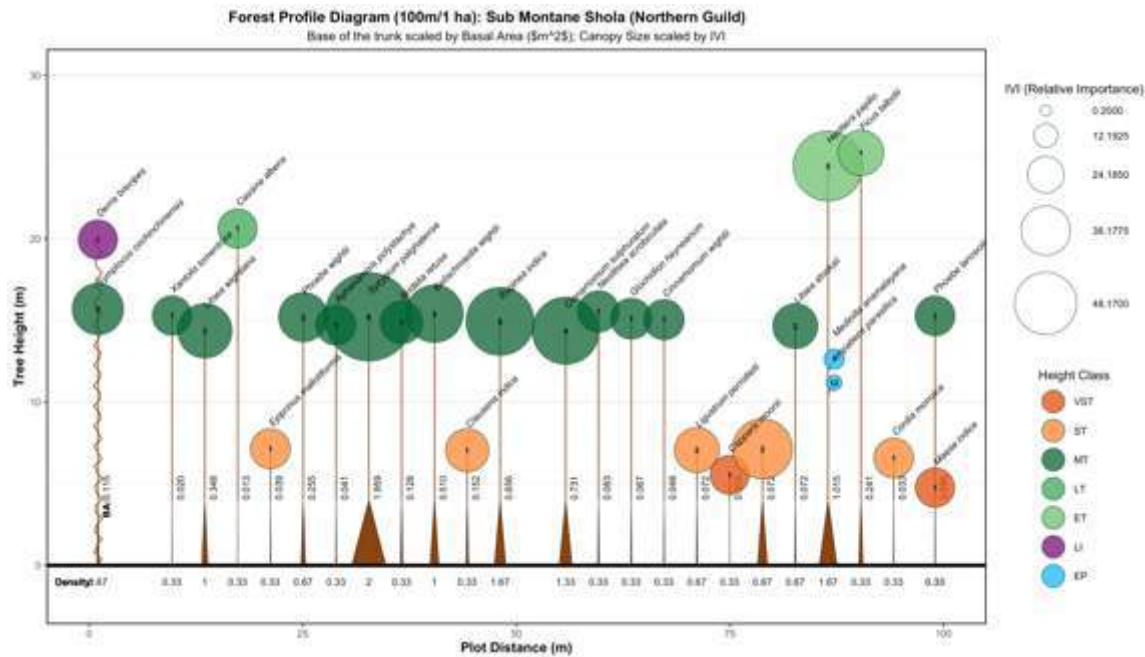


**Fig. 5.23. Structural profile of Sub-montane Shola Forest (Northern Guild)**

#### **v. Medium Elevation Sub-montane Wet Evergreen (Cluster G)**

The Medium Elevation Sub-montane Wet Evergreen association represents a highly diverse and structurally dense forest type, occupying an ecological transition zone. This complexity is reflected in the large number of associate species and a pronounced, multi-layered vertical structure. The Emergent Tree stratum is dominated by canopy giants such as *Heritiera papilio*, *Syzygium gardneri*, and *Ficus beddomei*, *Canarium strictum*, which provide temporal canopy gaps and contribute to litter input. The dense Large Tree layer acts as the main crown cover, featuring a high diversity of families (Lauraceae, Myristicaceae, Anacardiaceae), including *Litsea oleoides*, *Persea macrantha*, *Myristica beddomei*, and the presence of the endemic species *Elaeocarpus munroi*, underscoring its biogeographic connection to montane regions. The Medium Tree layer is exceptionally speciose, defined by a strong concentration of Lauraceae members such as *Litsea stocksii*, *Phoebe lanceolata*, and *Cryptocarya lawsonii*. These associates, along with species like *Syzygium lanceolatum* and *Schleichera oleosa*, form a continuous, light-filtering understory canopy. The Small Tree and Very Small Tree strata are composed of specialised understory species, including *Memecylon* and *Symplocos* species, as well as climbers and shrubs like *Capparis moonii* and *Tabernaemontana alternifolia*. These lower layers are functionally crucial for nutrient cycling and providing shelter for ground fauna.



The Eltonian niche of this association is characterised by its role as a key biodiversity repository, maintaining a complex vertical niche partitioning that supports numerous genera. The association's distinctiveness is reinforced by its focal species *Ficus beddomei* (a canopy dominant), *Litsea oleoides*, *Elaeocarpus munroi*, *Cryptocarya lawsonii*, and *Syzygium densiflorum* all of which require specific moisture and shade conditions indicative of a specialised, high-integrity wet evergreen habitat (Fig. 5.24).

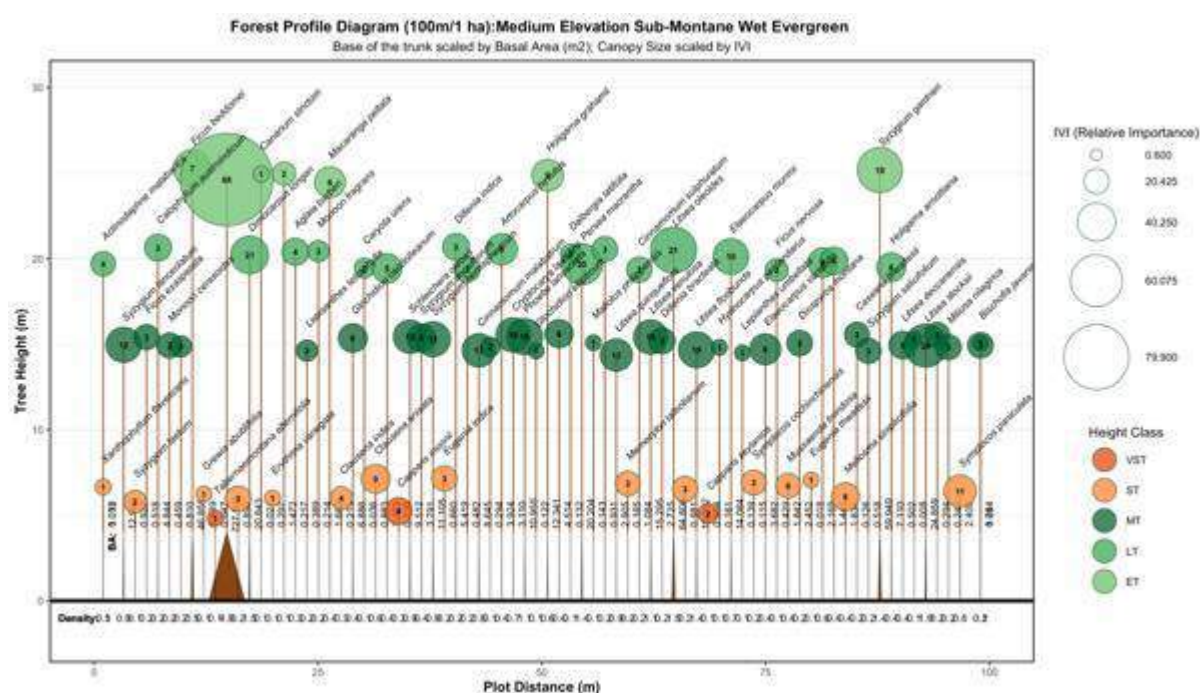


**Fig. 5.24. Structural profile of Medium Elevation Sub-montane Wet Evergreen Forest**

#### vi. Medium Elevation Wet Evergreen (Cluster F)

The Medium Elevation Wet Evergreen association (Cluster F) is one of the most structurally complex and species-rich communities identified, characterised by high biomass and a well-developed, multi-strata canopy. This association forms the ecological core of the Wet Evergreen belt in the study area. The Emergent Tree stratum is defined by the presence of large-stature, pillar-like species, notably *Cullenia exarillata*, *Elaeocarpus tuberculatus*, and the culturally and ecologically significant *Dipterocarpus indicus*, which is a functional cornerstone of this community. Other primary canopy associates include *Holigarna grahamii*, *Hopea parviflora*, and large figs like *Ficus beddomei*, all of which function as primary light interceptors and biomass

accumulators. The dense Large Tree layer features a high diversity of species known for timber quality and specialised seed dispersal, such as *Palaquium ellipticum*, *Myristica beddoemi*, *Vateria indica*, and various species of the Lauraceae and Myristicaceae families. The presence of *Cryptocarya lawsonii* and *Cryptocarya anamalayana* highlights the specific microclimate requirements of this cluster. The sub-canopy layers (Medium Tree and Small Tree) are dominated by species that thrive in deep shade. The Medium Tree layer includes *Schleichera oleosa* and members of the Sapindaceae and Euphorbiaceae families. The Small Tree layer is characterised by shade-tolerant species like *Oreocnide integrifolia* and *Baccaurea courtallensis*. The lowest woody strata (Very Small Tree) and the liana component (LI), represented by *Goniothalamus wightii* and *Gnetum edule*, respectively, are functionally important for maintaining understory microclimate stability (Fig. 5.25).

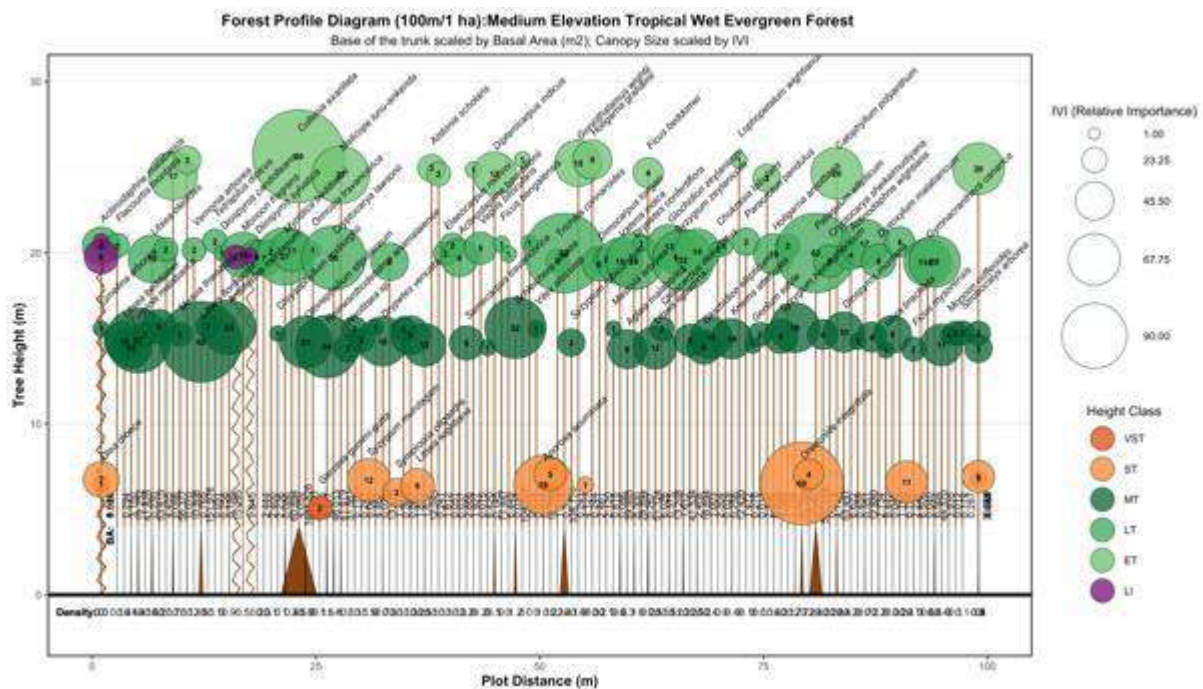


**Fig. 5.25. Structural profile of Medium Elevation Wet Evergreen Forest**

The Eltonian niche of this association is that of a climax forest ecosystem. It supports a guild of species that specialise in high nutrient and water retention, with the Emergent Tree layer providing a crucial resource base and protection for the entire community. The high integrity of this habitat is reflected in the focal species including the indicator species *Dipterocarpus indicus*, *Ficus beddoei*, and specialised endemics like *Goniothalamus*

*wightii* and *Meiogyne pannosa* which collectively define the unique moisture and shade profiles of this medium-elevation wet evergreen type.

#### **vii. Low Elevation Evergreen**

The Low Elevation Evergreen association (Cluster E) represents a species-rich forest characterised by high stature and a notable mix of primary evergreen canopy formers and semi-evergreen associates, reflecting warmer temperatures and higher light penetration compared to montane forests. The Emergent Tree stratum is particularly well-developed, dominated by large buttressed trees such as *Tetrameles nudiflora* and *Dipterocarpus indicus*. Other significant canopy giants include *Lophopetalum wightianum*, *Alstonia scholaris*, and *Elaeocarpus tuberculatus*. This layer's functional role is primarily in high biomass storage and creating the specific shade conditions essential for the lower strata. The Large Tree layer is characterised by species like *Vateria indica*, *Chukrasia tabularis*, and *Myristica beddomei*, with the presence of *Prioria pinnata* and *Diospyros crumenata* indicating specialised substrate or dispersal requirements. The Medium Tree layer is defined by several endemic and specialised genera. The association of *Schleichera oleosa*, *Hydnocarpus pentandrus*, and *Hydnocarpus alpinus* highlights this forest's role in supporting species whose seeds are dispersed by animals (frugivores). Crucially, the presence of *Humboldtia vahliana*, often associated with moisture regimes or riparian zones, indicates a specific microhabitat requirement within this low-elevation belt. The Small Tree and Very Small Tree layers feature specialised shade-tolerant and understory elements, most notably the high structural importance of the endemic reed, *Ochlandra scriptoria*. The lowest strata also contain a mix of specialised shrubs and small trees such as *Garcinia wightii* and *Psychotria anamallayana*. The presence of large lianas, including *Entada rheedei* and *Gnetum edule* (LI), significantly contributes to the forest's structural connectivity. The Eltonian niche of this association is one of maximizing resource utilization in a hot, humid environment. Its distinctiveness is reinforced by the presence of focal species, *Dipterocarpus indicus* and *Ficus beddomei* (as canopy stabilisers), and specialised endemics like *Prioria pinnata*, *Humboldtia vahliana*, and *Garcinia wightii* which define a critical biodiversity bridge between the coast and the mid-elevations (Fig. 5.26).

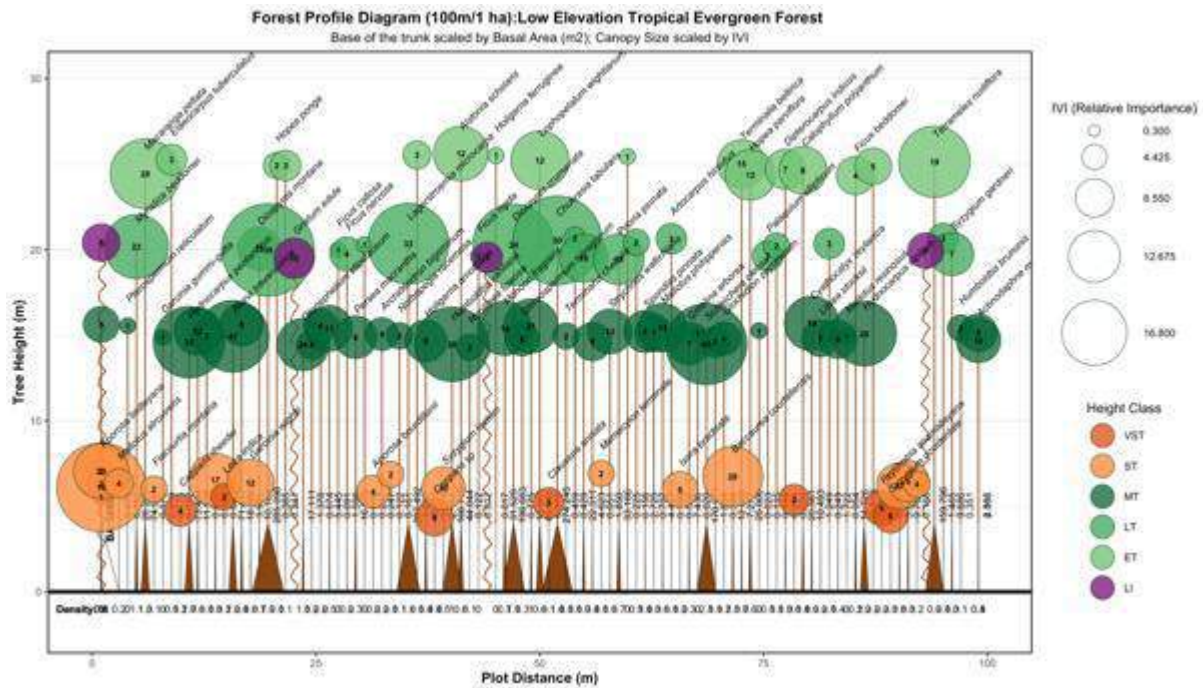


**Fig. 5.26. Structural profile of Low Elevation Evergreen Forest**

#### viii. Very Low Elevation Evergreen

The Very Low Elevation Evergreen Forest association (Cluster D) represents a specialised community found closest to the coast, adapted to a hot, very humid environment but distinct from riparian zones. This cluster is marked by a mix of key endemic species and robust generalists. The Emergent Tree stratum is defined by high-stature, valuable species such as *Dipterocarpus indicus*, *Tetrameles nudiflora*, and *Hopea parviflora*, which collectively function as the primary structural anchors of the forest. The presence of *Gluta travancorica* highlights the specific biogeographic importance of this low-elevation, specialised habitat. The Large Tree layer is characterised by species requiring high soil moisture, including *Hydnocarpus pentandrus* and the indicator species *Poeciloneuron indicum*, alongside a variety of species from the Myristicaceae and Ebenaceae families (e.g., *Knema attenuata*, *Diospyros sylvatica*). This layer emphasises the forest's functional role in supporting species crucial for local traditional medicine and industry. The Medium Tree layer is exceptionally diverse, featuring a strong component of understory canopy formers like *Chionanthus malaelengi*, *Myristica beddomei*, and various species of *Aglaia*. The presence of figs such as *Ficus racemosa* and *Ficus exasperata* in this layer ensures continuous fruit availability, playing a significant Eltonian niche role as primary resource providers for frugivores. The lower strata (Small Tree and Liana) include shade-tolerant shrubs and climbers that maintain understory



humidity. *Mallotus tetracoccus* and the presence of large woody lianas, specifically *Gnetum edule* and the cane *Calamus thwaitesii*, contribute significantly to the structural complexity and habitat connectivity within the cluster. The integrity of this specialised habitat is reinforced by its focal species *Dipterocarpus indicus* and *Hydnocarpus pentandrus* (as essential resource providers), and specialised endemics like *Aglaia malabarica* and *Meiogyne pannosa* which define a unique niche profile adapted to the warmest, most humid environments of the study area (Fig. 5.27).

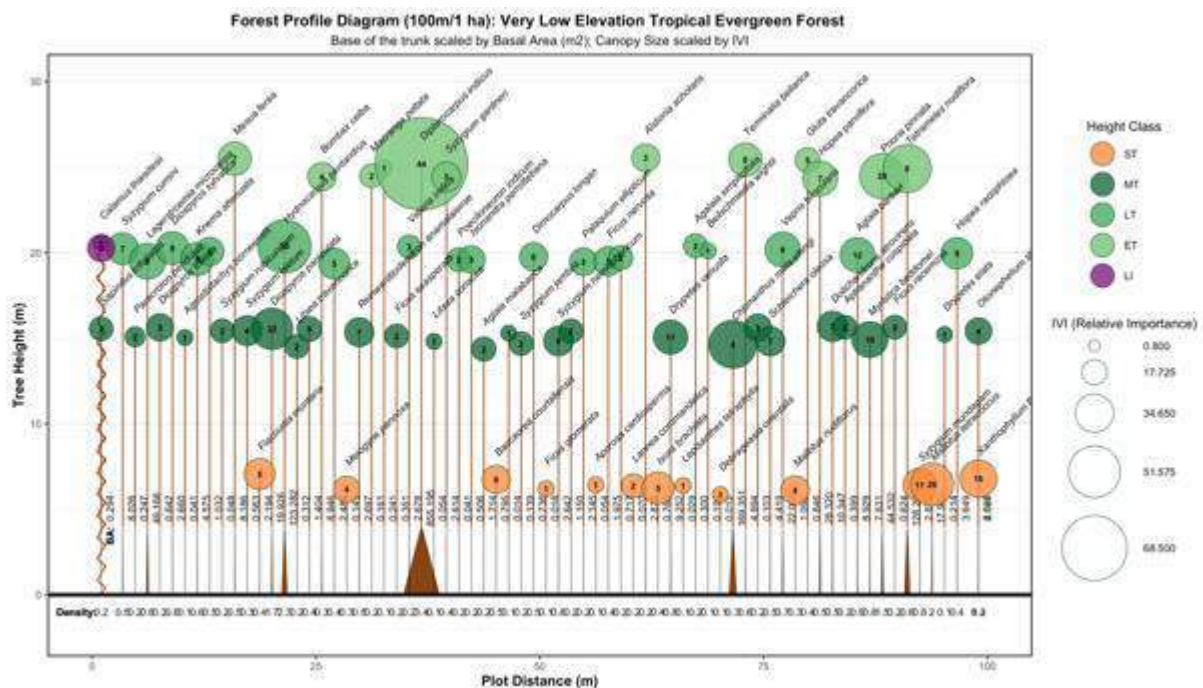


**Fig. 5.27. Structural profile of Very Low Elevation Evergreen Forest**

#### ix. Low Elevation Riparian Evergreen

The Low Elevation Riparian Evergreen association is structurally and compositionally distinct, defined by its adaptation to permanent water availability and the characteristic fluvial conditions of stream banks. This cluster provides a key ecological corridor and a unique hydric habitat. The Emergent Tree and Large Tree strata are dominated by species tolerant of high moisture and transient flooding, acting as crucial bank stabilisers. The Emergent Tree layer includes large trees such as *Hopea parviflora* and *Vateria indica*. The Large Tree layer is marked by characteristic riparian species such as *Terminalia arjuna* and *Ochreinauclea missionis*, alongside high-value associates like *Syzygium occidentale* and *Calophyllum inophyllum*. The presence of *Entada scandens* (LI) in this upper canopy adds

significant structural connectivity across the stream boundary. The Medium Tree layer is defined by several unique hydro-specialist genera, notably *Humboldtia vahliana* and *Pongamia pinnata*, which are functional indicators of riparian zones. This layer also features a concentration of species whose seeds are water-dispersed, such as *Syzygium cumini* and *Carallia brachiata*, highlighting the forest's Eltonian niche as a primary corridor for seed and nutrient transfer. The presence of both *Hydnocarpus alpinus* and *Hydnocarpus pentandrus* emphasises the localised importance of the cluster for species requiring perennial water. The Small Tree stratum is dominated by specialist shrubs and smaller trees that form a dense, protective understory against erosion. Key elements include the specialised stream-edge species *Barringtonia acutangula*, the reed bamboos *Ochlandra scriptoria* and *Ochlandra travancorica*, and the screw pine *Pandanus furcatus* (Fig. 5.28).

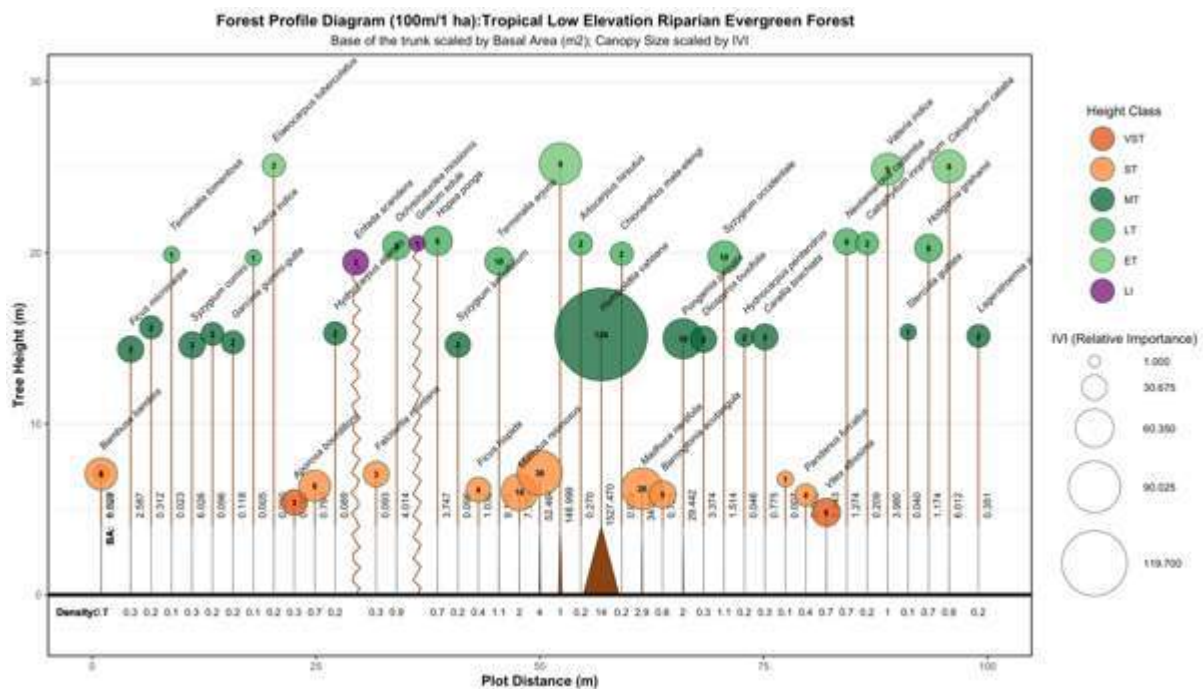


**Fig. 5.28. Structural profile of Low Elevation Riparian Evergreen**

The lowest stratum (Very Small Tree) is completed by shade-tolerant endemics like *Aporosa bourdillonii* and specialised shrubs like *Garcinia wightii*. The functional role of this riparian association is critical for regulating water flow, stabilizing stream banks, and serving as a dispersal bridge. This is reinforced by the focal species, particularly the hydro-tolerant dominants *Syzygium occidentale* and *Humboldtia vahliana*, along with specialised



low-strata species like *Garcinia wightii* and *Aporosa bourdillonii* all of which are integral to defining the unique ecological profile of this riverine habitat.

#### **x. Low Elevation Coastal Evergreen**

The Low Elevation Coastal Evergreen association represents a unique community structure influenced by its proximity to coastal environments, characterised by species adapted to wind, higher light intensity, and often modified habitats. The resulting cluster exhibits a mix of robust evergreen trees, large figs, and disturbance-tolerant associates. The Emergent Tree and Large Tree strata define a relatively open, yet tall, canopy. The Emergent Tree layer includes primary evergreen associates such as *Hopea parviflora* and *Vateria indica*, alongside significant fig species like *Ficus benghalensis* and *Ficus virens*. The Large Tree layer is notable for the presence of widespread, ecologically important species like *Artocarpus hirsutus* and *Syzygium cumini*, as well as species often associated with human landscapes, such as *Mangifera indica* and the palm *Caryota urens*. The presence of *Albizia odoratissima* and *Acacia auriculiformis* suggests a functional role in primary succession or modified landscapes. The Medium Tree layer contains a rich array of species critical for local resources. Associates include *Olea dioica*, *Garcinia gummi-gutta*, and the oil-rich *Hydnocarpus pentandrus*. The presence of *Anacardium occidentale* (cashew) and species like *Pongamia pinnata* further highlights the association's successional and often fragmented Eltonian niche as a robust, low-elevation community capable of stabilizing the environment near the coast. The lower strata (Small Tree and Very Small Tree) are characterised by shrubs and small trees adapted to high light conditions. The specialised reed bamboo *Ochlandra travancorica* persists here, along with wind-tolerant shrubs like *Memecylon umbellatum*. The lowest stratum includes specialised species like *Ochna gamblei*, *Samadera indica*, and the surprisingly present arid specialist, *Opuntia elatior*, indicating localised pockets of disturbed or dry coastal micro-environments. The Eltonian niche of this association is one of resilience and boundary stability. Its distinctiveness is defined by its focal species, *Prioria pinnata* (a structural component), *Hydnocarpus pentandrus* (a resource specialist), and the specialised understory component *Ochna gamblei* which collectively characterise this dynamic, low-elevation coastal forest edge (Fig. 5.29).

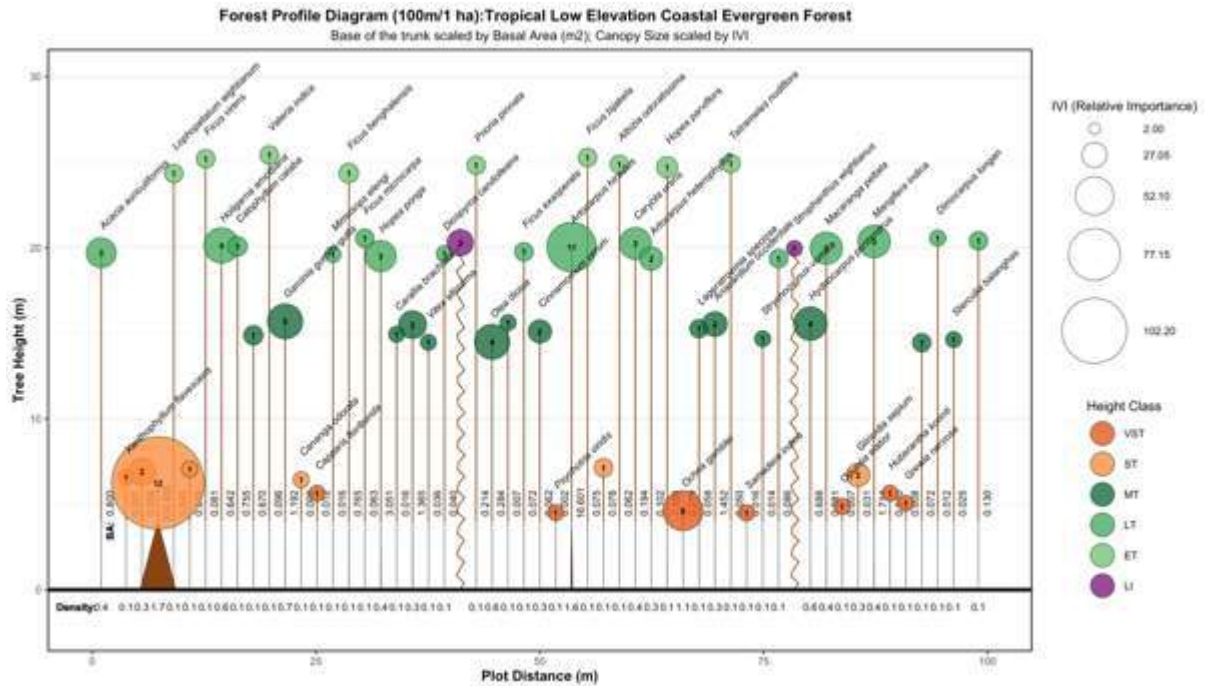


Fig. 5.29. Structural profile of Low Elevation Coastal Evergreen

#### 5.4. Discussion

In the Western Ghats, one of the world's biodiversity hotspots, the structure and composition of evergreen and semi-evergreen forests reflect complex interaction networks among trees, understorey flora, and faunal assemblages (Pascal, 1988; Davidar et al., 2005). Many threatened angiosperms endemic to this region, such as *Dipterocarpus indicus*, *Hopea ponga*, *Syzygium spp* and *Madhuca spp* are integral components of specific community assemblages. Their persistence depends on ecological associations such as canopy stratification, shade tolerance, mycorrhizal symbiosis, and animal-mediated dispersal (Sukumar et al., 1992; Joshi et al., 2015). These Eltonian interactions regulate recruitment, regeneration, and competitive balance, and thus serve as critical indicators of ecosystem integrity. The Eltonian niche framework also integrates functional and trophic dimensions. Traits such as dispersal mechanism, growth form, phenology, and canopy position define ecological strategies and resource partitioning within communities (Violle et al., 2007). Functional trait analysis, when coupled with species composition data, reveals guild structures and ecological complementarity, thereby identifying the roles of threatened species in maintaining community function. For instance, shade-tolerant climax species with large, animal-dispersed fruits depend on intact faunal networks, while pioneer

or gap-phase species rely on disturbance-mediated regeneration niches (Connell, 1978; Wright, 2002). Such relationships form the core of the Eltonian niche, linking population ecology with community-level dynamics. The methodological framework employed here combining Bray-Curtis dissimilarity, Importance Value Index (IVI), and Niche profiling was specifically designed to capture and visualise these complex Eltonian dynamics across the highly heterogeneous Western Ghats landscape.

#### **5.4.1. The Efficacy of Bray-Curtis Dissimilarity in Delineating Community Structure**

The cluster analysis, based on the Bray-Curtis dissimilarity index, provided a statistically rigorous and robust framework for partitioning the vast floristic  $\gamma$ -diversity. The Bray-Curtis metric was chosen for its efficacy in community ecology, as it accounts for both the qualitative presence/absence and the quantitative abundance of species, offering a nuanced assessment of  $\beta$ -diversity and species turnover (Bray & Curtis, 1957; Legendre & Legendre, 2012). The analysis clearly separated ten distinct vegetation compositions: i. Montane Grassland, Montane Shola Forest, ii. Sub-montane Shola Forest (a. Southern and b. Northern guilds), iii. Medium Elevation Sub-montane Wet Evergreen Forest, iv. Medium Elevation Wet Evergreen Forest, v. Low Elevation Evergreen Forest, vi. Very Low Elevation Evergreen Forest, vii. Low Elevation Riparian Evergreen Forest, and viii. Low Elevation Coastal Evergreen Forest.

A defining outcome of this study is the extreme level of species dissimilarity observed among these communities, with Bray-Curtis values consistently ranging from 0.95 to 1.0. This extremely high threshold underscores that these ten vegetation types are non-substitutable ecological assemblages (Magurran, 2004; Kent, 2012). This strong segregation reflects clear ecological boundaries driven by both abiotic gradients (Grinnellian filters) and specialised biotic interactions (Eltonian filters). The distinctiveness of communities such as Montane Grasslands, Shola Forests, and Low-Elevation Coastal Evergreens illustrates how floristic assemblages respond acutely to altitudinal and microclimatic gradients, a pattern well documented in Western Ghats vegetation zonation (Pascal, 1988; Joshi et al., 2015; Davidar et al., 2018). The species associations within these distinct vegetation compositions, as identified in this study, are represented by 25 selected threatened and endemic focal species, sampled across the Western Ghats with 126 plots comprising 389 associate species. The functional role of

these focal species, from the density-dependent regeneration of *Dipterocarpus indicus* to the specialised high-altitude endemism of *Elaeocarpus recurvatus*, highlights their criticality in defining the unique ecological function of each cluster

#### **5.4.2. Functional and Structural Ecology: Elucidating the Eltonian Niche**

The ten vegetation groups mirror a continuum of ecological conditions, but the association of certain species, especially endemic and threatened taxa, highlights the critical role of biotic interactions and niche partitioning. Such patterns exemplify Eltonian niche dynamics, where species coexistence is shaped not only by physical conditions but also by trophic, mutualistic, and competitive relationships (Soberón, 2007; Devictor et al., 2010).

The Importance Value Index (IVI), derived as the sum of relative frequency, density, and basal area (Daubenmire, 1949), was employed to objectively assess the ecological dominance of species within each community (Misra, 1968; Weaver & Clements, 1983; Romesburg, 1984; Jongman et al., 1995). IVI serves as a more powerful indicator than simple abundance, quantifying a species' integrated success in resource monopolization, competitive superiority, and spatial distribution. Species exhibiting high IVI such as *Elaeocarpus recurvatus* in the Montane Shola or *Cullenia exarillata* in the Medium Elevation Wet Evergreen act as structural keystones that define the canopy architecture and fundamentally influence the understory light and humidity, thereby creating the secondary niche space for subordinate taxa (Gunawardene et al., 2007; Bhat et al., 2011).

#### **Height Classes and Vertical Niche Partitioning**

The stratification of species into five height classes Emergent Tree (ET), Large Tree (LT), Medium Tree (MT), Small Tree (ST), and Very Small Tree (VST) provided the necessary empirical data for analyzing vertical niche partitioning (Whitmore, 1975; Devika & Bachan, 2021). The distribution of species across these strata reflects the successional maturity and the allocation of biomass and functional roles along the vertical gradient. For example, the presence of multiple ET species (*Cullenia exarillata*, *Macaranga peltata*, *Elaeocarpus tuberculatus*, *Dipterocarpus indicus*) in the Medium Elevation Wet Evergreen cluster signifies a structurally stable, climax community where light is the primary limiting resource, driving specialised shade-tolerant strata in the lower MT and ST classes (*Schleichera oleosa*, *Syzygium laetum*, *Meiogyne pannosa*). This structural partitioning is a core, quantifiable expression of the Eltonian niche.

### 5.4.3. Biogeographic and Ecological Significance of Community Differentiation

The clustering based on  $\geq 95\%$  species dissimilarity facilitates a nuanced discussion of the ecological and biogeographic drivers shaping specific community groups:

#### **The Montane Grassland–Shola Complex: Ecotonal Dynamics**

In the montane systems, the strong association between the dwarf, endemic shrub *Strobilanthes kunthiana* and the high-altitude grasslands represents a specialised community governed by recurrent frost and fire disturbances (Joshi & Gadgil, 1991; Thomas & Palmer, 2007). This contrasts sharply with the adjacent Montane Shola Forest, a Tropical Cloud Forest characterised by dense, microphyllous-leaved trees like *Syzygium densiflorum*, *Litsea wightiana*, *Rhododendron arboretum*, and *Beilschmiedia wightii*. The strong floristic boundaries observed are consistent with the hypothesis that community structure in shola grassland mosaics is mediated by light availability and fire history (Mohandass & Davidar, 2010; Arasumani et al., 2018).

#### **Unraveling the Montane and Sub Montane Shola Zonation**

Crucially, this study achieved a clear differentiation of the Montane Shola Forest from the Sub-montane shola Guilds a distinction that has historically been obscured by overlapping altitudinal definitions and generalised classifications in previous Western Ghats studies (Ranganathan, 1938; Meher-Homji, 1967). The present study differentiated these communities based on unique plant community composition (Eltonian) and bioclimatic factors (Grinnellian).

The Sub-montane shola represents a distinct cloud forest formation at slightly lower elevations, which itself is geographically segmented. The Southern Guild with focal species *Syzygium parameswaranii* is characterised by species such as *Vernonia travancorica*, *Cinnamomum wightii*, and *Elaeocarpus munroi*, suggesting a local assemblage defined by specific soil or moisture characteristics that promote the endemism of its defining species.

Whereas the Northern Guild with the focal species *Syzygium palghatense* is defined by dominant ET species like *Heritiera papilio* and a distinct set of associates including *Cassine albens*, *Eugenia indica*, and *Phoebe wightii*. This clear segmentation provides empirical evidence of biogeographic segmentation within the Western Ghats, suggesting that localised environmental barriers or historical isolation have promoted vicariance,

leading to the evolution of distinct ecological guilds at the subspecies or species level (Das et al., 2016).

### **Differentiation of Specialised Low-Elevation Habitats**

The analysis also provided a significant refinement of the low-elevation forest classification:

**Low Elevation Wet Evergreen:** This cluster is structurally defined by large climax species such as *Tetrameles nudiflora*, *Dipterocarpus indicus*, *Hopea parviflora*, and *Calophyllum polyanthum* in the ET class, and LT species including *Vateria indica* and *Diospyros crumenata*. These forests represent climax evergreen conditions with stable canopy interactions.

**Low Elevation Riparian Evergreen:** This community is distinctly separated, exhibiting a high species turnover yet maintaining key indicators such as *Hopea ponga*, *Calophyllum calaba*, *Terminalia arjuna*, and the defining abundance of *Garcinia wightii*, *Humboldtia vahliana*, *Aporosa bourdillonii* and *Syzygium occidentale*. The uniqueness of this cluster, often maintained in the context of sacred groves, suggests a community assembly influenced by frequent fluvial disturbance regimes and specialised hydrological conditions, highlighting the dual role of environmental heterogeneity and local cultural protection in maintaining its high dissimilarity (Bachan, 2010; Naskar & Mandal, 1999).

**Low Elevation Coastal Evergreen:** This cluster, characterised by species adapted to wind, higher light intensity, and often modified habitats, features *Prioria pinnata*, *Ficus benghalensis*, *Albizia odoratissima*, and the coastal specialist *Ochna gamblei*. The high Bray-Curtis dissimilarity within this cluster suggests dynamic structuring influenced by salinity gradients and proximity effects, reinforcing that environmental heterogeneity coupled with biotic feedbacks drives strong community differentiation even across short spatial scales.

#### **5.4.4. The Niche Profile: Empirical Evidence for the Functional Interaction Space**

The integration of IVI and Height Class data into the Niche profile provided the final, powerful step, moving the analysis into the spatial and functional domain of the Eltonian niche. The Niche profile, visualised here as a two-dimensional spatial plan, serves not merely as a descriptive figure, but as a hypothesis-generating tool for understanding how the most dominant species occupy and define their functional spaces. Unlike traditional niche models that often rely solely on Grinnellian (abiotic) variables (Soberón & Peterson,

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2005), the profile provides empirical evidence of interaction-based habitat differentiation (Dormann et al., 2012).

The final methodological step, the construction of the Niche profile from quantitative phytosociological data represents a crucial methodological pivot toward an Eltonian-niche perspective (Weber et al., 2017; Bachan & Devika, 2022). While the Grinnellian niche addresses abiotic requirements, this profile emphasises a species' functional role and impact within the realised interaction space. This modelling approach achieves its goal by spatially depicting each species, integrating its measured density, basal area, and Importance Value Index (IVI) within its specific Height Class (ET to VST), thereby providing a unique, consolidated representation of its realised ecological role (Bachan & Devika, 2022). The resulting spatial distribution of species with respect to others in its habitat is a direct reflection of total species interaction. For instance, the profile visually places structural dominants like *Dipterocarpus indicus* in relation to the recruitment pool of VST species (e.g., *Goniothalamus wightii*), illuminating potential facilitative or competitive relationships that maintain ecological balance and coexistence (Ashton, 2014; Bachan & Devika, 2022).

By synthesizing vertical structure with dominance, the profile provides a comprehensive, ecologically realistic spatial map of the community's assembly rules. The clear stratification of species, especially the co-occurrence patterns observed between emergent canopy species like *Persea macrantha* and shade-tolerant understory specialists such as *Cryptocarya lawsonii* in the Medium Elevation forests, effectively highlights resource partitioning and microhabitat specialization, which are critical, measurable aspects of Eltonian niche structuring (Chittibabu & Parthasarathy, 2000). The Niche profiling is, therefore, designated as an empirical reflection of the Eltonian Niche, effectively covering the limitations of purely Grinnellian niche modelling (Weber et al., 2017; Bachan & Devika, 2022).

#### **5.4.5. Conservation and Management Implications**

From a conservation standpoint, the high Bray-Curtis dissimilarity (0.95–1.0) provides a robust, functional framework for prioritizing restoration and monitoring efforts. Recognizing that this dissimilarity denotes distinct ecological assemblages, each of the ten vegetation types, particularly the two shola guilds and the highly specialised Riparian Evergreen, must be treated as a separate, non-substitutable management unit (Faith, 2002).

The functional importance of the 25 threatened and endemic focal species underscores their integral role in community stability. Their co-occurrence patterns illuminate potential facilitative or competitive relationships that maintain ecological balance. For example, the persistence of species like *Hydnocarpus pentandrus* across multiple low-elevation zones suggests the need for management strategies that protect both its riparian and general wet evergreen microhabitats.

Ultimately, the floristic stratification and the captured Eltonian niche dimensions enhance the predictive accuracy of conservation planning by moving beyond broad environmental correlates. Maintaining interaction networks such as pollination, seed dispersal, and mycorrhizal associations is essential for sustaining these communities (Harrison et al., 2020). The identified clusters represent empirical evidence of interaction-based habitat differentiation, which can be incorporated into ecorestoration planning to improve site-species matching and ensure the long-term resilience of the Western Ghats' unique biodiversity.

## **5.6. Summary**

This chapter presented a rigorous multivariate statistical analysis of floristic data from 126 plots to quantify and interpret the complex community structure within the Western Ghats, a global biodiversity hotspot. The methodological framework employed the Bray-Curtis dissimilarity index for community delineation, supplemented by the Importance Value Index (IVI) and Height Class distribution analysis for structural characterization, culminating in the visualization of the Niche profile. The cluster analysis yielded a fundamental finding: the regional  $\gamma$ -diversity is partitioned into ten distinct vegetation compositions, ranging across the elevational gradient from Montane Grassland and Shola Forests to various Wet Evergreen, Riparian, and Coastal associations. A critical result was the documentation of extreme  $\beta$ -diversity, with species dissimilarity consistently ranging from 0.95 to 1.0. This high dissimilarity confirms that these communities are non-substitutable ecological assemblages, structured by strong environmental and historical filters, and necessitates their treatment as separate conservation units.

The analysis provided crucial biogeographic resolution, achieving a clear differentiation of the Montane Shola Forest from the Sub-montane shola guilds (Southern and Northern), a distinction previously ambiguous in the literature. This segregation, defined by unique endemic species like *Syzygium parameswaranii* and *Syzygium palghatense*, provides

empirical evidence of regional vicariance and fine-scale ecological steering. Furthermore, the analysis successfully segregated highly specialised microhabitats, including the Low Elevation Riparian Evergreen and Coastal Evergreen forests, from the adjacent general Low Elevation Evergreen matrix.

A primary theoretical contribution was the successful application of the framework to elucidate the Eltonian Niche. The Niche profile by integrating IVI (ecological dominance) and Height Class (vertical structure) provides an empirical and spatial representation of a species' functional role and competitive impact, moving beyond the Grinnellian niche concept. The co-occurrence patterns of 25 threatened and endemic focal species (e.g., *Dipterocarpus indicus*, *Elaeocarpus recurvatus*) within these distinct structural contexts highlight the critical role of niche complementarity in maintaining the species-richness of this ecosystem. The high dissimilarity and structural uniqueness of the ten identified communities underscore that preserving the integrity of the threatened species' interaction networks is paramount for sustaining the unique floristic heritage of the Western Ghats.



## Chapter 6

Niche Specificity and Niche Overlap of Selected Threatened  
Angiosperms

## **Chapter 6**

### **Niche Specificity and Niche Overlap of Selected Threatened Angiosperms**

#### **6.1. Introduction**

Understanding the ecological niches of species that are at risk of extinction represents a critical step in biodiversity conservation, especially in regions of significant biodiversity such as the Western Ghats of India. The definition of the ecological niche encompasses the spectrum of environmental parameters and biological interactions essential for a species to thrive, reproduce, and sustain populations over time (Hutchinson, 1957). Within this conceptual framework, niche specificity pertains to the extent to which a species is confined to a limited array of environmental conditions or habitats, whereas niche overlap denotes the degree to which various species share analogous ecological needs and distributions (Pianka, 1974).

The Western Ghats biodiversity hotspot, recognised possess an extraordinary degree of plant endemism, with more than 1,500 species of flowering plants identified as endemic (Myers et al., 2000; Nayar et al., 2014). Nevertheless, the area faces escalating threats from habitat fragmentation, climate change, alterations in land use, and the introduction of invasive species, all of which exacerbate the decline of species with narrow distributions and ecological specializations (Das et al., 2006; Sharma, 2017; Shigwan et al., 2020; Warriar et al., 2020; Sakkamuthu et al., 2024). In such scenarios, it is vital to identify species exhibiting high niche specificity, as these organisms are frequently the most susceptible to extinction owing to their constrained adaptive capacity and limited geographic distributions (Slatyer et al., 2013). Despite extensive research, a clear understanding of niche specificity and overlap remains elusive due to conceptual ambiguities and methodological challenges. The problem lies in reconciling different niche definitions Grinnellian, Eltonian, and Hutchinsonian and their operationalization in empirical studies (Leibold, 1995; Gallopin, 1989). Moreover, the quantification of niche overlap varies widely, with competing metrics yielding divergent interpretations of species interactions and coexistence potential (Spaak et al., 2022; Ganis, 1991; Langthaler et al., 2024).

The extent of niche overlap among species is frequently employed as an indicator of the strength of interspecific interactions, particularly in the context of competition (Pianka, 1974). In accordance with the competitive exclusion principle (Hardin, 1960), species that occupy identical ecological niches are unable to coexist perpetually. Nonetheless, ecological communities commonly manifest high species richness, which suggests either minimal niche overlap or the presence of mechanisms such as niche partitioning, temporal segregation, or facilitative interactions that permit coexistence (MacArthur & Levins, 1967; Chesson, 2000). An array of quantitative methodologies has been devised to assess niche overlap. Pianka's index (1973) continues to be one of the most extensively utilised metrics, grounded in data concerning resource utilization or habitat occupancy. Alternative methodologies, including Schoener's D (Schoener, 1970) and Morisita's overlap index, have also been utilised, particularly in investigations employing dietary, spatial, or temporal resource utilization data (Krebs, 1999). With the emergence of species distribution modelling (SDM), niche overlap can now be quantified within environmental space through the utilization of presence-only or presence-absence data (Broennimann et al., 2012). Ecological niche models (ENMs), such as MaxEnt (Phillips et al., 2006), empower researchers to project the niches of species onto geographical landscapes, thereby facilitating comparisons among species or populations and predicting potential competitive interactions.

Investigations into niche overlap are particularly valuable within the field of conservation biology for the identification of species that are at risk due to competitive displacement, habitat degradation, or alterations induced by climate change (Warren et al., 2008). For threatened and endemic taxa, particularly within biodiversity hotspots such as the Western Ghats, assessments of niche overlap are instrumental in elucidating species-specific habitat requirements, forecasting the repercussions of invasive species, and informing restoration initiatives (Guisan & Thuiller, 2005; Elith & Leathwick, 2009). In the Indian context, studies on niche overlap have been applied to taxa such as birds (Chatterjee, 2020; Kumar et al., 2020), and plants (Bisht, 1993; Pandey et al., 1999; Anthwal et al., 2008; Athamanakath et al., 2024) to elucidate niche segregation and distributional limitations. Recent investigations advocate for the incorporation of functional traits, phylogenetic affiliations, and intraspecific variability into niche models to yield more mechanistic interpretations of niche overlap (Violle et al., 2007; Kraft et al., 2015; Wang et al., 2025). Moreover, the integration of SDMs with dynamic models that account for dispersal,



demographic factors, and landscape connectivity is increasingly recommended to enhance predictive efficacy in the face of global change scenarios (Thuiller et al., 2014, 2015). Prior investigations have emphasised the importance of niche-based methodologies in conservation biology, particularly for evaluating extinction risk, identifying critical habitats, and guiding ecological restoration efforts (Thuiller et al., 2005; Raxworthy et al., 2007; Broennimann et al., 2012). Crucially, such detailed analyses are notably lacking for the endemic and threatened flora of the Western Ghats. This chapter addresses this gap by examining the niche specificity and overlap among 25 threatened angiosperm species endemic to the region. Endemic species often exhibit greater niche specificity compared to generalist and widespread taxa. Furthermore, tree species form important lifeforms that determine the microclimate within forest ecosystems, especially in Tropical Moist Forest formations. The unique assemblage and structural profile of different tree species determine the variations within the tropical rainforest and differentiate distinct vegetation types, subtypes, and guilds across the Western Ghats. Some species, particularly endemics, act as known indicators of these specific forest types, while others may indicate distinct guilds within the same forest type, a relationship that needs formal establishment. In this context, understanding the niche specificity and overlap among our sample of 25 endemic and threatened taxa, including 22 tree species, one shrub, and two epiphytes representing major tropical and montane evergreen forest types, has the potential to yield diverse and significant inferences. Therefore, these 25 taxa, representing a diverse range of unique habitats and vegetation types, were carefully selected to facilitate this investigation.

For instance, *Strobilanthes kunthiana* represents the montane grassland, while *Medinilla anamalayana* and *Impatiens parasitica* are montane and sub-montane epiphytes. The remaining 22 species are trees representing various major tropical Moist Forest types across different elevations of the Western Ghats. This careful selection provides a unique opportunity to investigate three key questions: i. Is the observed niche overlap and specificity of these species determined by bioclimatic factors (Grinnellian niche)? ii. Do the determined niche overlap and specificity patterns correspond to the major known vegetation types, sub types or guilds and are they corroborated by species composition? iii. Are the unique niches, represented by single or multiple species, differentiated primarily by bioclimatic or species interaction factors, or by a combination of both? iv. Is there any particular pattern for the niche overlap and specificity of endemic and threatened

species with respect to their differential population size, distribution, elevation, and bioclimatic ranges?

## **6.2. Methodology**

To evaluate the extent of ecological congruence among the selected endangered angiosperms of the Western Ghats, pairwise niche overlap analyses were executed utilizing two complementary indices: Hellinger's I and Schoener's D (Hellinger, 1909; Schoener, 1970; Warren et al., 2008). These indices serve to quantify the degree of similarity between species' ecological niche models within environmental space, thereby elucidating aspects of niche conservatism, potential interspecific competition, and habitat co-occurrence.

### **6.2.1. Calculation of Pairwise Niche Overlap**

The ENM Tools and *ecospat* packages within the R programming environment (Broennimann et al., 2012; Warren et al., 2010) were employed to ascertain niche overlap between species pairs. The outputs generated from the MaxEnt models were transformed into normalised suitability grids, and pairwise comparisons were executed utilizing:

#### **Niche Overlap Calculation (Schoener's D & Hellinger's I)**

This part of the R script calculates two widely used niche overlap indices, Schoener's D and Hellinger's I. Both indices range from 0 (no overlap) to 1 (complete overlap) and provide a quantitative measure of how similar the predicted distributions of species are in geographic or environmental space.

**Schoener's D:** This index is highly sensitive to the spatial overlap of high-suitability areas. A high D-value suggests that the two species not only share geographic space but also that the areas with the highest predicted habitat suitability for one species are also highly suitable for the other. It is a common metric in niche modelling and is straightforward to interpret (Schoener, 1968; Schoener, 1970; Warren et al., 2008).

**Hellinger's I:** Based on Hellinger's distance, this index is a true metric that measures the proportional similarity of the suitability distributions. It is less sensitive to small areas of high suitability and provides a more balanced assessment of overall niche similarity across the entire environmental gradient. A high I-value indicates that the species' suitability maps are proportionally very similar, meaning they share not only suitable areas but also the relative quality of those areas (Hellinger, 1909).

Pairwise comparisons were performed for all possible species combinations ( $n = 25$ ), resulting in a total of 300 unique species pairs. The *ecospat.niche.overlap* function in the *ecospat package* R was used to compute both indices for each pair using the PCA-env approach, which reduces multicollinearity among variables and allows comparisons in a standardised environmental space. The R script creates two separate matrices (*overlap\_D\_matrix* and *overlap\_I\_matrix*) to store the results, allowing for a side-by-side comparison of the two metrics. The resultant overlap matrices were visualised through *heatmaps* and *clustered dendrograms* to discern species exhibiting elevated niche similarity or segregation patterns. Based on common ecological practice, these are the general ranges used to describe the degree of niche overlap:

**High Overlap:**

Schoener's  $D > 0.6$

Hellinger's  $I > 0.7$

Values in this range suggest a very strong similarity between the two species' niches.

**Moderate Overlap:**

Schoener's  $D$  between 0.2 and 0.6

Hellinger's  $I$  between 0.5 and 0.7

This indicates that the species share a significant portion of their niches, but there are clear differences.

**Low Overlap:**

Schoener's  $D < 0.2$

Hellinger's  $I < 0.5$

Values in this range show that the species' environmental niches are largely distinct (Warren et al., 2010, 2019; Brown et al., 2019; Zhang et al., 2022).

**6.2.2. Visualization with Heatmaps**

The script then uses *ggplot2* to visualise these overlap matrices as heatmaps. This is a crucial step for making sense of the large amount of data (25x25 matrices). The heatmaps use a color gradient (blue-white-red) to represent the level of overlap, with hotter colors (red) indicating higher overlap and cooler colors (blue) indicating lower overlap. This visual representation allows quickly identify clusters of high niche similarity (red squares)

and pairs with highly distinct niches (blue squares). The labels on the axes and within the tiles allow for easy identification of which species pairs have the highest or lowest overlap. This makes it simple to pick out pairs for further ecological investigation.

### **6.2.3. Statistical Significance Test (Null Model)**

The statistical significance test is essential for the validation of the model and its suitability to the selected species. In the R package this is the most critical part of the script, as it adds a layer of statistical rigor to the raw overlap values. A raw overlap value (e.g.,  $D = 0.6$ ) doesn't tell if that overlap is ecologically meaningful or simply what expect by random chance. All statistical analysis were conducted in R programme using the scripts developed by Broennimann et al. (2012), which are currently accessible within the 'ecospat' R package (Di Cola et al., 2017). The *ecospat.niche.overlap* function tests the null hypothesis that the observed niche overlap is not greater than what would be expected from a random distribution of species. The script uses *nreps\_null\_model* (e.g., 99) to run null models. It shuffles or randomises the species' occurrences within the study area and then calculates the overlap for each randomised pair. This process generates a null distribution of overlap values. The p-value is calculated by comparing the observed Schoener's D value to this null distribution. A low p-value (e.g.,  $< 0.05$ ) means that the observed overlap is statistically significant, falling outside the range of what would be expected by chance. This gives a strong evidence that the shared niche is a real ecological phenomenon. Conversely, a high p-value means the overlap could have occurred randomly, and its ecological significance is questionable (Zaret et al., 1984; Rödger, 2011).

## **6.3. Results**

### **6.3.1. High Niche Overlap: Evidence of Shared Niches**

The results indicate several species pairs show very high Schoener's D values (typically above 0.700), indicating a strong overlap in their environmental niches. These species are likely to co-occur and thrive under very similar bioclimatic conditions, such as temperature, rainfall, and elevation (Appendix IV).

Top Overlap Pairs: The highest overlaps are observed between:

*Dipterocarpus indicus* and *Meiogyne pannosa* ( $D = 0.766$ )

*Syzygium parameswaranii* and *Syzygium sahyadricum* ( $D = 0.754$ )

*Elaeocarpus recurvatus* and *Syzygium sahyadricum* ( $D = 0.723$ )

*Ficus beddomei* and *Meiogyne pannosa* ( $D = 0.725$ )

*Cryptocarya anamalayana* and *Syzygium palghatense* ( $D = 0.717$ )

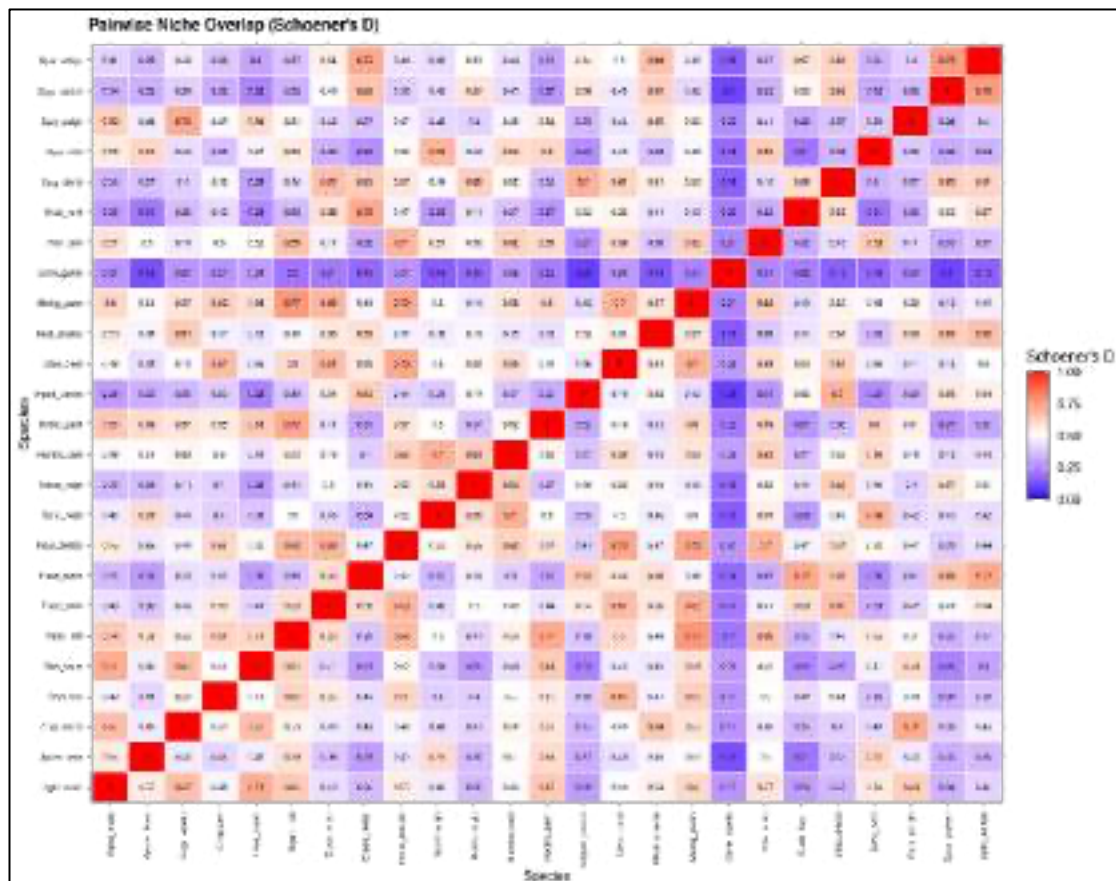


**Fig. 6.1. Pairwise niche overlap (Schoener's D)**

This high degree of niche sharing is particularly notable within the *Syzygium* and *Elaeocarpus* genera. The high overlap between these species and others from different genera (e.g., *Cryptocarya*, *Meiogyne*) suggests that their ecological requirements are driven by a similar set of broad-scale environmental factors, rather than just their taxonomic relatedness (Fig. 6.1).

### 6.3.2. Low Niche Overlap: Niche Differentiation and Specialization

In contrast, many species pairs have very low Schoener's D values (below 0.250), pointing to significant niche differentiation. This suggests these species are adapted to distinctly different environmental conditions and are unlikely to co-occur in the same habitat patches (Appendix IV).

Most Distinct Niches: The lowest overlap values are seen in the following pairs:

*Ochna gamblei* and *Impatiens parasitica* ( $D = 0.089$ )

*Ochna gamblei* and *Syzygium parameswaranii* ( $D = 0.101$ )

*Ochna gamblei* and *Aporosa bourdillonii* ( $D = 0.123$ )

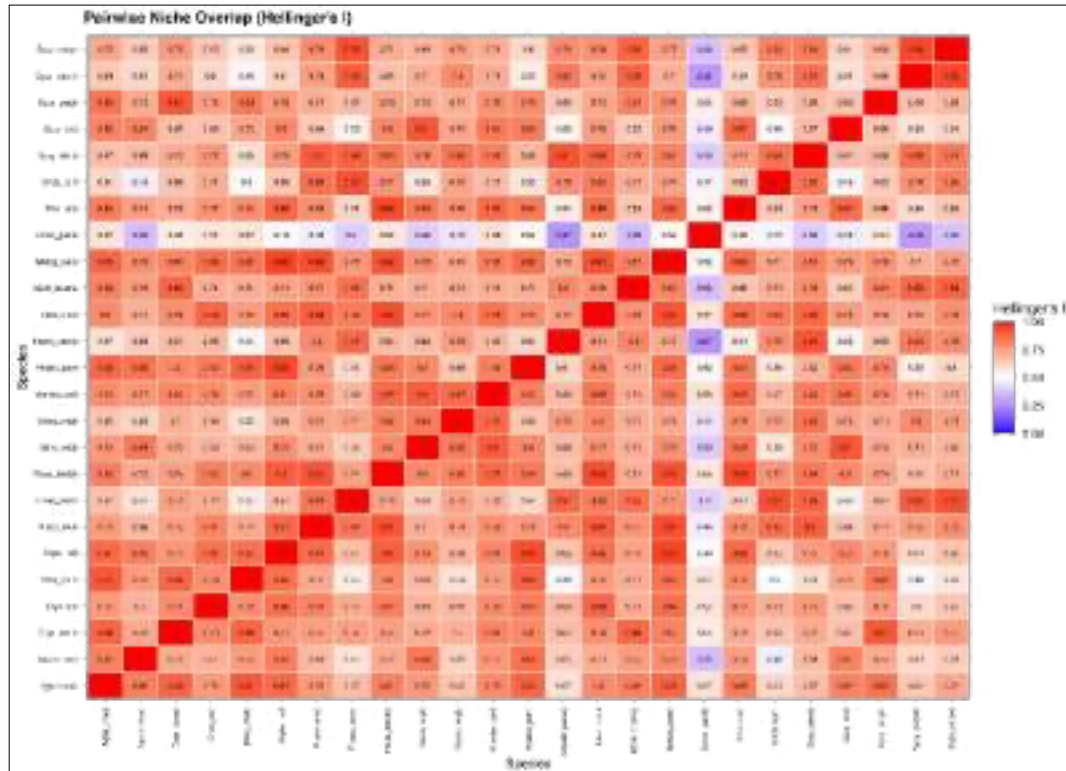


**Fig. 6.2. Pairwise niche overlap (Hellinger's I)**

The consistently low overlap values for *Ochna gamblei* and *Impatiens parasitica* suggest that these are ecological specialists. Their niches are likely defined by very specific conditions that are not widely shared by the other species in the analysis. This corroborates the initial hypothesis that species with unique habitat affiliations, such as the montane grassland specialist *Strobilanthes kunthiana* or the epiphyte *Impatiens parasitica*, would exhibit low niche overlap with the generalist tree species (Fig. 6.2).

### 6.3.3. High Niche Overlap: A General Trend

The majority of values in the matrix are above 0.700, indicating a widespread pattern of ecological similarity. This suggests that most of these endemic species are fundamentally adapted to the same broad bioclimatic zone of the Western Ghats, with their individual distribution differences likely driven by micro-environmental factors or historical events.



Top Overlap Pairs: The highest values highlight species that are almost interchangeable from a probabilistic niche perspective.

*Syzygium parameswaranii* and *Syzygium sahyadricum* (I = 0.935)

*Elaeocarpus recurvatus* and *Syzygium sahyadricum* (I = 0.920)

*Impatiens parasitica* and *Syzygium densiflorum* (I = 0.913)

*Meiogyne pannosa* and *Dipterocarpus indicus* (I = 0.946)

These results confirm the strong ecological relationships initially identified by Schoener's D but show even higher values with Hellinger's I, reinforcing the conclusion that these species pairs occupy very similar ecological spaces. In the case of *Syzygium sahyadricum*, it shares a significant niche overlap with other montane shola species, such as *Elaeocarpus recurvatus*, and with the sub-montane shola species *Syzygium parameswaranii*. This indicates that *Syzygium sahyadricum* possesses a broader niche within the Montane and Sub-montane Shola bioclimate. Importantly, these specific montane taxa show less niche overlap with all other species representing the medium and low elevation forests. Furthermore, the high niche overlap observed between the epiphyte and the montane shola species *Syzygium densiflorum* strongly suggests its specificity as a cloud forest epiphyte. The high niche overlap of the medium elevation evergreen epiphyte *Medinilla anamalayana* with sub montane and medium elevation species (such as *Cryptocarya anamalayana*) and the low niche overlap with the low elevation tree *Dipterocarpus indicus* clearly differentiate the niches of the two epiphyte groups. The high overlap between species from different genera (e.g., *Meiogyne pannosa* and *Dipterocarpus indicus*) is a particularly important finding, as it points to the existence of ecological guilds that are not strictly based on taxonomic relationships. Conversely, the consistently low niche overlap values, especially for *Ochna gamblei*, are a powerful indicator of a highly specialised niche. Even with a more forgiving metric like Hellinger's I, this species shows minimal overlap with the others, suggesting it is a true habitat specialist that persists in environmental conditions fundamentally different from the majority of the species included in the study.

#### **6.4. Discussion**

The MANOVA of the bioclimatic factors indicated that the four major vegetation groups high elevation, medium elevation, low elevation, and low elevation riparian are clearly delineated by these factors. The species dissimilarity index further corroborated this,

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showing a 90-100% dissimilarity within these major vegetation types. This dual delineation, based on both Grinnellian (environmental) niche and Eltonian (species composition and interaction) niche, establishes that these vegetation types are ecologically distinct. Consequently, the methodology of using niche modelling for the prediction of species distributions is well-justified for representative species from these major vegetation types. The analysis of niche overlap in this chapter, using Schoener's D and Hellinger's I indices, further corroborates these findings. It provides a more detailed insight into the specific level at which Grinnellian and Eltonian factors define the niches of species within the montane and tropical biomes of the Western Ghats.

#### **6.4.1. Niche Specificity and Overlap Based on the Eltonian Factors (Species composition)**

The analysis of species composition using the Bray-Curtis dissimilarity index yielded results that strongly align with the bioclimatic delineation of major vegetation groups. The index showed a high degree of dissimilarity (0.95-1.0) among high-elevation, medium-elevation, low-elevation, and low-elevation riparian zones. This finding is identical to the patterns identified by the bioclimatic factors, reinforcing the conclusion that the Grinnellian niche plays a primary role in structuring the major vegetation types in the region.

##### **(a) The High Elevation Species**

A comprehensive analysis of niche overlap, employing both the Schoener's D and Hellinger's I indices, revealed a robust pattern of high niche similarity between *Strobilanthes kunthiana* (indicator species of the Montane Grassland) and a select group of high-elevation species (Montane Shola Forest). The most pronounced overlap was observed with *Elaeocarpus recurvatus*, where a Schoener's D value of 0.723 and a Hellinger's I value of 0.917 demonstrate a strong alignment in their fundamental ecological niches. This finding suggests a high degree of co-adaptation to the specific bioclimatic conditions of the montane shola-grassland ecosystem. Furthermore, a broader cluster of species, including *Syzygium densiflorum* and *Syzygium sahyadricum*, also exhibited significant niche sharing, with Hellinger's I values consistently exceeding 0.800, which points to a shared probabilistic distribution across the high-elevation landscape. The high overlap values among these species support the hypothesis that they form a core ecological guild, occupying similar environmental spaces within the Western Ghats. A high degree

of shared niche space (niche overlap) in ecological guilds, particularly those in stable environments, can be interpreted as indicative of a broad, generalist community where inter-specific competition is equal in strength to intra-specific competition (Higgins et al., 2024). This significant niche overlap is defined by the Bioclimatic and topographical (Grinnellian Niche factors) considered in the analysis. Hence the niche specificity of these species guilds can be explained further by the species composition or interaction (Eltonian niche) factors. It is wide evident that the Montane grasslands, represented with *Strobilanthes kunthiana* and the Shola forest represented with others has 100% dissimilarity in species composition (Dissimilarity index value =1).

#### **(b) Niche Overlap Analysis of High-Elevation Montane Shola Forest Species**

The combined analysis of niche overlap between the two high-elevation subgroups based on environmental factors reveals a compelling pattern of strong ecological interconnectedness rather than distinct partitioning. The findings suggest that these species form a single, cohesive ecological guild, highly adapted to the unique conditions of the shola forest ecosystem.

Subgroup 1: *Elaeocarpus recurvatus*, *Syzygium densiflorum*, and *Syzygium sahyadricum*

Subgroup 2: *Elaeocarpus munroi*, *Impatiens parasitica*, and *Syzygium parameswaranii*

The Schoener's D and Hellinger's I matrices consistently show that the overlap values between species in these two subgroups are uniformly high, indicating a lack of significant niche specificity. The Schoener's D values range from a lowest of 0.589 (between *Elaeocarpus recurvatus* and *Elaeocarpus munroi*) to an exceptionally high 0.935 (between *Syzygium sahyadricum* and *Syzygium parameswaranii*). The Hellinger's I values reinforce this conclusion, ranging from 0.788 to 0.935. This consistently high overlap challenges the notion that these subgroups occupy discrete ecological spaces.

#### ***Niche Delineation in High-Elevation Species: Grinnellian vs. Eltonian Factors***

The analysis of high-elevation species reveals a compelling divergence in niche delineation when viewed through the lens of Grinnellian and Eltonian factors. While Grinnellian niche models indicate a broad, unified high-elevation niche, species dissimilarity analyses based on Eltonian factors unveil finer-scale partitioning into distinct ecological clusters. The theoretical distinction between a species' requirement niche (abiotic/Grinnellian factors) and its impact niche (functional/Eltonian factors) is a cornerstone of modern niche synthesis (Leibold, 1995).

***Grinnellian Niche: A Unified High-Elevation Niche***

The niche overlap results, derived from bioclimatic factors, support the existence of a single core high-elevation niche to which all species are well-adapted. This suggests that at a broad scale, environmental variables such as high rainfall, persistent cloud cover, and specific temperature regimes drive the presence of all high-elevation species. The generalist nature of this shared Grinnellian niche provides the foundational environmental space for these species to thrive.

***Eltonian Niche: Finer-Scale Partitioning***

In contrast, species dissimilarity clustering based on field plot data indicates a more complex community structure, revealing two distinct clusters among the high-elevation species with a dissimilarity index of 0.92. This finding points to significant ecological segregation not captured by broad-scale environmental variables alone. All high-elevation species, with the notable exception of *Syzygium parameswaranii*, form a unique cluster, reinforcing their identity as a cohesive ecological unit.

The shola forest species are further represented by two distinct guilds with a dissimilarity value of 0.85: **The True Shola Forest Guild:** Composed of *Elaeocarpus recurvatus*, *Syzygium sahyadricum*, *Syzygium densiflorum*, and *Elaeocarpus munroi*. **A Transitional Guild:** Characterised by a composition of *Elaeocarpus munroi* and *Impatiens parasitica*, this guild represents a transition zone between shola forests and wet evergreen hill forests. statistical tools such as hypervolume estimation, facilitating more accurate quantification of niche breadth and overlap (Blonder, 2018).

The Grinnellian and Eltonian factors particularly separate the niche of *Syzygium parameswaranii* from all other shola species, as evidenced by a species dissimilarity index of 0.92, and from sub-montane species with a dissimilarity index of 0.95. This pronounced niche segregation can be attributed to the species' unique distribution, which extends across the southern extreme of the Western Ghats and down to lower elevations (1200m to 1800m), but only in hilltops exposed to clouds, mists, and winds. This suggests that the species composition including *Syzygium parameswaranii* can be considered a distinct sub-montane shola forest formation, commonly observed in landscapes like the Periyar-Agasthyamala range. While all these guilds and clusters are driven by the overarching climatic conditions of the upper montane zones, the species dissimilarity data reveals that Eltonian factors, likely including competitive interactions and species-specific dispersal

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patterns, play a crucial role in shaping the finer-scale community composition and creating the distinct guilds observed in the field.

### **(c) Niche Overlap and Specificity of Medium-Elevation Species**

#### **Niche of *Syzygium palghatense* – the Sub montane Shola Forest Species**

##### **The Grinnellian Factor**

While the overall pattern in the Grinnellian niche overlap points to extensive niche sharing, a subtle degree of specificity can be observed in a few species. *Syzygium palghatense* and *Medinilla anamalaiana* show slightly lower niche overlap values with the central guild compared to the core-to-core species. For example, the Schoener's D value between *Syzygium palghatense* and *Ficus beddomei* is 0.597, and between *Medinilla anamalaiana* and *Cryptocarya lawsonii* is 0.697. These values, while still in the moderate-to-high range, are notably lower than the near-perfect overlaps seen elsewhere. This suggests that while these species are part of the broader medium-elevation community, they may occupy subtly different micro-habitats or have slightly distinct resource requirements that contribute to a minor degree of niche partitioning. Furthermore, the medium elevation specialist species *Cryptocarya lawsonii* shows maximum overlap with other medium elevation trees such as *Litsea oleoides* and the medium elevation small tree *Meiogyne pannosa*, but exhibits low overlap with all other species. Conversely, the medium elevation species *Aglaia malabarica* shows low overlap even with these medium elevation specialists, indicating that it possesses unique bioclimatic requirements differentiating its niche from the core medium-elevation guild.

##### **The Eltonian Factor**

The species dissimilarity analysis clustered the niche represented by the *Syzygium palghatense* a species known only from two submontane hill tops in the Palakkad district of Kerala at an elevation of 800-1000m, among the montane shola cluster but has remarkable difference with a dissimilarity value 0.96. This has confirmed the existence of niche of sub montane shola forest formation in the Western Ghats, among which the guilds are represented with *Syzygium palghatense* in the northern part of the Southern Western Ghats, which are dominated with trees such as *Heritiera papilio*. Whereas similar habitats in the extreme southern parts of the Western Ghats the sub-montane shola forests are represented with *Syzygium parameswaranii* and *Vernonia travancorica*. The analysis of niche overlap among the eight medium-elevation species reveals a dominant pattern of

strong ecological interconnectedness, with a relative absence of significant niche specificity. Rather than forming distinct, specialised guilds, these species collectively appear to constitute a broad, generalist-type community well-adapted to the transitional environmental conditions of their habitat.

A central group of species exhibits consistently high niche overlap, forming a broad, generalist core. The two *Cryptocarya* species, *C. anamalayana* and *C. lawsonii*, demonstrate a near-identical niche with exceptionally high overlap values (Schoener's  $D = 0.864$ , Hellinger's  $I = 0.865$ ). Similarly, *Ficus beddomei* acts as a central hub for this group, showing strong overlap with a range of species, including *Aglaia malabarica* ( $D = 0.812$ ,  $I = 0.887$ ) and *C. lawsonii* ( $D = 0.810$ ,  $I = 0.854$ ). This high degree of shared niche space among *Ficus beddomei*, *Aglaia malabarica*, *Goniothalamus wightii*, and the two *Cryptocarya* species suggests that they form a core ecological guild, sharing fundamental requirements for light, moisture, and temperature.

#### **(d) Niche Overlap and Specificity of Low-Elevation Species**

The Grinnellian analysis of niche overlap between the low-elevation evergreen and low-elevation riparian vegetation groups reveals a clear pattern of niche segregation, indicating a high degree of specialization between these two distinct habitats. This finding is in stark contrast to the interconnectedness observed in the high-elevation flora. The Eltonian factors also indicate clear difference in species compositions between the Medium elevation, low elevation and low elevation riparian vegetation groups with dissimilarity value 0.95.

#### ***Niche Specificity Between Subgroups***

The low-elevation evergreen and low-elevation riparian species show a pronounced lack of niche overlap, with consistently low values across all pairwise comparisons. This is particularly evident with *Ochna gamblei*, a species representing the evergreen group that shows exceptionally low overlap with all four riparian species. For instance, the Schoener's  $D$  and Hellinger's  $I$  values between *Ochna gamblei* and *Syzygium occidentale* are a mere 0.209 and 0.487, respectively. The species dissimilarity index indicated clear separation of the low elevation evergreen vegetation with low elevation riparian with high value (1.0). Similarly the low elevation coastal vegetation represented with *Ochna gamblei* and *Hydnocarpus pentandrus* also separated as different vegetating composition with high dissimilarity index (1.0). Among these the low elevation evergreen coastal vegetation



represented with the *Ochna gamblei* stood unique in species composition (dissimilarity index 0.95) with that represented with *Hydnocarpus pentandrus*. This is in concordant with other studies indicating difference in specie composition of coastal vegetation, especially in the sandy edaphic forms dominated with *Hopea ponga*, *Vateria indica*, *Calophyllum inophyllum* etc. This finding indicates that these three groups are adapted to fundamentally different environmental conditions, with the evergreen species likely thriving in moist, stable forest interiors, coastal areas with more sandy vegetation and the riparian species occupying more hydrologically dynamic habitats near water bodies.

#### **(e) Niche Overlap and Specificity of Low-Elevation Species**

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##### **(i) Niche Specificity Between Subgroups**

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##### **(ii) Niche Specificity Within Subgroups**

While the inter-group analysis highlights a strong divide, the intra-group analysis reveals a different dynamic.

#### **Low-Elevation Evergreen Group**

This group, represented by *Diospyros crumenata*, *Dipterocarpus indicus*, *Hydnocarpus pentandrus*, *Meiogyne pannosa*, *Ochna gamblei*, and *Prioria pinnata*, forms a cohesive generalist guild. With the notable exception of *Ochna gamblei* (which exhibits a high degree of specificity), the other species demonstrate high mutual overlap. For example, the

Schoener's D and Hellinger's I values between *Meiogyne pannosa* and *Dipterocarpus indicus* are exceptionally high (0.946 and 0.972), confirming a near-identical niche. This suggests that the core evergreen flora is broadly adapted to the common environmental envelope of the region's wet forests.

### **Low-Elevation Riparian Group**

This group, consisting of *Syzygium occidentale*, *Aporosa bourdillonii*, *Garcinia wightii*, and *Humboldtia vahliana*, also shows a high degree of internal niche overlap. These species form a specialised guild adapted to the unique conditions of riparian zones. For example, the overlap between *Aporosa bourdillonii* and *Humboldtia vahliana* is high (0.854 and 0.903), indicating a shared niche tied to specific water-related environmental factors. This internal cohesion contrasts sharply with their low overlap with the evergreen species.

The most pronounced finding is the strong niche specificity between the low-elevation evergreen and low-elevation riparian guilds. The evergreen species, including *Diospyros crumenata* and *Meiogyne pannosa*, form a cohesive guild adapted to the moist, stable conditions of the forest interior. In contrast, the riparian species, such as *Syzygium occidentale* and *Aporosa bourdillonii*, form a separate guild with a high degree of internal overlap, reflecting their shared adaptation to hydrologically active habitats. This clear niche segregation between the two groups underscores the importance of micro-habitat heterogeneity in driving speciation and biodiversity in low-elevation ecosystems.

### **(f) Niche Overlap and Specificity of the two Epiphytes**

*Impatiens parasitica*, a high-elevation epiphyte, shows very high overlap with other high-elevation species, confirming its role as a key member of that guild. For example, its overlap with *Syzygium densiflorum* is exceptionally high (Schoener's D = 0.771, Hellinger's I = 0.913). Similarly, *Medinilla anamalaiana* from the medium-elevation guild shows a strong overlap with its peers, such as *Goniothalamus wightii* (Schoener's D = 0.710, Hellinger's I = 0.710). Most significantly, the two epiphyte species themselves share a substantial niche, despite being from different general elevational categories. The overlap between *Impatiens parasitica* and *Medinilla anamalaiana* is high (Schoener's D = 0.611, Hellinger's I = 0.708). This strong connection suggests that their shared life form creates a unified "epiphyte niche" that transcends simple elevational stratification. The high degree

of overlap indicates a shared dependency on aerial environmental factors like humidity and light availability, which are likely more influential than ground-level conditions.

The niche analysis of the two epiphytic species, *Impatiens parasitica* and *Medinilla anamalaiana*, reveals a compelling dual pattern: strong niche sharing within their specialised guild, yet pronounced niche specificity against other vegetation types. This specificity is evidenced by their consistently low overlap values with low-elevation flora (e.g., *Impatiens parasitica* vs. *Ochna gamblei*, Schoener's  $D \approx 0.266$ ), confirming that the environmental conditions required by epiphytes are fundamentally distinct from terrestrial low-elevation species. This significant separation underscores the role of elevational, edaphic, habitat, and life-form-specific factors as critical constraints on species' geographic ranges. The most prominent limitations observed are elevational and climatic, confirming that each major vegetation group is adapted to a unique climatic envelope (e.g., *Syzygium sahyadricum* requires high-elevation cool moisture, while *Dipterocarpus indicus* is restricted to lower altitudes). Edaphic limitations are crucial for specialists like *Ochna gamblei*, which is strictly confined to coastal sandy conditions, creating a powerful distributional barrier. Furthermore, habitat and life-form limitations are demonstrated by the clear niche segregation between the evergreen forest (*Diospyros crumenata*) and riparian (*Aporosa bourdillonii*) guilds, and by the epiphytes' distribution being limited primarily by suitable host trees and canopy microclimates. Finally, topographical limitations are evident in the pronounced niche specificity of *Syzygium parameswaranii*, whose distribution is dictated by cloud- and wind-exposed hilltops, even at lower elevations. Thus, species distribution is tightly constrained by a combination of factors that define a unique realised niche for each threatened endemic taxon.

#### **6.4.2. Synthesis and Conservation Implications: Niche-Based Strategies for Western Ghats Flora**

This analysis moves beyond the traditional delineation of species distribution by broad elevational bands, demonstrating that the future persistence of the Western Ghats' endemic flora hinges on securing fine-scale micro bioclimatic regimes. The combined evidence from Grinnellian (bioclimatic) overlap and Eltonian (species composition) dissimilarity provides a crucial framework for refining extinction risk, prioritizing management actions, and guiding future eco-restoration efforts.

**(a) Refining Extinction Risk: The Niche Dichotomy**

The study establishes a fundamental ecological dichotomy among the threatened species that must be incorporated into conservation planning:

**Niche Specialists (High Intrinsic Risk):** Species with narrow, highly specific niches (e.g., *Ochna gamblei* in coastal sands, *Syzygium parameswaranii* on cloud-exposed hilltops) face an acute intrinsic vulnerability. Their reliance on unique, localised micro bioclimatic regimes means that even minor environmental shifts or localised disturbances (e.g., sand mining, temporary changes in cloud cover) can lead to rapid extinction. Their low niche overlap values (e.g.,  $D$  for *Ochna gamblei* is  $\sim 0.209$ ) serve as a quantitative indicator of their ecological fragility. Threatened species with small populations and limited geographic distributions are demonstrably less tolerant and more vulnerable to future climate change impacts compared to common species, validating their classification as high intrinsic risk taxa (Zhang et al., 2022).

**Niche Conserved Guilds (High Extrinsic Risk):** Species that exhibit high niche overlap (e.g., the Montane Shola guild, with  $D \approx 0.72$  between *Strobilanthes kunthiana* and *Elaeocarpus recurvatus*) show niche conservatism. Their shared, relatively broad Grinnellian niche suggests they are well-adapted to the general montane climate. However, their high vulnerability is driven by extrinsic, ecosystem-wide threats such as fragmentation, fire, and widespread habitat conversion, which compromise the structural integrity of the entire shared habitat (e.g., the Shola-Grassland complex). Where realised niche overlap between ecologically similar species is low, it often suggests that the restricted species is a refugee species confined to marginal or suboptimal habitats due to competitive exclusion or long-term disturbance, rather than inhabiting its optimal ecological space (Bleyhl et al., 2019).

**(b) The Imperative of Micro-Habitat Specific Conservation**

The findings emphatically underscore that generic protected area management is insufficient. The pronounced niche segregation driven by non-bioclimatic factors clearly shown by the high dissimilarity among low-elevation guilds demands specialised strategies: Climate-related risk assessments for endemic Western Ghats avifauna underscore that small-ranged species are exceptionally vulnerable and require the

proactive preservation of mid-altitude Wet Evergreen Forest patches to serve as indispensable climate refugia (Manna et al., 2024).

*Hydrological Management:* The clear niche segregation between the Low-Elevation Riparian guild (e.g., *Aporosa bourdillonii*) and the Low-Elevation Evergreen guild necessitates specific management of hydrologically dynamic habitats. Conservation plans must prioritise maintaining perennial water flow and bank stability to secure the unique riparian micro bioclimate.

*Edaphic and Topographical Protection:* Local endemic species confined to specific, small habitats, referred to as 'hot specks,' are defined by highly specific ecological niches and edaphic gradients, directly underscoring that these micro-scale environmental constraints drive the high intrinsic threat level observed (Trivedi & Bharchula, 2023). The strong specificity of species like *Ochna gamblei* confirms that the protection of edaphic (soil-based) micro-habitats and unique topographical features (e.g., wind-exposed ridges for *Syzygium parameswaranii*) is often more critical than protecting a broad area defined by elevation alone.

*Canopy and Host Protection:* The high niche sharing observed between the two epiphyte species (e.g., *Impatiens parasitica* and *Medinilla anamalaiana*) confirms that their persistence is tied to a specific canopy microclimate. Management must focus not just on the ground-level flora, but on maintaining the integrity and diversity of suitable host tree species and the vertical forest structure.

### **(c) Policy Integration and Defining Ecological Guilds**

This niche analysis offers objective evidence to enhance policy and restoration:

*Supplementing IUCN Criteria:* The low niche overlap values identified for highly restricted species (e.g.,  $D=0.597$  for *Syzygium palghatense*) provide a quantitative, niche-based rationale to support IUCN Red List assessments. This method can be used to robustly justify highly restricted Extent of Occurrence (EOO) and Area of Occupancy (AOO) values, particularly for neo-endemics where population data may be scarce, thereby ensuring their appropriate threatened status.

*Guiding Eco-Restoration:* The species dissimilarity analysis, based on Eltonian factors, formally defines the ecological guilds (e.g., True Shola Forest Guild, Transitional Guild, Riparian Guild). Future eco-restoration efforts must target the re-establishment of these defined, functionally coherent guilds, rather than simply replanting individual threatened species. Success in restoration is contingent upon recreating the complex, species-interaction-driven community structure.

The findings advocate for an urgent shift toward niche-specific conservation planning. By integrating bioclimatic and compositional data, this research provides the necessary spatial and ecological precision to secure climate refugia and ensure the long-term survival of the Western Ghats' unique and the niche overlap analysis, integrating bioclimatic and compositional data, provides a quantitative framework for transitioning conservation in the Western Ghats from generic management to niche-specific planning, which is vital for the future persistence of endemic flora. This approach's utility is demonstrated by its ability to differentiate species into two risk categories: High-Risk Niche Specialists (e.g., *Ochna gamblei*,  $D \approx 0.209$ ) are confirmed as habitat specialists reliant on unique micro bioclimatic regimes, necessitating specialised protection of micro-habitats and strict management of edaphic or hydrological stability.

Ecosystem-Dependent Niche Conserved Guilds (e.g., the Shola core guild,  $D \approx 0.72$ ) exhibit niche conservatism and require a landscape-scale functional approach to mitigate extrinsic, ecosystem-wide threats like fragmentation. Furthermore, the analysis facilitates effective eco-restoration by formally defining ecological guilds (e.g., Riparian Guild) and highlighting the need for biotic management, such as securing host tree diversity to maintain the unique canopy microclimate required by epiphytes. Critically, the data for these 25 threatened species establishes an invaluable baseline for comparative conservation planning across the wider region, providing objective niche metrics ( $D$  and  $I$  indices) that can be used to compare and categorise other data-deficient species, thereby lending quantitative support for stringent IUCN Red List classifications where high intrinsic vulnerability is indicated. The study provides the necessary spatial and ecological precision to align resource allocation strategically with the realised threats facing the Western Ghats' unique endemic and threatened flora.



### 6.5. Summary

This chapter utilised the integration of Grinnellian (bioclimatic) and Eltonian (compositional) niche modelling to define the realised niches of 25 threatened endemic species across the Western Ghats, thereby moving beyond macro-climatic generalizations. The analysis confirmed that while climate defines the broad elevational segregation of major forest types, the observed high endemic threat is fundamentally linked to ecological specialization driven by micro bioclimatic regimes. High-elevation species demonstrated a compelling divergence: a broad Grinnellian Unified Niche (high overlap) contrasted sharply with finer-scale Eltonian partitioning (high dissimilarity indices  $\geq 0.85$ ) into functional guilds, with topographical factors dictating specific clusters. Conversely, low-elevation species showed pronounced niche segregation driven by sub-habitat heterogeneity, evidenced by the absolute separation of the riparian and evergreen guilds, and the extreme specialization of taxa like *Ochna gamblei* ( $D \approx 0.209$ ), where edaphic factors function as the primary distributional filter. Furthermore, the high overlap observed among epiphytes (*Impatiens parasitica* and *Medinilla anamalaiana*) confirmed that life-form constraints and the canopy microclimate can supersede elevational boundaries as niche determinants.

This robust delineation allows for the strategic classification of the endemic flora into a Niche Dichotomy, where Niche Specialists (low overlap) face acute intrinsic vulnerability tied to securing microclimatic refugia, while Niche Conserved Guilds (high overlap) face extrinsic vulnerability linked to the degradation of the entire ecosystem structure. The quantitative metrics (Schoener's D and Hellinger's I) established herein constitute an essential baseline for comparative conservation, enabling the objective assessment of intrinsic threat for other data-deficient endemics across the region. In conclusion, the findings mandate an urgent shift toward niche-informed conservation planning, emphasizing the necessity of securing the functional integrity of specific micro-habitats and their defining biotic and abiotic parameters to ensure the long-term persistence of the Western Ghats' unique flora.



# Chapter 7

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Summary and Conclusion

## **Chapter 7**

### **Summary and Conclusion**

#### **7.1. Rationale**

The conservation of global biodiversity is predicated on robust, empirically grounded assessments, especially within high-endemism zones like the Western Ghats (Ceballos et al., 2015; Warrier et al., 2020). This doctoral research was fundamentally driven by the need to move beyond generalised conservation management by establishing a comprehensive, integrated niche framework for 25 threatened and endemic angiosperms in the Southern Western Ghats. The thesis aimed to overcome the limitations of single-criteria threat assessments and the inherent ambiguity in distinguishing between the Grinnellian Niche (abiotic potential and environmental suitability) and the Eltonian Niche (realised role defined by biotic interactions, resource competition, and community structure).

The overarching objective was to develop and validate a multi-criteria approach that integrates rigorous taxonomic, demographic, and ecological data to achieve three specific goals: Establish a definitive, contemporary population baseline for the endemic taxa, thereby filling critical data gaps. Accurately predict the realised distribution of these species by integrating structural (Eltonian) filters with bioclimatic (Grinnellian) models, leading to refined spatial planning. Provide a quantitative, niche-based rationale for refining extinction risk and prioritizing specialised micro-habitat management and restoration efforts. The core hypothesis guiding this research asserted that the integrated framework provides a superior, more comprehensive understanding of species partitioning and vulnerability than either single-niche model in isolation. The subsequent chapters systematically provided the necessary field-based data, computational modelling, and quantitative ecological metrics to validate this hypothesis, thereby transforming conservation strategy for this globally important hotspot.

#### **7.2. Critical Summary of Chapter Findings: An Integrated Perspective**

The thesis adopted a methodical, multi-tool approach, ensuring that each analytical chapter built upon the empirical foundation established by the preceding one. The synthesised findings are critical for a holistic understanding of the endemic flora's conservation status and ecological constraints.

### 7.2.1 A. Multi Criteria based IUCN Assessments of the 25 endemic and Threatened Species

The findings of this chapter present a novel approach to the assessment of threatened species in the Western Ghats, moving beyond simple data collection to implement a more nuanced, multi-criteria framework for IUCN Red List evaluations. By meticulously selecting a diverse set of 25 endemic and threatened angiosperm taxa, the study not only fills critical data gaps but also pioneers a methodology designed to capture the complex, real-world factors influencing a species' conservation status. This foundational work provides the first formal assessments for several key species, setting a new standard for conservation science in the region.

1. First-Time Red List Assessments: The study provides the first-ever IUCN Red List assessments for nine previously not-evaluated (NE) species, including the popular flagship species *Strobilanthes kunthiana*. A total of 15 IUCN Red List assessments published in IUCN official Red List, three completed review and under publication and amendments suggested based on multicriteria assessments for the remaining seven species. This is a critical contribution to global conservation databases.

2. Threat Assessment and Categorization: A total of 25 threatened species were assessed, resulting in a breakdown of one Critically Endangered, 14 Endangered, eight Vulnerable, and two Near Threatened taxa. This provides a clear, data-driven picture of the conservation status of these species.

3. Comprehensive Methodology for "Reversal of the Red": The research demonstrates a new modality for multi-criteria IUCN assessments by including a gradient of species with varying characteristics. The inclusion of species like *Prioria pinnata* shows the potential for "reversing" a threatened status through targeted conservation efforts.

4. Insights into Climate Change Impacts: The study provides unique insights into how climate change-induced factors, such as flash floods, impact conservation status. It specifically highlights this vulnerability in riparian species like *Syzygium occidentale*, *Aporosa bourdillonii*, and epiphytic species from fragile Shola ecosystems, like *Impatiens parasitica*.

5. Benchmarking for Future Assessments: The research establishes a benchmark for future assessments and reassessments of threatened species in the Western Ghats. It goes beyond

simply filling data gaps by providing a model that can be used for multi-criteria evaluations across the region.

The findings of this research represent a significant leap forward in regional conservation planning. The multi-criteria framework developed here not only provides a precise, data-driven snapshot of the current threat landscape but also offers a proactive model for future conservation efforts. By officially assessing nine previously unevaluated species and providing a benchmark for the reassessment of others, this study moves the conversation from simply identifying threats to actively strategizing for the potential "reversal of the red." It underscores the urgent need for a more holistic approach that integrates climate vulnerability and tailored conservation plans to protect the unique biodiversity of the Western Ghats.

### **7.2.2. Niche modelling and prediction of potential areas integrating Grinnellian and Eltonian niche factors**

Finding of this chapter explores a sophisticated approach to predicting potential habitats for threatened species, moving beyond the limitations of traditional bioclimatic models. By integrating both the physical environment and the biotic community, the research develops an innovative framework that more accurately captures the complex factors shaping species distribution. This methodology not only provides a powerful tool for habitat suitability assessment but also offers a scientifically robust basis for prioritizing conservation efforts in a changing climate.

1. **Integrated Niche Modelling:** The study successfully conducted a comprehensive habitat suitability assessment for 25 species by integrating both Grinnellian (bioclimatic and topographical) and Eltonian (vegetation-based) niche factors. This dual-factor approach provides a more robust and refined model for predicting species distribution.
2. **Key Environmental Variables:** The analysis identified Elevation, Precipitation of the driest quarter, and Precipitation of the wettest quarter as the most significant environmental variables influencing species distribution. These factors are critical in driving the ecological separation of distinct vegetation formations like montane and riparian habitats.
3. **Delineation of Conservation Priorities:** The study spatially delineated three distinct conservation priority zones: intact primary forests (e.g., Anamalai, Belgaum, Coorg), restorable degraded habitats (e.g., Cannanore, Comorin, Varushanad), and areas with

irreversible habitat loss (e.g., Anamalai, Palani, Coorg). This provides a clear, actionable framework for conservation planning.

4. Universal Niche Factor Importance: The findings confirm that the identified bioclimatic and vegetation factors are universally important across the studied species, which represent diverse life forms, from flagship grassland species to endemic epiphytes and trees of various forest types.

5. Multi-Faceted Conservation Framework: The study concludes that conservation in the Western Ghats cannot rely on a single strategy. Instead, it must be multi-faceted and data-driven, tailoring efforts to the specific ecological status of each ecoregion and focusing on a deep understanding of the species' fundamental niche requirements. By spatially delineating distinct conservation zones and identifying the critical environmental drivers of species distribution, the study moves beyond general recommendations to offer a concrete, actionable plan. The findings underscore that a successful conservation strategy must be multi-faceted, leveraging a deep understanding of species' ecological requirements to protect intact ecosystems, restore degraded areas, and inform urgent policy interventions.

6. Strategic Shift to Functional NbS: The study advocates for a strategic policy shift toward Nature-based Solutions (NbS) using the integrated methodology framework, moving beyond species-count metrics to a functional ecorestoration framework. This framework, driven by the Niche Profile analysis, ensures restoration is targeted at re-establishing critical interaction networks. This approach is essential for achieving concurrent Ecosystem-based Adaptation (EbA) goals and meeting international targets, particularly SDG 13 and SDG 15, thus providing a strategic, evidence-based pathway for sustainable conservation in the Western Ghats.

### **7.2.3. Niche profiling - Structural and Compositional Analysis to Elucidate the Eltonian Niche and Guild Definition**

The findings delve into the intricate ecological structure of the Western Ghats' forests by profiling the Eltonian niche factors that define species' roles within their communities. Through a meticulous analysis of species associations across nine distinct vegetation clusters, the study moves beyond broad habitat descriptions to reveal the precise relationships and dependencies that govern these unique ecosystems. This detailed

profiling of biotic interactions provides a foundational understanding of why certain threatened species are confined to specific microhabitats.

1. High Habitat Specificity and Species Dissimilarity: The study demonstrates an extremely high degree of species dissimilarity, with Bray-Curtis values of 0.95 to 1.0, among the nine distinct vegetation types examined. This confirms that these ecosystems are highly specialised and host unique species associations, even for the 25 focal threatened and endemic species.

2. Validation of Ecological Associations: The research successfully validated the existence of specific plant communities across different elevations and habitats, from Montane Grasslands to Low Elevation Coastal Evergreens. Each cluster (A-I) is defined by a distinct set of dominant species, including both common associates and the selected focal species.

3. Comprehensive Floristic Inventory: The study provides a detailed floristic inventory for each 25 focal threatened species but also a total of 389 associated species. This rich dataset outlines the structural composition of each community, from emergent trees to very small trees and lianas.

4. Species Distribution by Height Class: The findings precisely categorise the distribution of species within each habitat by height class (e.g., Emergent Tree, Large Tree, etc.). This provides a nuanced understanding of forest structure and the vertical niche occupied by key species hence the niche profile, such as *Elaeocarpus recurvatus* as an emergent tree in Montane Shola and *Goniothalamus wightii* as a very small tree in Medium Elevation Wet Evergreen forests.

5. Habitat-Specific Presence of Focal Species: The analysis reveals that the 25 focal threatened and endemic species are not uniformly distributed but are instead tied to specific clusters. For example, *Strobilanthes kunthiana* is exclusively a part of the Montane Grassland community, while species like *Prioria pinnata* and *Hydnocarpus pentandrus* are found across multiple clusters, including Low Elevation Evergreen and Coastal Evergreen forests.

6. Identification of Unique Community-Defining Species: The study identifies and lists the specific species that define each of the nine unique plant communities. This clear delineation of species associations provides valuable ecological data for conservation, demonstrating which groups of plants rely on which distinct habitats for their survival.



7. Role of Endemic Species as Habitat Indicators: The study identifies and lists several narrow endemic species, such as *Syzygium palghatense* and *Strobilanthes kunthiana*, that are exclusively found within specific vegetation clusters. This finding underscores the potential of these endemic plants to serve as indicator species, providing valuable insights into the ecological health and integrity of their specialised microhabitats, such as Submontane Shola and Montane Grasslands.

8. Varying Niche Breadth among Threatened Species: The research reveals a crucial distinction among the threatened focal species based on their habitat breadth. While many species are highly specialised and confined to a single cluster (e.g., *Syzygium occidentale* in riparian zones), others, like *Hydnocarpus pentandrus* and *Dipterocarpus indicus*, are found across multiple, ecologically distinct habitats (e.g., Medium Elevation Wet Evergreen, Low Elevation Evergreen, and Riparian). This finding highlights the need for differentiated conservation strategies tailored to either habitat specialists or more generalised threatened species.

This part of the study provides a powerful, data-driven methodology for understanding and profiling the ecological niches of threatened species. By confirming the high degree of specialization and unique species associations within each vegetation cluster, the study underscores the critical importance of preserving habitat heterogeneity. The insights gained from the universal role of key associates to the varying niche breadth of threatened species provide an indispensable framework for developing nuanced, effective conservation strategies that are tailored to the specific ecological needs of each unique plant community in the Western Ghats.

#### **7.2.4. Niche Overlap and Specificity Analysis: Quantitative Proof of Niche Partitioning**

This final session of the thesis delves into the intricate concepts of niche overlap and specificity, providing a nuanced understanding of how threatened species are distributed across the Western Ghats. By integrating both Grinnellian and Eltonian factors, the study successfully dissects the fundamental drivers of species assembly, revealing that habitat structure is a product of both broad climatic gradients and fine-scale biotic interactions. The findings challenge simplified notions of elevational zonation by uncovering distinct ecological guilds and unique specialist niches.

1. **Dual Niche Delineation:** The study confirms that vegetation types are distinct ecological units, clearly delineated by both Grinnellian (environmental) and Eltonian (species composition) factors. The strong alignment between these two independent analyses validates the overall methodology.
2. **Elevational Zonation:** The major vegetation groups high, medium, and low-elevation are well-differentiated by both bioclimatic factors and species dissimilarity, confirming the primary role of elevational gradients in structuring the flora of the Western Ghats.
3. **Grinnellian vs. Eltonian Factors:** A critical divergence was found between niche concepts. While broad-scale Grinnellian factors suggest a single, unified niche for high-elevation species, Eltonian factors reveal finer-scale partitioning, creating distinct ecological guilds within that same biome.
4. **Sub-Montane Shola Forest Guilds:** The species dissimilarity analysis identified two distinct high-elevation guilds: a "True Shola Forest Guild" and a "Transitional Guild." This finding highlights a finer-scale community structure driven by factors not captured by broad bioclimatic variables.
5. **Specialised Niche of *Syzygium parameswaranii*:** This species stands out as a unique specialist. Its niche is distinct from all other high-elevation species and represents a separate sub-montane "Submontane-shola" formation, reinforcing the role of unique, localised environmental conditions.
6. **Medium-Elevation Generalist Guild:** The medium-elevation species form a cohesive, generalist guild with consistently high internal niche overlap. This suggests a resilient community well-adapted to the transitional environmental conditions of their habitat without strong fine-scale partitioning.
7. **Clear Niche Segregation at Low Elevations:** In contrast to the high-elevation interconnectedness, the low-elevation evergreen and low-elevation riparian guilds exhibit strong niche segregation. This demonstrates that micro-habitat heterogeneity is a primary driver of speciation and distinct community assembly at lower altitudes.
8. **Niche Specificity of *Ochna gamblei*:** The species *Ochna gamblei* shows pronounced specificity, its niche is distinct from both the evergreen and riparian guilds. This finding is consistent with its unique distribution in coastal sandy areas, validating the model's ability to capture highly specialised and geographically isolated niches.

9. Epiphyte Niche: The two epiphyte species, *Impatiens parasitica* and *Medinilla anamalayana*, share a significant ecological niche, despite belonging to different general elevational groups. This suggests their shared life form creates a unique "epiphyte niche" that transcends simple elevational stratification.

10. Validation of Species Selection: The overall analysis of niche overlap and specificity confirms that the selected species effectively represent the key ecological niches and vegetation subtypes of the Western Ghats. This validates the study's methodological approach and the representativeness of the data.

Elevational Zonation: The study confirms that elevation is the primary driver of species distribution, with distinct high-, medium-, and low-elevation vegetation groups adapted to unique climatic conditions.

Micro-Habitat Specialization: Beyond elevation, species are limited by fine-scale habitat factors. This is shown by the niche segregation between evergreen and riparian guilds and the specialization of species like *Ochna gamblei* to coastal sandy conditions.

Topographical Constraints: Topography and physiography act as key distributional filters. The distribution of species like *Syzygium parameswaranii* is tightly linked to specific features such as hilltops exposed to clouds and winds, even within a broad elevational range.

Life-Form as a Determinant: The niche of epiphytic species is determined more by their life form than by ground-level environmental factors. The shared niche of *Impatiens parasitica* and *Medinilla anamalayana* confirms that a single conservation strategy may not apply to all flora within an elevational band.

Integrated Limitations: The distribution of flora in the Western Ghats is not random but is tightly constrained by a combination of elevational, edaphic, habitat, and life-form-specific factors, highlighting the complexity of ecological niche modelling.

### **7.3. The Integrated Niche Framework and Conservation Implications**

The integration of the chapter findings culminates in a powerful, predictive model for conservation planning, demonstrating that the future persistence of the Western Ghats' endemic flora hinges on securing fine-scale micro bioclimatic regimes.

### 7.3.1. The Principle of Differentiated Risk: Niche Specialists vs. Conserved Guilds

The study establishes a fundamental ecological dichotomy among the threatened species that must be incorporated into conservation planning, providing the necessary spatial and ecological precision to align resource allocation strategically with the realised threats facing the Western Ghats' unique endemic and threatened flora.

**Niche Specialists (High Intrinsic Risk):** These species, such as *Ochna gamblei* ( $D \sim 0.209$ ) and *Syzygium parameswaranii*, *Syzygium occidentale* etc. are confirmed as habitat specialists reliant on unique, localised micro bioclimatic regimes (Trivedi & Bharchula, 2023). Their reliance on specific edaphic (coastal sands) or topographical (cloud-exposed ridges) factors means that even minor localised disturbances (e.g., sand mining, hydrological shifts) can lead to rapid extinction. Their low niche overlap values serve as a direct quantitative indicator of their extreme ecological fragility and confirm that these species are less tolerant and more vulnerable to future climate change impacts compared to common species (Zhang et al., 2022). Critically, where realised niche overlap is low, it often suggests that the restricted species is a refugee species confined to marginal or suboptimal habitats due to competitive exclusion or long-term disturbance, rather than inhabiting its optimal ecological space (Bleyhl et al., 2019).

**Niche Conserved Guilds (High Extrinsic Risk):** Species that exhibit high niche overlap (e.g., the Montane Shola core guild, with  $D \sim 0.72$ ) show niche conservatism. Their shared, relatively broad Grinnellian niche suggests they are well-adapted to the general montane climate. However, their high vulnerability is driven by extrinsic, ecosystem-wide threats such as fragmentation, fire, and widespread habitat conversion, which compromise the structural integrity of the entire shared habitat (e.g., the Shola-Grassland complex). Management must, therefore, adopt a landscape-scale functional approach to mitigate these ecosystem-wide pressures.

### 7.3.2. The Imperative of Micro-Habitat Specific Conservation

The clear niche segregation driven by non-bioclimatic factors demands specialised, targeted strategies that move beyond generic protected area management.

**Hydrological Management:** The clear niche segregation between the Low-Elevation Riparian guild (e.g., *Aporosa bourdillonii*) and the Low-Elevation Evergreen guild necessitates specific management of hydrologically dynamic habitats. Conservation plans

must prioritise maintaining perennial water flow and bank stability to secure the unique riparian micro bioclimate.

**Edaphic and Topographical Protection:** The strong specificity of species like *Ochna gamblei* confirms that the protection of edaphic (soil-based) micro-habitats and unique topographical features (e.g., wind-exposed ridges for *Syzygium parameswaranii*) is often more critical than protecting a broad area defined by elevation alone. Local endemic species confined to these highly specific ecological niches are referred to as 'hot specks,' directly underscoring that these micro-scale environmental constraints drive the high intrinsic threat level observed (Trivedi & Bharchula, 2023).

**Canopy and Host Protection:** The high niche sharing observed between the two epiphyte species confirms that their persistence is tied to a specific canopy microclimate. Management must focus not just on the ground-level flora, but on maintaining the integrity and diversity of suitable host tree species and the vertical forest structure to secure this life-form specific niche. This specialised biotic management is essential for preserving the unique canopy microclimate required by epiphytes.

#### **7.4. Major Contributions to Conservation Science and Policy**

This research has resulted in several distinct contributions that collectively advance conservation science in the Western Ghats and provide a model for global biodiversity hotspots facing similar data challenges.

##### **7.4.1. Scientific Contributions: A Quantitative Baseline**

**First-Time Assessments and Baseline Data:** The thesis provided the first-ever contemporary demographic baseline for 25 threatened species, including the formal assessment of nine previously Not Evaluated (NE) taxa. This is a fundamental update to the global IUCN catalogue, replacing inferred rarity with quantified imperilment.

**Validation of the Niche Dichotomy:** The quantitative proof that High Grinnellian Niche Overlap is functionally constrained by High Eltonian Dissimilarity validates the thesis's core hypothesis. This provides a robust methodological framework for understanding species coexistence and endemism in complex tropical ecosystems.

**Establishing Comparative Niche Metrics:** The derived objective niche metrics (Schoener's D and Hellinger's I indices) establish an invaluable baseline for comparative conservation planning across the wider Western Ghats. These metrics can be used to compare and

categorise other data-deficient species, thereby lending quantitative support for stringent IUCN Red List classifications where high intrinsic vulnerability is indicated.

#### **7.4.2. Policy and Management Contributions: Defining Ecological Guilds**

**Supplementing IUCN Criteria:** The low niche overlap values identified for highly restricted species (e.g.,  $D \sim 0.597$  for *Syzygium palghatense*) provide a quantitative, niche-based rationale to support stringent IUCN Red List assessments. This method can be used to robustly justify highly restricted Extent of Occurrence (EOO) and Area of Occupancy (AOO) values, particularly for neo-endemics where population data may be scarce, thereby ensuring their appropriate threatened status is accurately reflected.

**Guiding Eco-Restoration and Spatial Planning:** The species dissimilarity analysis, based on Eltonian factors, formally defines the Ecological Guilds (e.g., True Shola Forest Guild, Riparian Guild). Future eco-restoration efforts must target the re-establishment of these defined, functionally coherent guilds, rather than simply replanting individual threatened species. Success in restoration is contingent upon recreating the complex, species-interaction-driven community structure. The utility of this approach is demonstrated by its ability to differentiate species into two risk categories, providing the necessary spatial and ecological precision to align resource allocation strategically with the realised threats facing the Western Ghats' unique endemic and threatened flora.

#### **7.4.3. Future Research Trajectories**

The validated framework establishes a critical foundation for several future research directions:

**Climate Change Vulnerability and Refugia Identification:** The most pressing next step is to integrate the current niche models with regional climate change projections. This will enable the prediction of future range shifts and the identification of the most stable mid-altitude Wet Evergreen Forest patches to serve as indispensable climate refugia for small-ranged species (Manna et al., 2024).

**Functional Trait Analysis:** Future research should move towards quantifying the functional traits that underpin the observed Eltonian partitioning. By linking the (Niche Profile) to specific functional traits (e.g., wood density, leaf area index, dispersal syndromes), the study can definitively correlate structural role with physiological adaptation, providing a deeper understanding of competitive exclusion and coexistence.

**Phylogeographic Integration:** Integrating the niche framework with molecular phylogeography for key endemic species can help test the hypothesis that the high dissimilarity observed in the Submontane Shola Guilds is a result of vicariance driven by historical topographical and microclimatic isolation, providing deeper insight into the evolutionary history of endemism in the Western Ghats.

This research, by successfully linking species' IUCN status with their precise ecological niches, not only provides the first-ever assessments for nine key species but also highlights the critical need for a differentiated approach to conservation. The findings confirm that while broad elevational gradients are primary drivers of species distribution, it is the fine-scale micro-habitat heterogeneity and species interactions that ultimately define a species' vulnerability and potential for recovery. This work serves as a foundational resource for future studies and a clear call to action, providing a spatially explicit guide for protecting intact ecosystems, actively restoring degraded habitats, and ensuring the long-term survival of the region's unique and irreplaceable flora.

The successful validation of the integrated niche framework provides a quantitative and scientifically defensible model for conservation planning that is transferable to other global biodiversity hotspots facing similar pressures of data deficiency and environmental change.

In essence, this research provides a powerful framework for understanding the complex ecological architecture of the Western Ghats. The findings not only validate the study's innovative methodology but also highlight the critical need for a multi-layered approach to conservation. By demonstrating that species niches are structured by a combination of large-scale elevational gradients and fine-scale habitat segregation, the study offers an indispensable tool for prioritizing conservation efforts. It confirms that the preservation of highly specific micro-habitats and unique ecological guilds is just as vital as protecting entire biomes for the long-term survival of the region's threatened flora.

This research provides a powerful, integrated framework for the conservation of threatened species in the Western Ghats. By successfully linking species' IUCN status with their precise ecological niches, the study not only provides the first-ever assessments for nine key species but also highlights the critical need for a differentiated approach to conservation. The findings confirm that while broad elevational gradients are primary drivers of species distribution, it is the fine-scale microhabitat heterogeneity and species



interactions that ultimately define a species' vulnerability and potential for recovery. This work serves as a foundational resource for future studies and a clear call to action, providing a spatially explicit guide for protecting intact ecosystems, actively restoring degraded habitats, and ensuring the long-term survival of the region's unique and irreplaceable flora.



# Chapter 8

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Recommendations

## **Chapter 8**

### **Recommendations**

The thesis, with its robust, multi-criteria approach integrating field-based empirical data, historical collection records, and integrated niche modelling of 25 threatened plant taxa, establishes a foundational ecological understanding of conservation requirements and challenges. Building directly on a synthesis of the quantitative findings from the integrated niche framework, specifically the demographic validation (Chapter 3), refined spatial modelling (Chapter 4), delineation of ecological guilds (Chapter 5), and the proof of the Niche Dichotomy (Chapter 6), this chapter delivers a focused set of actionable recommendations for conservation and future research in the Western Ghats. The recommendations are organised into three key sections for clarity, impact, and actionability. Given their quantitative and spatially explicit basis, these recommendations are directly applicable for integration into the working plans and management plans of forest administrative divisions, and the Biodiversity Strategy Action Plans of Local Self-Governments, thereby providing state-level agencies (e.g., Biodiversity Boards and Forest Departments) with a scientifically defensible roadmap for intervention.

#### **8.1. IUCN Assessment and Policy Recommendations**

The findings provide objective, quantitative evidence that must be leveraged at the policy level to secure the long-term persistence of the endemic flora.

1. **Submit New and Updated IUCN Assessments:** Formally submit the first-time IUCN Red List assessments for the nine previously unevaluated species to the IUCN. This is crucial for gaining global recognition of their conservation status and providing an international benchmark for future monitoring.

2. **Adopt a Gradient-Based Assessment Model:** The study's use of a gradient of species, from Critically Endangered to Near Threatened, proved effective in understanding risk across the bioclimatic spectrum. Future regional assessments should adopt a similar multi-criteria approach to provide a more comprehensive and nuanced understanding of conservation needs.

3. **Integrate Climate Change Vulnerability Criteria:** Given the insights into the impacts of climate-induced events on riparian and epiphytic species, future IUCN assessments should systematically incorporate climate change vulnerability criteria to provide a more realistic and forward-looking evaluation of species risk under anticipated future warming and hydrological shifts.

4. **Promote Policy Intervention for Irreversible Habitats:** The findings on irreversible habitat loss in regions like Anamalai and Palani necessitate urgent policy-level intervention and land-use planning that accounts for permanent ecological damage. Policies should prohibit large-scale development or conversion in areas identified as remaining suitable habitat pockets.

5. **Establish Policy for Edaphic and Topographical Integrity (Hot Specks):** Establish stringent regulatory policies to prohibit resource extraction (e.g., sand mining, quarrying, soil modification) and uncontrolled land-use change in areas identified as 'hot specks.' These are defined as sites hosting High-Risk Niche Specialists (confirmed by low Schoener's D values, e.g., *Ochna gamblei*) that rely on specific edaphic or topographical conditions (e.g., coastal sands and cloud-exposed ridges). This ensures the protection of non-substitutable micro-refugia.

6. **Formal Adoption of the Integrated Niche Framework:** The research demonstrates that combining Grinnellian (abiotic potential) and Eltonian (biotic structure) niche concepts provides a superior understanding of species vulnerability. This multi-criteria framework should be formally adopted as a standard by relevant government and conservation agencies for future conservation status assessments and prioritization.

## **8.2. Conservation Management Recommendations**

These recommendations transition conservation efforts from generalised protection to precise, niche-specific interventions guided by the integrated framework.

7. **Implement Integrated Fire Management Plans:** Develop and enforce comprehensive, ecologically sensitive fire management protocols, especially in the transition zones between Montane Grassland and Shola Forests. Management must focus on prescribed

burning and fire breaks that minimise damage to the sensitive Shola Forest core, recognizing the high intrinsic threat to these fire-averse species.

8. Conduct Long-Term Demographic Monitoring: Establish a dedicated monitoring program focused on the demographic health of the (25) focal species, including annual tracking of population size, recruitment, and mortality. This ensures that conservation status is dynamically updated in response to real-time ecological changes.

9. Revise EOO and AOO Calculations: The field-validated distribution data from this study should be used by protected area managers to update official Extent of Occurrence (EOO) and Area of Occupancy (AOO) figures for the endemic species, leading to more accurate mapping of critical habitats within sanctuaries.

10. Promote Trans-boundary Conservation Collaboration: Given that species distributions and climatic gradients often cross state lines (Kerala and Tamil Nadu), establish formal, collaborative trans-boundary agreements between relevant Forest Departments. This is essential for managing species that occupy a single ecological guild spanning multiple jurisdictions.

11. Prioritise Riparian Micro-Habitat Protection: Based on the strong niche segregation of the Low-Elevation Riparian Guild, management must prioritise specific hydrological interventions. This includes ensuring perennial water flow, preventing bank erosion, and minimizing non-point source pollution to maintain the unique bioclimatic conditions required by these fluvial-dependent species.

12. Direct Eco-Restoration to High-Potential Sites: Utilise the refined (MaxEnt) models (Chapter 4) to precisely target conservation resources toward defined Potential Ecorestoration Areas (suitable but degraded habitats), particularly in high-loss regions like Cannanore, Comorin, and Varushanad.

13. Differentiate Management by Risk Category: Adopt a management strategy that formally recognises the High Intrinsic Risk Niche Specialists (requiring micro-habitat security) and the High Extrinsic Risk Niche Conserved Guilds (requiring landscape-scale anti-fragmentation efforts). This ensures resource allocation is strategically aligned with the primary threat driver.

14. Mandate Ecological Guild-Based Restoration Protocols: All future ecorestoration projects must adopt the formally defined Ecological Guilds (e.g., True Shola Forest Guild, Riparian Guild) as the unit of restoration, rather than focusing on individual species abundance. This protocol must ensure the recreation of the non-substitutable community structure (Eltonian Niche) confirmed by the high Bray-Curtis dissimilarity (0.95) to (1.0), which is vital for long-term ecological function.

15. A Nature based Solution (NbS) ensuring EbA and SDG for Ecorestoration: The findings of this study provide empirical evidence supporting a strategic shift in conservation policy towards Nature-based Solutions (NbS), explicitly designed to achieve Ecosystem-based Adaptation (EbA) and align with the Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action) and SDG 15 (Life on Land). The framework developed through integrated niche modelling and utilising the Niche Profile is considered as an NbS to prioritise the Eco restoration areas as well as restoration of functional groups, not just species counts, focusing on replacing structural dominants.

16. Integrate Structural Keystones and Biotic Management: Management must prioritise the protection and active regeneration of specific structural keystone species (identified by high IVI, e.g., *Cullenia exarillata*), as their presence defines the physical architecture and creates specialised secondary niches. Furthermore, explicitly implement targeted management to secure the integrity and diversity of suitable host trees for the unified epiphyte niche, recognizing their dependence on intact canopy microclimates.

17. Secure the Integrity of Edaphic Micro-Habitats: Implement specialised protection measures for identified micro-habitats, such as rocky outcrops, perennial stream banks, and specific soil types. This level of granular management is critical for species whose persistence is tied to conditions not captured by broad regional climate data.

### **8.3. Future Research Trajectories**

The validated integrated niche framework provides a robust platform for further research that should focus on predicting future vulnerability and understanding the evolutionary processes driving endemism.

18. **Refine Fine-Scale Drivers:** Future research should focus on quantifying the specific drivers of fine-scale limitations, such as edaphic conditions and microclimates. Understanding these factors will be crucial for developing targeted conservation measures, especially for specialised species that do not conform to broad elevational patterns.

19. **Utilise Digital Platforms for Long-Term Monitoring:** A key recommendation is to establish an accessible, public-facing database that integrates the niche profiles, population baselines, and taxonomic data gathered in this study. This platform would allow for the long-term monitoring of focal species and enable a dynamic approach to conservation.

20. **Expand Sampling and Species Coverage:** Future studies should expand the number of sampling plots and species to increase the statistical power and generalizability of the findings, providing a more robust foundation for large-scale conservation planning.

21. **Integrate Phylogenetic Analysis:** Future research should incorporate phylogenetic analysis to understand the role of evolutionary relationships in niche overlap. This would provide deeper insights into whether niche similarity is driven by environmental factors or shared ancestry.





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## Appendices



**APPENDIX I****Distribution Records of Selected 25 Species****1. *Aglaia malabarica* Sasidh., in C.M. Pannell, Taxon. Monog. Gen. *Aglaia* (Kew Bull. Addit. Ser., 16) 369 (1992).**

| SL No. | Country | State      | Location                        | Latitude | Longitude | Recorded By                  | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|---------------------------------|----------|-----------|------------------------------|---------------|------|--------------------|
| 1      | India   | Kerala     | Velakketupara, Peechi, Thrissur | 10.58307 | 76.32134  | N Sasidharan                 | 5027          | 1988 | Preserved Specimen |
| 2      | India   | Kerala     | Rosemala, Shendhurney, Kollam   | 8.93339  | 77.17176  | N Sasidharan                 | 10957         | 1994 | Preserved Specimen |
| 3      | India   | Kerala     | Chalhiipara, Peechi, Thrissur   | 10.60969 | 76.33879  | N Sasidharan                 | 5657          | 1999 | Preserved Specimen |
| 4      | India   | Kerala     | Vythiri, Ghats, Wayanad         | 11.55220 | 76.03764  | Ratheesh Narayanan           | 3385          | 2009 | Preserved Specimen |
| 5      | India   | Kerala     | Vythiri, Wayanad                | 11.55400 | 76.01000  | Ravindran AE & Thoppil JE    | 123754        | 2019 | Preserved Specimen |
| 6      | India   | Tamil Nadu | Sheikelmudi                     | 10.31363 | 76.83270  | Amitha Bachan KH             | AH25201       | 2021 | Preserved Specimen |
| 7      | India   | Kerala     | Shendhurney, Kollam             | 8.91644  | 77.17365  | Devika MA & Amitha Bachan KH | CU216195      | 2024 | Preserved Specimen |
| 8      | India   | Kerala     | Kakkadumpoyil, Malappuram       | 11.30422 | 76.10378  | Devika MA & Amitha Bachan KH | CU216199      | 2025 | Preserved Specimen |
| 9      | India   | Kerala     | Vythiri, Wayanad                | 11.54473 | 76.02809  | Devika MA & Amitha Bachan KH | CU216191      | 2025 | Preserved Specimen |
| 10     | India   | Kerala     | Kakkadumpoyil, Malappuram       | 11.33818 | 76.10886  | Devika MA & Amitha Bachan KH | CU216200      | 2025 | Preserved Specimen |

2. *Aporosa bourdillonii* Stapf, Hooker's Icon. Pl. 23: t. 2204 (1892).

| SL No. | Country | State  | Location                                           | Latitude | Longitude | Recorded By                                               | Herbarium No. | Year | Basis of Record    |
|--------|---------|--------|----------------------------------------------------|----------|-----------|-----------------------------------------------------------|---------------|------|--------------------|
| 1      | India   | Kerala | Vazhachal, Chalakkudy, Thrissur                    | 10.30124 | 76.60313  | K Ramamurthy                                              | 27035         | 1966 | Preserved Specimen |
| 2      | India   | Kerala | Bhagavathikulam, Malayattoor RF, Aluva, Ernakulam  | 10.16196 | 76.64171  | BV Shetty                                                 | 33467         | 1970 | Preserved Specimen |
| 3      | India   | Kerala | Bhagavathikulam, Malayattoor RF, Aluva, Ernakulam  | 10.21098 | 76.49661  | BV Shetty                                                 | 33453         | 1970 | Preserved Specimen |
| 4      | India   | Kerala | Kannankuzhi, Chalakkudy, Thrissur                  | 10.29168 | 76.55698  | K Ramamurthy                                              | 49338         | 1977 | Preserved Specimen |
| 5      | India   | Kerala | Iringole Kavu, Perumbavoor, Kunnathunad, Ernakulam | 10.10886 | 76.50118  | UV Chandrashekar & S. Sankar                              |               | 1998 | Human Observation  |
| 6      | India   | Kerala | Anaikulam river side, Kuttumpuzha                  | 10.14560 | 76.90110  | S, Aravajy; P.V, Karunakaran                              | 007001        | 2005 | Preserved Specimen |
| 7      | India   | Kerala | Vazhachal Bridge, Chalakkudy, Thrissur             | 10.30128 | 76.60018  | Amitha Bachan KH                                          |               | 2010 | Preserved Specimen |
| 8      | India   | Kerala | Campshed, Kanavam, Wayanad north                   | 11.80344 | 75.76319  | K A Sreejith, V B Sreekumar, UM Chandrashekar & TV Sajeev |               | 2012 | Human Observation  |
| 9      | India   | Kerala | Pakuthipalam, Nelliampathy, Nemmara                | 10.45670 | 76.68074  | K A Sreejith, V B Sreekumar, UM Chandrashekar & TV Sajeev |               | 2012 | Human Observation  |

|    |       |        |                                                          |          |          |                                                                        |          |      |                       |
|----|-------|--------|----------------------------------------------------------|----------|----------|------------------------------------------------------------------------|----------|------|-----------------------|
| 10 | India | Kerala | Palaruvi, Aryankavu,<br>Thenmala, Kollam                 | 8.94204  | 77.12562 | K A Sreejith, V<br>B Sreekumar,<br>UM<br>Chandrashekara<br>& TV Sajeer |          | 2012 | Human<br>Observation  |
| 11 | India | Kerala | Valliyamkulam,<br>Malayattor, Ernakulam                  | 10.20316 | 76.51127 | Devika MA &<br>Amitha Bachan<br>KH                                     | AH25268  | 2022 | Preserved<br>Specimen |
| 12 | India | Kerala | Vazhachal river side,<br>Chalakkudy, Thrissur            | 10.30367 | 76.60661 | Devika MA &<br>Amitha Bachan<br>KH                                     | CU216101 | 2022 | Preserved<br>Specimen |
| 13 | India | Kerala | Iringole Kavu,<br>Perumbavoor,<br>Kunnathunad, Ernakulam | 10.10945 | 76.50080 | Devika MA &<br>Amitha Bachan<br>KH                                     | CU216111 | 2023 | Preserved<br>Specimen |
| 14 | India | Kerala | Athirappally, Chalakkudy,<br>Thrissur                    | 10.28867 | 76.51430 | S.M. Shareef                                                           | 72496    |      | Preserved<br>Specimen |
| 15 | India | Kerala | Athirappally, Chalakkudy,<br>Thrissur                    | 10.30199 | 76.57711 | S.M. Shareef                                                           | 70697    |      | Preserved<br>Specimen |
| 16 | India | Kerala | Karantode, Chalakkudy,<br>Thrissur                       | 10.35085 | 76.63377 | Devika MA &<br>Amitha Bachan<br>KH                                     | CU216102 | 2023 | Preserved<br>Specimen |
| 17 | India | Kerala | Kuttampuzha range,<br>Ernakulam                          | 10.08440 | 76.54040 | S, Aravajy; P.V,<br>Karunakaran                                        | 006997   |      | Preserved<br>Specimen |
| 18 | India | Kerala | Manikandchal,<br>Kuttampuzha range,<br>Ernakulam         | 10.17080 | 76.82220 | B.R, Ramesh; De<br>Franceschi,<br>Dario; B,<br>Montfraix               | 006996   |      | Preserved<br>Specimen |
| 19 | India | Kerala | Palaruvi to Rosemala,<br>Punalur, Kollam                 | 8.94390  | 77.16410 | G. Rajkumar                                                            | 77193    |      | Preserved<br>Specimen |

|    |       |        |                                              |          |          |                                               |          |        |                    |
|----|-------|--------|----------------------------------------------|----------|----------|-----------------------------------------------|----------|--------|--------------------|
| 20 | India | Kerala | Paniyeliporu, Malayattoor RF, Ernakulam      | 10.22908 | 76.67162 | Devika MA & Amitha Bachan KH                  | CU216123 | 2023   | Preserved Specimen |
| 21 | India | Kerala | Pokayilappara, Chalakkudy, Thrissur          | 10.30047 | 76.60808 | Somen CK, Jose PA, Sujanapal P & Sreekumar VB |          |        | Human Observation  |
| 22 | India | Kerala | Thodupuzha R.F. Idukki                       | 9.94167  | 76.84170 | Jean-Pierre, Pascal                           |          | 006993 | Preserved Specimen |
| 23 | India | Kerala | Travancore, Thiruvananthapuram               | 8.59251  | 77.12119 | RH Bourdillon                                 | 544      |        | Preserved Specimen |
| 24 | India | Kerala | Vazhachal, Bridge, Chalakkudy, Thrissur      | 10.30126 | 76.60199 | Devika MA & Amitha Bachan KH                  | CU216103 | 2023   | Preserved Specimen |
| 25 | India | Kerala | Vazhachal, Iron bridge, Chalakkudy, Thrissur | 10.30122 | 76.60284 | M Alister                                     | 88631    |        | Preserved Specimen |

**3. *Cryptocarya anamalayana* Gamble, Bull. Misc. Inform. Kew 1925(3): 126 (1925).**

| SL No. | Country | State      | Location                   | Latitude | Longitude | Recorded By  | Herbarium No.    | Year | Basis of Record    |
|--------|---------|------------|----------------------------|----------|-----------|--------------|------------------|------|--------------------|
| 1      | India   | Tamil Nadu | Anamalai hills, Tamil Nadu | 10.29845 | 76.99880  | RH Beddome   | 270 (K000768404) | 1872 | Preserved Specimen |
| 2      | India   | Tamil Nadu | Punachi, Coimbatore        | 10.90941 | 76.73708  | CA Barber    | 6008             | 1903 | Preserved Specimen |
| 3      | India   | Kerala     | Valayar, Palakkad          | 10.85074 | 76.78317  | Bhargavan    | 47462            | 1976 | Preserved Specimen |
| 4      | India   | Kerala     | Kallar, Thiruvananthapuram | 8.71476  | 77.12929  | N Sasidharan | 10361            | 1993 | Preserved Specimen |
| 5      | India   | Tamil Nadu | Alwarkurichi, Tirunelveli  | 8.75752  | 77.33482  | N Sasidharan | 11419            | 1995 | Preserved Specimen |

|    |       |        |                                                               |          |          |                                  |          |      |                       |
|----|-------|--------|---------------------------------------------------------------|----------|----------|----------------------------------|----------|------|-----------------------|
| 6  | India | Kerala | Chandanthodu,<br>Chalakkudy,<br>Thrissur                      | 10.31332 | 76.77733 | Amitha Bachan KH                 | 98740    | 2004 | Preserved<br>Specimen |
| 7  | India | Kerala | Chandanthodu,<br>Chalakkudy,<br>Thrissur                      | 10.29781 | 76.79777 | P S Udayan et al.                | 6734     | 2010 | Preserved<br>Specimen |
| 8  | India | Kerala | Chandanthodu,<br>Chalakkudy,<br>Thrissur                      | 10.31323 | 76.77735 | Amitha Bachan KH                 | 137305   | 2014 | Preserved<br>Specimen |
| 9  | India | Kerala | Chandanpara,<br>Chalakkudy -<br>Anamala Road,<br>Thrissur     | 10.29046 | 76.81639 | Amitha Bachan KH &<br>Devika M.A | AH19945  | 2020 | Preserved<br>Specimen |
| 10 | India | Kerala | 46-Malakkappara,<br>Chalakkudy -<br>Anamala Road,<br>Thrissur | 10.29372 | 76.83925 | Devika MA &<br>Amitha Bachan KH  | AH19962  | 2020 | Preserved<br>Specimen |
| 11 | India | Kerala | Sheikalmudi,<br>Chalakkudy,<br>Thrissur                       | 10.31521 | 76.81011 | Amitha Bachan KH                 | CU216105 | 2020 | Preserved<br>Specimen |
| 12 | India | Kerala | Sholayar Dam site,<br>Chalakkudy,<br>Thrissur                 | 10.31762 | 76.75475 | Amitha Bachan KH                 | CU216107 | 2020 | Preserved<br>Specimen |
| 13 | India | Kerala | Chandanthodu,<br>Chalakkudy,<br>Thrissur                      | 10.32332 | 76.77623 | Devika MA &<br>Amitha Bachan KH  | CU216120 | 2023 | Preserved<br>Specimen |



4. *Cryptocarya lawsonii* Gamble, Bull. Misc. Inform. Kew 1925(3): 127 (1925).

| SL No. | Country | State      | Location                                      | Latitude  | Longitude | Recorded By                     | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|-----------------------------------------------|-----------|-----------|---------------------------------|---------------|------|--------------------|
| 1      | India   | Kerala     | Wayanad                                       | 11.54020  | 76.06212  | RH Beddomei                     |               | 1869 | Preserved Specimen |
| 2      | India   | Tamil Nadu | Kotagiri-Dodabetta                            | 11.42177  | 76.86173  | Miss Nosworth                   | 83299         | 1937 | Preserved Specimen |
| 3      | India   | Tamil Nadu | Vellingiri, 7th hill top                      | 10.989072 | 76.688478 | S Karthikeyan and M Chandrabose | 31803         | 1969 | Preserved Specimen |
| 4      | India   | Tamil Nadu | Gudallur-Ooty Road, Udthagamandalam, Nilgiris | 11.48017  | 76.54433  | F. Blasco                       | HIFP011528    | 1969 | Preserved Specimen |
| 5      | India   | Kerala     | Way to Bison Swamp                            | 10.00882  | 77.11569  | BV Shetty                       | 34190         | 1970 | Preserved Specimen |
| 6      | India   | Tamil Nadu | Perumalmudi, Tamil nadu                       | 11.05308  | 76.81375  | MV Viswanathan                  | 777           | 1970 | Preserved Specimen |
| 7      | India   | Tamil Nadu | Avalanche, Nilgiris                           | 11.31676  | 76.59867  | BV Shetty                       | 37644         | 1970 | Preserved Specimen |
| 8      | India   | Tamil Nadu | Mudimund, Nilgiri                             | 11.39966  | 76.50185  | J.L. Ellis                      | 34801         | 1970 | Preserved Specimen |
| 9      | India   | Tamil Nadu | Near fast Varahapallam, Nilgiri               | 11.41360  | 76.70247  | BV Shetty                       | 37536         | 1970 | Preserved Specimen |
| 10     | India   | Tamil Nadu | Perumalmudi, Tamil nadu                       | 11.05308  | 76.81375  | MV Viswanathan                  | 1033          | 1971 | Preserved Specimen |
| 11     | India   | Tamil Nadu | Carrington, Nilgiris                          | 11.22778  | 76.72472  | K Vivekananthan                 | 40709         | 1972 | Preserved Specimen |

|    |       |             |                                              |          |          |                          |            |      |                    |
|----|-------|-------------|----------------------------------------------|----------|----------|--------------------------|------------|------|--------------------|
| 12 | India | Tamil Nadu  | Avalanche                                    | 11.30213 | 76.59452 | K Vivekananthan          | 40610      | 1972 | Preserved Specimen |
| 13 | India | Kerala      | Kumily, Peerumade, Idukki                    | 9.59167  | 77.17500 | A.J.G.H, Kostermans      | HIFP011529 | 1976 | Preserved Specimen |
| 14 | India | Kerala      | Pamba Dam, above Kakkada River, Ranni Valley | 9.20289  | 77.15349 | C.E.Ridsdale             | 608        | 1980 | Preserved Specimen |
| 15 | India | Karnataka   | Kolluru, Udupi                               | 13.85830 | 74.81670 | B.R, Ramesh              | HIFP011531 | 1982 | Preserved Specimen |
| 16 | India | Kerala      | Calvery mount                                | 9.81644  | 77.01406 | CN Mohanan               | 77916      | 1983 | Preserved Specimen |
| 17 | India | Kerala      | Calvery mount                                | 9.81646  | 77.01407 | CN Mohanan               | 77304      | 1983 | Preserved Specimen |
| 18 | India | Kerala      | Valiyaparathode, Kerala                      | 11.08714 | 76.47935 | T.Sabu                   | 11075      | 1983 | Preserved Specimen |
| 19 | India | Tamil Nadu  | Sispara, Palakkad, Kerala                    | 11.20309 | 76.45035 | T.Sabu                   | 11364      | 1983 | Preserved Specimen |
| 20 | India | Tamil Nadu  | Doddakombai, Kundah, Nilgiris                | 11.27060 | 76.62580 | N, Ayyappan; B.R, Ramesh | HIFP024308 | 2007 | Preserved Specimen |
| 21 | India | Maharashtra | Khalapur Taluka, Raigad                      | 18.85188 | 73.23353 | Radha Veach              | 144321188  | 2013 | Human Observation  |
| 22 | India | Maharashtra | Karjat Taluka, Raigad                        | 18.90437 | 73.35287 | Radha Veach              | 144320665  | 2013 | Human Observation  |
| 23 | India | Maharashtra | Dhangarwada, Katwan, Khalapur Taluka, Raigad | 18.98783 | 73.28129 | Radha Veach              | 144319952  | 2018 | Human Observation  |
| 24 | India | Maharashtra | Mary Point, Matheran, Karjat Taluka, Raigad  | 19.00471 | 73.27904 | Radha Veach              | 144318481  | 2018 | Human Observation  |

|    |       |             |                                        |          |          |                                  |           |      |                    |
|----|-------|-------------|----------------------------------------|----------|----------|----------------------------------|-----------|------|--------------------|
| 25 | India | Maharashtra | Matheran, Karjat Taluka, Raigad        | 19.00309 | 73.27511 | Radha Veach                      | 144319432 | 2019 | Human Observation  |
| 26 | India | Kerala      | Pathadipalam, Vahzachal FD, Chalakkudy | 10.28744 | 76.76805 | Devika M.A.& Amitha Bachan K.H.  | CU216110  | 2022 | Preserved Specimen |
| 27 | India | Tamil Nadu  | Valparai, Coimbatore                   | 10.33182 | 76.84670 | Amitha Bachan K.H. & Devika M.A. | CU216110  | 2022 | Preserved Specimen |
| 28 | India | Kerala      | Way to Mannampara, Palakkad            | 10.58890 | 76.71490 | Devika M.A.& Amitha Bachan K.H.  | CU216135  | 2022 | Preserved Specimen |
| 29 | India | Kerala      | Sholayar, Vahzachal FD, Chalakkudy     | 10.31332 | 76.77733 | Devika M.A.& Amitha Bachan K.H.  | CU216121  | 2023 | Preserved Specimen |
| 30 | India | Kerala      | Chempakapalam, Karimala, Nelliampathy  | 10.52857 | 76.73899 | Devika M.A.& Amitha Bachan K.H.  | CU216140  | 2024 | Preserved Specimen |
| 31 | India | Kerala      | Nelliampathy                           | 10.53043 | 76.73614 | Devika M.A.& Amitha Bachan K.H.  | CU216146  | 2024 | Preserved Specimen |
| 32 | India | Tamil Nadu  | Valparai, Coimbatore                   | 10.30076 | 76.99977 | Rogier de Kok                    |           |      | Preserved Specimen |
| 33 | India | Kerala      | Palakkad                               | 10.83909 | 76.66740 | Rogier de Kok                    |           |      | Preserved Specimen |
| 34 | India | Tamil Nadu  | Coimbatore South, Coimbatore           | 10.98244 | 76.69255 | Rogier de Kok                    |           |      | Preserved Specimen |
| 35 | India | Tamil Nadu  | Coimbatore South, Coimbatore           | 11.05283 | 76.81489 | Rogier de Kok                    |           |      | Preserved Specimen |
| 36 | India | Kerala      | Attappadi, Mannarkad, Palakkad         | 11.07229 | 76.57036 | Rogier de Kok                    |           |      | Preserved Specimen |

|    |       |            |                                |          |          |                                    |      |  |                       |
|----|-------|------------|--------------------------------|----------|----------|------------------------------------|------|--|-----------------------|
| 37 | India | Kerala     | Mannarkad,<br>Palakkad         | 11.19783 | 76.42250 | Rogier de Kok                      |      |  | Preserved<br>Specimen |
| 38 | India | Tamil Nadu | Emerald, Kundah,<br>Nilgiris   | 11.31669 | 76.59357 | Rogier de Kok                      |      |  | Preserved<br>Specimen |
| 39 | India | Tamil Nadu | Emerald, Kundah,<br>Nilgiris   | 11.31863 | 76.59409 | Rogier de Kok                      |      |  | Preserved<br>Specimen |
| 40 | India | Tamil Nadu | Udhagamandalam,<br>Nilgiris    | 11.40105 | 76.73605 | Rogier de Kok                      |      |  | Preserved<br>Specimen |
| 41 | India | Tamil Nadu | Aravenu, Kotagiri,<br>Nilgiris | 11.41625 | 76.86476 | Rogier de Kok                      |      |  | Preserved<br>Specimen |
| 42 | India | Karnataka  | Kodchadri,<br>Shimoga          | 13.87432 | 74.86646 | K R<br>Kesavamurthy<br>& BR Ramesh | 6175 |  | Preserved<br>Specimen |

**5. *Diospyros crumenata* Thwaites, Enum. Pl. Zeyl. [Thwaites] 179 (1860).**

| SL<br>No. | Country   | State               | Location                              | Latitude | Longitude | Recorded By                | Herbarium<br>No.       | Year | Basis of<br>Record    |
|-----------|-----------|---------------------|---------------------------------------|----------|-----------|----------------------------|------------------------|------|-----------------------|
| 1         | Sri Lanka | Central<br>Province | Ceylon                                | 7.26827  | 80.59660  | Thwaites G.H.K.            | CP2438                 | 1860 | Preserved<br>Specimen |
| 2         | India     | Karnataka           | Attahalla, Bisle<br>Ghat              | 12.75778 | 75.71022  | CJ Saldanha                | CJS13202,<br>CJS 16025 | 1969 | Preserved<br>Specimen |
| 3         | Srilanka  | Eastern<br>Province | Libana estate,<br>Madhuchelle area    | 7.58686  | 81.09110  | Kostermans &<br>Jauasuriya | 202400                 | 1978 | Preserved<br>Specimen |
| 4         | India     | Karnataka           | Dakshina<br>Kannada                   | 12.75765 | 75.71021  | Talbot                     | 3560                   | 1979 | Preserved<br>Specimen |
| 5         | India     | Kerala              | Baranipachamala,<br>Thrissur Division | 10.63311 | 76.23928  | Jean-Pierre, Pascal        | HIFP005925             | 1979 | Preserved<br>Specimen |

|    |       |           |                                                          |          |          |                                                    |                    |      |                    |
|----|-------|-----------|----------------------------------------------------------|----------|----------|----------------------------------------------------|--------------------|------|--------------------|
| 6  | India | Kerala    | Vellani Mala (Pattikad), Thrissur                        | 10.58611 | 76.33056 | B.R, Ramesh; Viet, Pham Bach; De Franceschi, Dario | HIFP005927         | 1993 | Preserved Specimen |
| 7  | India | Kerala    | Vellanimala                                              | 10.58380 | 76.33160 | Sasidharan                                         | NS3122, 3377, 3954 | 1996 | Preserved Specimen |
| 8  | India | Karnataka | Ulavi-Shuralkoppa, Shimoga                               | 14.28194 | 75.11694 | B.R, Ramesh                                        | HIFP005928         | 1998 | Preserved Specimen |
| 9  | India | Karnataka | Malemane (Mavinagundi-Gerusoppa Road), Honnavar Division | 14.27500 | 74.73278 | B.R, Ramesh                                        | HIFP005929         | 1999 | Preserved Specimen |
| 10 | India | Kerala    | Palaruvi, Aryankavu, Thenmala                            | 8.94390  | 77.16410 | U.M.Chandrashekara and K.Jayaraman                 |                    | 2002 | Human Observation  |
| 11 | India | Kerala    | Chippilithode, Thamarassery, Kozhikode                   | 11.50400 | 76.02810 | U.M.Chandrashekaraand K.Jayaraman                  |                    | 2002 | Human Observation  |
| 12 | India | Kerala    | Orukumabu Reserve Forest, Parambikulam WLS               | 10.39806 | 76.65222 | B.R, Ramesh; S, Aravajy                            | HIFP005930         | 2004 | Preserved Specimen |
| 13 | India | Kerala    | Chimmini WLS                                             | 10.45806 | 76.49611 | B.R, Ramesh; S, Aravajy                            | HIFP005931         | 2004 | Preserved Specimen |
| 14 | India | Karnataka | Devimaneghat, MPCA Plot                                  | 14.52556 | 74.56139 | N, Ayyappan; B.R, Ramesh                           | HIFP005932         | 2006 | Preserved Specimen |
| 15 | India | Karnataka | Magod falls road                                         | 14.86035 | 74.75784 | Pierre Grard                                       |                    | 2007 | Human Observation  |
| 16 | India | Karnataka | Gerusoppa Forest Range                                   | 14.35806 | 74.63769 | Roy et al.                                         |                    | 2010 | Human Observation  |

|    |       |           |                                              |          |          |                                       |          |      |                    |
|----|-------|-----------|----------------------------------------------|----------|----------|---------------------------------------|----------|------|--------------------|
| 17 | India | Kerala    | Charpathodu                                  | 10.33054 | 76.58981 | Amitha Bachan KH                      | 123612   | 2010 | Preserved Specimen |
| 18 | India | Karnataka | Sarekoppa Kaan                               | 14.43786 | 75.06516 | Shruthi et al                         |          | 2016 | Human Observation  |
| 19 | India | Kerala    | Pachakkad                                    | 10.32949 | 76.58920 | Amitha Bachan KH & Devika M.A.        | 19947    | 2020 | Preserved Specimen |
| 20 | India | Kerala    | Vazhachal                                    | 10.30283 | 76.60445 | Amitha Bachan KH & Devika M.A.        | 19952    | 2020 | Preserved Specimen |
| 21 | India | Kerala    | Karanthodu                                   | 10.35074 | 76.63202 | Devika MA & Amitha Bachan KH          | 19996    | 2022 | Preserved Specimen |
| 22 | India | Kerala    | Vazhachal near bridge                        | 10.30431 | 76.60603 | Devika MA & Amitha Bachan KH          | CU216112 | 2022 | Preserved Specimen |
| 23 | India | Kerala    | Mannamangalam, Pattikkad                     | 10.48868 | 76.34029 | Jithu K Jose, K Anuraj, K.G. Gokul    |          | 2023 | Human Observation  |
| 24 | India | Kerala    | Vellanimala, Pattikad                        | 10.62041 | 76.31070 | Jithu K Jose, K Anuraj                |          | 2024 | Human Observation  |
| 25 | India | Karnataka | Hosagunda, Sagra Taluk                       | 14.10400 | 75.14368 | Shashwathi, H.S. & Y.L. Krishnamurthy |          | 2024 | Preserved Specimen |
| 26 | India | Karnataka | Joga, Sagra Taluk                            | 14.22055 | 74.81396 | Shashwathi, H.S. & Y.L. Krishnamurthy |          | 2024 | Preserved Specimen |
| 27 | India | Karnataka | Malur, Hosanagara Taluk, Shivamogga District | 13.91060 | 75.19110 | Shashwathi, H.S. & Y.L. Krishnamurthy | KUAB807  | 2024 | Preserved Specimen |
| 28 | India | Karnataka | Kalikapura, Hosanagara Taluk                 | 13.95155 | 75.07267 | Shashwathi, H.S. & Y.L. Krishnamurthy |          | 2024 | Preserved Specimen |

**6. *Dipterocarpus indicus* Bedd., in Conserv. For. Rep. (1864-65) 17.**

| SL No. | Country | State      | Location                                  | Latitude | Longitude | Recorded By         | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|-------------------------------------------|----------|-----------|---------------------|---------------|------|--------------------|
| 1      | India   | Karnataka  | South Canara                              | 13.34088 | 74.74214  | RH Beddome          |               | 1873 | Preserved Specimen |
| 2      | India   | Kerala     | Kulathupuzha, Kollam                      | 8.88490  | 77.13301  | K Chriyan Jacob     |               | 1901 | Preserved Specimen |
| 3      | India   | Tamil Nadu | Aramby shola, Nilgiris                    | 11.41360 | 76.70247  | A.G.W. De Silva     |               | 1937 | Preserved Specimen |
| 4      | India   | Karnataka  | Makut, Coorg                              | 12.11717 | 75.79014  | Sharma              |               | 1942 | Preserved Specimen |
| 5      | India   | Tamil Nadu | Dodabetta hilltop, Nilgiris               | 11.40073 | 76.73582  | K N Subramanian     | 551           | 1963 | Preserved Specimen |
| 6      | India   | Kerala     | Valara, Adimali range, Idukki             | 10.01150 | 76.95278  | KN Subramanian      | 1422          | 1964 | Preserved Specimen |
| 7      | India   | Kerala     | Ayyappankovil                             | 9.68331  | 77.05084  | E Vajravelu         | 46184         | 1975 | Preserved Specimen |
| 8      | India   | Karnataka  | Madikeri, Madikeri taluku, Kodagu         | 12.43356 | 75.74009  | Jean-Pierre, Pascal | HIFP005550    | 1975 | Human Observation  |
| 9      | India   | Karnataka  | Kollamogru, Sulya taluk, Dakshina Kannada | 12.56670 | 75.57500  | Jean-Pierre, Pascal | HIFP00551     | 1975 | Preserved Specimen |
| 10     | India   | Karnataka  | Kollamogru, Sulya taluk, Dakshina Kannada | 12.56670 | 75.57500  | Jean-Pierre, Pascal | HIFP00552     | 1975 | Preserved Specimen |
| 11     | India   | Kerala     | Ponmudi, Thiruvananthapuram               | 8.75310  | 77.12493  | A.J.G.H, Kostermans | HIFP00554     | 1976 | Preserved Specimen |
| 12     | India   | Kerala     | Moozhiyar, Konni, Pathanamthitta          | 9.31391  | 77.06665  | Jean-Pierre, Pascal | HIFP00553     | 1976 | Preserved Specimen |



|    |       |               |                                                         |          |          |                            |           |      |                       |
|----|-------|---------------|---------------------------------------------------------|----------|----------|----------------------------|-----------|------|-----------------------|
| 13 | India | Kerala        | Alathur, Palakkad                                       | 10.50000 | 76.50000 | Kostermans<br>AJGH         | L 0387135 | 1976 | Preserved<br>Specimen |
| 14 | India | Kerala        | Chittoormuzhy,<br>Achankovil, Kollam                    | 9.07914  | 77.13052 | N Sasidharan               |           | 1977 | Preserved<br>Specimen |
| 15 | India | Kerala        | Ambayathode, Iritty,<br>Kannur                          | 11.88113 | 75.88892 | Jean-Pierre,<br>Pascal     | HIFP00555 | 1978 | Preserved<br>Specimen |
| 16 | India | Kerala        | Ayyappankovil                                           | 9.69002  | 77.04466 | E Vajravelu                | 49706     | 1979 | Preserved<br>Specimen |
| 17 | India | Kerala        | Kothamangalam,<br>Ernakulam                             | 10.24167 | 76.77500 | Jean-Pierre,<br>Pascal     | HIFP00556 | 1979 | Preserved<br>Specimen |
| 18 | India | Kerala        | Kodakkathodu,<br>Thachanadu area,<br>Palpilly, Chalkudy | 10.41454 | 76.34826 | KN<br>Subramanian          | 7996      | 1982 | Preserved<br>Specimen |
| 19 | India | Kerala        | Peechi, Thrissur                                        | 10.58872 | 76.33923 | N.G. Nair                  | 1652      | 1982 | Preserved<br>Specimen |
| 20 | India | Kerala        | Vazhchal FD, Thrissur                                   | 10.31721 | 76.58929 | KN<br>Subramanian          |           | 1984 | Preserved<br>Specimen |
| 21 | India | Kerala        | Kaikatty,<br>Nelliyampathy,<br>Palakkad                 | 10.52688 | 76.67533 | N Sasidharan &<br>Swarupan | 3108      | 1984 | Preserved<br>Specimen |
| 22 | India | Tamil<br>Nadu | Nadugani, Gudalur,<br>Nilgiris                          | 11.45833 | 76.40833 | B.R, Ramesh                | HIFP00557 | 1984 | Preserved<br>Specimen |
| 23 | India | Karnataka     | Sollekallu RF,<br>Makkutta                              | 12.07698 | 75.72837 | E Vajravelu                | 77808     | 1984 | Preserved<br>Specimen |
| 24 | India | Kerala        | Kunjiyar to<br>Anakulam, Idukki                         | 10.16236 | 76.91253 | KK N Nair                  | 4400      | 1986 | Preserved<br>Specimen |
| 25 | India | Kerala        | Velakkettupara,<br>Peechi, Thrissur                     | 10.58307 | 76.32134 | N Sasidharan               | 5031      | 1988 | Preserved<br>Specimen |
| 26 | India | Kerala        | Attayar,<br>Thiruvananthapuram                          | 8.62189  | 77.21705 | N. Mohanan                 | 5561      | 1989 | Preserved<br>Specimen |

|    |       |            |                                                                |          |          |                                    |           |      |                    |
|----|-------|------------|----------------------------------------------------------------|----------|----------|------------------------------------|-----------|------|--------------------|
| 27 | India | Tamil Nadu | Way to Ainthuhalai pothigai                                    | 8.62346  | 77.27109 | R Gopalan                          | 90519     | 1989 | Preserved Specimen |
| 28 | India | Kerala     | Attayar, Thiruvananthapuram                                    | 8.68008  | 77.17638 | N. Mohanan                         | 8253      | 1989 | Preserved Specimen |
| 29 | India | Karnataka  | Thalakaveri                                                    | 12.38359 | 75.49418 | V.N.Ushakumari                     | 4886      | 1989 | Preserved Specimen |
| 30 | India | Tamil Nadu | Ambasamudram, Tirunelveli                                      | 8.59167  | 77.31667 | B.R, Ramesh; De Franceschi, Dario  | HIFP00554 | 1992 | Preserved Specimen |
| 31 | India | Tamil Nadu | Ambasamudram, Tirunelveli                                      | 8.64444  | 77.27222 | B.R, Ramesh; De Franceschi, Dario  | HIFP00558 | 1992 | Preserved Specimen |
| 32 | India | Kerala     | Bonacaud, Nedumangad, Thiruvananthapuram                       | 8.69722  | 77.17222 | B.R, Ramesh; De Franceschi, Dario  | HIFP00550 | 1992 | Preserved Specimen |
| 33 | India | Kerala     | Nedumangad, Thiruvananthapuram                                 | 8.70000  | 77.16389 | B.R, Ramesh; De Franceschi, Dario  | HIFP00552 | 1992 | Preserved Specimen |
| 34 | India | Kerala     | Nedumangad, Thiruvananthapuram                                 | 8.70000  | 77.16389 | B.R, Ramesh; De Franceschi, Dario  | HIFP00553 | 1992 | Preserved Specimen |
| 35 | India | Kerala     | Neyyattinkara, Thiruvananthapuram                              | 8.37361  | 77.10420 | R, Pelissier                       | HIFP00555 | 1993 | Preserved Specimen |
| 36 | India | Tamil Nadu | Thovalai, Kanniyakumari                                        | 8.37500  | 77.48056 | B, Montfraix; De Franceschi, Dario | HIFP00558 | 1993 | Preserved Specimen |
| 37 | India | Tamil Nadu | Balamore Road, Kalikesam, Thiruvattar, Kalkulam, Kanniyakumari | 8.45278  | 77.38750 | B, Montfraix; De Franceschi, Dario | HIFP00557 | 1993 | Preserved Specimen |

|    |       |        |                                  |          |          |                                                                |           |      |                       |
|----|-------|--------|----------------------------------|----------|----------|----------------------------------------------------------------|-----------|------|-----------------------|
| 38 | India | Kerala | Kulathupuzha,<br>Punalur, Kollam | 8.85417  | 77.08750 | B.R, Ramesh;<br>De Franceschi,<br>Dario                        | HIFP00550 | 1993 | Preserved<br>Specimen |
| 39 | India | Kerala | Konni, Pathanamthitta            | 9.38234  | 77.10445 | B.R, Ramesh                                                    | HIFP00556 | 1993 | Preserved<br>Specimen |
| 40 | India | Kerala | Chittur, Palakkad                | 10.41944 | 76.70556 | B.R, Ramesh,<br>Viet, Pham<br>Bach, De<br>Franceschi,<br>Dario | HIFP00553 | 1993 | Preserved<br>Specimen |
| 41 | India | Kerala | Chittur, Palakkad                | 10.44556 | 76.69459 | B.R, Ramesh;<br>Viet, Pham<br>Bach, De<br>Franceschi,<br>Dario | HIFP00554 | 1993 | Preserved<br>Specimen |
| 42 | India | Kerala | Kollengode, Chittur,<br>Palakkad | 10.58610 | 76.70560 | R, Pelissier                                                   | HIFP00552 | 1993 | Preserved<br>Specimen |
| 43 | India | Kerala | Pattikad, Thrissur               | 10.58611 | 76.33056 | B.R, Ramesh,<br>Viet, Pham<br>Bach, De<br>Franceschi,<br>Dario | HIFP00556 | 1993 | Preserved<br>Specimen |
| 44 | India | Kerala | Peechi, Thrissur                 | 10.51306 | 76.36317 | N Sasidharan                                                   | 5031      | 1996 | Preserved<br>Specimen |
| 45 | India | Kerala | Vellanimala, Thrissur            | 10.58380 | 76.33160 | N Sasidharan                                                   | 3967      | 1996 | Preserved<br>Specimen |
| 46 | India | Kerala | Rosemala,<br>Shendhurney, Kollam | 8.91128  | 77.17781 | N Sasidharan                                                   | 11247     | 1997 | Preserved<br>Specimen |
| 47 | India | Kerala | Rosemala,<br>Shendhurney, Kollam | 8.91644  | 77.17365 | N Sasidharan                                                   | 10982     | 1997 | Preserved<br>Specimen |

|    |       |            |                                             |          |           |                                                          |           |      |                    |
|----|-------|------------|---------------------------------------------|----------|-----------|----------------------------------------------------------|-----------|------|--------------------|
| 48 | India | Kerala     | Uppangala, Kadamakal Reserve Forest, Kodagu | 12.30000 | 75.39000  | Elouard C et al.                                         |           | 1997 | Human Observation  |
| 49 | India | Kerala     | Chenthamarakokk, Periyar, Pathanamthitta    | 9.45243  | 77.12819  | Jomy Augustine                                           | 13444     | 1998 | Preserved Specimen |
| 50 | India | Kerala     | Varagalaiar, Anamalais                      | 10.25000 | 76.52000  | N. Ayyappan & N. Parthasarathy                           |           | 1999 | Preserved Specimen |
| 51 | India | Kerala     | Pezha, Parambikulam                         | 10.44681 | 76.61151  | P Sujanapal                                              | 19362     | 2002 | Preserved Specimen |
| 52 | India | Karnataka  | Bilimale, Sulya taluk, Dakshina Kannada     | 12.56026 | 75.65598  | Pierre Grard                                             | 327207    | 2003 | Human Observation  |
| 53 | India | Karnataka  | Bhadra WLS, Karnataka                       | 13.21000 | 75.15000  | M Parinitha, GU Harish, NC Vivek, T Mahesh & MB Shivanna |           | 2004 | Human Observation  |
| 54 | India | Tamil Nadu | Ambasamudram, Tirunelveli                   | 8.80750  | 77.23278  | B.R, Ramesh, N, Ayyappan                                 | HIFP02682 | 2005 | Preserved Specimen |
| 55 | India | Kerala     | Palaruvi, Punalur, Kollam                   | 8.93120  | 77.14462  | B.R, Ramesh, N, Ayyappan                                 | HIFP02681 | 2005 | Preserved Specimen |
| 56 | India | Karnataka  | Uppangala                                   | 12.5375  | 75.662778 | N, Ayyappan, S, Ramalingam, N, Barathan                  | HIFP02521 | 2007 | Preserved Specimen |
| 57 | India | Kerala     | Vythiri Ghats, Wayanad                      | 11.50379 | 76.02896  | Ratheesh Narayanan                                       | 2281      | 2009 | Preserved Specimen |
| 58 | India | Kerala     | Vazhachal, Thrissur                         | 10.30080 | 76.60957  | Amitha Bachan KH                                         | 98697     | 2010 | Preserved Specimen |
| 59 | India | Karnataka  | Makuta                                      | 12.10000 | 75.75000  | Nageeb A. Al-Sagheer & A.G. Devi Prasad                  |           | 2010 | Preserved Specimen |

|    |       |           |                                           |          |          |                                         |        |      |                    |
|----|-------|-----------|-------------------------------------------|----------|----------|-----------------------------------------|--------|------|--------------------|
| 60 | India | Karnataka | Sakaleshpura,<br>Karnataka                | 12.87000 | 75.75000 | Nageeb A. Al-Sagheer & A.G. Devi Prasad |        | 2010 | Preserved Specimen |
| 61 | India | Karnataka | Gundya, Karnataka                         | 12.97000 | 75.69000 | Nageeb A. Al-Sagheer & A.G. Devi Prasad |        | 2010 | Preserved Specimen |
| 62 | India | Karnataka | Mudigere, Karnataka                       | 13.11000 | 75.56000 | Nageeb A. Al-Sagheer & A.G. Devi Prasad |        | 2010 | Preserved Specimen |
| 63 | India | Karnataka | Sringeri                                  | 13.51000 | 75.20000 | Nageeb A. Al-Sagheer & A.G. Devi Prasad |        | 2010 | Preserved Specimen |
| 64 | India | Karnataka | Sampaje                                   | 13.59000 | 75.77000 | Nageeb A. Al-Sagheer & A.G. Devi Prasad |        | 2010 | Preserved Specimen |
| 65 | India | Karnataka | Kattalekan                                | 14.37000 | 74.93000 | Nageeb A. Al-Sagheer & A.G. Devi Prasad |        | 2010 | Preserved Specimen |
| 66 | India | Karnataka | Devimane                                  | 14.57000 | 74.70000 | Nageeb A. Al-Sagheer & A.G. Devi Prasad |        | 2010 | Preserved Specimen |
| 67 | India | Karnataka | Anegadde, Honnavar taluku, Uttara Kannada | 14.26995 | 74.75724 |                                         |        | 2013 | Human Observation  |
| 68 | India | Karnataka | Anegadde, Honnavar taluku, Uttara Kannada | 14.27663 | 74.73857 |                                         |        | 2013 | Human Observation  |
| 69 | India | Kerala    | Madathara, Kottarakkara, Kollam           | 8.82991  | 77.01919 | Chief RedEarth                          | 339031 | 2014 | Human Observation  |

|    |       |            |                                                                |          |          |                                                                     |           |      |                    |
|----|-------|------------|----------------------------------------------------------------|----------|----------|---------------------------------------------------------------------|-----------|------|--------------------|
| 70 | India | Karnataka  | Agumbe, Someshwara Wildlife Sanctuary, Shivamogga              | 13.51377 | 75.08199 | D. Shivaprasad, C.N. Prasanna Kumar, R.K. Somashekar, B.C. Nagaraja |           | 2017 | Preserved Specimen |
| 71 | India | Tamil Nadu | Valparai, Coimbatore                                           | 10.42114 | 76.87295 | Akshay Surendra                                                     |           | 2019 | Human Observation  |
| 72 | India | Tamil Nadu | Valparai, Coimbatore                                           | 10.42235 | 76.88236 | Akshay Surendra                                                     |           | 2019 | Human Observation  |
| 73 | India | Tamil Nadu | Valparai, Coimbatore                                           | 10.42293 | 76.88317 | Akshay Surendra                                                     |           | 2019 | Human Observation  |
| 74 | India | Karnataka  | Vanake Abbi Trekking Trail, Agumbe, Tirthahalli taluk, Shimoga | 13.50869 | 75.08712 | Siddarth Machado                                                    | 67960495  | 2020 | Human Observation  |
| 75 | India | Tamil Nadu | Pollachi - Valparai Road, Iyerpaddy, Valparai, Coimbatore      | 10.37921 | 76.99003 | Madhavan A.P.                                                       | 114199235 | 2022 | Human Observation  |
| 76 | India | Kerala     | Attayar, Thiruvananthapuram                                    | 8.63527  | 77.20915 | Devika MA & Amitha Bachan KH                                        | CU216113  | 2023 | Preserved Specimen |
| 77 | India | Karnataka  | Hebri taluku, Udupi, Karnataka                                 | 13.44582 | 75.05932 | Paul Antony Mangaly                                                 | 162787935 | 2023 | Human Observation  |
| 78 | India | Karnataka  | Malanduru, Tirthahalli taluk, Shimoga                          | 13.48882 | 75.11816 | Aditya Bari                                                         | 162435824 | 2023 | Human Observation  |
| 79 | India | Karnataka  | Madamakki, Hebri taluku, Udupi                                 | 13.51659 | 75.01028 | Samrudh Nandagopal                                                  | 162180363 | 2023 | Human Observation  |
| 80 | India | Karnataka  | Hosuru, Tirthahalli taluk, Shimoga                             | 13.54761 | 75.08631 | Aditya Bari                                                         | 162429887 | 2023 | Human Observation  |

|    |       |        |                                          |          |          |                                    |          |      |                       |
|----|-------|--------|------------------------------------------|----------|----------|------------------------------------|----------|------|-----------------------|
| 81 | India | Kerala | Dharpakulam,<br>Shendurney               | 8.91238  | 77.19287 | Devika MA &<br>Amitha Bachan<br>KH | CU216155 | 2024 | Preserved<br>Specimen |
| 82 | India | Kerala | Rosemala,<br>Shendurney                  | 8.92054  | 77.18441 | Devika MA &<br>Amitha Bachan<br>KH | CU216160 | 2024 | Preserved<br>Specimen |
| 83 | India | Kerala | Malayatoor,<br>Ernakulam                 | 10.16196 | 76.64171 | Devika MA &<br>Amitha Bachan<br>KH | AH25227  | 2023 | Preserved<br>Specimen |
| 84 | India | Kerala | Pachakkad,<br>Vazhachal, Thrissur        | 10.32949 | 76.58920 | Devika MA &<br>Amitha Bachan<br>KH | CU216115 | 2023 | Preserved<br>Specimen |
| 85 | India | Kerala | Karanthode,<br>Vazhachal FD,<br>Thrissur | 10.35085 | 76.63377 | Devika MA &<br>Amitha Bachan<br>KH | CU216117 | 2023 | Preserved<br>Specimen |
| 86 | India | Kerala | Orukombankutty,<br>Parambikulam          | 10.37543 | 76.65404 | Devika MA &<br>Amitha Bachan<br>KH | AH25228  | 2024 | Preserved<br>Specimen |
| 87 | India | Kerala | Pothundi,<br>Nelliyampathi,<br>Palakkad  | 10.52130 | 76.63131 | Devika MA &<br>Amitha Bachan<br>KH | AH25234  | 2024 | Preserved<br>Specimen |
| 88 | India | Kerala | Meenmutty, Nilambur                      | 11.28554 | 76.23858 | Devika MA &<br>Amitha Bachan<br>KH | AH25236  | 2024 | Preserved<br>Specimen |
| 89 | India | Kerala | Vythiri Ghats,<br>Wayanad                | 11.54020 | 76.06212 | Devika MA &<br>Amitha Bachan<br>KH | AH25245  | 2024 | Preserved<br>Specimen |
| 90 | India | Kerala | Aralam Wild life<br>Sanctuary, Kannur    | 11.92198 | 75.79040 | Devika MA &<br>Amitha Bachan<br>KH | AH25248  | 2024 | Preserved<br>Specimen |



**7. *Elaeocarpus munroi* (Wight) Mast., Fl. Brit. India [J. D. Hooker] 1(2): 407 (1874).**

| SL No. | Country | State      | Location                     | Latitude | Longitude | Recorded By     | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|------------------------------|----------|-----------|-----------------|---------------|------|--------------------|
| 1      | India   | Tamil Nadu | Palani Hills, Dindigul       | 10.18956 | 77.50195  | R.H. Beddome    |               | 1804 | Preserved Specimen |
| 2      | India   | Tamil Nadu | Anamalai                     | 10.32814 | 77.08946  | Beddome         |               | 1804 | Preserved Specimen |
| 3      | India   | Tamil Nadu | Udhagamandalam, Nilgiris     | 11.41040 | 76.72490  | JS Gamble       | 12635         | 1883 | Preserved Specimen |
| 4      | India   | Tamil Nadu | Travancore                   | 8.45453  | 77.42656  | T.F.Bourdillon  | 334           | 1894 | Preserved Specimen |
| 5      | India   | Tamil Nadu | Monica, Coimbatore           | 10.32483 | 76.92879  | C.A. Barber     | 3885          | 1901 | Preserved Specimen |
| 6      | India   | Tamil Nadu | Punachi, Coimbatore          | 11.45818 | 76.95930  | C.A. Barber     | 3715          | 1901 | Preserved Specimen |
| 7      | India   | Kerala     | Anamalais                    | 10.10782 | 77.03224  | C.A. Barber     | 5456          | 1903 | Preserved Specimen |
| 8      | India   | Tamil Nadu | Attapara, Malayatur          | 10.26709 | 76.89394  | CEO Fischer     | 2316          | 1910 | Preserved Specimen |
| 9      | India   | Tamil Nadu | Madura                       | 9.63669  | 77.35889  | KC Jacob        | 17563         | 1925 | Preserved Specimen |
| 10     | India   | Tamil Nadu | Anaikatty, Coimbatore        | 11.08966 | 76.76126  | V Narayanaswami | 3986          | 1930 | Preserved Specimen |
| 11     | India   | Tamil Nadu | Aramby shola, Nilgiri        | 11.35768 | 76.81000  | A.G.W.De Silva  |               | 1937 | Preserved Specimen |
| 12     | India   | Kerala     | Muthikulam, Siruvani, Madras | 10.94270 | 76.65161  | A.N.Henry       | 639           | 1960 | Preserved Specimen |
| 13     | India   | Kerala     | Muthikulam, Siruvani, Madras | 10.95353 | 76.64992  | A.N.Henry       | 640           | 1960 | Preserved Specimen |

|    |       |               |                                                |          |          |                             |       |      |                       |
|----|-------|---------------|------------------------------------------------|----------|----------|-----------------------------|-------|------|-----------------------|
| 14 | India | Kerala        | Muthikulam,<br>Siruvani, Madras                | 10.95782 | 76.64966 | A.N.Henry                   | 406   | 1960 | Preserved<br>Specimen |
| 15 | India | Tamil<br>Nadu | Manjanamparai,<br>Tirunelveli                  | 8.58418  | 77.37867 | A N Henry                   | 16380 | 1963 | Preserved<br>Specimen |
| 16 | India | Tamil<br>Nadu | Manjanamparai,<br>Tirunelveli                  | 8.58516  | 77.37868 | A N Henry                   | 17463 | 1963 | Preserved<br>Specimen |
| 17 | India | Tamil<br>Nadu | 19+20 mile from<br>ooty to gudalur road        | 11.48795 | 76.48975 | N Subramaian                | 659   | 1963 | Preserved<br>Specimen |
| 18 | India | Tamil<br>Nadu | Kanikketty,<br>Tirunelveli                     | 8.67101  | 77.25680 | N Subramaian                |       | 1964 | Preserved<br>Specimen |
| 19 | India | Tamil<br>Nadu | Kanikatti,<br>Tirunelvelli, Madras             | 8.59446  | 77.52748 | AN Henry & M<br>Chandrabose | 19294 | 1964 | Preserved<br>Specimen |
| 20 | India | Kerala        | Walayar, Palakkad                              | 10.84554 | 76.79803 | E Vajravelu                 | 19149 | 1964 | Preserved<br>Specimen |
| 21 | India | Kerala        | Silent valley,<br>Munnar, Devikulam,<br>Idukki | 10.09868 | 77.05647 | E Vajravelu                 | 26121 | 1965 | Preserved<br>Specimen |
| 22 | India | Tamil<br>Nadu | Kodaikanal,<br>Dindigul                        | 10.35100 | 77.51700 | F, Blasco                   |       | 1966 | Preserved<br>Specimen |
| 23 | India | Tamil<br>Nadu | Way to Naterikal,<br>Tirunelveli               | 8.56536  | 77.30491 | E Vajravelu                 | 29230 | 1967 | Preserved<br>Specimen |
| 24 | India | Tamil<br>Nadu | Udhagamandalam,<br>Nilgiris                    | 11.40830 | 76.73330 | Ph, Guinet                  |       | 1967 | Preserved<br>Specimen |
| 25 | India | Tamil<br>Nadu | Coonor-Mettu<br>palayam road                   | 11.35687 | 76.79678 | N Subramaian                |       | 1969 | Preserved<br>Specimen |
| 26 | India | Karnataka     | Genkelbetta, Hassan<br>district                | 13.29682 | 76.21488 | CJ Saldanha                 | 16147 | 1970 | Preserved<br>Specimen |
| 27 | India | Tamil<br>Nadu | Kinnakurai to<br>Carrington                    | 11.20834 | 76.63618 | B V Shetty                  | 37684 | 1971 | Preserved<br>Specimen |
| 28 | India | Tamil<br>Nadu | Lamb's rock -<br>coonoor                       | 11.35256 | 76.83803 | N C Rathakrishnan           | 39103 | 1971 | Preserved<br>Specimen |

|    |       |            |                                 |          |          |                     |       |                    |                    |
|----|-------|------------|---------------------------------|----------|----------|---------------------|-------|--------------------|--------------------|
| 29 | India | Tamil Nadu | Naduvattam                      | 11.46995 | 76.54963 | N C Rathakrishnan   | 39056 | 1971               | Preserved Specimen |
| 30 | India | Tamil Nadu | Uthamapalayam, Theni            | 9.64028  | 77.36670 | F, Blasco           |       | 1972               | Preserved Specimen |
| 31 | India | Tamil Nadu | Bikkamara RF                    | 11.43465 | 76.78381 | E Vajravelu         | 41960 | 1972               | Preserved Specimen |
| 32 | India | Tamil Nadu | Andiparai shola, Coimbatore     | 10.33005 | 76.93366 | E Vajravelu         | 44319 | 1973               | Preserved Specimen |
| 33 | India | Tamil Nadu | Andiparai shola, Coimbatore     | 10.33005 | 76.93366 | E Vajravelu         | 46079 | 1974               | Preserved Specimen |
| 34 | India | Tamil Nadu | Way to Muthukuzhyvayal          | 8.47650  | 77.38466 | A.N.Henry           | 48184 | 1976               | Preserved Specimen |
| 35 | India | Tamil Nadu | Ambasamudram, Tirunelveli       | 8.72500  | 77.24170 | A.J.G.H, Kostermans |       | 1976               | Preserved Specimen |
| 37 | India | Kerala     | Ponmudi, Thiruvananthapuram     | 8.76850  | 77.10822 | CE Ridsdale         | 84    | 1976               | Preserved Specimen |
| 38 | India | Kerala     | Kumily Peerumade, Idukki        | 9.59167  | 77.17500 | A.J.G.H, Kostermans | 1976  | Preserved Specimen |                    |
| 39 | India | Tamil Nadu | Mettu palayam, Nilgiri          | 11.35566 | 76.93174 | N Subramaian        |       | 1977               | Preserved Specimen |
| 40 | India | Karnataka  | Madikeri taluku, Kodagu         | 12.47642 | 75.66143 | Jean-Pierre, Pascal |       | 1977               | Preserved Specimen |
| 41 | India | Kerala     | RF above damsite, Silent valley | 11.07371 | 76.42387 | NC Nair             | 56702 | 1978               | Preserved Specimen |
| 42 | India | Kerala     | Pathanthode                     | 9.94746  | 77.03386 | N Saidharan         |       | 1979               | Preserved Specimen |
| 43 | India | Kerala     | Aruvampara slope SVRF, Palghat  | 11.09313 | 76.46589 | NC Nair             | 64545 | 1979               | Preserved Specimen |
| 44 | India | Karnataka  | Chickmagalur                    | 13.29010 | 75.70809 | CJ Saldanha         | 9734  | 1979               | Preserved Specimen |

|    |       |            |                                               |          |          |                            |       |      |                    |
|----|-------|------------|-----------------------------------------------|----------|----------|----------------------------|-------|------|--------------------|
| 45 | India | Tamil Nadu | Kanikketty, Tirunelveli                       | 8.59075  | 77.44850 | AN Henry & M S Swaminathan | 68818 | 1980 | Preserved Specimen |
| 46 | India | Kerala     | Upper sanitorium, Ponmudi                     | 8.75790  | 77.11691 | M Mohanan                  | 66613 | 1980 | Preserved Specimen |
| 47 | India | Kerala     | Ponmudi, Thiruvananthapuram                   | 8.76573  | 77.10844 | M Mohanan                  | 66093 | 1980 | Preserved Specimen |
| 48 | India | Kerala     | Way to lower sanitorium, Ponmudi              | 8.76870  | 77.10822 | K Vivekananthan            | 66133 | 1980 | Preserved Specimen |
| 49 | India | Kerala     | Pamba dam to Kakki dam, Konni, Pathanamthitta | 9.20289  | 77.15349 | K Vivekananthan            | 66214 | 1980 | Preserved Specimen |
| 50 | India | Tamil Nadu | Donnington, Kotagiri, Nilgiris                | 11.42033 | 76.86019 | Muthu Karthick             |       | 1980 | Human Observation  |
| 51 | India | Kerala     | Ponmudi, Thiruvananthapuram                   | 8.76091  | 77.11155 | N Ssidharan                |       | 1982 | Preserved Specimen |
| 52 | India | Kerala     | Bison Valley, Devikulam                       | 10.00882 | 77.11569 | Nambiar & N Sasidharan     | 1982  |      | Preserved Specimen |
| 53 | India | Kerala     | Vattavada, Munnar                             | 10.17301 | 77.26181 | Nambiar & N Sasidharan     | 1982  |      | Preserved Specimen |
| 54 | India | Kerala     | Damsite, Silent Valley                        | 11.06956 | 76.42629 | T. Sabu                    | 11191 | 1983 | Preserved Specimen |
| 55 | India | Kerala     | Thiruvananthapuram                            | 8.76524  | 77.10695 | T.F.Bourdillon             |       | 1984 | Preserved Specimen |
| 56 | India | Kerala     | Pamba, Konni, Pathanamthitta                  | 9.39526  | 77.15585 | N Saidharan                |       | 1984 | Preserved Specimen |
| 57 | India | Kerala     | Mannarkad, Palakkad                           | 11.13330 | 76.41670 | B.R, Ramesh                |       | 1984 | Preserved Specimen |
| 58 | India | Tamil Nadu | Gudallur-Ooty Road, Udthagamandalam, Nilgiris | 11.48017 | 76.54433 | B.R, Ramesh                |       | 1984 | Preserved Specimen |

|    |       |            |                                                |          |          |                                   |              |      |                    |
|----|-------|------------|------------------------------------------------|----------|----------|-----------------------------------|--------------|------|--------------------|
| 59 | India | Tamil Nadu | Kakachi, Kalakad WLS                           | 8.70952  | 77.28939 | KN Subramanian & B Gurudevasingh  |              | 1987 | Preserved Specimen |
| 60 | India | Kerala     | Karamanayar, Thiruvananthapuram                | 8.65211  | 77.18592 | N. Mohanan                        | 4474         | 1988 | Preserved Specimen |
| 61 | India | Kerala     | Athirumala, Thiruvananthapuram                 | 8.68195  | 77.19013 | N. Mohanan                        | 4228         | 1988 | Preserved Specimen |
| 62 | India | Kerala     | Athirumala, Thiruvananthapuram                 | 8.64412  | 77.21091 | N. Mohanan                        | 9297         | 1988 | Preserved Specimen |
| 63 | India | Kerala     | Athirumala, Thiruvananthapuram                 | 8.60396  | 77.23880 | N. Mohanan                        | 9633         | 1988 | Preserved Specimen |
| 64 | India | Kerala     | Kakki forest, Pathanamthitta                   | 9.32670  | 77.14481 | R Chandrashekar                   | 88526        | 1988 | Preserved Specimen |
| 65 | India | Kerala     | Way to Kakki forest, Pathanamthitta            | 9.36841  | 77.15664 | R Chandrashekar                   | 88506        | 1988 | Preserved Specimen |
| 66 | India | Tamil Nadu | TNEB shed area HW estate, Madurai              | 9.63747  | 77.35391 | V Lakshmanan                      | 89037        | 1988 | Preserved Specimen |
| 67 | India | Kerala     | Mannarkad, Palakkad                            | 11.06328 | 76.47816 | SV                                | 10692, 11191 | 1988 | Preserved Specimen |
| 68 | India | Tamil Nadu | Kanikketty, Tirunelveli                        | 8.67101  | 77.25680 | Shanavas Khan                     | 5314         | 1989 | Preserved Specimen |
| 69 | India | Kerala     | Athirumala, Thiruvananthapuram                 | 8.62246  | 77.23159 | N. Mohanan                        | 5105         | 1989 | Preserved Specimen |
| 70 | India | Tamil Nadu | Nanguneri, Tirunelveli                         | 8.44167  | 77.47500 | B.R, Ramesh; De Franceschi, Dario |              | 1990 | Preserved Specimen |
| 71 | India | Tamil Nadu | Upper manalar estate, Madurai                  | 9.69547  | 77.39886 | V Lakshmanan                      | 93505        | 1990 | Preserved Specimen |
| 72 | India | Tamil Nadu | Vellainimoodu way to Nagapothigai, Tirunelveli | 8.53396  | 77.44542 | R Gopalan                         | 91783        | 1991 | Preserved Specimen |

|    |       |            |                                            |          |          |                                    |       |      |                    |
|----|-------|------------|--------------------------------------------|----------|----------|------------------------------------|-------|------|--------------------|
| 73 | India | Tamil Nadu | Thiruvattar, Kanniyakumari, Tamil Nadu     | 8.48333  | 77.38610 | B.R, Ramesh; De Franceschi, Dario  |       | 1992 | Preserved Specimen |
| 74 | India | Tamil Nadu | Lengaltheri estate river bank, Tirunelveli | 8.53397  | 77.44542 | R Gopalan                          | 99498 | 1992 | Preserved Specimen |
| 75 | India | Tamil Nadu | Kanikketty, Tirunelveli                    | 8.58039  | 77.46178 | R Gopalan                          | 99478 | 1992 | Preserved Specimen |
| 76 | India | Kerala     | Silent valley, Munnar, Devikulam, Idukki   | 10.09769 | 77.05825 | A Nazarudeen                       | 15011 | 1992 | Preserved Specimen |
| 77 | India | Tamil Nadu | Thiruvattar, Kanniyakumari                 | 8.47083  | 77.39030 | De Franceschi, Dario; B, Montfraix |       | 1993 | Preserved Specimen |
| 78 | India | Tamil Nadu | Agasthyamala                               | 8.61759  | 77.24392 | A Nazarudeen                       | 16711 | 1993 | Preserved Specimen |
| 79 | India | Kerala     | Bonaccord, Thiruvananthapuram              | 8.67594  | 77.18192 | A Nazarudeen                       | 17147 | 1993 | Preserved Specimen |
| 80 | India | Kerala     | Devikulam                                  | 10.05407 | 77.10775 | A Nazarudeen                       | 17829 | 1993 | Preserved Specimen |
| 81 | India | Kerala     | Silent valley, Munnar, Devikulam, Idukki   | 10.09444 | 77.05710 | A Nazarudeen                       | 18718 | 1993 | Preserved Specimen |
| 82 | India | Kerala     | Bonaccord, Thiruvananthapuram              | 8.68055  | 77.16703 | A Nazarudeen                       | 21768 | 1994 | Preserved Specimen |
| 83 | India | Kerala     | Ponmudi, Thiruvananthapuram                | 8.76755  | 77.10965 | N. Mohanan                         | 8106  | 1994 | Preserved Specimen |
| 84 | India | Kerala     | Pachakkanam                                | 9.45974  | 77.15405 | Jomy Augustine                     | 14086 | 1994 | Preserved Specimen |
| 85 | India | Kerala     | Athirumala riverside way to Agasthyamala   | 8.62096  | 77.22246 | C. Satheeshkumar                   | 24381 | 1995 | Preserved Specimen |

|     |       |            |                                   |          |          |                                      |       |      |                    |
|-----|-------|------------|-----------------------------------|----------|----------|--------------------------------------|-------|------|--------------------|
| 86  | India | Kerala     | Silent valley camp shed, Palakkad | 11.08277 | 76.42243 | Saji T.G. & Ajanatind B.             | 25801 | 1995 | Preserved Specimen |
| 87  | India | Kerala     | Sairandhri, Palakkad              | 11.09235 | 76.44425 | T.S. Nayar                           | 25836 | 1996 | Preserved Specimen |
| 88  | India | Kerala     | Aladi, Pathanamthitta             | 9.43354  | 77.17974 | Jomy Augustine                       | 13555 | 1998 | Preserved Specimen |
| 89  | India | Kerala     | Pachakkanam                       | 9.46243  | 77.15542 | Jomy Augustine                       | 12293 | 1998 | Preserved Specimen |
| 90  | India | Kerala     | Bhadrakali chola, Idukki          | 9.94939  | 77.08955 | S. D. Biju                           | 37443 | 1998 | Preserved Specimen |
| 91  | India | Kerala     | Rajmalai, Idukki                  | 10.18025 | 77.01027 | S. D. Biju                           | 38301 | 1998 | Preserved Specimen |
| 92  | India | Tamil Nadu | Erumbala New Amarambalam          | 11.37230 | 76.51520 | R Jayakumar                          |       | 1999 | Preserved Specimen |
| 93  | India | Karnataka  | Kalasa taluk, Chikkamagaluru      | 13.23280 | 75.17920 | B.R, Ramesh                          |       | 1999 | Preserved Specimen |
| 94  | India | Kerala     | Chemunji, Thiruvananthapuram      | 8.67198  | 77.18391 | G. Rajkumar                          | 46569 | 2001 | Preserved Specimen |
| 95  | India | Kerala     | Silent Valley NP, Palakkad        | 11.07218 | 76.41958 | C Kunhikannan & N Venkatasubramanian |       | 2003 | Preserved Specimen |
| 96  | India | Kerala     | Kakki hills, Pathanamthitta       | 9.33222  | 77.14213 | N Anilkumar                          | 1349  | 2005 | Preserved Specimen |
| 97  | India | Karnataka  | Kalasa taluk, Chikkamagaluru      | 13.21140 | 75.21080 | N, Ayyappan; B.R, Ramesh             |       | 2006 | Preserved Specimen |
| 98  | India | Kerala     | Munnar, Devikulam, Idukki         | 10.06000 | 77.10330 | N, Ayyappan; P.V, Karunakaran        |       | 2007 | Preserved Specimen |
| 99  | India | Kerala     | Silent valley, Munnar, Devikulam  | 10.11486 | 77.01363 | Geetha, Deepthi and A.G. Pandurangan | 60436 | 2008 | Preserved Specimen |
| 100 | India | Kerala     | Pookodu, Vythiri, Wayanad         | 11.54081 | 76.02533 | Ratheesh Narayanan                   | 2190  | 2009 | Preserved Specimen |



|     |       |               |                                          |          |          |                          |       |      |                       |
|-----|-------|---------------|------------------------------------------|----------|----------|--------------------------|-------|------|-----------------------|
| 101 | India | Kerala        | Kurichiarmala,<br>Wayanad                | 11.61193 | 76.10258 | Ratheesh Narayanan       | 1426  | 2009 | Preserved<br>Specimen |
| 102 | India | Kerala        | Periya,<br>Mananthavady,<br>Wayanad      | 11.84448 | 75.85701 | Ratheesh Narayanan       | 2788  | 2009 | Preserved<br>Specimen |
| 103 | India | Kerala        | Devikulam                                | 10.05404 | 77.10777 | S. M. Shareef            | 69331 | 2010 | Preserved<br>Specimen |
| 104 | India | Kerala        | Attayar,<br>Thiruvananthapuram           | 8.62189  | 77.21705 | G. Rajkumar              | 42830 | 2011 | Preserved<br>Specimen |
| 105 | India | Kerala        | Vaguari , Idukki                         | 10.17995 | 77.10408 | T. Shaju                 | 66705 | 2011 | Preserved<br>Specimen |
| 106 | India | Tamil<br>Nadu | Vellaisngiri hills,<br>coimbatore        | 10.98514 | 76.69569 | Aravindhan V             | 8095  | 2012 | Preserved<br>Specimen |
| 107 | India | Kerala        | Mannavan chola,<br>Idukki                | 10.20028 | 77.19661 | S. M. Shareef            | 72470 | 2013 | Preserved<br>Specimen |
| 108 | India | Kerala        | Periya,<br>Mananthavady,<br>Wayanad      | 11.83563 | 75.85630 | Vinayaraj V R            |       | 2013 | Human<br>Observation  |
| 109 | India | Kerala        | Way to Amar<br>solar,Idukki              | 10.15417 | 77.07862 | S. M. Shareef            | 76150 | 2014 | Preserved<br>Specimen |
| 110 | India | Tamil<br>Nadu | Solai kuruku,<br>Valparai,<br>Coimbatore | 10.33704 | 76.96886 | M Alister                | 85740 | 2015 | Preserved<br>Specimen |
| 111 | India | Karnataka     | Talakaveri, Madikeri<br>taluku, Kodagu   | 12.38293 | 75.49393 | Siddarth Jude<br>Machado |       | 2015 | Human<br>Observation  |
| 112 | India | Kerala        | Palode,<br>Thiruvananthapuram            | 8.72775  | 77.02340 | G. Rajkumar              |       | 2017 | Preserved<br>Specimen |
| 113 | India | Karnataka     | Karungala,<br>Bhagamandala               | 12.38638 | 75.52130 | G. Rajkumar              | 91628 | 2017 | Preserved<br>Specimen |

|     |       |               |                                                |          |          |                                 |          |      |                       |
|-----|-------|---------------|------------------------------------------------|----------|----------|---------------------------------|----------|------|-----------------------|
| 114 | India | Karnataka     | Kabbinakadu,<br>Madikeri taluku,<br>Kodagu     | 12.22454 | 75.64957 | Siddarth Jude<br>Machado        |          | 2018 | Human<br>Observation  |
| 115 | India | Kerala        | Way to Kanketty,<br>Mankulam                   | 10.11855 | 76.93055 | Vishu Mohan                     | 164582   | 2019 | Preserved<br>Specimen |
| 116 | India | Kerala        | Pambadum Shola<br>National park,<br>Idukki     | 10.12768 | 77.26072 | Vishu Mohan                     | 167838   | 2019 | Preserved<br>Specimen |
| 117 | India | Tamil<br>Nadu | Biligiri Rangaswamy<br>Temple Tiger<br>Reserve | 11.72700 | 77.00700 | J Jayanthi                      | 207032   | 2023 | Preserved<br>Specimen |
| 118 | India | Kerala        | Chathurangapara,<br>Idukki                     | 9.88482  | 77.21907 | Devika MA &<br>Amitha Bachan KH | CU216159 | 2024 | Preserved<br>Specimen |
| 119 | India | Kerala        | Meesapulimala,<br>Idukki                       | 10.09558 | 77.18607 | Devika MA &<br>Amitha Bachan KH | AH25253  | 2024 | Preserved<br>Specimen |
| 120 | India | Kerala        | Pampadumshola NP,<br>Idukki                    | 10.12386 | 77.25479 | Devika MA &<br>Amitha Bachan KH | CU216158 | 2024 | Preserved<br>Specimen |
| 121 | India | Kerala        | Gundumallay Estate,<br>Devikulam               | 10.12581 | 77.13597 | Devika MA &<br>Amitha Bachan KH | AH25250  | 2024 | Preserved<br>Specimen |
| 122 | India | Kerala        | Pampadumshola NP,<br>Idukki                    | 10.14152 | 77.25662 | Devika MA &<br>Amitha Bachan KH | AH25249  | 2024 | Preserved<br>Specimen |
| 123 | India | Kerala        | Pettimudi, Idukki                              | 10.17427 | 77.02352 | Devika MA &<br>Amitha Bachan KH | CU216157 | 2023 | Preserved<br>Specimen |
| 124 | India | Kerala        | Anamudi Shola NP                               | 10.18826 | 77.18116 | Devika MA &<br>Amitha Bachan KH | CU216154 | 2023 | Preserved<br>Specimen |
| 125 | India | Kerala        | Eravikulam, Idukki                             | 10.21758 | 77.07598 | Devika MA &<br>Amitha Bachan KH | CU216144 | 2023 | Preserved<br>Specimen |
| 126 | India | Kerala        | Varattukulam,<br>Idukki                        | 10.23359 | 77.10299 | Devika MA &<br>Amitha Bachan KH | CU216143 | 2023 | Preserved<br>Specimen |
| 127 | India | Tamil<br>Nadu | Valparai                                       | 10.39165 | 76.99965 | Devika MA &<br>Amitha Bachan KH |          | 2023 | Human<br>Observation  |

|     |       |        |                           |          |          |                                 |          |      |                       |
|-----|-------|--------|---------------------------|----------|----------|---------------------------------|----------|------|-----------------------|
| 128 | India | Kerala | Chembara peak,<br>Wayanad | 11.50657 | 76.08350 | Devika MA &<br>Amitha Bachan KH | CU216166 | 2023 | Preserved<br>Specimen |
|-----|-------|--------|---------------------------|----------|----------|---------------------------------|----------|------|-----------------------|

**8. *Elaeocarpus recurvatus* Corner, Gard. Bull. Straits Settlem. 10: 325 (1939).**

| SL No. | Country | State      | Location                                  | Latitude | Longitude | Recorded By                 | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|-------------------------------------------|----------|-----------|-----------------------------|---------------|------|--------------------|
| 1      | India   | Tamil Nadu | Kodaikanal, Palani, Idukki                | 10.24208 | 77.47318  | Bourne                      | 220           | 1897 | Preserved Specimen |
| 2      | India   | Tamil Nadu | Koramparai, Anamalai Hills                | 10.32814 | 77.08946  | CEO Fischer                 | 3560          | 1913 | Preserved Specimen |
| 3      | India   | Tamil Nadu | Observatory, Road Kodaikanal Palani hills | 10.23574 | 77.47863  | KC Jacob                    | 16195         | 1919 | Preserved Specimen |
| 4      | India   | Kerala     | Nedungayam, Malappuram                    | 11.35266 | 76.54238  | M M Appayya                 |               | 1962 | Preserved Specimen |
| 5      | India   | Tamil Nadu | Kundah Researve Forest                    | 11.26612 | 76.63751  | KN Subramanian              | 617           | 1963 | Preserved Specimen |
| 6      | India   | Tamil Nadu | Tamil Nadu                                | 10.20830 | 77.45000  | F, Blasco; V.M, Meher-Homji | HIFP006563    | 1965 | Preserved Specimen |
| 7      | India   | Kerala     | Umayamala margin of shola, Munnar         | 10.25305 | 77.05572  | BV Shetty                   | 26481         | 1965 | Preserved Specimen |
| 8      | India   | Kerala     | Umayamala margin of shola, Munnar         | 10.25100 | 77.05500  | BV Shetty                   | 27315         | 1966 | Preserved Specimen |
| 9      | India   | Tamil Nadu | Kodaikanal, Dindigul                      | 10.24170 | 77.51670  | Legriss, Pierre             | HIFP006566    | 1967 | Preserved Specimen |
| 10     | India   | Tamil Nadu | TR Bazar shola, Nilgiris                  | 11.46293 | 76.55087  | JL Ellis                    | 34754         | 1970 | Preserved Specimen |
| 11     | India   | Tamil Nadu | Carriott shola, Mudimund                  | 11.42738 | 76.71152  | JL Ellis                    | 37865         | 1971 | Preserved Specimen |

|    |       |            |                                     |          |          |                                                             |            |      |                       |
|----|-------|------------|-------------------------------------|----------|----------|-------------------------------------------------------------|------------|------|-----------------------|
| 12 | India | Tamil Nadu | Lakkadi, Nilgiri                    | 11.34246 | 76.59129 | K<br>Vivekananthan                                          | 40391      | 1972 | Preserved<br>Specimen |
| 13 | India | Tamil Nadu | Mudimumdu, Nilgiri                  | 11.37900 | 76.58621 | JL Ellis                                                    | 43407      | 1972 | Preserved<br>Specimen |
| 14 | India | Tamil Nadu | Tamil Nadu                          | 10.26670 | 77.51670 | Jean-Pierre,<br>Pascal                                      | HIFP006568 | 1974 | Preserved<br>Specimen |
| 15 | India | Kerala     | Anginda, Silent valley,<br>Palakkad | 11.18802 | 76.45530 | K.S.Prasanna<br>kumar                                       | 11171      | 1983 | Preserved<br>Specimen |
| 16 | India | Kerala     | Western Slope<br>Eravikulam hut     | 10.22020 | 77.08026 | P Bhargavan                                                 | 82341      | 1987 | Preserved<br>Specimen |
| 17 | India | Tamil Nadu | Sispara                             | 11.20309 | 76.45035 | KSP-SV                                                      | 11171      | 1988 | Preserved<br>Specimen |
| 18 | India | Tamil Nadu | Way to Dhanar Valley                | 11.40311 | 76.78326 | P Bhargavan                                                 | 90956      | 1989 | Preserved<br>Specimen |
| 19 | India | Kerala     | Anamudi, Idukki                     | 10.16381 | 77.06326 | S. D. Biju                                                  | 36119      | 1992 | Preserved<br>Specimen |
| 20 | India | Kerala     | Mattupetty- Kodaikanal,<br>Idukki   | 10.13009 | 77.16572 | A Nazarudeen                                                | 17894      | 1993 | Preserved<br>Specimen |
| 21 | India | Kerala     | Devikulam, Idukki                   | 10.17360 | 77.02920 | B.R, Ramesh;<br>De Franceschi,<br>Dario; Viet,<br>Pham Bach | HIFP006571 | 1993 | Preserved<br>Specimen |
| 22 | India | Kerala     | Devikulam, Idukki                   | 10.18750 | 77.19310 | B.R, Ramesh;<br>De Franceschi,<br>Dario; Viet,<br>Pham Bach | HIFP006572 | 1993 | Preserved<br>Specimen |
| 23 | India | Kerala     | Anamudi Motta, Idukki               | 10.08639 | 77.06294 | A Nazarudeen                                                | 20369      | 1994 | Preserved<br>Specimen |
| 24 | India | Kerala     | Silent Valley, Idukki               | 10.16381 | 77.06326 | A Nazarudeen                                                | 20332      | 1994 | Preserved<br>Specimen |

|    |       |            |                                                  |          |          |                                                                                          |            |      |                       |
|----|-------|------------|--------------------------------------------------|----------|----------|------------------------------------------------------------------------------------------|------------|------|-----------------------|
| 25 | India | Kerala     | Kirukkan Shola,<br>Eravikulam, Idukki            | 10.14497 | 77.03503 | K.N. Nair and<br>Saji                                                                    | 23441      | 1995 | Preserved<br>Specimen |
| 26 | India | Kerala     | Rajamala, Idukki                                 | 10.15929 | 77.02402 | K.N. Nair and<br>Saji                                                                    | 23580      | 1995 | Preserved<br>Specimen |
| 27 | India | Kerala     | Shola fringe, Idukki                             | 10.08639 | 77.17243 | Manoj                                                                                    | 35102      | 1997 | Preserved<br>Specimen |
| 28 | India | Kerala     | Vaguari, Idukki                                  | 10.18164 | 77.10332 | S. D. Biju                                                                               | 38212      | 1998 | Preserved<br>Specimen |
| 29 | India | Kerala     | Pothumala                                        | 11.50510 | 76.13456 | KKS                                                                                      | 17388      | 1999 | Preserved<br>Specimen |
| 30 | India | Kerala     | Devikulam, Idukki,<br>Kerala                     | 10.18080 | 77.19310 | N, Ayyappan;<br>B.R, Ramesh                                                              | HIFP006574 | 2007 | Preserved<br>Specimen |
| 31 | India | Kerala     | Silent Valley, Near Plot<br>no. 8 (KFDC), Munnar | 10.08507 | 77.07546 | Manudev &<br>Robi                                                                        | 5608       | 2012 | Preserved<br>Specimen |
| 32 | India | Tamil Nadu | Kanuvai and Madukkarai,<br>Nilgiri               | 11.02648 | 76.84284 | K.M. Prabhu<br>Kumar, V.<br>Sreeraj , Binu<br>Thomas , K.M.<br>Manudev & A.<br>Rajendran |            | 2012 | Human<br>Observation  |
| 33 | India | Kerala     | Thenmala, Idukki                                 | 10.16141 | 77.06145 | S. M. Shareef                                                                            | 72463      | 2013 | Preserved<br>Specimen |
| 34 | India | Kerala     | Amar Shola, Idukki                               | 10.15417 | 77.07862 | S. M. Shareef                                                                            | 76152      | 2014 | Preserved<br>Specimen |
| 35 | India | Kerala     | Devikulam, Idukki,<br>Kerala                     | 10.05407 | 77.10775 | Deepthi and<br>Usha                                                                      | 79747      | 2016 | Preserved<br>Specimen |
| 36 | India | Kerala     | Thenmala, Idukki                                 | 10.16151 | 77.06142 | S. M. Shareef                                                                            | 76183      | 2018 | Preserved<br>Specimen |
| 37 | India | Tamil Nadu | Kodaikanal, Dindigul                             | 10.39146 | 77.56905 | Ashwin<br>Srinivasan                                                                     |            | 2018 | Human<br>Observation  |

|    |       |        |                            |          |          |                              |          |      |                    |
|----|-------|--------|----------------------------|----------|----------|------------------------------|----------|------|--------------------|
| 38 | India | Kerala | Meesappulimala, Idukki     | 10.09131 | 77.19167 | Vishnu Mohan                 | 159141   | 2019 | Preserved Specimen |
| 39 | India | Kerala | Pampadum shola, NP, Idukki | 10.13701 | 77.26241 | Devika MA & Amitha Bachan KH | 25443    | 2023 | Preserved Specimen |
| 40 | India | Kerala | Anamudi Base camp, Idukki  | 10.16063 | 77.07218 | Devika MA & Amitha Bachan KH | CU216166 | 2023 | Preserved Specimen |
| 41 | India | Kerala | Anamudi, Idukki            | 10.16157 | 77.07122 | Devika MA & Amitha Bachan KH | CU216165 | 2023 | Preserved Specimen |
| 42 | India | Kerala | Anamudi Peak, Idukki       | 10.17322 | 77.06617 | Devika MA & Amitha Bachan KH | 25407    | 2023 | Preserved Specimen |
| 43 | India | Kerala | Pettimudi, Idukki          | 10.17427 | 77.02352 | Devika MA & Amitha Bachan KH | 25403    | 2023 | Preserved Specimen |
| 44 | India | Kerala | Anamudi shola, NP          | 10.17991 | 77.19015 | Devika MA & Amitha Bachan KH | 25438    | 2023 | Preserved Specimen |
| 45 | India | Kerala | Eravikulam, Idukki         | 10.21758 | 77.07598 | Devika MA & Amitha Bachan KH | 25425    | 2023 | Preserved Specimen |
| 46 | India | Kerala | Eravikulam Hut, Idukki     | 10.21993 | 77.07562 | Devika MA & Amitha Bachan KH | CU216163 | 2023 | Preserved Specimen |
| 47 | India | Kerala | Varattukulam, Idukki       | 10.23359 | 77.10299 | Devika MA & Amitha Bachan KH | 25419    | 2023 | Preserved Specimen |

|    |       |            |                        |          |          |                              |          |      |                    |
|----|-------|------------|------------------------|----------|----------|------------------------------|----------|------|--------------------|
| 48 | India | Kerala     | Meesappulimala, Idukki | 10.09229 | 77.18974 | Devika MA & Amitha Bachan KH | AH25254  | 2024 | Preserved Specimen |
| 49 | India | Kerala     | Meesapulimala, Idukki  | 10.09558 | 77.18607 | Devika MA & Amitha Bachan KH | CU216172 | 2025 | Preserved Specimen |
| 50 | India | Tamil Nadu | Kodaikanal, Dindigul   | 10.23000 | 77.49000 | S. John Britto               | RHT56114 |      | Preserved Specimen |

**9. *Ficus beddomei* King, Ann. Roy. Bot. Gard. (Calcutta) 1: 26, t. 24 (1888).**

| SL No. | Country | State      | Location                                  | Latitude | Longitude | Recorded By         | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|-------------------------------------------|----------|-----------|---------------------|---------------|------|--------------------|
| 1      | India   | Tamil Nadu | Tirunelvely Hills                         | 8.71502  | 77.76563  | R.H. Beddome        | 1814          | 1829 | Preserved Specimen |
| 2      | India   | Tamil Nadu | Coimbatore District, Anamalis             | 10.99737 | 76.95888  | C.A. Barber         | 4065          | 1901 | Preserved Specimen |
| 3      | India   | Tamil Nadu | Udumpanparai, Anamalais                   | 10.30000 | 77.00000  | C.A. Barber         | 5743          | 1903 | Preserved Specimen |
| 4      | India   | Tamil Nadu | Dindugal District, Sirumalais             | 10.19424 | 77.99670  | J. Pallithanam      | JP6436        | 1960 | Preserved Specimen |
| 5      | India   | Karnataka  | Shimoga district, Jogigundi falls, Agumbe | 13.48489 | 75.10862  | R. Sundara Raghavan | 86437         | 1963 | Preserved Specimen |
| 6      | India   | Karnataka  | Barakana, Agumbe, Shimoga                 | 13.52199 | 75.08711  | R. Sundara Raghavan | 90343         | 1963 | Preserved Specimen |
| 7      | India   | Karnataka  | Barakana, Agumbe, Shimoga                 | 13.50016 | 75.08312  | R. Sundara Raghavan | 97263         | 1964 | Preserved Specimen |
| 8      | India   | Kerala     | Kottayam District, Cheeyappara falls      | 9.59157  | 76.52215  | K.M. Sebastine      | 25342         | 1965 | Preserved Specimen |



|    |       |               |                                          |          |          |                               |       |      |                       |
|----|-------|---------------|------------------------------------------|----------|----------|-------------------------------|-------|------|-----------------------|
| 9  | India | Kerala        | Palakkad District,<br>Mukkali forest     | 11.05757 | 76.52679 | E. Vajravelu                  | 27776 | 1966 | Preserved<br>Specimen |
| 10 | India | Kerala        | Kannur District,<br>Chandanathode        | 11.84400 | 75.81195 | J.L. Ellis                    | 29488 | 1967 | Preserved<br>Specimen |
| 11 | India | Tamil<br>Nadu | Nilgiri District, Paridalur,<br>Devala   | 11.47255 | 76.38201 | E. Vajravelu                  | 43758 | 1973 | Preserved<br>Specimen |
| 12 | India | Kerala        | Kaikatty to Ayyappan<br>Kovil area       | 10.53747 | 76.67809 | E. Vajravelu                  | 45758 | 1975 | Preserved<br>Specimen |
| 13 | India | Tamil<br>Nadu | Tirunelveli District,<br>Cardamom estate | 8.27409  | 77.54800 | Kostermans                    | 26274 | 1976 | Preserved<br>Specimen |
| 14 | India | Kerala        | Idukki, way to mangala<br>devi temple    | 9.58120  | 77.23286 | K Vivekananthan               | 48665 | 1976 | Preserved<br>Specimen |
| 15 | India | Kerala        | Karapara estate, Palakkad                | 10.46646 | 76.64173 | E. Vajravelu                  | 48759 | 1976 | Preserved<br>Specimen |
| 16 | India | Kerala        | Vythiri, Wayanad                         | 11.54020 | 76.06212 | C.R. Suresh &<br>K.S. Manilal | 21722 | 1978 | Preserved<br>Specimen |
| 17 | India | Tamil<br>Nadu | Salem District,<br>Sottupparai           | 11.73446 | 78.20204 | K.M. Matthew                  | 18692 | 1978 | Preserved<br>Specimen |
| 18 | India | Karnataka     | Kemmangundi - Tarikere<br>road           | 13.54691 | 75.74907 | CJ Saldanha &<br>Ramesh       | 1754  | 1978 | Preserved<br>Specimen |
| 19 | India | Tamil<br>Nadu | Nadukani, Way to<br>Gudallore            | 11.50117 | 76.49216 | N. Sasidharan                 | 454   | 1979 | Preserved<br>Specimen |
| 20 | India | Kerala        | Peringamala,<br>Thiruvananthapuram       | 8.73333  | 77.06666 | Ridsdale CE                   |       | 1980 | Preserved<br>Specimen |
| 21 | India | Kerala        | Shola near upper<br>sanatorium           | 8.75769  | 77.10970 | K.<br>Vivekananthan           | 66153 | 1980 | Preserved<br>Specimen |
| 22 | India | Kerala        | Ponmudi,<br>Thiruvananthapuram           | 8.75811  | 77.11915 | C.E. Ridsdale                 | 510   | 1980 | Preserved<br>Specimen |
| 23 | India | Kerala        | Ponmudi,<br>Thiruvananthapuram           | 8.76850  | 77.10822 | M. Mohanan                    | 66608 | 1980 | Preserved<br>Specimen |

|    |       |            |                                                         |          |          |                               |                  |      |                    |
|----|-------|------------|---------------------------------------------------------|----------|----------|-------------------------------|------------------|------|--------------------|
| 24 | India | Kerala     | Ponmudi, Sholas and forest along road to old sanitorium | 8.76870  | 77.10822 | C.E.Ridsdale                  | 510              | 1980 | Preserved Specimen |
| 25 | India | Kerala     | Periakaul Estate, Idukki                                | 9.85840  | 76.95278 | K. Ramamurthy                 | 66539            | 1980 | Preserved Specimen |
| 26 | India | Kerala     | Nilambur, Thalichola                                    | 11.31620 | 76.48744 | N. Sasidharan                 | s.coll.<br>33919 | 1982 | Preserved Specimen |
| 27 | India | Kerala     | Meenmutty, Wayanad                                      | 11.72820 | 75.88613 | C.N. Mohanan                  | 73275            | 1982 | Preserved Specimen |
| 28 | India | Karnataka  | Chikkmagaluru                                           | 13.55268 | 75.78797 | Vajravelu                     | 77898            | 1984 | Preserved Specimen |
| 29 | India | Karnataka  | Kodagu, Umbalumotte, Pattighat, Baugamandala range      | 12.43369 | 75.53224 | B.R. Ramesh                   | BRR1558          | 1987 | Preserved Specimen |
| 30 | India | Kerala     | Pathanamthitta District, Anathode forest                | 9.33629  | 77.14996 | R. Chandrashekar              | 88501            | 1988 | Preserved Specimen |
| 31 | India | Kerala     | Athirumala, Thiruvananthapuram                          | 8.68303  | 77.18955 | Mohanan                       | 10029            | 1990 | Preserved Specimen |
| 32 | India | Tamil Nadu | Tirunelveli District, 4th Road, Deviyar (Deviar) Estate | 8.54882  | 77.65361 | S.R. Srinivasan               | 100044           | 1992 | Preserved Specimen |
| 33 | India | Kerala     | Uppupara, Idukki                                        | 9.60852  | 77.06984 | Jomy Augustine & N Sasidharan | 12695            | 1993 | Preserved Specimen |
| 34 | India | Kerala     | Adimaly, Idukki                                         | 10.01150 | 76.95278 | A. Nazarudean                 | 17811            | 1993 | Preserved Specimen |
| 35 | India | Kerala     | Adimali - Munnar                                        | 10.08893 | 77.05952 | A. Nazarudeen                 | 17811            | 1993 | Preserved Specimen |
| 36 | India | Kerala     | Muthappanpuzha                                          | 11.44415 | 76.08775 | A.K. Pradeep                  | 56141            | 1998 | Preserved Specimen |

|    |       |            |                                  |          |          |                                     |       |      |                    |
|----|-------|------------|----------------------------------|----------|----------|-------------------------------------|-------|------|--------------------|
| 37 | India | Tamil Nadu | Karayar, Tirunelvely             | 10.14870 | 77.38602 | E.S. Santhosh Kumar and P.C. Suresh | 40813 | 1999 | Preserved Specimen |
| 38 | India | Kerala     | Pooppara, Palakkad               | 10.34171 | 76.82977 | Sujanapal                           | 19768 | 2002 | Preserved Specimen |
| 39 | India | Kerala     | Velayudhankai, Palakkad          | 10.35731 | 76.81631 | Sujanapal                           | 19885 | 2002 | Preserved Specimen |
| 40 | India | Kerala     | Kalladi riverside, Wayanad       | 11.51231 | 76.13335 | C.Pramod                            | 81763 | 2002 | Preserved Specimen |
| 41 | India | Kerala     | Kalladi riverside, Wayanad       | 11.51038 | 76.14035 | C.Sunanda Kumari                    | 82438 | 2002 | Preserved Specimen |
| 42 | India | Kerala     | Kalladi riverside, Wayanad       | 10.51048 | 76.13489 | Seethal.J.Thattil                   | 82779 | 2002 | Preserved Specimen |
| 43 | India | Kerala     | Thrissur District, Malakkappara  | 10.27831 | 76.85840 | K.H. Amitha Bachan                  | 99076 | 2006 | Preserved Specimen |
| 44 | India | Kerala     | Vythiri, Wayanad                 | 11.51750 | 76.03618 | Ratheesh Narayanan                  | 4009  | 2009 | Preserved Specimen |
| 45 | India | Kerala     | Talimala, Wayanad                | 11.55092 | 76.04628 | Ratheesh Narayanan                  | 4003  | 2009 | Preserved Specimen |
| 46 | India | Kerala     | Periya, Wayanad                  | 11.83855 | 75.84240 | Ratheesh Narayanan                  | 4016  | 2009 | Preserved Specimen |
| 47 | India | Kerala     | Malakkapara                      | 10.28834 | 76.85114 | Amitha Bachan                       | 99076 | 2010 | Preserved Specimen |
| 48 | India | Kerala     | Pampa, Pathanamthitta            | 9.41980  | 76.93419 | Joby                                |       | 2012 | Preserved Specimen |
| 49 | India | Tamil Nadu | Attapadi, Coimbatore, Tamil Nadu | 11.09800 | 76.74700 | Ajit Ampalakkad                     |       | 2014 | Preserved Specimen |
| 50 | India | Tamil Nadu | Kolli hills- along the ghat road | 11.31478 | 78.34817 | Swamy et al.                        | 0649  | 2016 | Preserved Specimen |
| 51 | India | Kerala     | Kurichuyarmala, Wayanad          | 11.59044 | 75.99119 | G. Rajkumar                         | 87765 | 2016 | Preserved Specimen |

|    |       |               |                                          |          |          |                                             |          |      |                       |
|----|-------|---------------|------------------------------------------|----------|----------|---------------------------------------------|----------|------|-----------------------|
| 52 | India | Kerala        | Wayanad District,<br>Kurichiyamala       | 11.59640 | 75.98066 | A. Nazarudean &<br>P.M. Alister             | 87765    | 2016 | Preserved<br>Specimen |
| 53 | India | Kerala        | Tangal para, Kottayam                    | 9.66714  | 76.89923 | Sreehari S. Nair<br>& P.J. Ebin             | 12920    | 2019 | Preserved<br>Specimen |
| 54 | India | Kerala        | Sairandhri, Silent Valley,<br>Palakkad   | 11.09259 | 76.44946 | Sreehari S. Nair<br>& K.H. Amitha<br>Bachan | 12903    | 2019 | Preserved<br>Specimen |
| 55 | India | Tamil<br>Nadu | Mannampilli, Valparai                    | 10.37772 | 76.89965 | T R Shankar<br>Raman                        |          | 2021 | Preserved<br>Specimen |
| 56 | India | Kerala        | Sholayar, Vazhachal FD                   | 10.30282 | 76.72960 | Devika MA &<br>Amitha Bachan<br>KH          | AH25278  | 2023 | Preserved<br>Specimen |
| 57 | India | Kerala        | Chempakapalam,<br>Karimala, Nelliampathy | 10.52857 | 76.73899 | Devika MA &<br>Amitha Bachan<br>KH          | CU216145 | 2024 | Preserved<br>Specimen |
| 58 | India | Kerala        | Way to Minnampara,<br>Nelliampathi       | 10.54005 | 76.70553 | Devika MA &<br>Amitha Bachan<br>KH          | AH25274  | 2024 | Preserved<br>Specimen |
| 59 | India | Kerala        | Athirumala                               | 8.62096  | 77.22246 | Devika MA &<br>Amitha Bachan<br>KH          | CU216193 | 2024 | Preserved<br>Specimen |
| 60 | India | Kerala        | Shendhurney                              | 8.91644  | 77.17365 | Devika MA &<br>Amitha Bachan<br>KH          | AH25279  | 2024 | Preserved<br>Specimen |
| 61 | India | Kerala        | Way to Karappara,<br>Nelliampathi        | 10.46056 | 76.64983 | Devika MA &<br>Amitha Bachan<br>KH          | AH25291  | 2024 | Preserved<br>Specimen |

**10. *Garcinia wightii* T.Anderson, Fl. Brit. India [J. D. Hooker] 1(2): 265 (1874).**

| SL No. | Country | State  | Location                              | Latitude | Longitude | Recorded By                   | Herbarium No. | Year | Basis of Record    |
|--------|---------|--------|---------------------------------------|----------|-----------|-------------------------------|---------------|------|--------------------|
| 1      | India   | Kerala | Athirapilly, Chalakkudy, Thrissur     | 10.28867 | 76.51430  | N Sasidharan                  | 5337          | 1989 | Preserved Specimen |
| 2      | India   | Kerala | Pooyamkutty, Ernakulam                | 10.15779 | 76.78560  | AES Khan & E.S. SanthoshKumar | 18367         | 1993 | Preserved Specimen |
| 3      | India   | Kerala | Attathode, Pathanamthitta             | 9.39622  | 77.01913  | A.Nazarudeen                  | 19596         | 1994 | Preserved Specimen |
| 4      | India   | Kerala | Attathodu, Konni, Pathanamthitta      | 9.40358  | 77.02449  | Jomy Augustine                | JA12746       | 1998 | Preserved Specimen |
| 5      | India   | Kerala | Athirumala, Thiruvananthapuram        | 8.68195  | 77.19013  | Mohanan                       | NM5106        | 2002 | Preserved Specimen |
| 6      | India   | Kerala | Orukomban, Parambikulam               | 10.39365 | 76.66985  | P Sujanapal 30170             |               | 2002 | Preserved Specimen |
| 7      | India   | Kerala | Thenkudippara, Parambikulam           | 10.40327 | 76.69691  | P Sujanapal 19342             |               | 2002 | Preserved Specimen |
| 8      | India   | Kerala | Kakki hills, Konni, Pathanamthitta    | 9.32670  | 77.14481  | Anilkumar                     | NAK59         | 2005 | Preserved Specimen |
| 9      | India   | Kerala | Pathanamthitta District, Attathode    | 9.40630  | 77.02287  | Joby & George                 | 1536          | 2009 | Preserved Specimen |
| 10     | India   | Kerala | Edakadathi, Pathanamthitta            | 9.42225  | 76.90789  | Joby & Vipin                  | 1544          | 2010 | Preserved Specimen |
| 11     | India   | Kerala | Vazhachal, Chalakkudy, Thrissur       | 10.29877 | 76.58548  | Amitha Bachan                 | 98965         | 2010 | Preserved Specimen |
| 12     | India   | Kerala | Perumthenaruvi, Ranni, Pathanamthitta | 9.39623  | 76.90168  | S.M. Shareef                  | 70653         | 2011 | Preserved Specimen |
| 13     | India   | Kerala | Edakadathi, Pathanamthitta            | 9.42054  | 76.90482  | Joby & Rogimon                | 1550          | 2011 | Preserved Specimen |

|    |       |            |                                     |          |          |                                   |              |      |                    |
|----|-------|------------|-------------------------------------|----------|----------|-----------------------------------|--------------|------|--------------------|
| 14 | India | Kerala     | Paniyeli poru                       | 10.17190 | 76.60118 | PS. Shameer                       | 86648, 86649 | 2017 | Preserved Specimen |
| 15 | India | Kerala     | Museum compound, Thiruvananthapuram | 8.51204  | 76.95471 | Deepthi and Usha                  | 92284        | 2018 | Preserved Specimen |
| 16 | India | Kerala     | Thommankuthu, Thodupuzha, Idukki    | 9.95801  | 76.82365 | Vishnu Mohan                      | 164659       | 2019 | Preserved Specimen |
| 17 | India | Kerala     | Athirumala, Thiruvananthapuram      | 8.61812  | 77.22836 | Divya N Murali                    | 95600        | 2020 | Preserved Specimen |
| 18 | India | Tamil Nadu | Chittar river, Thiruvananthapuram   | 8.40463  | 77.42410 | Anoosh Varghese and A.K. Sreekala |              | 2017 | Preserved Specimen |
| 19 | India | Kerala     | Athirapilly, Thrissur               | 10.28649 | 76.56837 | Devika MA & Amitha Bachan KH      | CU216118     | 2024 | Preserved Specimen |
| 20 | India | Kerala     | Vettilapara, Vazhachal FD           | 10.29072 | 76.47237 | Devika MA & Amitha Bachan KH      | AH25293      | 2023 | Preserved Specimen |
| 21 | India | Kerala     | Vazhachal, river side               | 10.30800 | 76.60943 | Devika MA & Amitha Bachan KH      | CU216116     | 2023 | Preserved Specimen |
| 22 | India | Kerala     | Karanthode, Vazhachal FD            | 10.35074 | 76.63202 | Devika MA & Amitha Bachan KH      | AH25291      | 2023 | Preserved Specimen |
| 23 | India | Kerala     | Orukomban, Parambikulam             | 10.37435 | 76.65805 | Devika MA & Amitha Bachan KH      | CU216114     | 2023 | Preserved Specimen |

**11. *Goniothalamus wightii* Hook.f. & Thomson, Fl. Ind. [Hooker f. & Thomson] i. 106. (1855).**

| SL No. | Country | State      | Location         | Latitude | Longitude | Recorded By | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|------------------|----------|-----------|-------------|---------------|------|--------------------|
| 1      | India   | Tamil Nadu | Travancore Hills | 8.61631  | 77.24605  | RH Beddome  | MH00152094    | 1808 | Preserved Specimen |
| 2      | India   | Kerala     | Travancore Hills | 8.62713  | 77.21698  | Bourdillon  | 48            | 1889 | Preserved Specimen |

|    |       |            |                                                           |          |          |                 |            |      |                    |
|----|-------|------------|-----------------------------------------------------------|----------|----------|-----------------|------------|------|--------------------|
| 3  | India | Tamil Nadu | Sheragherry Hills, Madras                                 | 11.85156 | 78.22317 | Wight. R        | K000691813 | 1936 | Preserved Specimen |
| 4  | India | Tamil Nadu | Courtallem, Madras                                        | 8.92294  | 77.26731 | Wight. R        | K000691811 | 1936 | Preserved Specimen |
| 5  | India | Kerala     | Pachakkanam                                               | 9.55888  | 76.68219 | BD Sharma       | 43943      | 1973 | Preserved Specimen |
| 6  | India | Kerala     | Idukki                                                    | 9.85840  | 76.95278 | CN Mohanan      | 72825      | 1981 | Preserved Specimen |
| 7  | India | Kerala     | Near Anakkal Kayam - Way to Mlappara                      | 9.46665  | 77.26350 | P Bhargavan     | 69889      | 1981 | Preserved Specimen |
| 8  | India | Tamil Nadu | Way to Chokkanpatty Hills                                 | 9.59316  | 77.74217 | CN Mohanan      | 73414      | 1982 | Preserved Specimen |
| 9  | India | Tamil Nadu | Kakkachi way-Sengaltheri, Tirunelveli                     | 8.55834  | 77.38821 | E Vajravelu     | 76557      | 1983 | Preserved Specimen |
| 10 | India | Kerala     | Athirumala                                                | 8.62074  | 77.23105 | N. Mohanan      | 9238       | 1988 | Preserved Specimen |
| 11 | India | Tamil Nadu | Nagariyar estate, Saithur Hills                           | 9.44153  | 77.36106 | S.R. Srinivasan | 89481      | 1988 | Preserved Specimen |
| 12 | India | Kerala     | Chemunji                                                  | 8.69565  | 77.16939 | N. Mohanan      | 8206       | 1990 | Preserved Specimen |
| 13 | India | Tamil Nadu | Nagariyar estate, Kamarajar                               | 9.43196  | 77.35955 | SR Srinivasan   | 94440      | 1990 | Preserved Specimen |
| 14 | India | Tamil Nadu | Nagariyar estate, Kamarajar                               | 9.44233  | 77.35498 | SR Srinivasan   | 94449      | 1990 | Preserved Specimen |
| 15 | India | Kerala     | Bonacaud to Attayar                                       | 8.62712  | 77.21697 | R Gopalan       | 91705      | 1991 | Preserved Specimen |
| 16 | India | Tamil Nadu | Nagariyar to Kurathi, Viduthai estate, Kamarahar district | 9.44052  | 77.35696 | SR Srinivasan   | 98209      | 1991 | Preserved Specimen |
| 17 | India | Tamil Nadu | Peedakkadu, Tirunelveli                                   | 8.60084  | 77.48272 | R Gopalan       | 91761      | 1991 | Preserved Specimen |



|    |       |            |                                          |         |          |                           |        |      |                       |
|----|-------|------------|------------------------------------------|---------|----------|---------------------------|--------|------|-----------------------|
| 18 | India | Tamil Nadu | Way to Pothigaimalai,<br>Tirunelveli     | 8.55992 | 77.29629 | R Gopalan                 | 99341  | 1992 | Preserved<br>Specimen |
| 19 | India | Tamil Nadu | Sengaltheri to Kakkachi,<br>Thirunelveli | 8.56626 | 77.39549 | R Gopalan                 | 99941  | 1992 | Preserved<br>Specimen |
| 20 | India | Tamil Nadu | Nagariyar estate,<br>Kamarajar           | 9.43466 | 77.35240 | S.R.<br>Srinivasan        | 100001 | 1992 | Preserved<br>Specimen |
| 21 | India | Tamil Nadu | Nagariyar estate,<br>Kamarajar           | 9.43733 | 77.35716 | S.R.<br>Srinivasan        | 99108  | 1992 | Preserved<br>Specimen |
| 22 | India | Tamil Nadu | Kalpalaruvi, Tirunelveli                 | 8.71502 | 77.76563 | R Gopalan                 | 99388  | 1992 | Preserved<br>Specimen |
| 23 | India | Kerala     | Chemunji                                 | 8.70591 | 77.18803 | N. Mohanan                | 11141  | 1993 | Preserved<br>Specimen |
| 24 | India | Kerala     | Chemunji                                 | 8.71291 | 77.17233 | N. Mohanan                | 11326  | 1993 | Preserved<br>Specimen |
| 25 | India | Kerala     | Athirumala                               | 8.61978 | 77.22533 | N. Mohanan                | 11244  | 1993 | Preserved<br>Specimen |
| 26 | India | Kerala     | Peppara                                  | 8.63059 | 77.21672 | N. Mohanan<br>& T. Shaju  | 1998   | 1994 | Preserved<br>Specimen |
| 27 | India | Kerala     | Chemunji                                 | 8.71601 | 77.20177 | G. Rajkumar               | 11707  | 1994 | Preserved<br>Specimen |
| 28 | India | Kerala     | Chemunji                                 | 8.71257 | 77.15677 | G. Rajkumar               | 11731  | 1994 | Preserved<br>Specimen |
| 29 | India | Kerala     | Bonaccord                                | 8.66280 | 77.17803 | Shaju T                   | 11635  | 1994 | Preserved<br>Specimen |
| 30 | India | Kerala     | Vandamettu, Tranvancore                  | 9.72965 | 77.15427 | T.F.<br>Bourdillon        | 496    | 1995 | Preserved<br>Specimen |
| 31 | India | Kerala     | Chemunji                                 | 8.70929 | 77.18356 | A Nazarudeen              | 27471  | 1996 | Preserved<br>Specimen |
| 32 | India | Kerala     | Chemunji                                 | 8.70956 | 77.19445 | T. Shaju and<br>R. Rajesh | 33115  | 1997 | Preserved<br>Specimen |

|    |       |            |                      |          |          |                                       |              |      |                    |
|----|-------|------------|----------------------|----------|----------|---------------------------------------|--------------|------|--------------------|
| 33 | India | Kerala     | Alvarakurichi        | 8.83629  | 77.22906 | Sasidharan                            | NS 11376     | 1997 | Preserved Specimen |
| 34 | India | Kerala     | Chemunji             | 8.69543  | 77.19273 | G. Rajkumar                           | 32796        | 1998 | Preserved Specimen |
| 35 | India | Kerala     | Chemunji             | 8.73276  | 77.16304 | G. Rajkumar                           | 42838, 41852 | 2000 | Preserved Specimen |
| 36 | India | Kerala     | Mlappara             | 9.41289  | 77.26664 | Jomy Augustine                        | JA I3316     | 2000 | Preserved Specimen |
| 37 | India | Kerala     | Pachakkanam          | 9.46571  | 77.11302 | Jomy Augustine                        | JA 12317     | 2000 | Preserved Specimen |
| 38 | India | Tamil Nadu | Karayar, Tirunelveli | 8.59709  | 77.33068 | G. Rajkumar                           | 45608        | 2001 | Preserved Specimen |
| 39 | India | Kerala     | Chemunji             | 8.71253  | 77.18074 | Geethakumary and A.G. Pandurangan     | 49415        | 2003 | Preserved Specimen |
| 40 | India | Kerala     | Chemunji             | 8.73276  | 77.16304 | G. Rajkumar                           | 42501        | 2008 | Preserved Specimen |
| 41 | India | Kerala     | Chemunji             | 8.69857  | 77.16106 | Geetha, Deepthi and A. G. Pandurangan | 60574        | 2008 | Preserved Specimen |
| 42 | India | Kerala     | Chemunji             | 8.69857  | 77.16106 | G. Rajkumar                           | 44770        | 2009 | Preserved Specimen |
| 43 | India | Kerala     | Chemunji             | 8.70451  | 77.17456 | Geetha, Deepthi and A. G. Pandurangan | 65282        | 2009 | Preserved Specimen |
| 44 | India | Kerala     | Bonaccord            | 8.70399  | 77.16686 | Sheeba P.M.                           | 66300        | 2010 | Preserved Specimen |
| 45 | India | Kerala     | Sholayar             | 10.32809 | 76.75398 | Amitha Bachan                         | 99080        | 2010 | Preserved Specimen |

|    |       |            |                               |          |          |                               |        |      |                    |
|----|-------|------------|-------------------------------|----------|----------|-------------------------------|--------|------|--------------------|
| 46 | India | Kerala     | Chemunji                      | 8.70273  | 77.18827 | G. Rajkumar                   | 68853  | 2011 | Preserved Specimen |
| 47 | India | Kerala     | Chemunji                      | 8.69293  | 77.18690 | Sheeba P.M.                   | 66276  | 2011 | Preserved Specimen |
| 48 | India | Kerala     | Athirumala                    | 8.68195  | 77.19013 | G. Rajkumar                   | 64633  | 2011 | Preserved Specimen |
| 49 | India | Kerala     | Chemunji hills                | 8.70272  | 77.18827 | G. Rajkumar                   | 77156  | 2013 | Preserved Specimen |
| 50 | India | Kerala     | Chemunji                      | 8.69895  | 77.17932 | Deepthy and Usha              | 82246  | 2014 | Preserved Specimen |
| 51 | India | Kerala     | Chemunji                      | 8.79203  | 77.21831 | AG. Pandurangan and Kaikho D. | 83656  | 2014 | Preserved Specimen |
| 52 | India | Kerala     | Chemunji                      | 8.70272  | 77.18827 | M. Alister and G. Rajkumar    | 80645  | 2014 | Preserved Specimen |
| 53 | India | Kerala     | Ponmudi                       | 8.78304  | 77.09451 | Stephan J                     | 83862  | 2015 | Preserved Specimen |
| 54 | India | Kerala     | Chemunji                      | 8.71796  | 77.16971 | Alfiya and Soumya             | 88837  | 2016 | Preserved Specimen |
| 55 | India | Kerala     | Kullar Gavi, Pathanamthitta   | 9.19200  | 76.82900 | M. Alister and G. Rajkumar    | 87526  | 2016 | Preserved Specimen |
| 56 | India | Kerala     | Guntar, Gavi , Pathanamthitta | 9.44988  | 77.19419 | M. Alister and G. Rajkumar    | 87521  | 2016 | Preserved Specimen |
| 57 | India | Tamil Nadu | Karayar, Tirunelveli          | 8.63935  | 77.29451 | G. Rajkumar                   | 90742  | 2017 | Preserved Specimen |
| 58 | India | Kerala     | Chemunji                      | 8.70528  | 77.16561 | G. Rajkumar                   | 91642  | 2018 | Preserved Specimen |
| 59 | India | Kerala     | Nakshathrakuthu               | 10.08839 | 76.94661 | Vishnu Mohan                  | 168852 | 2018 | Preserved Specimen |
| 60 | India | Kerala     | Edamalakkudi                  | 10.06765 | 77.10064 | Vishnu Mohan                  | 168968 | 2019 | Preserved Specimen |

|    |       |        |          |          |          |                              |          |      |                    |
|----|-------|--------|----------|----------|----------|------------------------------|----------|------|--------------------|
| 61 | India | Kerala | Sholayar | 10.32005 | 76.72498 | Devika MA & Amitha Bachan KH | CU216119 | 2022 | Preserved Specimen |
|----|-------|--------|----------|----------|----------|------------------------------|----------|------|--------------------|

**12. *Humboldtia vahliana* Wight, Icon. Pl. Ind. Orient. [Wight] iv. t. 1607.**

| SL No. | Country | State      | Location                                              | Latitude | Longitude | Recorded By         | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|-------------------------------------------------------|----------|-----------|---------------------|---------------|------|--------------------|
| 1      | India   | Tamil Nadu | Tirunelvelly                                          | 8.421    | 77.516    | RH Beddome          |               | 1873 | Preserved Specimen |
| 2      | India   | Tamil Nadu | Tirunelvelly                                          | 8.427    | 77.527    | R H Beddome         | MH00220680    | 1873 | Preserved Specimen |
| 3      | India   | Kerala     | Travancore                                            | 8.92182  | 77.14144  | TF Bourdillon       | 64            | 1889 | Preserved Specimen |
| 4      | India   | Kerala     | Near Koni River bank                                  | 9.23351  | 76.85125  | TF Bourdillon       | 441           | 1894 | Preserved Specimen |
| 5      | India   | Kerala     | Aryankavu Ghat, Travancore                            | 8.98921  | 77.14713  | CA Barber           | 6650          | 1904 | Preserved Specimen |
| 6      | India   | Kerala     | Vazhachal, Thrissur                                   | 10.30347 | 76.59738  | K Subramanian       | 1183          | 1964 | Preserved Specimen |
| 7      | India   | Kerala     | Thiruvananthapuram                                    | 8.56111  | 76.85830  | M, Chandrabose      | HIFP 008720   | 1976 | Preserved Specimen |
| 8      | India   | Kerala     | Beyond Anchunazhikathode - Kottur, Thiruvananthapuram | 8.55278  | 77.15639  | M Mohanan           | 54680         | 1978 | Preserved Specimen |
| 9      | India   | Kerala     | Kattakkada, Thiruvananthapuram                        | 8.56112  | 77.21240  | Jean-Pierre, Pascal | HIFP 008722   | 1979 | Preserved Specimen |
| 10     | India   | Kerala     | Vazhachal                                             | 10.30283 | 76.60445  | N Sasidharan        | 721           | 1979 | Preserved Specimen |

|    |       |        |                                                                    |          |          |                                                    |       |      |                    |
|----|-------|--------|--------------------------------------------------------------------|----------|----------|----------------------------------------------------|-------|------|--------------------|
| 11 | India | Kerala | Vazhachal, Thrissur                                                | 10.30313 | 76.59380 | N Sasidharan                                       | 729   | 1979 | Preserved Specimen |
| 12 | India | Kerala | Vazhachal                                                          | 10.30431 | 76.60603 | N Sasidharan                                       | 717   | 1979 | Preserved Specimen |
| 13 | India | Kerala | Anchunazhikathode - Kottur, Thiruvananthapuram                     | 8.55715  | 77.15870 | M Mohanan                                          | 66074 | 1980 | Preserved Specimen |
| 14 | India | Kerala | Thenmala - Punalur, Kallada River                                  | 8.99389  | 76.95533 | C.E.Ridsdale                                       | 519   | 1980 | Preserved Specimen |
| 15 | India | Kerala | Puliyar, Munnar - Alwaye road c. 15 km from Munnar Cardamom Hills. | 10.05972 | 76.80041 | C.E.Ridsdale                                       | 759   | 1980 | Preserved Specimen |
| 16 | India | Kerala | Kottur, Thiruvananthapuram FD                                      | 8.55299  | 77.15833 | PF & NV                                            | 26    | 1981 | Preserved Specimen |
| 17 | India | Kerala | Kuttur, Paritipalli range, Thiruvananthapuram                      | 8.61305  | 77.11405 | N Venkatasubramanian                               | 10067 | 1981 | Preserved Specimen |
| 18 | India | Kerala | Moozhiyar, East Sabarigiri                                         | 9.30849  | 77.06801 | B.K.Nayar, K.Rajappan & Party                      | 10405 | 1981 | Preserved Specimen |
| 19 | India | Kerala | Sholayar                                                           | 10.31769 | 76.72149 | N G Nair                                           | 1526  | 1981 | Preserved Specimen |
| 20 | India | Kerala | Aryankavu                                                          | 8.95375  | 77.17870 | N Sasidharan and NG Nair                           | 1669  | 1982 | Preserved Specimen |
| 21 | India | Kerala | Kandankayam, Azhutha river bank, Ranni reserve forest              | 9.55497  | 77.00758 | K Subramanian, CKJ, NV, KRS                        | 8633  | 1982 | Preserved Specimen |
| 22 | India | Kerala | Kakkad, River bank, Ranni                                          | 9.34240  | 76.82819 | NP, Mahadevan, N Venkatasubramanian, KR Sasidharan | 9211  | 1983 | Preserved Specimen |

|    |       |            |                                                    |          |          |                                      |             |      |                    |
|----|-------|------------|----------------------------------------------------|----------|----------|--------------------------------------|-------------|------|--------------------|
| 23 | India | Kerala     | Vazhachal, Thrissur                                | 10.30366 | 76.59124 | N Sasidharan                         | 4807        | 1988 | Preserved Specimen |
| 24 | India | Kerala     | Thenmalai                                          | 8.92803  | 77.09295 | Beena T. Cheriyan                    |             | 1989 | Preserved Specimen |
| 25 | India | Kerala     | Thenmalai                                          | 8.99645  | 76.97354 | Betsy K Mathai                       |             | 1989 | Preserved Specimen |
| 26 | India | Kerala     | Meenmutty                                          | 8.71008  | 77.13529 | N. Mohanan                           | 10126       | 1990 | Preserved Specimen |
| 27 | India | Kerala     | Adimali                                            | 10.01168 | 77.01095 | AE Shanavas Khan                     | 7525        | 1991 | Preserved Specimen |
| 28 | India | Kerala     | Kattakkada,<br>Thiruvananthapuram                  | 8.56111  | 77.21250 | B.R, Ramesh; De<br>Franceschi, Dario | HIFP 008723 | 1992 | Preserved Specimen |
| 29 | India | Kerala     | Banana farm,<br>Peringamala,<br>Thiruvananthapuram | 8.75806  | 77.04208 | A. Nazarudeen                        | 13850       | 1992 | Preserved Specimen |
| 30 | India | Kerala     | Konni,<br>Pathanamthitta,                          | 9.11667  | 77.21250 | B.R, Ramesh; De<br>Franceschi, Dario | HIFP 008724 | 1992 | Preserved Specimen |
| 31 | India | Kerala     | Kurumbanmoozhy,<br>Ranni,<br>Pathanamthitta        | 9.40139  | 76.90830 | B.R, Ramesh; De<br>Franceschi, Dario | HIFP 008727 | 1992 | Preserved Specimen |
| 32 | India | Kerala     | Konni,<br>Pathanamthitta,                          | 9.40139  | 77.21250 | B.R, Ramesh; De<br>Franceschi, Dario | HIFP 008725 | 1992 | Preserved Specimen |
| 33 | India | Kerala     | Sasthanada,<br>Thiruvananthapuram                  | 8.71208  | 77.12845 | A. Nazarudeen                        | 15084       | 1993 | Preserved Specimen |
| 34 | India | Tamil Nadu | Aryankavu                                          | 9.01162  | 77.17160 | S. Binu                              | 21560       | 1993 | Preserved Specimen |
| 35 | India | Kerala     | Konni,<br>Pathanamthitta                           | 9.15000  | 77.10000 | B.R, Ramesh; B,<br>Montfraix         | HIFP 008730 | 1993 | Preserved Specimen |
| 36 | India | Kerala     | Konni,<br>Pathanamthitta                           | 9.15000  | 77.10000 | B.R, Ramesh; B,<br>Montfraix         | HIFP 008731 | 1993 | Preserved Specimen |

|    |       |           |                                              |          |          |                                                               |             |      |                       |
|----|-------|-----------|----------------------------------------------|----------|----------|---------------------------------------------------------------|-------------|------|-----------------------|
| 37 | India | Kerala    | Konni,<br>Pathanamthitta                     | 9.19028  | 77.15000 | B.R, Ramesh; B,<br>Montfraix                                  | HIFP 008732 | 1993 | Preserved<br>Specimen |
| 38 | India | Kerala    | Konni,<br>Pathanamthitta                     | 9.19028  | 77.15000 | De Franceschi,<br>Dario; B, Montfraix;<br>Jean-Pierre, Pascal | HIFP 008733 | 1993 | Preserved<br>Specimen |
| 39 | India | Kerala    | Athumpukulam,<br>Konni,<br>Pathanamthitta    | 9.26667  | 76.88890 | B.R, Ramesh; De<br>Franceschi, Dario; B,<br>Montfraix         | HIFP 008738 | 1993 | Preserved<br>Specimen |
| 40 | India | Kerala    | Athumpukulam,<br>Konni,<br>Pathanamthitta    | 9.26667  | 76.88890 | B.R, Ramesh; De<br>Franceschi, Dario; B,<br>Montfraix         | HIFP 008739 | 1993 | Preserved<br>Specimen |
| 41 | India | Kerala    | Rajampara, Ranni,<br>Pathanamthitta          | 9.39028  | 76.90830 | B.R, Ramesh; B,<br>Montfraix                                  | HIFP 008728 | 1993 | Preserved<br>Specimen |
| 42 | India | Kerala    | Rajampara, Ranni,<br>Pathanamthitta          | 9.39028  | 76.90830 | B.R, Ramesh; B,<br>Montfraix                                  | HIFP 008729 | 1993 | Preserved<br>Specimen |
| 43 | India | Kerala    | Murikkattukudy,<br>Swaraj, Idukki            | 9.75000  | 77.03470 | De Franceschi,<br>Dario; B, Montfraix;<br>Jean-Pierre, Pascal | HIFP 008734 | 1993 | Preserved<br>Specimen |
| 44 | India | Kerala    | Naliyani,<br>Thodupuzha, Idukki              | 9.82917  | 76.90000 | De Franceschi,<br>Dario; B, Montfraix;<br>Jean-Pierre, Pascal | HIFP 008736 | 1993 | Preserved<br>Specimen |
| 45 | India | Karnataka | Timmanahosuru,<br>Mandya taluk,<br>Mandya    | 12.45833 | 76.93330 | B.R, Ramesh; De<br>Franceschi, Dario;<br>Viet, Pham Bach      | HIFP 008741 | 1993 | Preserved<br>Specimen |
| 46 | India | Karnataka | Upparahalli,<br>Nagamangala taluk,<br>Mandya | 12.83984 | 76.75470 | B.R, Ramesh; De<br>Franceschi, Dario;<br>Viet, Pham Bach      | HIFP 008742 | 1993 | Preserved<br>Specimen |
| 47 | India | Kerala    | Goodrich,<br>Pathanamthitta                  | 9.36470  | 76.98749 | A.P. Panduranagan<br>and Raveendran                           | 16124       | 1994 | Preserved<br>Specimen |
| 48 | India | Kerala    | Kurumbanmalay,<br>Pathanamthitta             | 9.40965  | 77.01087 | S. Binu                                                       | 21568       | 1994 | Preserved<br>Specimen |



|    |       |        |                                              |          |          |                    |        |      |                       |
|----|-------|--------|----------------------------------------------|----------|----------|--------------------|--------|------|-----------------------|
| 49 | India | Kerala | Sawarnagiri,<br>Arienkavu                    | 8.95353  | 77.15274 | A. Nazarudeen      | 23064  | 1995 | Preserved<br>Specimen |
| 50 | India | Kerala | Sabarimala                                   | 9.39912  | 77.07464 | Jomy Augustine     | 15466  | 1995 | Preserved<br>Specimen |
| 51 | India | Kerala | Bonaccord                                    | 8.65978  | 77.17748 | P.S. Jothish       | 27676  | 1996 | Preserved<br>Specimen |
| 52 | India | Kerala | Kannankuzy,<br>Athirapilly                   | 10.28411 | 76.55933 | A.G. Panduranagan  | 30484  | 1996 | Preserved<br>Specimen |
| 53 | India | Kerala | Kallar                                       | 9.24784  | 76.91948 | M. Abdul Jabbar    | 41275  | 1997 | Preserved<br>Specimen |
| 54 | India | Kerala | Pamba, Konni,<br>Pathanamthitta              | 9.41486  | 77.07647 | Pierre Grard       | 327298 | 2002 | Human<br>Observation  |
| 55 | India | Kerala | Palode,<br>Nedumangad,<br>Thiruvananthapuram | 8.71781  | 77.02858 | Dr.N.Mohanan       | 339405 | 2005 | Human<br>Observation  |
| 56 | India | Kerala | Bonaccord                                    | 8.65835  | 77.17355 | C. Satheesh kumar  | 58016  | 2006 | Preserved<br>Specimen |
| 57 | India | Kerala | Aryankavu                                    | 8.94390  | 77.16410 | Deepthikumary K.P. | 54328  | 2006 | Preserved<br>Specimen |
| 58 | India | Kerala | Vazhachal, Thrissur                          | 10.30217 | 76.60086 | K.H.Amitha Bachan  | 98996  | 2007 | Preserved<br>Specimen |
| 59 | India | Kerala | Koruthodu,<br>Kottayam                       | 9.46785  | 76.97894 | Krishnaraj M.V.    | 61849  | 2008 | Preserved<br>Specimen |
| 60 | India | Kerala | Kanamala,<br>Pathanamthitta                  | 9.42060  | 76.93793 | Joby & George      | 954    | 2009 | Preserved<br>Specimen |
| 61 | India | Kerala | Aryankavu                                    | 8.94231  | 77.16198 | Deepthikumary K.P. | 48559  | 2010 | Preserved<br>Specimen |
| 62 | India | Kerala | Perunthenaruvi                               | 9.41016  | 76.87379 | Joby & George      | 984    | 2010 | Preserved<br>Specimen |
| 63 | India | Kerala | Sabarimala                                   | 9.39911  | 77.07463 | Joby & Rogimon     | 1411   | 2011 | Preserved<br>Specimen |

|    |       |            |                                         |          |          |                                |          |      |                    |
|----|-------|------------|-----------------------------------------|----------|----------|--------------------------------|----------|------|--------------------|
| 64 | India | Kerala     | Rosemala stream side                    | 8.92179  | 77.15521 | Deepthi and Usha               | 76219    | 2012 | Preserved Specimen |
| 65 | India | Tamil Nadu | Chittar                                 | 8.40463  | 77.42410 | R. Vikram and Chitra V.M.      | 67061    | 2014 | Preserved Specimen |
| 66 | India | Kerala     | Rosemala                                | 8.91433  | 77.16352 | Deepthi and Usha               | 75103    | 2014 | Preserved Specimen |
| 67 | India | Tamil Nadu | Chittar river                           | 8.40590  | 77.42813 | Sinchu Yesudasan               | 84381    | 2015 | Preserved Specimen |
| 68 | India | Kerala     | Aryankavu                               | 8.94780  | 77.15715 | G . Rajkumar and M. Alister    | 84199    | 2015 | Preserved Specimen |
| 69 | India | Kerala     | Aryankavu                               | 8.93841  | 77.11258 | Deepthi and Usha               | 79730    | 2016 | Preserved Specimen |
| 70 | India | Kerala     | Pambla dam                              | 9.96406  | 76.94907 | Vishnu Mohan & Santhosh Nampy  | 152005   | 2017 | Preserved Specimen |
| 71 | India | Kerala     | Ponmudi                                 | 9.95664  | 77.04741 | Usha and Deepthy               | 92950    | 2018 | Preserved Specimen |
| 72 | India | Tamil Nadu | Valparai, Coimbatore,                   | 10.30000 | 77.00000 | Siddarth Jude Machado          | 2E+06    | 2018 | Human Observation  |
| 73 | India | Kerala     | Sooryakanthi forest, Thiruvananthapuram | 8.51219  | 76.95447 | Deepthi and Usha               | 93555    | 2019 | Preserved Specimen |
| 74 | India | Kerala     | Meenachil, Kottayam                     | 9.71315  | 76.84726 | Harikrishnan S.                | 2E+06    | 2019 | Human Observation  |
| 75 | India | Kerala     | Sawarnagiri                             | 8.95353  | 77.15274 | Geethakumary and Deepu Sivadas | 88087    | 2021 | Preserved Specimen |
| 76 | India | Kerala     | Makarachal, Kothamangalam, Ernakulam    | 10.22039 | 76.72528 | Srinivasan Kasinathan          | 1E+08    | 2022 | Human Observation  |
| 77 | India | Kerala     | Anakayam, bridge, Vazhachal FD          | 10.29637 | 76.68350 | Devika MA & Amitha Bachan KH   | CU216104 | 2023 | Preserved Specimen |
| 78 | India | Kerala     | Vazhachal, Thrissur                     | 10.30412 | 76.60718 | Devika MA & Amitha Bachan KH   | CU216124 | 2023 | Preserved Specimen |

|    |       |        |                                               |          |          |                                                 |             |      |                    |
|----|-------|--------|-----------------------------------------------|----------|----------|-------------------------------------------------|-------------|------|--------------------|
| 79 | India | Kerala | Bonaccord                                     | 8.65754  | 77.16995 | Devika MA & Amitha Bachan KH                    | CU216175    | 2024 | Preserved Specimen |
| 80 | India | Kerala | Rosemala                                      | 8.87184  | 77.19704 | Devika MA & Amitha Bachan KH                    | AH25271     | 2024 | Human Observation  |
| 81 | India | Kerala | Thenmalai                                     | 8.95212  | 77.07171 | A.Mini                                          |             |      | Preserved Specimen |
| 82 | India | Kerala | Pooaymkutty Mankulam Road, Devikulam, Idukki  | 10.12140 | 76.93330 | B.R, Ramesh; De Franceschi, Dario; B, Montfraix | HIFP 008740 |      | Preserved Specimen |
| 83 | India | Kerala | Elamblassery Colony, Kothamangalam, Ernakulam | 10.12500 | 76.84170 | Jean-Pierre, Pascal                             | HIFP 008719 |      | Preserved Specimen |
| 84 | India | Kerala | Vazhachal, river side                         | 10.30800 | 76.60943 | Devika MA & Amitha Bachan KH                    | AH25294     | 2022 | Preserved Specimen |
| 85 | India | Kerala | Orukombankutty                                | 10.37543 | 76.65404 | Devika MA & Amitha Bachan KH                    | AH25296     | 2023 | Preserved Specimen |

**13. *Hydnocarpus pentandrus* (Buch.-Ham.) Oken, Allg. Naturgesch. 3(2): 1381 (1841).**

| SL No. | Country | State       | Location                     | Latitude | Longitude | Recorded By         | Herbarium No. | Year | Basis of Record    |
|--------|---------|-------------|------------------------------|----------|-----------|---------------------|---------------|------|--------------------|
| 1      | India   | Maharashtra | Kanheri Cave Complex, Mumbai | 19.20585 | 72.90685  | Shevade             | 1.2345E+11    | 1939 | Preserved Specimen |
| 2      | India   | Kerala      | Peerumade, Idukki            | 9.52500  | 77.25830  | K.A, Shankarnarayan | HIFP 010326   | 1959 | Preserved Specimen |
| 3      | India   | Kerala      | Mukkali Forest               | 11.06242 | 76.53627  | E Vajravelu         | 33346         | 1969 | Preserved Specimen |

|    |       |            |                                                                                        |          |          |                        |             |      |                       |
|----|-------|------------|----------------------------------------------------------------------------------------|----------|----------|------------------------|-------------|------|-----------------------|
| 4  | India | Karnataka  | Maranahalli,<br>Sakaleshapura taluk,<br>Hassan                                         | 12.90000 | 75.70000 | W. D. Stevens          | 101196826   | 1969 | Preserved<br>Specimen |
| 5  | India | Kerala     | Palaruvi, Punalur,<br>Kollam                                                           | 8.95556  | 77.15056 | Peter Karl Endress     | Z-000152762 | 1972 | Preserved<br>Specimen |
| 6  | India | Kerala     | Munnar Bazaar,<br>Mattupetty,<br>Devikulam, Idukki                                     | 10.09167 | 77.09167 | Jean-Pierre, Pascal    | HIFP 010328 | 1975 | Preserved<br>Specimen |
| 7  | India | Kerala     | Thiruvananthapuram<br>- Ponmudi Road,<br>Ponmudi,<br>Nedumangad,<br>Thiruvananthapuram | 8.75000  | 77.12500 | C.E, Ridsdale          | HIFP 010333 | 1976 | Preserved<br>Specimen |
| 8  | India | Kerala     | Ponmudi Tea<br>Plantations                                                             | 8.75994  | 77.11688 | CE Ridsdale            | 141         | 1976 | Preserved<br>Specimen |
| 9  | India | Kerala     | Konni,<br>Pathanamthitta                                                               | 9.30000  | 77.05000 | Jean-Pierre, Pascal    | HIFP 010330 | 1976 | Preserved<br>Specimen |
| 10 | India | Tamil Nadu | Parambikulam Road,<br>Valparai,<br>Coimbatore                                          | 10.45000 | 76.83330 | A.J.G.H,<br>Kostermans | HIFP 010334 | 1976 | Preserved<br>Specimen |
| 11 | India | Kerala     | Sirunelli Forest -<br>Nelliyampathy                                                    | 10.53539 | 76.69361 | E Vajravelu            | 48849       | 1976 | Preserved<br>Specimen |
| 12 | India | Kerala     | Nedunkayam                                                                             | 11.29242 | 76.34050 | N Sasidharan           | 214         | 1978 | Preserved<br>Specimen |
| 13 | India | Karnataka  | Baralkota, Supa<br>taluk, Uttara<br>Kannada                                            | 15.42500 | 74.35830 | Jean-Pierre, Pascal    | HIFP 010335 | 1978 | Preserved<br>Specimen |
| 14 | India | Kerala     | Vazhachal, Thrissur                                                                    | 10.30141 | 76.59259 | N. Sasidharan          | 718         | 1979 | Preserved<br>Specimen |
| 15 | India | Kerala     | Walayar                                                                                | 10.84283 | 76.83880 | N Sasidharan           | 744         | 1979 | Preserved<br>Specimen |

|    |       |            |                                                   |          |          |                                      |             |      |                       |
|----|-------|------------|---------------------------------------------------|----------|----------|--------------------------------------|-------------|------|-----------------------|
| 16 | India | Kerala     | Peringamala,<br>Nedumangad,<br>Thiruvananthapuram | 8.73333  | 77.06666 | Ridsdale CE                          | L 0088939   | 1980 | Preserved<br>Specimen |
| 17 | India | Kerala     | Pulimath,<br>Thiruvananthapuram                   | 8.74676  | 76.89227 | M Mohanan                            | 66680       | 1980 | Preserved<br>Specimen |
| 18 | India | Kerala     | Punalur, Kollam                                   | 9.00000  | 76.93333 | Ridsdale CE                          | L.2470194   | 1980 | Preserved<br>Specimen |
| 19 | India | Tamil Nadu | Sholayar, Thrissur                                | 10.31261 | 76.87498 | NG Nair                              | 1534        | 1981 | Preserved<br>Specimen |
| 20 | India | Kerala     | Pattikad Range                                    | 10.54963 | 76.33516 | N Sasidharan                         | 1153        | 1981 | Preserved<br>Specimen |
| 21 | India | Karnataka  | Kadiyal, Moodabidri<br>taluk, Dakshina<br>Kannada | 13.14170 | 75.09170 | B.R, Ramesh                          | HIFP 010337 | 1982 | Preserved<br>Specimen |
| 22 | India | Karnataka  | Bilimale, Sulya<br>taluk, Dakshina<br>Kannada     | 12.55000 | 75.66670 | B.R, Ramesh                          | HIFP 010339 | 1985 | Preserved<br>Specimen |
| 23 | India | Kerala     | Elanad                                            | 10.62752 | 76.39556 | N Sasidharan                         | 4652        | 1987 | Preserved<br>Specimen |
| 24 | India | Karnataka  | Sakaleshapura taluk,<br>Hassan                    | 12.72140 | 75.65585 | De Franceschi,<br>Dario              | HIFP 010340 | 1989 | Preserved<br>Specimen |
| 25 | India | Kerala     | Kurisumalashola,<br>Idukki                        | 9.85840  | 76.95278 | Biju S.D                             | 38041       | 1990 | Preserved<br>Specimen |
| 26 | India | Tamil Nadu | Topslip, Anamalai                                 | 10.42410 | 77.12556 | VB Hosagousan                        | 94513       | 1990 | Preserved<br>Specimen |
| 27 | India | Karnataka  | Bilimale, Sulya<br>taluk, Dakshina<br>Kannada     | 12.56670 | 75.65830 | De Franceschi,<br>Dario              | HIFP 010341 | 1990 | Preserved<br>Specimen |
| 28 | India | Kerala     | Nedumangad,<br>Thiruvananthapuram                 | 8.81944  | 77.04720 | B.R, Ramesh; De<br>Franceschi, Dario | HIFP 010343 | 1992 | Preserved<br>Specimen |

|    |       |            |                                               |          |          |                                                                   |             |      |                       |
|----|-------|------------|-----------------------------------------------|----------|----------|-------------------------------------------------------------------|-------------|------|-----------------------|
| 29 | India | Kerala     | Achancoli,<br>Pathanamthitta                  | 9.23011  | 76.77739 | A. Nazarudeen                                                     | 14213       | 1992 | Preserved<br>Specimen |
| 30 | India | Tamil Nadu | Aralvaimozhi,<br>Thovalai,<br>Kanniyakumari   | 8.29722  | 77.50830 | De Franceschi,<br>Dario; B,<br>Montfraix                          | HIFP 010349 | 1993 | Preserved<br>Specimen |
| 31 | India | Kerala     | Sasthanada,<br>Thiruvananthapuram             | 8.52414  | 76.93664 | A. Nazarudeen                                                     | 16424       | 1993 | Preserved<br>Specimen |
| 32 | India | Kerala     | Konni,<br>Pathanamthitta                      | 9.17222  | 77.17500 | De Franceschi,<br>Dario; B,<br>Montfraix; Jean-<br>Pierre, Pascal | HIFP 010345 | 1993 | Preserved<br>Specimen |
| 33 | India | Kerala     | Konni,<br>Pathanamthitta                      | 9.18056  | 77.09720 | De Franceschi,<br>Dario; B,<br>Montfraix; Jean-<br>Pierre, Pascal | HIFP 010347 | 1993 | Preserved<br>Specimen |
| 34 | India | Kerala     | Cholaravayil,<br>Pathanamthitta               | 9.26476  | 76.78704 | S. Binu                                                           | 14990       | 1993 | Preserved<br>Specimen |
| 35 | India | Kerala     | Mullikavu, Shornur                            | 10.76775 | 76.27638 | A. Nazarudeen                                                     | 17445       | 1993 | Preserved<br>Specimen |
| 36 | India | Kerala     | Thirunelli, Wynad                             | 11.90812 | 75.99712 | A. Nazarudeen                                                     | 16476       | 1993 | Preserved<br>Specimen |
| 37 | India | Kerala     | Mannanpurath kavu ,<br>Neeleshwaram           | 12.25849 | 75.13216 | A. Nazarudeen                                                     | 16577       | 1993 | Preserved<br>Specimen |
| 38 | India | Karnataka  | Bilimale, Sulya<br>taluk, Dakshina<br>Kannada | 12.55830 | 75.66110 | S, Aravajy                                                        | HIFP 010350 | 1993 | Preserved<br>Specimen |
| 39 | India | Kerala     | Ammavayal, Wynad                              | 11.61837 | 76.21116 | A. Nazarudeen                                                     | 24641       | 1995 | Preserved<br>Specimen |
| 40 | India | Kerala     | Nallila, Kollam                               | 8.92486  | 76.70912 | M. Rajendra prasad                                                | 58859       | 1997 | Preserved<br>Specimen |

|    |       |            |                                                         |          |          |                                                                               |              |      |                    |
|----|-------|------------|---------------------------------------------------------|----------|----------|-------------------------------------------------------------------------------|--------------|------|--------------------|
| 41 | India | Karnataka  | Ponnampete taluk, Kodagu                                | 11.99170 | 76.12500 | N, Balachandran; N, Barathan                                                  | HIFP 010354  | 1998 | Preserved Specimen |
| 42 | India | Kerala     | Muthappanpuzha                                          | 11.44384 | 76.08778 | A.K.Pradeep                                                                   | 56430        | 1999 | Preserved Specimen |
| 43 | India | Karnataka  | Ponnampete, Ponnampete taluk, Kodagu                    | 12.14085 | 75.94066 | C, Garcia; S, Ramalingam; N, Barathan                                         | HIFP 010355  | 2001 | Preserved Specimen |
| 44 | India | Tamil Nadu | Anaimalai Loop Road, Old Valparai, Valparai, Coimbatore | 10.34800 | 76.93172 | N. Ayyappan S. Muthuramkumar N. Parthasarathy T R Shankar Raman Divya Mudappa |              | 2003 | Human Observation  |
| 45 | India | Tamil Nadu | Valparai, Coimbatore                                    | 10.35803 | 76.89029 | N. Ayyappan S. Muthuramkumar N. Parthasarathy T R Shankar Raman Divya Mudappa |              | 2003 | Human Observation  |
| 46 | India | Karnataka  | Holebail, Kumata taluk, Uttara Kannada                  | 14.58330 | 74.56420 | N, Ayyappan; B.R, Ramesh                                                      | HIFP 010357  | 2006 | Preserved Specimen |
| 47 | India | Kerala     | Ammayambalam, Kollam                                    | 8.89321  | 76.61414 | C.G Vishnu                                                                    | 63062        | 2009 | Preserved Specimen |
| 48 | India | Tamil Nadu | Karandamalai hills, Dindigul                            | 10.30138 | 78.21343 | R Kottaimuthu & Kalidas                                                       | 40012, 40512 | 2011 | Preserved Specimen |
| 49 | India | Kerala     | Madayippara, near Fort                                  | 12.03235 | 75.25666 | Pramod C.                                                                     |              | 2011 | Preserved Specimen |
| 50 | India | Kerala     | Sasthanada                                              | 9.10700  | 76.63130 | M. Rajendra prasad                                                            | 62809        | 2012 | Preserved Specimen |



|    |       |            |                                                             |          |          |                            |           |      |                    |
|----|-------|------------|-------------------------------------------------------------|----------|----------|----------------------------|-----------|------|--------------------|
| 51 | India | Kerala     | Pampa                                                       | 9.96406  | 76.94907 | Joby                       |           | 2012 | Preserved Specimen |
| 52 | India | Kerala     | Kolakkad, Iritty, Kannur                                    | 11.88263 | 75.76936 | shivaprakash               | 82423998  | 2012 | Human Observation  |
| 53 | India | Karnataka  | Soppina Hosalli, Kumata taluk, Uttara Kannada               | 14.41939 | 74.63313 | Radha Veach                | 147409403 | 2013 | Human Observation  |
| 54 | India | Kerala     | Kaleeshwari sarppa kaavu, Chandapura, Kodungallur, Thrissur | 10.22658 | 76.17631 | Rohit                      | 32884831  | 2014 | Human Observation  |
| 55 | India | Karnataka  | Aluvalli, Kadagaravalli, Sakaleshapura taluk, Hassan        | 12.84073 | 75.70474 | Siddarth Machado           | 35870340  | 2014 | Human Observation  |
| 56 | India | Kerala     | Kandanchira                                                 | 9.65025  | 76.56370 | Shafeek S.                 | 87601     | 2016 | Preserved Specimen |
| 57 | India | Kerala     | Vazhachal, Thrissur                                         | 10.30141 | 76.59259 | G .Rajkumar and M. Alister | 88630     | 2016 | Preserved Specimen |
| 58 | India | Kerala     | Palode                                                      | 8.72443  | 77.02478 | Sabu T.                    | 78135     | 2017 | Preserved Specimen |
| 59 | India | Kerala     | Rosemala                                                    | 8.91845  | 77.17440 | Ranjith                    | 88425     | 2017 | Preserved Specimen |
| 60 | India | Tamil Nadu | Sholayar Dam, Valparai, Coimbatore                          | 10.30128 | 76.87181 | Akshay Surendra            |           | 2019 | Human Observation  |
| 61 | India | Tamil Nadu | Valparai, Coimbatore                                        | 10.35567 | 76.88788 | Akshay Surendra            |           | 2019 | Human Observation  |
| 62 | India | Tamil Nadu | Valparai, Coimbatore                                        | 10.41900 | 76.87216 | Akshay Surendra            |           | 2019 | Human Observation  |

|    |       |            |                                                                             |          |          |                  |          |      |                       |
|----|-------|------------|-----------------------------------------------------------------------------|----------|----------|------------------|----------|------|-----------------------|
| 63 | India | Tamil Nadu | Valparai,<br>Coimbatore                                                     | 10.41916 | 76.87102 | Akshay Surendra  |          | 2019 | Human<br>Observation  |
| 64 | India | Tamil Nadu | Valparai,<br>Coimbatore                                                     | 10.41973 | 76.86941 | Akshay Surendra  |          | 2019 | Human<br>Observation  |
| 65 | India | Tamil Nadu | Valparai,<br>Coimbatore                                                     | 10.42017 | 76.86860 | Akshay Surendra  |          | 2019 | Human<br>Observation  |
| 66 | India | Tamil Nadu | Valparai,<br>Coimbatore                                                     | 10.42050 | 76.87012 | Akshay Surendra  |          | 2019 | Human<br>Observation  |
| 67 | India | Tamil Nadu | Valparai,<br>Coimbatore                                                     | 10.42156 | 76.87943 | Akshay Surendra  |          | 2019 | Human<br>Observation  |
| 68 | India | Tamil Nadu | Valparai,<br>Coimbatore                                                     | 10.47473 | 76.83353 | Akshay Surendra  |          | 2019 | Human<br>Observation  |
| 69 | India | Kerala     | Nagakannyaka<br>Temple Kavu,<br>Atthipattamana,<br>Chethallur,<br>Mannarkad | 10.62858 | 76.65489 | MS Nair et al.   |          | 2019 | Preserved<br>Specimen |
| 70 | India | Kerala     | Tharavath Tharavad<br>Kavu, Nagaripuram,<br>Mannur                          | 10.80362 | 76.46925 | MS Nair et al.   |          | 2019 | Preserved<br>Specimen |
| 71 | India | Kerala     | Pachiri Tharavad<br>Nagakavu,<br>Sreekrishnapuram                           | 10.90667 | 76.41581 | MS Nair et al.   |          | 2019 | Preserved<br>Specimen |
| 72 | India | Kerala     | Chola Kavu, Siva<br>Temple,<br>Thiruvegapara,<br>Pallippuram,<br>Pattambi   | 10.80573 | 76.19566 | MS Nair et al.   |          | 2020 | Preserved<br>Specimen |
| 73 | India | Karnataka  | Taruve, Mudigere<br>taluk,<br>Chikkamagaluru                                | 13.10631 | 75.51570 | Siddarth Machado | 39346847 | 2020 | Human<br>Observation  |

|    |       |             |                                                                           |          |          |                                 |           |      |                       |
|----|-------|-------------|---------------------------------------------------------------------------|----------|----------|---------------------------------|-----------|------|-----------------------|
| 74 | India | Kerala      | Sastrinagar,<br>Poojappura,<br>Thiruvananthapuram                         | 8.48130  | 76.97467 | Pranav Chandra<br>Bose          | 89175897  | 2021 | Human<br>Observation  |
| 75 | India | Kerala      | Vellikulangara,<br>Chalakkudy,<br>Thrissur                                | 10.38462 | 76.42061 | sreenivasan                     | 88374214  | 2021 | Human<br>Observation  |
| 76 | India | Goa         | Mollem,<br>Dharbandora, Goa                                               | 15.35725 | 74.24477 | Shiwalee Samant                 | 107425313 | 2021 | Human<br>Observation  |
| 77 | India | Kerala      | Thyckal, Cherthala,<br>Alappuzha                                          | 9.67347  | 76.30628 | Renjus box                      | 156854363 | 2023 | Human<br>Observation  |
| 78 | India | Kerala      | Sholayar, Thrissur                                                        | 10.29637 | 76.68350 | Devika MA &<br>Amitha Bachan KH | CU216131  | 2023 | Preserved<br>Specimen |
| 79 | India | Kerala      | Vazhachal Iron<br>bridge                                                  | 10.30265 | 76.60429 | Devika MA &<br>Amitha Bachan KH | CU216125  | 2023 | Preserved<br>Specimen |
| 80 | India | Tamil Nadu  | Valparai,<br>Coimbatore                                                   | 10.34549 | 76.95064 | Madhavan A.P.                   | 148171020 | 2023 | Human<br>Observation  |
| 81 | India | Kerala      | Nilambur                                                                  | 11.28554 | 76.23858 | Devika MA &<br>Amitha Bachan KH | CU216198  | 2023 | Preserved<br>Specimen |
| 82 | India | Kerala      | Ikkara Colony, P<br>Vemballur,<br>Kodungallur,<br>Thrissur                | 10.26117 | 76.14949 | Devika MA &<br>Amitha Bachan KH | AH25273   | 2023 | Human<br>Observation  |
| 83 | India | Kerala      | Pozhankavu, Netaji<br>nagar road, S.N.<br>Puram, Kodungallur,<br>Thrissur | 10.27508 | 76.16176 | Devika MA &<br>Amitha Bachan KH | AH25281   | 2023 | Human<br>Observation  |
| 84 | India | Kerala      | Aralam, Iritty,<br>Kannur                                                 | 11.96519 | 75.71947 | Paul Antony<br>Mangaly          | 245217911 | 2024 | Human<br>Observation  |
| 85 | India | Maharashtra | Sripur Nagar,<br>Mumbai                                                   | 19.13321 | 72.88335 | Soham Gajre                     | 196924952 | 2024 | Human<br>Observation  |

|    |       |             |                                        |          |          |                           |                |             |                       |
|----|-------|-------------|----------------------------------------|----------|----------|---------------------------|----------------|-------------|-----------------------|
| 86 | India | Tamil Nadu  | Sethumadai,<br>Pollachi, Coimbatore    | 10.49933 | 76.86975 | T R Shankar<br>Raman      | 261636314      | 2025        | Human<br>Observation  |
| 87 | India | Maharashtra | Gimona, Dodamarg<br>Taluka, Sindhudurg | 15.65632 | 74.01606 | Aditya Satish             | 259725728      | 2025        | Human<br>Observation  |
| 88 | India | Maharashtra | Dodamarg Taluka,<br>Sindhudurg         | 15.71952 | 74.08215 | Aditya Satish             | 258107270      | 2025        | Human<br>Observation  |
| 89 | India | Tamil Nadu  | Udumalaipettai,<br>Tiruppur            | 10.37662 | 77.09311 | W.A. Rodgers              | WII00625700200 | 1988-<br>02 | Preserved<br>Specimen |
| 90 | India | Kerala      | Braimore,<br>Thiruvananthapuram        | 8.76933  | 77.07659 | Soumya L.A.               | 88969          |             | Preserved<br>Specimen |
| 91 | India | Kerala      | Wayanad                                | 11.54020 | 76.06212 | M.K.Ratheesh<br>Narayanan | 8030           |             | Preserved<br>Specimen |

**14. *Impatiens parasitica* Bedd., Madras J. Lit. Sci. Ser. II, xx. (1859) 66.**

| SL<br>No. | Country | State         | Location                                   | Latitude | Longitude | Recorded By  | Herbarium<br>No. | Year | Basis of<br>Record    |
|-----------|---------|---------------|--------------------------------------------|----------|-----------|--------------|------------------|------|-----------------------|
| 1         | India   | Tamil<br>Nadu | Anamalais                                  | 10.30562 | 76.98262  | Beddom       | K000694777       | 1861 | Preserved<br>Specimen |
| 2         | India   | Tamil<br>Nadu | Anamalais                                  | 10.30682 | 76.98175  | CA Barber    | 4033             | 1901 | Preserved<br>Specimen |
| 3         | India   | Tamil<br>Nadu | Anamalais                                  | 10.30683 | 76.98176  | CA Barber    | 3800             | 1901 | Preserved<br>Specimen |
| 4         | India   | Kerala        | Lockhart Gap                               | 10.03591 | 77.12357  | KM Sebastine | 16499            | 1963 | Preserved<br>Specimen |
| 5         | India   | Kerala        | Lakshmi estate,<br>Kottayam                | 10.06308 | 76.99871  | D B Deb      | 30755            | 1968 | Preserved<br>Specimen |
| 6         | India   | Tamil<br>Nadu | Uthamapalayam, Theni,<br>Tamil Nadu, India | 9.64028  | 77.36670  | F, Blasco    |                  | 1970 | Human<br>Observation  |

|    |       |        |                                             |          |          |                                                    |       |      |                    |
|----|-------|--------|---------------------------------------------|----------|----------|----------------------------------------------------|-------|------|--------------------|
| 7  | India | Kerala | Calvary mount, Idukki                       | 9.81646  | 77.01407 | A G Pandurangan                                    | 79270 | 1983 | Preserved Specimen |
| 8  | India | Kerala | Upper moozhiyar                             | 9.28637  | 77.06218 | R Chandrasekaran                                   | 90729 | 1989 | Preserved Specimen |
| 9  | India | Kerala | Way to Eravikulam hut                       | 10.16677 | 77.10152 | P Bhargavan                                        | 90932 | 1989 | Preserved Specimen |
| 10 | India | Kerala | Umayal mala                                 | 10.25305 | 77.05572 | S.D. Biju                                          | 38267 | 1990 | Preserved Specimen |
| 11 | India | Kerala | Meenmutty, Idukki                           | 9.84226  | 76.88232 | C N Mohanan                                        | 79991 | 1993 | Preserved Specimen |
| 12 | India | Kerala | Neymakad Estate, Devikulam, Idukki          | 10.13788 | 77.05948 | B.R, Ramesh; Viet, Pham Bach; De Franceschi, Dario |       | 1993 | Human Observation  |
| 13 | India | Kerala | Petimudi division, Idukki                   | 10.16176 | 77.00451 | P. A. Jose, M. A. Jabbar and E.A. Santhosh Kumar   | 14485 | 1993 | Preserved Specimen |
| 14 | India | Kerala | Above Olichuchattam, Vellarimala, Kozhikode | 11.46261 | 76.09563 | A. K. Pradeep                                      | 56049 | 1997 | Preserved Specimen |
| 15 | India | Kerala | Way to Vellarimala                          | 11.49042 | 76.14000 | A.K.Pradeep                                        | 56160 | 1997 | Preserved Specimen |
| 16 | India | Kerala | Pothumala                                   | 10.29630 | 77.15256 | KK Sajeev                                          | I7345 | 1999 | Preserved Specimen |
| 17 | India | Kerala | Karimala, Parambikulam                      | 10.36116 | 76.72399 | P Sujanapal                                        | 30507 | 2002 | Preserved Specimen |
| 18 | India | Kerala | Sholayar, Chandanthodu                      | 10.30003 | 76.78901 | K.H.Amitha Bachan                                  | 72080 | 2004 | Preserved Specimen |
| 19 | India | Kerala | Kattimattam                                 | 11.45438 | 76.36921 | Ratheesh Narayanan M K                             | 854   | 2009 | Preserved Specimen |
| 20 | India | Kerala | Eravikulam, Idukki, Kerala                  | 10.14293 | 77.03786 | Deepu Sivadas                                      | 78809 | 2012 | Preserved Specimen |

|    |       |            |                                                 |          |          |                                    |        |      |                    |
|----|-------|------------|-------------------------------------------------|----------|----------|------------------------------------|--------|------|--------------------|
| 21 | India | Kerala     | Devikulam, Idukki                               | 10.16319 | 77.01312 | Ansil B. R.                        |        | 2013 | Preserved Specimen |
| 22 | India | Kerala     | Mathikettan Shola National Park (Sivanpara)     | 9.97462  | 77.22976 | Syam Radh. S & Santhosh Nampy      | 143541 | 2014 | Preserved Specimen |
| 23 | India | Kerala     | Mathikettan Shola National Park (Survikal para) | 9.97971  | 77.24532 | Syam Radh .S                       | 145052 | 2015 | Preserved Specimen |
| 24 | India | Tamil Nadu | Megamalai Wildlife Sanctuary, Tamil Nadu        | 9.62804  | 77.35831 | V. Ravichandran and S. Karupuswamy |        | 2016 | Human Observation  |
| 25 | India | Kerala     | Pettimudi, Idukki                               | 10.17293 | 77.01020 | Remasabbu and Kulloli              | 61522  | 2016 | Preserved Specimen |
| 26 | India | Kerala     | Ernakulam (High forest edamalayar)              | 10.23268 | 76.89818 | Sunil                              |        | 2016 | Preserved Specimen |
| 27 | India | Kerala     | Mankulam                                        | 10.11855 | 76.93055 | Vishnu Mohan & Santhosh Nampy      | 170400 | 2018 | Preserved Specimen |
| 28 | India | Kerala     | Meesappulimala                                  | 10.09558 | 77.18607 | Vishnu Mohan & Santhosh Nampy      | 170365 | 2019 | Preserved Specimen |
| 29 | India | Kerala     | Shola forest - on the way to Chinna Anamudi     | 10.16270 | 77.06741 | Vishnu Mohan & Santhosh Nampy      | 170258 | 2019 | Preserved Specimen |
| 30 | India | Kerala     | Eravikulam NP, Idukki, Kerala                   | 10.13697 | 77.05960 | Ramaa Shenoy                       |        | 2022 | Human Observation  |
| 31 | India | Kerala     | Devikulam, Idukki                               | 10.17594 | 77.03069 | Jaya Rakesh                        |        | 2022 | Human Observation  |
| 32 | India | Kerala     | Kothamangalam, Ernakulam                        | 10.20720 | 76.90953 | T R Shankar Raman                  |        | 2022 | Human Observation  |
| 33 | India | Tamil Nadu | Valparai, Coimbatore                            | 10.36092 | 76.87878 | T R Shankar Raman                  |        | 2022 | Human Observation  |
| 34 | India | Tamil Nadu | Valparai, Coimbatore                            | 10.38810 | 76.99179 | Madhavan A.P.                      |        | 2022 | Human Observation  |

|    |       |            |                            |          |          |                              |          |      |                    |
|----|-------|------------|----------------------------|----------|----------|------------------------------|----------|------|--------------------|
| 35 | India | Tamil Nadu | Iyerpaddy, Valparai        | 10.39078 | 76.98252 | Madhavan A.P.                |          | 2022 | Human Observation  |
| 36 | India | Kerala     | Nelliyampathy              | 10.52234 | 76.75562 | Devika MA & Amitha Bachan KH | AH25256  | 2022 | Preserved Specimen |
| 37 | India | Kerala     | Nelliyampathy              | 10.52480 | 76.77410 | Devika MA & Amitha Bachan KH | CU216109 | 2022 | Preserved Specimen |
| 38 | India | Tamil Nadu | Nilgiris                   | 11.48316 | 76.56621 | S. Jeevith et al.            |          | 2022 | Preserved Specimen |
| 39 | India | Kerala     | Pettimudi, Eravikulam NP   | 10.17421 | 77.02352 | Arjun & Jameson              | 586      | 2024 | Preserved Specimen |
| 40 | India | Kerala     | Uppupara, Periyar          | 9.60852  | 77.06984 | Jomy Augustine               | 12390    |      | Preserved Specimen |
| 41 | India | Kerala     | Pampadum shola, NP, Idukki | 10.13701 | 77.26241 | Devika MA & Amitha Bachan KH | AH25230  |      | Preserved Specimen |
| 42 | India | Kerala     | Anamudi, Idukki            | 10.16157 | 77.07122 | Devika MA & Amitha Bachan KH | CU216171 | 2023 | Preserved Specimen |
| 43 | India | Kerala     | Anamudi                    | 10.16157 | 77.03203 | Arjun & Jameson              | 534      |      | Preserved Specimen |
| 44 | India | Kerala     | Pettimudi, Idukki          | 10.17427 | 77.02352 | Devika MA & Amitha Bachan KH | CU216167 | 2023 | Preserved Specimen |
| 45 | India | Kerala     | Eravikulam, Idukki         | 10.21758 | 77.07598 | Devika MA & Amitha Bachan KH | CU216169 | 2023 | Preserved Specimen |
| 46 | India | Kerala     | Varattukulam, Idukki       | 10.23359 | 77.10299 | Devika MA & Amitha Bachan KH | AH25233  | 2023 | Preserved Specimen |



**15. *Litsea oleoides* Hook.f., Fl. Brit. India [J. D. Hooker] 5(13): 175 (1886).**

| SL No. | Country | State      | Location                 | Latitude | Longitude | Recorded By     | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|--------------------------|----------|-----------|-----------------|---------------|------|--------------------|
| 1      | India   | Tamil Nadu | Palney Hills             | 10.24208 | 77.47318  | R.H. Beddome    |               | 1804 | Preserved Specimen |
| 2      | India   | Tamil Nadu | Valparai, Anamalai       | 10.33704 | 76.96886  | C.A. Barber     | 4003          | 1901 | Preserved Specimen |
| 3      | India   | Tamil Nadu | Udumanparai, Anamalai    | 10.46031 | 76.94351  | C.A. Barber     | 5909          | 1903 | Preserved Specimen |
| 4      | India   | Tamil Nadu | Udumanparai, Anamalai    | 10.43970 | 76.95241  | C.A. Barber     | 5832          | 1903 | Preserved Specimen |
| 5      | India   | Tamil Nadu | Avalanchi                | 11.30213 | 76.59452  | K Vivekananthan | 40654         | 1950 | Preserved Specimen |
| 6      | India   | Kerala     | Silent Valley            | 10.09191 | 77.05894  | E Vajravelu     | 33265         | 1969 | Preserved Specimen |
| 7      | India   | Tamil Nadu | Thia Shola, Tamil Nadu   | 11.229   | 76.616    | BV Shetty       | 34290         | 1970 | Preserved Specimen |
| 8      | India   | Tamil Nadu | Upper Bhavani            | 11.22261 | 76.60352  | BV Shetty       | 34151         | 1970 | Preserved Specimen |
| 9      | India   | Tamil Nadu | T.R. Bazar shola         | 11.46293 | 76.55087  | J. L. Ellis     | 34771         | 1970 | Preserved Specimen |
| 10     | India   | Kerala     | Below Kaikaty            | 10.52688 | 76.67533  | E Vajravelu     | 48945         | 1974 | Preserved Specimen |
| 11     | India   | Tamil Nadu | Naduvattam               | 11.48316 | 76.56621  | E Vajravelu     | 46062         | 1974 | Preserved Specimen |
| 12     | India   | Kerala     | Anamooly Eastern slopes  | 11.03717 | 76.50964  | N C Nair        | 56788         | 1978 | Preserved Specimen |
| 13     | India   | Kerala     | Pamba Dam - Vandiperiyar | 9.20289  | 77.15349  | K Vivekananthan | 66196         | 1980 | Preserved Specimen |

|    |       |            |                                                |          |          |                                 |       |      |                    |
|----|-------|------------|------------------------------------------------|----------|----------|---------------------------------|-------|------|--------------------|
| 14 | India | Kerala     | Mangayam-Karapara River side                   | 10.45968 | 76.64865 | N C Nair                        | 69725 | 1980 | Preserved Specimen |
| 15 | India | Kerala     | Sholayar                                       | 10.33789 | 76.73148 | NG Nair                         | 49    | 1981 | Preserved Specimen |
| 16 | India | Kerala     | Nelliyampathi                                  | 10.52234 | 76.75562 | N Sasidharan & Swaroopananadhan | 3110  | 1984 | Preserved Specimen |
| 17 | India | Kerala     | Ampumala                                       | 11.33959 | 76.12927 | Philip Mathew                   | 34570 | 1984 | Preserved Specimen |
| 18 | India | Kerala     | Panthenthode - Silent Valley RF                | 11.06956 | 76.42629 | P. Bhargavan                    | 87479 | 1988 | Preserved Specimen |
| 19 | India | Kerala     | Bonaccord                                      | 8.68055  | 77.16703 | N. Mohanan                      | 8247  | 1990 | Preserved Specimen |
| 20 | India | Kerala     | Attayar                                        | 8.62189  | 77.21705 | N. Mohanan                      | 10830 | 1991 | Preserved Specimen |
| 21 | India | Kerala     | Thekkady, Periyar Tiger Reserve                | 9.59600  | 77.15792 | Jomy Augustine                  | 12518 | 1993 | Preserved Specimen |
| 22 | India | Kerala     | Kallar, Shenduruny Wild life Sanctuary, Kollam | 8.88473  | 77.16836 | N Sasidharan & Jomy Augustine   | 10766 | 1994 | Preserved Specimen |
| 23 | India | Kerala     | Kokkara, Periyar Tiger Reserve                 | 9.46314  | 77.22865 | N Sasidharan & Jomy Augustine   | 12022 | 1994 | Preserved Specimen |
| 24 | India | Tamil Nadu | Upper manalar                                  | 9.58354  | 77.33303 | Jomy Augustine                  | 13723 | 1994 | Preserved Specimen |
| 25 | India | Kerala     | Mannavan shola                                 | 10.21352 | 77.19722 | A. Nazamudeen                   | 20723 | 1994 | Preserved Specimen |
| 26 | India | Tamil Nadu | Anamudi                                        | 10.39208 | 77.14840 | S. P. Biju                      | 34570 | 1997 | Preserved Specimen |
| 27 | India | Kerala     | Varagalaiar, Anamalais                         | 10.25000 | 76.52000 | N. Ayyappan & N. Parthasarathy  |       | 1999 | Human Observation  |
| 28 | India | Kerala     | Manikkunnumala                                 | 11.60024 | 76.11329 | M.K.Ratheesh Narayanan          | 3228  | 2000 | Preserved Specimen |

|    |       |             |                               |          |          |                                                     |           |      |                    |
|----|-------|-------------|-------------------------------|----------|----------|-----------------------------------------------------|-----------|------|--------------------|
| 29 | India | Kerala      | Kurichiarmala                 | 11.58721 | 75.98916 | M.K.Ratheesh Narayanan                              | 1688      | 2001 | Preserved Specimen |
| 30 | India | Kerala      | Kurichiarmala                 | 11.61181 | 76.10258 | M.K.Ratheesh Narayanan                              | 2640      | 2002 | Preserved Specimen |
| 31 | India | Kerala      | Silent Valley National Park   | 11.07218 | 76.41958 | C. Kunhikannan, N. Krishnakumar                     |           | 2011 | Preserved Specimen |
| 32 | India | Kerala      | Thollayiram, South Wayanad    | 11.50163 | 76.11567 | Aneesh, K S                                         |           | 2011 | Preserved Specimen |
| 33 | India | Maharashtra | Maharashtra, Raigad, Matheran | 18.98866 | 73.27118 | Gurumurthi Hegde & Radha Veach                      | 20130725  | 2013 | Preserved Specimen |
| 34 | India | Tamil Nadu  | Kolli hills                   | 11.24851 | 78.33871 | Tamil Selvan B, Udayakumar M, Manikandan S, Sekar T |           | 2016 | Preserved Specimen |
| 35 | India | Karnataka   | Karnataka                     | 15.31728 | 75.71389 | S.G. Srinivas and Y.L. Krishnamurth                 | KUABL1010 | 2019 | Preserved Specimen |
| 36 | India | Kerala      | Minnampara, Nellyyamapathy    | 10.83678 | 76.71165 | Devika MA & Amitha Bachan KH                        | CU216147  | 2024 | Preserved Specimen |
| 37 | India | Kerala      | Thottapura, Sholayar          | 10.30232 | 76.75619 | Devika MA & Amitha Bachan KH                        | AH25235   | 2023 | Preserved Specimen |
| 38 | India | Kerala      | Sholayar                      | 10.35383 | 76.72131 | Amitha Bachan KH & Devika MA                        | AH25246   | 2023 | Preserved Specimen |
| 39 | India | Kerala      | Karapara, Nellyyamapathy      | 10.46056 | 76.64983 | Devika MA & Amitha Bachan KH                        | AH25257   | 2024 | Preserved Specimen |
| 40 | India | Kerala      | Minnampara, Nellyampathy      | 10.54005 | 76.70553 | Devika MA & Amitha Bachan KH                        | AH25261   | 2024 | Preserved Specimen |

|    |       |        |                          |          |          |                                    |          |      |                       |
|----|-------|--------|--------------------------|----------|----------|------------------------------------|----------|------|-----------------------|
| 41 | India | Kerala | Chempra peak,<br>Wayanad | 11.50657 | 76.08350 | Devika MA &<br>Amitha Bachan<br>KH | CU216197 | 2023 | Preserved<br>Specimen |
|----|-------|--------|--------------------------|----------|----------|------------------------------------|----------|------|-----------------------|

**16. *Medinilla anamalaiana* Sasidh. & Sujanapal, Sida 20(1): 110 (2002).**

| SL No. | Country | State      | Location                                     | Latitude | Longitude | Recorded By                | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|----------------------------------------------|----------|-----------|----------------------------|---------------|------|--------------------|
| 1      | India   | Kerala     | Agasthyamala,<br>Thiruvananthapuram          | 8.61986  | 77.22889  | N. Mohanan                 | 5528          | 1989 | Preserved Specimen |
| 2      | India   | Kerala     | Goodrical Range, Moozhiya,<br>Pathanamthitta | 9.36601  | 76.94582  | N Sasidharan               | 3142          | 1989 | Preserved Specimen |
| 3      | India   | Kerala     | Vallakkadavu, Periyar Tiger Reserve          | 9.52457  | 77.11469  | Jomy Augustine & KP Rajesh | 15429         | 1995 | Preserved Specimen |
| 4      | India   | Kerala     | Sheikelmudi, Parambikulam                    | 10.33689 | 76.81785  | P Sujanapal                | 9431          | 2000 | Preserved Specimen |
| 5      | India   | Kerala     | Puliyala, Parambikulam                       | 10.35849 | 76.76616  | P Sujanapal                | 30043         | 2000 | Preserved Specimen |
| 6      | India   | Kerala     | Kulamavu                                     | 9.80044  | 76.88444  | T. Shaju                   |               | 2008 | Preserved Specimen |
| 7      | India   | Kerala     | Way to Karayar                               | 8.62505  | 77.24660  | Usha and Deepthy           | 92232         | 2018 | Preserved Specimen |
| 8      | India   | Tamil Nadu | Way to Karayar                               | 8.62950  | 77.25504  | Deepthy and Usha           | 93552, 93550  | 2019 | Preserved Specimen |
| 9      | India   | Kerala     | Vallavarkudy, Idukki                         | 10.21826 | 76.97207  | T R Shankar Raman          |               | 2021 | Preserved Specimen |
| 10     | India   | Tamil Nadu | Sheikelmudi                                  | 10.31759 | 76.83292  | Srinivasan Kasinathan      |               | 2021 | Preserved Specimen |

|    |       |            |                                    |          |          |                              |          |      |                    |
|----|-------|------------|------------------------------------|----------|----------|------------------------------|----------|------|--------------------|
| 11 | India | Kerala     | Chandanthodu, Chalakkudy, Thrissur | 10.31332 | 76.77733 | Devika MA & Amitha Bachan KH | CU216122 | 2023 | Preserved Specimen |
| 12 | India | Tamil Nadu | Thottapura, Sholayar, Thrissur     | 10.33750 | 76.85556 | Devika MA & Amitha Bachan KH | CU216108 | 2023 | Preserved Specimen |
| 13 | India | Kerala     | Meenmutty, Wayanad                 | 11.64140 | 75.88361 | E flora of Kerala            |          |      | Preserved Specimen |

**17. *Meiogyne pannosa* (Dalzell) J.Sinclair, Sarawak Mus. J. v. 604 (1951).**

| SL No. | Country | State      | Location             | Latitude | Longitude | Recorded By     | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|----------------------|----------|-----------|-----------------|---------------|------|--------------------|
| 1      | India   | Kerala     | Attayar              | 8.62189  | 77.21705  | Mohanan         | 10546         | 2002 | Preserved Specimen |
| 2      | India   | Kerala     | Chemungi             | 8.67052  | 77.17733  | Mohanan         | 11163         | 2002 | Preserved Specimen |
| 3      | India   | Kerala     | Base of Agasthyamala | 8.82201  | 77.21223  | Mohanan         | 10366         | 2002 | Preserved Specimen |
| 4      | India   | Kerala     | Meenmutty            | 8.71008  | 77.13529  | Mohanan         | 10487         | 2002 | Preserved Specimen |
| 5      | India   | Kerala     | Athirumala           | 8.68195  | 77.19013  | Mohanan         | 8948, 9645    | 2002 | Preserved Specimen |
| 6      | India   | Kerala     | Thalichola           | 11.31620 | 76.48744  | Philip Mathew   | 25663         | 1981 | Preserved Specimen |
| 7      | India   | Kerala     | Chandanathode        | 11.84673 | 75.84204  | VS Ramachandran |               | 1988 | Preserved Specimen |
| 8      | India   | Tamil Nadu | Deviar               | 9.58606  | 77.23981  | Jomy Augustine  | 12133         | 1998 | Preserved Specimen |

|    |       |             |                                                                  |          |          |                                   |       |      |                    |
|----|-------|-------------|------------------------------------------------------------------|----------|----------|-----------------------------------|-------|------|--------------------|
| 9  | India | Tamil Nadu  | Vellimala                                                        | 9.58159  | 77.33967 | Jomy Augustine                    | 14037 | 1998 | Preserved Specimen |
| 10 | India | Tamil Nadu  | Valparai, Coimbatore                                             | 10.35595 | 76.88876 | Akshay Surendra                   |       | 2019 | Human Observation  |
| 11 | India | Tamil Nadu  | Valparai, Coimbatore                                             | 10.35702 | 76.88808 | Akshay Surendra                   |       | 2019 | Human Observation  |
| 12 | India | Maharashtra | Mulshi, Pune District                                            | 18.64818 | 73.38600 | Aparna Watve                      |       | 1998 | Human Observation  |
| 13 | India | Tamil Nadu  | Ambasamudram, Tirunelveli                                        | 8.64500  | 77.30600 | B.R, Ramesh                       |       | 1998 | Preserved Specimen |
| 14 | India | Karnataka   | Hanur taluk, Chamarajanagar                                      | 11.89170 | 77.17500 | B.R, Ramesh                       |       | 1986 | Preserved Specimen |
| 15 | India | Karnataka   | Hanur taluk, Chamarajanagar                                      | 11.92588 | 77.19182 | B.R, Ramesh                       |       | 1987 | Preserved Specimen |
| 16 | India | Karnataka   | Madikeri taluku, Kodagu                                          | 12.47500 | 75.62500 | B.R, Ramesh                       |       | 1984 | Preserved Specimen |
| 17 | India | Karnataka   | Chadavu, Madikeri taluku, Kodagu                                 | 12.50000 | 75.57500 | B.R, Ramesh                       |       | 1982 | Preserved Specimen |
| 18 | India | Karnataka   | Thirthahalli - Udupi Highway, Agumbe, Tirthahalli taluk, Shimoga | 13.50000 | 75.07500 | B.R, Ramesh                       |       | 1982 | Preserved Specimen |
| 19 | India | Tamil Nadu  | Nanguneri, Tirunelveli                                           | 8.44167  | 77.47500 | B.R, Ramesh; De Franceschi, Dario |       | 1990 | Preserved Specimen |
| 20 | India | Tamil Nadu  | Nanguneri, Tirunelveli                                           | 8.52222  | 77.46110 | B.R, Ramesh; De Franceschi, Dario |       | 1992 | Preserved Specimen |
| 21 | India | Tamil Nadu  | Shenkottai, Tenkasi                                              | 9.11667  | 77.23330 | B.R, Ramesh; De Franceschi, Dario |       | 1992 | Preserved Specimen |

|    |       |            |                                                                  |          |          |                                                    |  |      |                    |
|----|-------|------------|------------------------------------------------------------------|----------|----------|----------------------------------------------------|--|------|--------------------|
| 22 | India | Tamil Nadu | Mangaladevi Temple Trekking Path, Thekkady, Uthamapalayam, Theni | 9.59444  | 77.22220 | B.R, Ramesh; De Franceschi, Dario; B, Montfraix    |  | 1992 | Preserved Specimen |
| 23 | India | Tamil Nadu | Ambasamudram, Tirunelveli                                        | 8.71944  | 77.27500 | B.R, Ramesh; De Franceschi, Dario; Viet, Pham Bach |  | 1993 | Preserved Specimen |
| 24 | India | Tamil Nadu | Ambasamudram, Tirunelveli                                        | 8.72500  | 77.24170 | C.E, Ridsdale                                      |  | 1976 | Preserved Specimen |
| 25 | India | Kerala     | Konni, Pathanamthitta                                            | 9.19583  | 77.15000 | De Franceschi, Dario                               |  | 1993 | Preserved Specimen |
| 26 | India | Kerala     | Mangaladevi Temple Trekking Path, Kumily, Peerumade, Idukki      | 9.59167  | 77.17500 | De Franceschi, Dario                               |  | 1990 | Preserved Specimen |
| 27 | India | Karnataka  | Chamarajanagara taluk, Chamarajanagar                            | 11.87500 | 77.15830 | De Franceschi, Dario                               |  | 1989 | Preserved Specimen |
| 28 | India | Tamil Nadu | Thiruvattar, Kalkulam, Kanniyakumari                             | 8.47083  | 77.39030 | De Franceschi, Dario; B, Montfraix                 |  | 1993 | Preserved Specimen |
| 29 | India | Kerala     | Chalakkudy, Thrissur                                             | 10.32500 | 76.70833 | Jean-Pierre, Pascal                                |  | 1979 | Preserved Specimen |
| 30 | India | Karnataka  | Kandimakki, Virajpet taluk, Kodagu                               | 12.11056 | 75.78467 | Jean-Pierre, Pascal                                |  | 1976 | Preserved Specimen |
| 31 | India | Karnataka  | Madikeri taluku, Kodagu                                          | 12.46670 | 75.67500 | Jean-Pierre, Pascal                                |  | 1977 | Preserved Specimen |

|    |       |             |                                                       |          |          |                                                                                                  |  |      |                       |
|----|-------|-------------|-------------------------------------------------------|----------|----------|--------------------------------------------------------------------------------------------------|--|------|-----------------------|
| 32 | India | Karnataka   | Kalasa taluk,<br>Chikkamagaluru                       | 13.20000 | 75.19170 | Jean-Pierre,<br>Pascal                                                                           |  | 1977 | Preserved<br>Specimen |
| 33 | India | Karnataka   | Kalasa taluk,<br>Chikkamagaluru                       | 13.20830 | 75.17500 | Jean-Pierre,<br>Pascal                                                                           |  | 1978 | Preserved<br>Specimen |
| 34 | India | Karnataka   | Kuppagadde, Soraba<br>taluk, Shimoga                  | 14.47500 | 75.10833 | Jean-Pierre,<br>Pascal                                                                           |  | 1978 | Preserved<br>Specimen |
| 35 | India | Maharashtra | Amba, Shahuwadi,<br>Kolhapur District,<br>Maharashtra | 16.97536 | 73.79632 | M. D. Nandikar                                                                                   |  | 2021 | Preserved<br>Specimen |
| 36 | India | Tamil Nadu  | Valparai,<br>Coimbatore                               | 10.34959 | 76.92830 | Madhavan A.P.                                                                                    |  | 2022 | Human<br>Observation  |
| 37 | India | Tamil Nadu  | Ambasamudram,<br>Tirunelveli                          | 8.63250  | 77.27110 | N, Ayyappan;<br>B.R, Ramesh                                                                      |  | 2007 | Preserved<br>Specimen |
| 38 | India | Karnataka   | Madikeri taluku,<br>Kodagu                            | 12.53720 | 75.66250 | N, Ayyappan;<br>B.R, Ramesh                                                                      |  | 2006 | Preserved<br>Specimen |
| 39 | India | Tamil Nadu  | Valparai,<br>Coimbatore                               | 10.34789 | 76.89254 | N. Ayyappan, S.<br>Muthuramkumar,<br>N. Parthasarathy,<br>T R Shankar<br>Raman, Divya<br>Mudappa |  | 2003 | Human<br>Observation  |
| 40 | India | Tamil Nadu  | Anaimalai Loop<br>Road, Valparai,<br>Coimbatore       | 10.34800 | 76.93172 | N. Ayyappan, S.<br>Muthuramkumar,<br>N. Parthasarathy,<br>T R Shankar<br>Raman, Divya<br>Mudappa |  | 2003 | Human<br>Observation  |
| 41 | India | Kerala      | Valparai,<br>Coimbatore                               | 10.35803 | 76.89029 | N. Ayyappan, S.<br>Muthuramkumar,<br>N. Parthasarathy,<br>T R Shankar                            |  | 2003 | Human<br>Observation  |



|    |       |             |                                                                     |          |          |                                                                                                  |  |      |                       |
|----|-------|-------------|---------------------------------------------------------------------|----------|----------|--------------------------------------------------------------------------------------------------|--|------|-----------------------|
|    |       |             |                                                                     |          |          | Raman, Divya<br>Mudappa                                                                          |  |      |                       |
| 42 | India | Tamil Nadu  | Pollachi - Valparai<br>Road, Iyerpaddy,<br>Valparai,<br>Coimbatore  | 10.36918 | 76.99411 | N. Ayyappan, S.<br>Muthuramkumar,<br>N. Parthasarathy,<br>T R Shankar<br>Raman, Divya<br>Mudappa |  | 2003 | Human<br>Observation  |
| 43 | India | Tamil Nadu  | Madura Coats,<br>Vikramasingapuram,<br>Ambasamudram,<br>Tirunelveli | 8.70000  | 77.38333 | Ridsdale CE                                                                                      |  | 1976 | Preserved<br>Specimen |
| 44 | India | Maharashtra | Parle, Chandgad,<br>Kolhapur                                        | 15.85649 | 74.20399 | S. Bramhadande                                                                                   |  | 2021 | Preserved<br>Specimen |
| 45 | India | Maharashtra | Manachnagar, Patan,<br>Satara                                       | 17.42905 | 73.72808 | S.MORE                                                                                           |  | 2021 | Human<br>Observation  |
| 46 | India | Kerala      | Poothole, Thrissur                                                  | 10.51667 | 76.21667 | Sasidharan N                                                                                     |  | 1984 | Preserved<br>Specimen |
| 47 | India | Tamil Nadu  | Valparai,<br>Coimbatore                                             | 10.35746 | 76.88351 | Siddarth Jude<br>Machado                                                                         |  | 2017 | Human<br>Observation  |
| 48 | India | Tamil Nadu  | Valparai,<br>Coimbatore                                             | 10.34889 | 76.89712 | Srinivasan<br>Kasinathan                                                                         |  | 2023 | Human<br>Observation  |
| 49 | India | Tamil Nadu  | Valparai,<br>Coimbatore                                             | 10.29899 | 76.89224 | T R Shankar<br>Raman, Divya<br>Mudappa                                                           |  | 2000 | Human<br>Observation  |
| 50 | India | Tamil Nadu  | Valparai - Manicka<br>Kurangumudi Road,<br>Valparai,<br>Coimbatore  | 10.31268 | 76.91016 | T R Shankar<br>Raman, Divya<br>Mudappa                                                           |  | 2000 | Human<br>Observation  |

|    |       |            |                                                           |          |          |                                  |              |      |                    |
|----|-------|------------|-----------------------------------------------------------|----------|----------|----------------------------------|--------------|------|--------------------|
| 51 | India | Tamil Nadu | Valparai - Manicka Kurangumudi Road, Valparai, Coimbatore | 10.31268 | 76.91016 | T R Shankar Raman, Divya Mudappa |              | 2000 | Human Observation  |
| 52 | India | Tamil Nadu | Valparai, Coimbatore                                      | 10.48095 | 76.83133 | T R Shankar Raman, Divya Mudappa |              | 2000 | Human Observation  |
| 53 | India | Kerala     | Sasthanada, Thiruvananthapuram                            | 8.71208  | 77.12845 | C.G. Vishnu                      | 63016        | 2009 | Preserved Specimen |
| 54 | India | Kerala     | Rosemala, Kollam                                          | 8.91644  | 77.17365 | Deepthy and Usha                 | 75131        | 1989 | Preserved Specimen |
| 55 | India | Kerala     | Pandimotta, Quilon                                        | 8.82408  | 77.21843 | E.S. Santhosh Kumar              | 18275        | 2009 | Preserved Specimen |
| 56 | India | Kerala     | Chemunji                                                  | 8.67252  | 77.18453 | G. Rajkumar                      | 32790        | 2015 | Preserved Specimen |
| 57 | India | Kerala     | Kallar                                                    | 8.87867  | 77.15864 | G. Rajkumar                      | 42577        | 2011 | Preserved Specimen |
| 58 | India | Kerala     | Bonaccord                                                 | 8.68055  | 77.16703 | G. Rajkumar                      | 44715        | 2003 | Preserved Specimen |
| 59 | India | Kerala     | Thenmala, earth dam                                       | 8.94751  | 77.04853 | G. Rajkumar                      | 64076        | 2000 | Preserved Specimen |
| 60 | India | Kerala     | Putharikandam, Athirumala                                 | 8.68195  | 77.19013 | G. Rajkumar                      | 64650        | 2015 | Preserved Specimen |
| 61 | India | Kerala     | Chemunji                                                  | 8.67198  | 77.18391 | G. Rajkumar                      | 68859        | 2015 | Preserved Specimen |
| 62 | India | Kerala     | Rosemala, Kollam                                          | 8.91128  | 77.17781 | G. Rajkumar                      | 85423        | 2004 | Preserved Specimen |
| 63 | India | Kerala     | Chemunji                                                  | 8.65493  | 77.08264 | G. Rajkumar and M. Alister       | 68856, 68859 | 1991 | Preserved Specimen |

|    |       |            |                                |          |          |                                      |              |      |                    |
|----|-------|------------|--------------------------------|----------|----------|--------------------------------------|--------------|------|--------------------|
| 64 | India | Kerala     | Thenmala damsite               | 8.92803  | 77.09295 | Geetha, Deepthi and A.G. Pandurangan | 53168        | 1991 | Preserved Specimen |
| 65 | India | Kerala     | Kulirkadu, Kollam              | 8.90397  | 77.19180 | Geethakumary and A.G. Pandurangan    | 48483        | 2012 | Preserved Specimen |
| 66 | India | Tamil Nadu | Way to Vetilakana, Aryamkavu   | 9.01162  | 77.17160 | M. Alister                           | 72837        |      | Preserved Specimen |
| 67 | India | Kerala     | Base of Agasthyamala           | 8.64892  | 77.20132 | N. Mohanan                           | 10366        |      | Preserved Specimen |
| 68 | India | Kerala     | Meenmutty, Thiruvananthapuram  | 8.71008  | 77.13528 | N. Mohanan                           | 10420        | 2014 | Preserved Specimen |
| 69 | India | Kerala     | Ponmudi                        | 8.76091  | 77.11155 | N. Mohanan                           | 3370         | 2011 | Preserved Specimen |
| 70 | India | Kerala     | Athirumala, Thiruvananthapuram | 8.61957  | 77.23094 | N. Mohanan                           | 5172         | 1988 | Preserved Specimen |
| 71 | India | Kerala     | Athirumala, Thiruvananthapuram | 8.62065  | 77.21620 | N. Mohanan                           | 8948         | 2011 | Preserved Specimen |
| 72 | India | Kerala     | Sasthanada, Thiruvananthapuram | 8.71208  | 77.12846 | Sheeba P.M.                          | 66218        | 1987 | Preserved Specimen |
| 73 | India | Kerala     | Kulathupuzha                   | 8.88490  | 77.13301 | Soumya A.                            | 84637, 84614 | 2001 | Preserved Specimen |
| 74 | India | Kerala     | Sholayar                       | 10.31643 | 76.72346 | N Sasidharan                         | 5604         | 1990 | Preserved Specimen |
| 75 | India | Kerala     | Nelliyampathi                  | 10.52234 | 76.75562 | UM Chandrashekara                    | 26           | 1987 | Preserved Specimen |
| 76 | India | Kerala     | Kottayam                       | 9.61628  | 76.81266 | Antony                               |              | 1989 | Preserved Specimen |
| 77 | India | Kerala     | Ampumala                       | 11.33959 | 76.12927 | Mathew                               | 34036        | 1997 | Preserved Specimen |

|    |       |           |                              |          |          |                                          |       |      |                    |
|----|-------|-----------|------------------------------|----------|----------|------------------------------------------|-------|------|--------------------|
| 78 | India | Kerala    | Thalichola                   | 11.31620 | 76.48744 | Mathew                                   | 25663 | 1997 | Preserved Specimen |
| 79 | India | Kerala    | Kariamchola                  | 10.48486 | 76.79323 | PS19125                                  |       | 2002 | Preserved Specimen |
| 80 | India | Kerala    | Poopara                      | 10.34936 | 76.82418 | Sasidharan                               | 19428 | 2002 | Preserved Specimen |
| 81 | India | Kerala    | Mannarapara                  | 9.28126  | 76.90895 | NAK2279                                  |       | 2005 | Preserved Specimen |
| 82 | India | Kerala    | Vazhachal                    | 10.30080 | 76.60957 | Amitha Bachan                            | 99144 | 2010 | Preserved Specimen |
| 83 | India | Kerala    | Kallar                       | 8.88473  | 77.16836 | Sasidharan                               | 10047 | 1997 | Preserved Specimen |
| 84 | India | Kerala    | Sholayar, Thrissur           | 10.33789 | 76.73148 | Sasidharan                               | 5604  | 1996 | Preserved Specimen |
| 85 | India | Kerala    | Aranapuzha                   | 11.51713 | 76.11486 | Ratheesh Narayanan                       | 4450  | 2009 | Preserved Specimen |
| 86 | India | Karnataka | Agumbe, Way to Abbe falls    | 13.51377 | 75.08199 | A.K. Pradeep                             | 52906 | 1996 | Preserved Specimen |
| 87 | India | Karnataka | Chandikkavana, Hulickalghat  | 13.72101 | 75.00772 | A.K. Pradeep                             | 52912 | 1996 | Preserved Specimen |
| 88 | India | Karnataka | Cauvery, Kodagu              | 12.45296 | 75.72760 | C. Sunil, R.K. Somashekar, B.C. Nagaraja |       | 2012 | Preserved Specimen |
| 89 | India | Karnataka | Chickmangalur, Sringeri road | 13.37461 | 75.81058 | C.J. Saldanha                            | 9722  | 1979 | Preserved Specimen |
| 90 | India | Kerala    | Pothumala, Nelliampathi      | 10.29630 | 77.15256 | N Sasidharan & Swrup                     | 3088  | 1984 | Preserved Specimen |

**18. *Ochna gamblei* King ex Brands, Indian Trees 128 (1906).**

| SL No. | Country | State          | Location                                | Latitude | Longitude | Recorded By                 | Herbarium No. | Year | Basis of Record    |
|--------|---------|----------------|-----------------------------------------|----------|-----------|-----------------------------|---------------|------|--------------------|
| 1      | India   | Andhra Pradesh | Andhra Pradesh, Kurnool                 | 15.81978 | 78.03203  | Beddome, R.H                | K0000685010   | 1915 | Preserved Specimen |
| 2      | India   | Karnataka      | Doddagonnakere, Tumkur                  | 12.50974 | 76.99774  | CJ. Saldanha                | 16633         | 1970 | Preserved Specimen |
| 3      | India   | Kerala         | Alappuzha, Vandanam (Ayyappakavu)       | 9.41330  | 76.34866  | Sunil C.N                   | 1476          | 1993 | Preserved Specimen |
| 4      | India   | Tamil Nadu     | Tiruvannamalai                          | 12.46608 | 78.82394  | R. Vijaya Shankar           | 16469         | 2004 | Preserved Specimen |
| 5      | India   | Andhra Pradesh | Batrepalli, Anantapur                   | 14.22819 | 78.18073  | Raja K Swamy                | 39157         | 2010 | Preserved Specimen |
| 6      | India   | Karnataka      | Hoskote                                 | 13.38135 | 77.65826  | Ganesan R                   |               | 2015 | Human Observation  |
| 7      | India   | Karnataka      | Near Chikkaballapur                     | 13.38194 | 77.65823  | Melekote conservation group |               | 2015 | Human Observation  |
| 8      | India   | Kerala         | VSSC Campus, Thumba, Thiruvananthapuram | 8.52407  | 76.88012  | Teema Joseph                | 86905         | 2016 | Preserved Specimen |
| 9      | India   | Chhattisgarh   | Dantewada, Chhathisgarh                 | 18.89985 | 81.34743  | Rajeev Kumar Singh          |               | 2016 | Preserved Specimen |
| 10     | India   | Chhattisgarh   | Raigarh, Chhathisgarh                   | 21.89740 | 83.39496  | Rajeev Kumar Singh          |               | 2016 | Preserved Specimen |
| 11     | India   | Kerala         | Aakulam, Thiruvananthapuram             | 8.53349  | 76.90474  | Deepthi Kumary              | 92917         | 2018 | Preserved Specimen |
| 12     | India   | Andhra Pradesh | Baireddipalle                           | 13.91487 | 78.48914  | Saneesh C S                 |               | 2018 | Human Observation  |

|    |       |           |                          |          |          |                              |          |      |                    |
|----|-------|-----------|--------------------------|----------|----------|------------------------------|----------|------|--------------------|
| 13 | India | Kerala    | Koolimuttam, Thrissur    | 10.28836 | 76.13426 | Amitha Bachan KH             | 19706    | 2019 | Preserved Specimen |
| 14 | India | Karnataka | Chikkaballapur           | 13.41809 | 77.68296 | Siddarth Machado             |          | 2020 | Human Observation  |
| 15 | India | Kerala    | P Vemballur, Kogungallur | 10.26696 | 76.14244 | Devika MA & Amitha Bachan KH | CU216150 | 2022 | Preserved Specimen |

**19. *Prioria pinnata* (Roxb. ex DC.) Breteler, Wageningen Agr. Univ. Pap. 99(3): 52 (1999).**

| SL No. | Country | State      | Location                                                   | Latitude | Longitude | Recorded By     | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|------------------------------------------------------------|----------|-----------|-----------------|---------------|------|--------------------|
| 1      | India   | Karnataka  | Karnataka                                                  | 13.81951 | 74.95925  | Roxburgh        | 5807          | 1825 | Preserved Specimen |
| 2      | India   | Tamil Nadu | Travancore                                                 | 8.45453  | 77.42656  | Beddomei        |               | 1873 | Preserved Specimen |
| 3      | India   | Tamil Nadu | Kodamudi, Mundanthorai, Tirunelveli                        | 8.54882  | 77.65361  | CA Barber       | 3200          | 1901 | Preserved Specimen |
| 4      | India   | Tamil Nadu | Kanikatti, Tirunelveli                                     | 8.59107  | 77.54251  | CA Barber       | 2963          | 1901 | Preserved Specimen |
| 5      | India   | Tamil Nadu | Kulukirapara 4th mile theni                                | 10.00793 | 77.47354  | V Narayanaswami | 77822         | 1928 | Preserved Specimen |
| 6      | India   | Tamil Nadu | Way to Ayilandam pillai estate, Thirukurugudi, Tirunelveli | 8.71502  | 77.76563  | B V Shetty      | 32929         | 1969 | Preserved Specimen |
| 7      | India   | Tamil Nadu | Way to Kunnimuthu Estate, Panagudi                         | 8.31987  | 77.57666  | S Karthikeyan   | 40108         | 1972 | Preserved Specimen |

|    |          |                     |                                                                         |          |          |                                                             |         |      |                       |
|----|----------|---------------------|-------------------------------------------------------------------------|----------|----------|-------------------------------------------------------------|---------|------|-----------------------|
| 8  | India    | Karnataka           | Kanchugara Koppalu,<br>Krishnarajanagara<br>taluk, Mysuru               | 12.50000 | 76.31670 | Jean-Pierre,<br>Pascal                                      |         | 1977 | Preserved<br>Specimen |
| 9  | Srilanka | Central<br>Province | Peradeniya, Hindagala,<br>Kandy District, Central<br>Province, Srilanka | 7.25000  | 80.60000 | Kostermans<br>AJGH                                          |         | 1980 | Preserved<br>Specimen |
| 10 | India    | Tamil<br>Nadu       | Ashambo RF,<br>Kanyakumari                                              | 8.373    | 77.474   | AN Henry                                                    | 68909   | 1980 | Preserved<br>Specimen |
| 11 | India    | Tamil<br>Nadu       | Way to Honey Falls,<br>Courtallum Forest                                | 8.93411  | 77.27794 | E Vajravelu                                                 | 6593    | 1983 | Preserved<br>Specimen |
| 12 | India    | Karnataka           | Sollekallu RF Makutta<br>range, Coorg                                   | 12.07496 | 75.72531 | E Vajravelu                                                 | 77814   | 1984 | Preserved<br>Specimen |
| 13 | India    | Karnataka           | Bisle state forest                                                      | 12.73060 | 75.66393 | Nicolson et al.                                             | HFP2871 | 1984 | Preserved<br>Specimen |
| 14 | India    | Tamil<br>Nadu       | Thovalai,<br>Kanniyakumari                                              | 8.29722  | 77.47500 | B.R, Ramesh;<br>De Franceschi,<br>Dario                     |         | 1992 | Preserved<br>Specimen |
| 15 | India    | Tamil<br>Nadu       | Melpuram,<br>Vilavancode,<br>Kanniyakumari                              | 8.52639  | 77.28610 | B.R, Ramesh;<br>De Franceschi,<br>Dario                     |         | 1992 | Preserved<br>Specimen |
| 16 | India    | Tamil<br>Nadu       | Alangulam, Tenkasi,                                                     | 8.86250  | 77.50830 | B.R, Ramesh;<br>De Franceschi,<br>Dario                     |         | 1992 | Preserved<br>Specimen |
| 17 | India    | Tamil<br>Nadu       | Thovalai,<br>Kanniyakumari                                              | 8.37083  | 77.48190 | B.R, Ramesh;<br>De Franceschi,<br>Dario; Viet,<br>Pham Bach |         | 1993 | Preserved<br>Specimen |
| 18 | India    | Tamil<br>Nadu       | Thovalai,<br>Kanniyakumari                                              | 8.37083  | 77.51110 | B.R, Ramesh;<br>De Franceschi,<br>Dario; Viet,<br>Pham Bach |         | 1993 | Preserved<br>Specimen |

|    |       |            |                                                    |          |          |                                                    |       |      |                    |
|----|-------|------------|----------------------------------------------------|----------|----------|----------------------------------------------------|-------|------|--------------------|
| 19 | India | Tamil Nadu | Melpuram, Manjalumoodu, Vilavancode, Kanniyakumari | 8.37361  | 77.24170 | B.R, Ramesh; De Franceschi, Dario; Viet, Pham Bach |       | 1993 | Preserved Specimen |
| 20 | India | Tamil Nadu | Thovalai, Kanniyakumari                            | 8.37361  | 77.48190 | B.R, Ramesh; De Franceschi, Dario; Viet, Pham Bach |       | 1993 | Preserved Specimen |
| 21 | India | Kerala     | Kattakada, Kattakkada, Thiruvananthapuram          | 8.50000  | 77.08750 | De Franceschi, Dario; B, Montfraix                 |       | 1993 | Preserved Specimen |
| 22 | India | Tamil Nadu | Nanguneri, Tirunelveli                             | 8.50000  | 77.50830 | De Franceschi, Dario; B, Montfraix                 |       | 1993 | Preserved Specimen |
| 23 | India | Tamil Nadu | Ambasamudram, Tirunelveli                          | 8.64993  | 77.31560 | B.R, Ramesh; De Franceschi, Dario; Viet, Pham Bach |       | 1993 | Preserved Specimen |
| 24 | India | Kerala     | Nilambur, Malappuram                               | 11.38330 | 76.33060 | B.R, Ramesh; De Franceschi, Dario; Viet, Pham Bach |       | 1993 | Preserved Specimen |
| 25 | India | Tamil Nadu | Udumalaipettai, Tiruppur                           | 10.45830 | 77.30250 | B.R, Ramesh; Krishnan, Rani                        |       | 1994 | Preserved Specimen |
| 26 | India | Kerala     | Kollam                                             | 8.89206  | 77.13241 | Subramanyan                                        |       | 1995 | Preserved Specimen |
| 27 | India | Kerala     | Adipparambu, Quilon, Kerala                        | 9.11295  | 77.02599 | A.E. Shanavas Khan                                 | 26849 | 1996 | Preserved Specimen |
| 28 | India | Kerala     | Peechi                                             | 10.51302 | 76.36313 | NG. Nair                                           | 1637  | 1996 | Preserved Specimen |



|    |       |            |                                                          |          |          |                                 |               |      |                    |
|----|-------|------------|----------------------------------------------------------|----------|----------|---------------------------------|---------------|------|--------------------|
| 29 | India | Kerala     | Peechi                                                   | 10.55004 | 76.37572 | Sasidharan                      | NS 4741, 5057 | 1996 | Preserved Specimen |
| 30 | India | Kerala     | Shendhurney, Kollam                                      | 8.87867  | 77.15864 | Sasidharan                      | NS10812       | 1997 | Preserved Specimen |
| 31 | India | Karnataka  | Charmady                                                 | 13.07239 | 75.44559 | Ravikumar & Udayan              | FRLH12061     | 1997 | Preserved Specimen |
| 32 | India | Kerala     | Koruthode                                                | 9.46034  | 76.95688 | Jomy Augustine                  | JA18427       | 1998 | Preserved Specimen |
| 33 | India | Karnataka  | Hariharapallathadka                                      | 12.59630 | 75.60661 | Pierre Grard                    |               | 2004 | Preserved Specimen |
| 34 | India | Karnataka  | Hara Palladka, Kollamogru, Sulya taluk, Dakshina Kannada | 12.59630 | 75.60661 | Pierre Grard                    |               | 2004 | Human Observation  |
| 35 | India | Tamil Nadu | Ambasamudram, Tirunelveli                                | 8.62972  | 77.30080 | N, Ayyappan; B.R, Ramesh        |               | 2007 | Preserved Specimen |
| 36 | India | Kerala     | Vythiri Ghat, Wayanad                                    | 11.54020 | 76.06212 | Narayanan                       | RNMK3732      | 2009 | Preserved Specimen |
| 37 | India | Kerala     | Kunchome                                                 | 11.74682 | 75.85312 | Narayanan                       | RNMK3154      | 2009 | Preserved Specimen |
| 38 | India | Kerala     | Vazhachal                                                | 9.42780  | 76.59827 | Amitha Bachan K.H               | 117704        | 2010 | Preserved Specimen |
| 39 | India | Karnataka  | Kollamogra Road                                          | 12.54912 | 75.68687 | Barathan                        |               | 2013 | Preserved Specimen |
| 40 | India | Karnataka  | Madikeri taluku, Kodagu                                  | 12.54912 | 75.68687 | Barathan.N                      |               | 2013 | Human Observation  |
| 41 | India | Kerala     | Thalassery Baveli Road                                   | 11.83528 | 75.83910 | Muthu Karthick & Vinayaraj V. R |               | 2014 | Preserved Specimen |
| 42 | India | Kerala     | Periya, Mananthavady, Wayanad                            | 11.83528 | 75.83910 | Vinayaraj V R                   |               | 2014 | Human Observation  |

|    |       |               |                                |          |          |                                                               |          |      |                       |
|----|-------|---------------|--------------------------------|----------|----------|---------------------------------------------------------------|----------|------|-----------------------|
| 43 | India | Karnataka     | Sakaleshapura taluk,<br>Hassan | 12.87339 | 75.64636 | Siddarth Jude<br>Machado                                      |          | 2014 | Human<br>Observation  |
| 44 | India | Tamil<br>Nadu | Nanguneri, Tirunelveli         | 8.50493  | 77.46645 | Siddarth Jude<br>Machado                                      |          | 2016 | Human<br>Observation  |
| 45 | India | Karnataka     | Makut Ghat, Kodagu             | 12.11717 | 75.79014 | Arun Singh et<br>al.                                          | HJCBN121 | 2017 | Preserved<br>Specimen |
| 46 | India | Kerala        | Kallar,<br>Thiruvananthapuram  | 8.74009  | 77.11972 | Jose et al.                                                   |          | 2018 | Preserved<br>Specimen |
| 47 | India | Kerala        | Orukomban, Palakkad            | 10.32444 | 76.75833 | Jose et al.                                                   |          | 2018 | Preserved<br>Specimen |
| 48 | India | Kerala        | Nadugani,<br>Malappuram        | 11.43390 | 76.38667 | Jose et al.                                                   |          | 2018 | Preserved<br>Specimen |
| 49 | India | Kerala        | Peruvannamoozhi,<br>Kozhikod   | 11.58344 | 75.86861 | Jose et al.                                                   |          | 2018 | Preserved<br>Specimen |
| 50 | India | Kerala        | Aralam, Kannur                 | 11.96069 | 75.83028 | Jose et al.                                                   |          | 2018 | Preserved<br>Specimen |
| 51 | India | Kerala        | Shabaripeedam                  | 9.42558  | 77.07111 | Nair et al.                                                   | SKC204   | 2019 | Preserved<br>Specimen |
| 52 | India | Kerala        | Vellayani thrissur             | 10.57810 | 76.33160 | Nair et al.                                                   | SKC201   | 2019 | Preserved<br>Specimen |
| 53 | India | Karnataka     | Makkutta, Kodagu               | 12.11440 | 75.79040 | Nair et al.                                                   | SKC103   | 2019 | Preserved<br>Specimen |
| 54 | India | Kerala        | Charpathodu                    | 10.33096 | 76.59070 | Amitha Bachan<br>& Devika M. A.                               | AHI9948  | 2020 | Preserved<br>Specimen |
| 55 | India | Kerala        | Vachumaram                     | 10.28235 | 76.67274 | Amitha Bachan<br>& Devika M. A.                               | AH19953  | 2021 | Preserved<br>Specimen |
| 56 | India | Kerala        | Kulathupuzha                   | 8.87170  | 77.08352 | P.A. Jose, K.<br>Subin, A.J.<br>Robi, T.K. Siju,<br>Binoy N.M |          | 2023 | Preserved<br>Specimen |

|    |       |            |                          |          |          |                                                      |          |      |                    |
|----|-------|------------|--------------------------|----------|----------|------------------------------------------------------|----------|------|--------------------|
| 57 | India | Kerala     | Peringalkuth             | 10.32194 | 76.64017 | P.A. Jose, K. Subin, A.J. Robi, T.K. Siju, Binoy N.M |          | 2023 | Preserved Specimen |
| 58 | India | Kerala     | Kottiyoor                | 11.86814 | 75.89822 | P.A. Jose, K. Subin, A.J. Robi, T.K. Siju, Binoy N.M |          | 2023 | Preserved Specimen |
| 59 | India | Kerala     | Athirumala               | 8.62096  | 77.22246 | Devika MA & Amitha Bachan KH                         | AH25292  | 2024 | Preserved Specimen |
| 60 | India | Kerala     | Pandimotta, Shendhurney  | 8.85530  | 77.17917 | Devika MA & Amitha Bachan KH                         | CU216176 | 2024 | Preserved Specimen |
| 61 | India | Kerala     | Dharpakulam, Shendhurney | 8.91238  | 77.19287 | Devika MA & Amitha Bachan KH                         | CU216177 | 2024 | Preserved Specimen |
| 62 | India | Kerala     | Rosemala, Shendhurney    | 8.93443  | 77.15748 | Devika MA & Amitha Bachan KH                         | AH25262  | 2024 | Preserved Specimen |
| 63 | India | Kerala     | Vazhachal iron bridge    | 10.30448 | 76.60743 | Devika MA & Amitha Bachan KH                         | AH25276  | 2024 | Preserved Specimen |
| 64 | India | Kerala     | Karanthode               | 10.35085 | 76.63377 | Devika MA & Amitha Bachan KH                         | AH25280  | 2024 | Preserved Specimen |
| 65 | India | Kerala     | Sholayar                 | 10.35383 | 76.72131 | Devika MA & Amitha Bachan KH                         | AH25282  | 2024 | Preserved Specimen |
| 66 | India | Tamil Nadu | Thalavadi, Erode         | 11.78332 | 77.30250 | N, Ayyappan; B.R, Ramesh                             |          | 2007 | Preserved Specimen |

**20. *Strobilanthes kunthiana* T.Anderson ex Benth., Fl. Hongk. 262, in nota. (1861).**

| SL No. | Country | State      | Location                   | Latitude | Longitude | Recorded By  | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|----------------------------|----------|-----------|--------------|---------------|------|--------------------|
| 1      | India   | Tamil Nadu | Tirunelveli hills          | 10.14870 | 77.38602  | Beddome 124  | 1859          | 1847 | Preserved Specimen |
| 2      | India   | Tamil Nadu | Coimbatore, Anamalia       | 10.34788 | 77.00886  | Robert Wight | 371431        | 1852 | Preserved Specimen |
| 3      | India   | Tamil Nadu | Udagamandalam (Ootacamund) | 11.42512 | 76.69187  | Clarke       | 61526         | 1870 | Preserved Specimen |
| 4      | India   | Tamil Nadu | Udagamandalam (Ootacamund) | 11.42530 | 76.72035  | Gamble       | 57877         | 1883 | Preserved Specimen |
| 5      | India   | Tamil Nadu | Dodda Betta                | 11.39972 | 76.73431  | Wight        | 23598         | 1885 | Preserved Specimen |
| 6      | India   | Tamil Nadu | Coonoor                    | 11.35687 | 76.79678  | Gamble       | 1.7E+08       | 1886 | Preserved Specimen |
| 7      | India   | Tamil Nadu | Udagamandalam (Ootacamund) | 11.38844 | 76.62363  | Perrotet     | 3.1E+07       | 1886 | Preserved Specimen |
| 8      | India   | Tamil Nadu | Udagamandalam (Ootacamund) | 11.38847 | 76.62366  | Perrotet     | 5.5E+07       | 1886 | Preserved Specimen |
| 9      | India   | Tamil Nadu | Udagamandalam (Ootacamund) | 11.38883 | 76.67953  | Lawson       | 7.5E+07       | 1886 | Preserved Specimen |
| 10     | India   | Tamil Nadu | Salem, Shevaroy            | 11.79385 | 78.20726  | Bourne       |               | 1897 | Preserved Specimen |
| 11     | India   | Tamil Nadu | Anaibetta, Coimbatore      | 10.99737 | 76.95889  | CEC Fischer  | 1.8E+07       | 1905 | Preserved Specimen |
| 12     | India   | Kerala     | Brahmagiris, Malabar North | 11.93173 | 75.99384  | CEC Fischer  |               | 1907 | Preserved Specimen |
| 13     | India   | Tamil Nadu | Kotagiri Road              | 11.41501 | 76.76481  | Bourne       | 75241         | 1910 | Preserved Specimen |

|    |       |            |                                         |          |          |                 |             |      |                    |
|----|-------|------------|-----------------------------------------|----------|----------|-----------------|-------------|------|--------------------|
| 14 | India | Tamil Nadu | Kundah, Nilgiris                        | 11.24438 | 76.61936 | CEC Fischer     | HIFP_000415 | 1911 | Preserved Specimen |
| 15 | India | Tamil Nadu | Nilgiri                                 | 11.48315 | 76.56622 | Robinson        |             | 1934 | Preserved Specimen |
| 16 | India | Tamil Nadu | Santhanpara, Idukki                     | 9.93924  | 77.24231 | Barnes          | 3842        | 1937 | Preserved Specimen |
| 17 | India | Tamil Nadu | Udhagamandalam, Nilgiris, Tamil Nadu    | 11.48016 | 76.54433 | G, Thanikaimoni | 2558        | 1960 | Preserved Specimen |
| 18 | India | Tamil Nadu | Moir's Point View, Kodaikanal, Dindigul | 10.20830 | 77.45000 | Ph, Guinet      |             | 1962 | Preserved Specimen |
| 19 | India | Tamil Nadu | Kundah RF, Nilgiris Forest Division     | 11.26612 | 76.63751 | KN Subramanian  | 8.6E+07     | 1963 | Preserved Specimen |
| 20 | India | Kerala     | Madupatti                               | 10.10696 | 77.13223 | Guyer           | 145078      | 1964 | Preserved Specimen |
| 21 | India | Kerala     | Umaiya malai, Devikulam                 | 10.25305 | 77.05572 | B V Shetty      | HIFP_000426 | 1965 | Preserved Specimen |
| 22 | India | Tamil Nadu | Gundar shola, Kodaikanal Madars state   | 10.24468 | 77.43494 | KN Subramanian  | HIFP_000430 | 1967 | Preserved Specimen |
| 23 | India | Tamil Nadu | Kovilpatti, Kodaikanal, Dindigul        | 10.26670 | 77.51670 | F, Blasco       | HIFP_000416 | 1967 | Preserved Specimen |
| 24 | India | Tamil Nadu | Udhagamandalam, Nilgiris                | 11.48017 | 76.54433 | F, Blasco       | 1288        | 1967 | Preserved Specimen |
| 25 | India | Tamil Nadu | Kaveri Peak Yercaud                     | 11.82091 | 78.23873 | D.B. Deb        | 2650        | 1968 | Preserved Specimen |

|    |       |            |                                                       |          |          |                             |              |      |                       |
|----|-------|------------|-------------------------------------------------------|----------|----------|-----------------------------|--------------|------|-----------------------|
| 26 | India | Tamil Nadu | Lakkidi park,<br>Korakunda range,<br>nilgiri          | 11.21423 | 76.61582 | KN Subramanian              | 1.3E+08      | 1969 | Preserved<br>Specimen |
| 27 | India | Tamil Nadu | Coonoor, Nilgiri                                      | 11.36950 | 76.80598 | KA Bhoja Shetty             | 5.3E+07      | 1969 | Preserved<br>Specimen |
| 28 | India | Kerala     | Umaiya malai,<br>Devikulam                            | 10.25301 | 77.05572 | B V Shetty                  | 6.4E+07      | 1970 | Preserved<br>Specimen |
| 29 | India | Tamil Nadu | Avalanchi                                             | 11.30213 | 76.59452 | Van der Maesen              | MW0747901    | 1970 | Preserved<br>Specimen |
| 30 | India | Karnataka  | Honnametti,<br>Biligiri Reagan<br>Hills               | 11.88798 | 77.17440 | R. Raghavendra Rao          |              | 1971 | Preserved<br>Specimen |
| 31 | India | Tamil Nadu | Dodebetta                                             | 11.39299 | 76.72710 | Townsend &<br>Ramamoorthy   | 17570        | 1973 | Preserved<br>Specimen |
| 32 | India | Tamil Nadu | Naidupuram,<br>Kodaikanal,<br>Kodaikanal,<br>Dindigul | 10.23330 | 77.48333 | Jean-Pierre, Pascal         | 6.1E+07      | 1974 | Preserved<br>Specimen |
| 33 | India | Tamil Nadu | Kodaikanal,<br>Dindigul                               | 10.17500 | 77.39170 | G, Thanikaimoni             | 1424 (BM, K) | 1976 | Preserved<br>Specimen |
| 34 | India | Tamil Nadu | Near Boxite mines<br>Yercaud Shevaroy                 | 11.83293 | 78.22981 | NC Nair                     | 2640         | 1978 | Preserved<br>Specimen |
| 35 | India | Tamil Nadu | Yercad Takul,<br>Servarayan Hills                     | 11.79380 | 78.20725 | Matthew, Btotto and<br>Rani |              | 1980 | Preserved<br>Specimen |
| 36 | India | Tamil Nadu | Yercad Takul,<br>Lady's seat                          | 11.79652 | 78.21318 | Matthew, Btotto and<br>Rani | 31254        | 1980 | Preserved<br>Specimen |
| 37 | India | Tamil Nadu | Ootacmund                                             | 11.36757 | 76.70226 | K. Satheesh kumar           | NCU00433648  | 1981 | Preserved<br>Specimen |
| 38 | India | Tamil Nadu | Kodaikanal                                            | 10.22551 | 77.45651 | K.Mary Mathew               | 3.1E+07      | 1982 | Human<br>Observation  |

|    |       |            |                                                  |          |          |                                                    |             |      |                    |
|----|-------|------------|--------------------------------------------------|----------|----------|----------------------------------------------------|-------------|------|--------------------|
| 39 | India | Tamil Nadu | Kodaikanal                                       | 10.23841 | 77.48176 | Van der Maesen                                     | HIFP_000425 | 1982 | Preserved Specimen |
| 40 | India | Karnataka  | Yalanduru taluk, Chamarajanagar                  | 11.94170 | 77.17500 | B.R, Ramesh                                        |             | 1986 | Preserved Specimen |
| 41 | India | Tamil Nadu | Kodaikanal, Vandaravu marian shola, Levinge path | 10.20891 | 77.43598 | Mathew                                             | 328023      | 1987 | Preserved Specimen |
| 42 | India | Kerala     | Dhanas Valley, Upper Vaguvarai                   | 10.18791 | 77.09939 | P Bhargavan                                        | 849         | 1989 | Preserved Specimen |
| 43 | India | Karnataka  | Hanur taluk, Chamarajanagar                      | 11.87500 | 77.19170 | De Franceschi, Dario                               | 2300        | 1989 | Preserved Specimen |
| 44 | India | Kerala     | Vaguvarrai, Devikulam, Idukki                    | 10.17500 | 77.09170 | B.R, Ramesh; De Franceschi, Dario; Viet, Pham Bach | 11930       | 1993 | Preserved Specimen |
| 45 | India | Tamil Nadu | Munnar - Kodaikanal                              | 10.23411 | 77.48173 | A. Nazarudeen                                      | 1.6E+07     | 1993 | Preserved Specimen |
| 46 | India | Kerala     | Eravikulam                                       | 10.14371 | 77.03497 | E.S. Santhosh kumar                                | 1068        | 1994 | Preserved Specimen |
| 47 | India | Kerala     | Eravikulam                                       | 10.14795 | 77.03686 | C. Satheesh Kumar                                  | 11086C      | 1994 | Preserved Specimen |
| 48 | India | Kerala     | Rajamala, Idukki                                 | 10.14268 | 77.03865 | B. Ajayakumar                                      | 2201        | 1995 | Preserved Specimen |
| 49 | India | Kerala     | Rajamala                                         | 10.14574 | 77.03565 | T.G. Saji                                          | 3 125 (BM)  | 1995 | Preserved Specimen |
| 50 | India | Kerala     | Kanthallur, Chinnar Wildlife Sanctuary Idukki    | 10.25323 | 77.23194 | N Sasidharan                                       | HIFP_000417 | 1995 | Preserved Specimen |
| 51 | India | Tamil Nadu | Naduvattam, Outcher honey Reserve Forest,        | 11.48315 | 76.56622 | Scotland                                           | 739         | 1995 | Preserved Specimen |

|    |       |            |                                        |          |          |                          |         |      |                       |
|----|-------|------------|----------------------------------------|----------|----------|--------------------------|---------|------|-----------------------|
|    |       |            | Rhododendron<br>arboretum              |          |          |                          |         |      |                       |
| 52 | India | Kerala     | Munnar, Idukki                         | 10.09119 | 77.06547 | Prathapan                | 112239  | 1996 | Preserved<br>Specimen |
| 53 | India | Kerala     | Silent Valley,<br>Palghat FD           | 11.14508 | 76.50239 | N<br>Venkatasubramanian  |         | 2003 | Preserved<br>Specimen |
| 54 | India | Kerala     | Achenkoil                              | 9.18664  | 77.23753 | N<br>Venkatasubramanian  | 31798   | 2004 | Preserved<br>Specimen |
| 55 | India | Kerala     | Madupatti                              | 10.10691 | 77.13221 | Amitha Bachan KH         | 145055  | 2006 | Preserved<br>Specimen |
| 56 | India | Kerala     | Rajamalai                              | 10.14556 | 77.03979 | Ramasubbu and<br>Kulloli | 4750    | 2006 | Preserved<br>Specimen |
| 57 | India | Kerala     | Devikulam, Idukki                      | 10.19031 | 77.17728 | Manoj                    |         | 2006 | Preserved<br>Specimen |
| 58 | India | Tamil Nadu | Pomparai,<br>Dindukkal                 | 10.25159 | 77.39274 | Ramasubbu and<br>Kulloli | 3E+07   | 2006 | Preserved<br>Specimen |
| 59 | India | Tamil Nadu | Coonoor, Nilgiris                      | 11.35000 | 76.85000 | Pimenov M. G.            | 4.2E+07 | 2006 | Preserved<br>Specimen |
| 60 | India | Kerala     | Way to Mannanvan<br>Shola              | 10.20098 | 77.19190 | Dhanya E.                | 88      | 2007 | Preserved<br>Specimen |
| 61 | India | Kerala     | Kanthallur ( Way<br>to Mannavan shola) | 10.20198 | 77.18692 | Adnaan Farook V.         | 46      | 2007 | Preserved<br>Specimen |
| 62 | India | Kerala     | Way to Mannan<br>Shola (Kanthalloor)   | 10.20417 | 77.19750 | Bushrabi N.K.            | 3396    | 2007 | Preserved<br>Specimen |
| 63 | India | Kerala     | Way to Mannanvan<br>Shola              | 10.20762 | 77.19033 | Preethi T.P.             |         | 2007 | Preserved<br>Specimen |
| 64 | India | Kerala     | Kanthallur village                     | 10.22017 | 77.20414 | Manju, Gibi,<br>Shivanna |         | 2008 | Preserved<br>Specimen |
| 65 | India | Tamil Nadu | Kundah, Nilgiris                       | 11.25502 | 76.52252 | Arundhati Das            | 6.8E+07 | 2011 | Preserved<br>Specimen |



|    |       |            |                                    |          |          |                                   |          |      |                    |
|----|-------|------------|------------------------------------|----------|----------|-----------------------------------|----------|------|--------------------|
| 66 | India | Tamil Nadu | Way to Kothagiri, Nilgiri          | 11.41504 | 76.76489 | Geethakumary and A.G. Pandurangan |          | 2012 | Preserved Specimen |
| 67 | India | Kerala     | Maesthrikketu, Idukki              | 10.18455 | 77.08827 | S.M. Shareef                      |          | 2013 | Preserved Specimen |
| 68 | India | Kerala     | Devikulam, Idukki                  | 10.19031 | 77.17727 | Ansil B. R.                       | 850      | 2013 | Preserved Specimen |
| 69 | India | Kerala     | MSNP (Choondal)                    | 10.00509 | 77.23874 | Syam Radh. S & Rajeevan. R        | 51539    | 2014 | Preserved Specimen |
| 70 | India | Kerala     | Munnar, Devikulam, Idukki          | 10.10000 | 77.06667 | ananth                            | 112743   | 2014 | Preserved Specimen |
| 71 | India | Kerala     | Survikal Para (MSNP)               | 9.97971  | 77.24532 | Syam Radh.                        |          | 2015 | Preserved Specimen |
| 72 | India | Kerala     | MSNP (Choondal)                    | 9.98616  | 77.23024 | Syam Radh.                        |          | 2015 | Preserved Specimen |
| 73 | India | Tamil Nadu | Mangaladevi                        | 9.59708  | 77.22189 | Jomy Augustine                    | 26516    | 2018 | Preserved Specimen |
| 74 | India | Kerala     | Munnar, Devikulam, Idukki          | 10.08893 | 77.05953 | Daniel V Raju                     | 113034   | 2018 | Preserved Specimen |
| 75 | India | Kerala     | Kadalar Estate, Devikulam, Idukki  | 10.13401 | 77.05439 | Abhilashk                         | 143591   | 2018 | Preserved Specimen |
| 76 | India | Kerala     | Kadalar Estate, Devikulam, Idukki  | 10.14074 | 77.04726 | Manoj Karingamadathil             | 1764 (K) | 2018 | Preserved Specimen |
| 77 | India | Kerala     | Rajamala Estate, Devikulam, Idukki | 10.14249 | 77.03614 | Aathira Perinchery                | 111 (K)  | 2018 | Preserved Specimen |
| 78 | India | Kerala     | Eravikulam National Park, Idukki   | 10.14340 | 77.04045 | Sriram Ranganathan                | 50528    | 2018 | Preserved Specimen |
| 79 | India | Tamil Nadu | Anna Nagar, Kodaikanal, Dindigul   | 10.22811 | 77.48749 | Viral joshi                       | 3.1E+07  | 2018 | Human Observation  |

|    |       |            |                                             |          |          |                    |             |      |                       |
|----|-------|------------|---------------------------------------------|----------|----------|--------------------|-------------|------|-----------------------|
| 80 | India | Tamil Nadu | Anna Nagar,<br>Kodaikanal,<br>Dindigul      | 10.23000 | 77.49000 | Srinivasan, Ashwin | 5.2E+07     | 2018 | Human<br>Observation  |
| 81 | India | Tamil Nadu | Anna Nagar,<br>Kodaikanal,<br>Dindigul      | 10.23048 | 77.49416 | Viral joshi        | 6.3E+07     | 2018 | Preserved<br>Specimen |
| 82 | India | Tamil Nadu | Anna Nagar,<br>Kodaikanal,<br>Dindigul      | 10.23125 | 77.49451 | Ashwin Srinivasan  | 1523365     | 2018 | Preserved<br>Specimen |
| 83 | India | Kerala     | Marayoor,<br>Devikulam, Idukki              | 10.27617 | 77.16146 | Amar Bharathy      | HIFP_000421 | 2018 | Preserved<br>Specimen |
| 84 | India | Kerala     | Devikulam, Idukki                           | 10.30824 | 77.16799 | Viral joshi        | HIFP_000422 | 2018 | Preserved<br>Specimen |
| 85 | India | Tamil Nadu | Valparai,<br>Coimbatore                     | 10.33265 | 77.04536 | Siddarth Machado   | HIFP_000419 | 2018 | Preserved<br>Specimen |
| 86 | India | Tamil Nadu | Aravenu,<br>Banagudi, Kotagiri,<br>Nilgiris | 11.39724 | 76.86658 | Varundevaraj       | 12568       | 2018 | Preserved<br>Specimen |
| 87 | India | Tamil Nadu | Dodebetta                                   | 11.40011 | 76.73636 | Amitha Bachan KH   | 20228       | 2018 | Preserved<br>Specimen |
| 88 | India | Tamil Nadu | Nilgiris                                    | 11.42177 | 76.86173 | Paulmathi Vinod    | 27811       | 2018 | Preserved<br>Specimen |
| 89 | India | Tamil Nadu | Kalhatty,<br>Udhagamandalam,<br>Nilgiris    | 11.46208 | 76.67525 | Morten Ross        | 36501       | 2018 | Preserved<br>Specimen |
| 90 | India | Tamil Nadu | Kalhatty,<br>Udhagamandalam,<br>Nilgiris    | 11.46241 | 76.68044 | aathiraperinchery  | 72481       | 2018 | Preserved<br>Specimen |
| 91 | India | Tamil Nadu | Kalhatty,<br>Udhagamandalam,<br>Nilgiris    | 11.46257 | 76.67981 | Morten Ross        | 23558       | 2018 | Preserved<br>Specimen |

|     |       |            |                             |          |          |                                  |          |      |                    |
|-----|-------|------------|-----------------------------|----------|----------|----------------------------------|----------|------|--------------------|
| 92  | India | Tamil Nadu | Kotagiri, Nilgiris,         | 11.50966 | 76.93358 | Chetanh joshi                    |          | 2018 | Preserved Specimen |
| 93  | India | Tamil Nadu | Shanthanpara, Idukki        | 9.93925  | 77.24230 | Amitha Bachan and Devika M.A.    | AH25300  | 2022 | Preserved Specimen |
| 94  | India | Tamil Nadu | Shanthanpara, Idukki        | 9.93924  | 77.24230 | Devika M.A. and Amitha Bachan KH | 2600     | 2023 | Preserved Specimen |
| 95  | India | Kerala     | Devikulam, Idukki           | 10.21035 | 77.16557 | Srinivasan Kasinathan            | 28107    | 2023 | Preserved Specimen |
| 96  | India | Kerala     | Eravikulam, Idukki          | 10.22240 | 77.05485 | Devika MA & Amitha Bachan KH     | CU216168 | 2023 | Preserved Specimen |
| 97  | India | Kerala     | Varattukulam, Idukki        | 10.23350 | 77.10299 | Devika MA & Amitha Bachan KH     | CU216170 | 2023 | Preserved Specimen |
| 98  | India | Tamil Nadu | Meesapulimala Peak          | 10.08744 | 77.20448 | Devika MA & Amitha Bachan KH     | 90965    | 2024 | Preserved Specimen |
| 99  | India | Kerala     | Meesapulimala hills         | 10.09156 | 77.18893 | Devika MA & Amitha Bachan KH     | 112442   | 2024 | Preserved Specimen |
| 100 | India | Kerala     | Meesapulimala base          | 10.09348 | 77.17489 | Devika MA & Amitha Bachan KH     | CU216164 | 2024 | Preserved Specimen |
| 101 | India | Kerala     | Eravikulam                  | 10.14690 | 77.03681 | S.D. Biju                        | 5394     |      | Preserved Specimen |
| 102 | India | Tamil Nadu | Palani hills, Lidcot valley | 10.19635 | 77.50754 | Bourne                           | 87 (BM)  |      | Preserved Specimen |
| 103 | India | Tamil Nadu | Udagamandalam (Ootacamund)  | 11.39624 | 76.77757 | Schmid                           | 7.5E+07  |      | Preserved Specimen |
| 104 | India | Tamil Nadu | Nigiris                     | 11.48316 | 76.56621 | Hohenacker                       | 10918    |      | Preserved Specimen |
| 105 | India | Tamil Nadu | Nigiris                     | 11.48315 | 76.56622 | Beddome                          | 16754    |      | Preserved Specimen |
| 106 | India | Tamil Nadu | Gudalur, Nilgiris           | 11.50000 | 76.50000 | Milagros Barcelo                 |          |      | Preserved Specimen |

**21. *Syzygium densiflorum* Wall. ex Wight & Arn., Prodr. Fl. Ind. Orient. 329 (1834).**

| SL No. | Country | State      | Location                                 | Latitude | Longitude | Recorded By                                                  | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|------------------------------------------|----------|-----------|--------------------------------------------------------------|---------------|------|--------------------|
| 1      | India   | Tamil Nadu | Sispara                                  | 11.20309 | 76.45035  | Philip Mathew                                                | 33846         | 1983 | Preserved specimen |
| 2      | India   | Tamil Nadu | Kundah, Nilgiris                         | 11.30000 | 76.58333  | Alwyn H. Gentry, H.S. Suresh, J. Radhakrishnan, R. Prabhakar |               | 1989 | Preserved specimen |
| 3      | India   | Kerala     | Arjunankotta, Periyar Tiger Reserve      | 9.37556  | 77.23084  | Jomy Augustine                                               | 13147         | 1994 | Preserved specimen |
| 4      | India   | Tamil Nadu | Vellimala, Periyar Tiger Reserve         | 9.58159  | 77.33967  | Jomy Augustine                                               | 13752         | 1994 | Preserved specimen |
| 5      | India   | Kerala     | Kathiramudi, Periyar Tiger Reserve       | 9.41507  | 77.25609  | Jomy Augustine                                               | 15264         | 1995 | Preserved specimen |
| 6      | India   | Kerala     | Vellarimala, way to Vavalmala, Kozhikode | 11.49042 | 76.14000  | A.K.Pradeep                                                  | 5491          | 1997 | Preserved specimen |
| 7      | India   | Kerala     | Vavalmala, Kozhikode                     | 11.42889 | 76.12947  | A.K.Pradeep                                                  | 56305         | 1998 | Preserved specimen |
| 8      | India   | Kerala     | Varagalaiar, Anamalais                   | 10.25000 | 76.52000  | N. Ayyappan & N. Parthasarathy                               |               | 1999 | Human Observation  |

|    |       |            |                                                           |          |          |                                  |          |      |                    |
|----|-------|------------|-----------------------------------------------------------|----------|----------|----------------------------------|----------|------|--------------------|
| 9  | India | Tamil Nadu | Anaimalai Loop Road, Old Valparai, Coimbatore             | 10.34728 | 76.93225 | T R Shankar Raman, Divya Mudappa |          | 2000 | Human Observation  |
| 10 | India | Tamil Nadu | Pollachi - Valparai Road, Iyerpaddy, Valparai, Coimbatore | 10.37167 | 76.99185 | T R Shankar Raman, Divya Mudappa |          | 2000 | Human Observation  |
| 11 | India | Tamil Nadu | Pollachi - Valparai Road, Iyerpaddy, Valparai, Coimbatore | 10.39761 | 76.98967 | T R Shankar Raman, Divya Mudappa |          | 2000 | Human Observation  |
| 12 | India | Tamil Nadu | Mukuruthi, New Amarambalam                                | 11.43911 | 76.56029 | R Jayakumar                      | RJ 20476 | 2000 | Preserved specimen |
| 13 | India | Kerala     | Bonaccord                                                 | 8.66396  | 77.18553 | Jabbar                           | 16040    | 2002 | Preserved specimen |
| 14 | India | Tamil Nadu | Sholayar Dam                                              | 10.26515 | 76.89203 | T R Shankar Raman, Divya Mudappa |          | 2002 | Human Observation  |
| 15 | India | Kerala     | Eravikulam, Idukki                                        | 10.21660 | 77.06025 | N.Shylaja                        | 88372    | 2003 | Preserved specimen |
| 16 | India | Kerala     | Eravikulam, Idukki                                        | 10.21670 | 77.06024 | Roshni Balakrishnan              | 89978    | 2003 | Preserved specimen |
| 17 | India | Kerala     | Eravikulam, Idukki                                        | 10.21680 | 77.06025 | P.Nisha Kumari                   | 88874    | 2003 | Preserved specimen |
| 18 | India | Kerala     | Eravikulam, Idukki                                        | 10.21590 | 77.06025 | Ligimol                          | 89877    | 2003 | Preserved specimen |
| 19 | India | Kerala     | Eravikulam, Idukki                                        | 10.21680 | 77.06025 | Reesha Karally                   | 89478    | 2003 | Preserved specimen |

|    |       |               |                                                                     |          |          |                                                                                                  |       |      |                       |
|----|-------|---------------|---------------------------------------------------------------------|----------|----------|--------------------------------------------------------------------------------------------------|-------|------|-----------------------|
| 20 | India | Kerala        | Eravikulam,<br>Idukki                                               | 10.21690 | 77.06025 | A.M.Dhanya                                                                                       | 89670 | 2003 | Preserved<br>specimen |
| 21 | India | Kerala        | Eravikulam,<br>Idukki                                               | 10.22240 | 77.05485 | Tomson Mani                                                                                      | 90873 | 2003 | Preserved<br>specimen |
| 22 | India | Kerala        | Eravikulam,<br>Idukki                                               | 10.22240 | 77.05485 | N.Divya                                                                                          | 90579 | 2003 | Preserved<br>specimen |
| 23 | India | Kerala        | Eravikulam,<br>Idukki                                               | 10.22450 | 77.05344 | A.Shahanaz<br>Beegum                                                                             | 90176 | 2003 | Preserved<br>specimen |
| 24 | India | Kerala        | Eravikulam,<br>Idukki                                               | 10.22911 | 77.05196 | I.K.Nishitha                                                                                     | 90472 | 2003 | Preserved<br>specimen |
| 25 | India | Kerala        | Eravikulam,<br>Idukki                                               | 10.22911 | 77.05196 | K.V.Radhika                                                                                      | 88671 | 2003 | Preserved<br>specimen |
| 26 | India | Kerala        | Kanthalloor,<br>Mannavan<br>Shola, Idukki                           | 10.22912 | 77.05195 | M.B.Reena                                                                                        | 89080 | 2003 | Preserved<br>specimen |
| 27 | India | Tamil<br>Nadu | Valparai,<br>Coimbatore                                             | 10.34789 | 76.89254 | N. Ayyappan, S.<br>Muthuramkumar,<br>N. Parthasarathy,<br>T R Shankar<br>Raman, Divya<br>Mudappa |       | 2003 | Human<br>Observation  |
| 28 | India | Tamil<br>Nadu | Anaimalai Loop<br>Road, Old<br>Valparai,<br>Valparai,<br>Coimbatore | 10.34800 | 76.93172 | N. Ayyappan, S.<br>Muthuramkumar,<br>N. Parthasarathy,<br>T R Shankar<br>Raman, Divya<br>Mudappa |       | 2003 | Human<br>Observation  |
| 29 | India | Tamil<br>Nadu | Valparai,<br>Coimbatore                                             | 10.35803 | 76.89029 | N. Ayyappan, S.<br>Muthuramkumar,<br>N. Parthasarathy,<br>T R Shankar                            |       | 2003 | Human<br>Observation  |

|    |       |               |                                                                       |          |          |                                                                                                  |        |      |                       |
|----|-------|---------------|-----------------------------------------------------------------------|----------|----------|--------------------------------------------------------------------------------------------------|--------|------|-----------------------|
|    |       |               |                                                                       |          |          | Raman, Divya<br>Mudappa                                                                          |        |      |                       |
| 30 | India | Tamil<br>Nadu | Pollachi -<br>Valparai Road,<br>Iyerpaddy,<br>Valparai,<br>Coimbatore | 10.36918 | 76.99411 | N. Ayyappan, S.<br>Muthuramkumar,<br>N. Parthasarathy,<br>T R Shankar<br>Raman, Divya<br>Mudappa |        | 2003 | Human<br>Observation  |
| 31 | India | Kerala        | Shabari hills                                                         | 9.45358  | 77.03292 | N Anilkumar                                                                                      | 1680   | 2005 | Preserved<br>specimen |
| 32 | India | Tamil<br>Nadu | Near Check<br>post, Mukurthy<br>NP                                    | 11.41204 | 76.53556 | M Mohanan &<br>JV Sudhakar                                                                       | 120584 | 2007 | Preserved<br>specimen |
| 33 | India | Tamil<br>Nadu | Naduvattam,<br>Mukurthy NP                                            | 11.45851 | 76.54100 | M Mohanan &<br>JV Sudhakar                                                                       | 122356 | 2008 | Preserved<br>specimen |
| 34 | India | Kerala        | Kundala dam<br>site                                                   | 10.14105 | 77.19933 | S M. Shareef                                                                                     | 69326  | 2010 | Preserved<br>specimen |
| 35 | India | Kerala        | Ponkalappara                                                          | 8.62100  | 77.24500 | S M. Shareef                                                                                     | 70609  | 2011 | Preserved<br>specimen |
| 36 | India | Tamil<br>Nadu | Kundah, Nilgiris                                                      | 11.24340 | 76.51664 | Arundhati Das                                                                                    |        | 2011 | Human<br>Observation  |
| 37 | India | Kerala        | Amar shola,<br>Idukki                                                 | 10.15417 | 77.07862 | S M. Shareef                                                                                     | 76149  | 2014 | Preserved<br>specimen |
| 38 | India | Tamil<br>Nadu | Agasthiyamalai                                                        | 10.20822 | 77.48064 | Manikandan &<br>Ramasubbu                                                                        | 209    | 2015 | Preserved<br>specimen |
| 39 | India | Kerala        | Vattakkanal,<br>Kodaikanal                                            | 8.68381  | 77.19000 | Felix Irudhyaraj<br>& Sasikala.                                                                  | 216    | 2016 | Preserved<br>specimen |
| 40 | India | Tamil<br>Nadu | Megamalai                                                             | 9.69899  | 77.39976 | Mohanraj &<br>Ramasubb                                                                           | 204    | 2016 | Preserved<br>specimen |

|    |       |            |                                                         |          |          |                       |        |      |                    |
|----|-------|------------|---------------------------------------------------------|----------|----------|-----------------------|--------|------|--------------------|
| 41 | India | Kerala     | Mathikettan Shola National Park                         | 9.97812  | 77.24624 | Syam Radh S.          | 149161 | 2016 | Preserved specimen |
| 42 | India | Kerala     | Mathikettan Shola National Park                         | 9.98549  | 77.24627 | Vishnu Mohan          | 151625 | 2017 | Preserved specimen |
| 43 | India | Tamil Nadu | Valparai, Coimbatore                                    | 10.27837 | 76.94423 | Siddarth Machado      |        | 2017 | Human Observation  |
| 44 | India | Tamil Nadu | Valparai, Coimbatore                                    | 10.35927 | 76.88986 | Siddarth Jude Machado |        | 2017 | Human Observation  |
| 45 | India | Kerala     | Eravikulam                                              | 10.22036 | 77.08014 | S M. Shareef          | 76188  | 2018 | Preserved specimen |
| 46 | India | Kerala     | Devikulam, Idukki                                       | 10.04527 | 77.15513 | Thomas Vattakaven     |        | 2019 | Human Observation  |
| 47 | India | Kerala     | Malakkappara, Chalakkudy                                | 10.28687 | 76.85179 | Akshay Surendra       |        | 2019 | Human Observation  |
| 48 | India | Tamil Nadu | Valparai, Coimbatore                                    | 10.29861 | 76.89086 | Akshay Surendra       |        | 2019 | Human Observation  |
| 49 | India | Tamil Nadu | Anaimalai Loop Road, Old Valparai, Coimbatore           | 10.34765 | 76.93045 | Akshay Surendra       |        | 2019 | Human Observation  |
| 50 | India | Tamil Nadu | Anaimalai Loop Road, Old Valparai, Valparai, Coimbatore | 10.34855 | 76.93377 | Akshay Surendra       |        | 2019 | Human Observation  |
| 51 | India | Tamil Nadu | Iyerpaddy, Valparai, Coimbatore                         | 10.35159 | 76.99261 | Akshay Surendra       |        | 2019 | Human Observation  |



|    |       |            |                                                           |          |          |                 |  |      |                   |
|----|-------|------------|-----------------------------------------------------------|----------|----------|-----------------|--|------|-------------------|
| 52 | India | Tamil Nadu | Iyerpaddy, Valparai, Coimbatore                           | 10.35232 | 76.99306 | Akshay Surendra |  | 2019 | Human Observation |
| 53 | India | Tamil Nadu | Iyerpaddy, Valparai, Coimbatore                           | 10.35466 | 76.99411 | Akshay Surendra |  | 2019 | Human Observation |
| 54 | India | Tamil Nadu | Iyerpaddy, Valparai, Coimbatore                           | 10.35532 | 76.99402 | Akshay Surendra |  | 2019 | Human Observation |
| 55 | India | Tamil Nadu | Iyerpaddy, Valparai, Coimbatore                           | 10.36301 | 77.00063 | Akshay Surendra |  | 2019 | Human Observation |
| 56 | India | Tamil Nadu | Iyerpaddy, Valparai, Coimbatore                           | 10.36406 | 76.99845 | Akshay Surendra |  | 2019 | Human Observation |
| 57 | India | Tamil Nadu | Iyerpaddy, Valparai, Coimbatore                           | 10.36486 | 77.00361 | Akshay Surendra |  | 2019 | Human Observation |
| 58 | India | Tamil Nadu | Iyerpaddy, Valparai, Coimbatore                           | 10.36854 | 76.99638 | Akshay Surendra |  | 2019 | Human Observation |
| 59 | India | Tamil Nadu | Pollachi - Valparai Road, Iyerpaddy, Valparai, Coimbatore | 10.37301 | 76.99323 | Akshay Surendra |  | 2019 | Human Observation |
| 60 | India | Tamil Nadu | Pollachi - Valparai Road, Iyerpaddy, Valparai, Coimbatore | 10.39332 | 76.99346 | Akshay Surendra |  | 2019 | Human Observation |

|    |       |               |                                                           |          |          |                                    |          |      |                       |
|----|-------|---------------|-----------------------------------------------------------|----------|----------|------------------------------------|----------|------|-----------------------|
| 61 | India | Kerala        | Devikulam,<br>Idukki                                      | 10.33429 | 77.19692 | Kshama Bhat                        |          | 2020 | Human<br>Observation  |
| 62 | India | Tamil<br>Nadu | Valparai,<br>Coimbatore                                   | 10.34166 | 76.89480 | Srinivasan<br>Kasinathan           |          | 2020 | Human<br>Observation  |
| 63 | India | Tamil<br>Nadu | Valparai,<br>Coimbatore                                   | 10.28381 | 76.99709 | Madhavan A.P.                      |          | 2021 | Human<br>Observation  |
| 64 | India | Kerala        | Kappayam<br>Tribal Colony,<br>Kothamangalam,<br>Ernakulam | 10.24055 | 76.86105 | Madhavan A.P.                      |          | 2022 | Human<br>Observation  |
| 65 | India | Tamil<br>Nadu | Upasi, Valparai,<br>Coimbatore                            | 10.26704 | 76.95451 | Srinivasan<br>Kasinathan           |          | 2022 | Human<br>Observation  |
| 66 | India | Tamil<br>Nadu | Valparai,<br>Coimbatore                                   | 10.34779 | 76.85516 | Madhavan A.P.                      |          | 2022 | Human<br>Observation  |
| 67 | India | Tamil<br>Nadu | Pollachi,<br>Coimbatore                                   | 10.47575 | 76.92753 | Madhavan A.P.                      |          | 2022 | Human<br>Observation  |
| 68 | India | Kerala        | Pampadumshola<br>NP, Idukki                               | 10.13464 | 77.26283 | Devika MA &<br>Amitha Bachan<br>KH | AH25297  | 2023 | Preserved<br>specimen |
| 69 | India | Kerala        | Pettimudi,<br>Idukki                                      | 10.15043 | 77.00834 | Devika MA &<br>Amitha Bachan<br>KH | CU216156 | 2023 | Preserved<br>specimen |
| 70 | India | Kerala        | Anamudi Base<br>camp                                      | 10.16157 | 77.03203 | Devika MA &<br>Amitha Bachan<br>KH | AH25299  | 2023 | Preserved<br>specimen |
| 71 | India | Kerala        | Anamudi peak                                              | 10.16998 | 77.06394 | Devika MA &<br>Amitha Bachan<br>KH | CU216173 | 2023 | Preserved<br>specimen |
| 72 | India | Kerala        | Eravikulam                                                | 10.18499 | 77.08914 | Devika MA &<br>Amitha Bachan<br>KH | CU216162 | 2023 | Preserved<br>specimen |

|    |       |            |                                          |          |          |                              |                      |      |                    |
|----|-------|------------|------------------------------------------|----------|----------|------------------------------|----------------------|------|--------------------|
| 73 | India | Kerala     | Eravikulam Hut                           | 10.22040 | 77.08027 | Devika MA & Amitha Bachan KH | AH25275              | 2023 | Preserved specimen |
| 74 | India | Kerala     | Chinnar, Marayoor                        | 10.25208 | 77.14856 | Madhavan A.P.                |                      | 2023 | Human Observation  |
| 75 | India | Kerala     | Varattukulam                             | 10.25382 | 77.10705 | Devika MA & Amitha Bachan KH | AH25283              | 2023 | Preserved specimen |
| 76 | India | Kerala     | Malakkappara, Chalakkudy, Thrissur       | 10.28295 | 76.85396 | Srinivasan Kasinathan        |                      | 2023 | Human Observation  |
| 77 | India | Tamil Nadu | Valparai, Coimbatore                     | 10.29930 | 76.97167 | Srinivasan Kasinathan        |                      | 2023 | Human Observation  |
| 78 | India | Tamil Nadu | Valparai, Coimbatore                     | 10.31280 | 76.83715 | Jyotsna Nag                  |                      | 2023 | Human Observation  |
| 79 | India | Tamil Nadu | Biligiri Rangaswamy Temple Tiger Reserve | 11.9960  | 77.1410  | J Jayanthi                   | JJ 206543, JJ 207041 | 2023 | Preserved specimen |
| 80 | India | Kerala     | Pongalappara, way to Agasthyamala        | 8.62191  | 77.24825 | Devika MA & Amitha Bachan KH | CU216178             | 2024 | Preserved specimen |
| 81 | India | Kerala     | Meesapulimala                            | 10.09117 | 77.19143 | Devika MA & Amitha Bachan KH | AH25247              | 2024 | Preserved specimen |
| 82 | India | Kerala     | Meesapulimala                            | 10.09217 | 77.18966 | Devika MA & Amitha Bachan KH | CU216149             | 2024 | Preserved specimen |

**22. *Syzygium occidentale* (Bourd.) Gandhi, Fl. Hassan Dist. [Saldanha & Nicolson] 282 (1976).**

| SL No. | Country | State     | Location                           | Latitude | Longitude | Recorded By           | Herbarium No. | Year | Basis of Record    |
|--------|---------|-----------|------------------------------------|----------|-----------|-----------------------|---------------|------|--------------------|
| 1      | India   | Kerala    | Udumanparai, Anamalais             | 11.37659 | 76.05842  | CA Barber             | 4101          | 1901 | Preserved Specimen |
| 2      | India   | Kerala    | Chittaur, near Palode              | 8.71377  | 77.03805  | Bourdillon s.n. (UCT) |               | 1904 | Preserved Specimen |
| 3      | India   | Karnataka | Shiradi                            | 12.82569 | 75.52954  | CJ Saldanah           | 11618, 13677  | 1976 | Preserved Specimen |
| 4      | India   | Kerala    | Malayattur Divison, Kodanadu Range | 10.19387 | 76.53555  | Pascal                | 1405          | 1979 | Preserved Specimen |
| 5      | India   | Kerala    | Malayattur                         | 10.19443 | 76.55836  | Pascal                | 1409          | 1979 | Preserved Specimen |
| 6      | India   | Kerala    | Thenmalai-Punalur, Kallada River   | 9.05613  | 76.87018  | C.E.Ridsdale          | 520           | 1980 | Preserved Specimen |
| 7      | India   | Kerala    | Kallada river side way to Punalur  | 9.07292  | 76.83577  | K Vivekananthan       | 66156         | 1980 | Preserved Specimen |
| 8      | India   | Kerala    | Lower Periyar                      | 9.96898  | 76.94197  | AG Pandurangan        | 76650         | 1983 | Preserved Specimen |
| 9      | India   | Kerala    | Thiruveni bank - Pamba             | 9.40139  | 77.07362  | E Vajravelu           | 80575         | 1984 | Preserved Specimen |
| 10     | India   | Kerala    | Pooyamkutty, submergebale area     | 10.15743 | 76.78552  | KK N. Nair            | 3225          | 1985 | Preserved Specimen |
| 11     | India   | Kerala    | Kunjiar Camp                       | 10.15623 | 76.78515  | KK N. Nair            | 3578          | 1986 | Preserved Specimen |
| 12     | India   | Kerala    | Pamba valley                       | 9.37524  | 76.77366  | Anilkumar N           | 1620          | 1989 | Preserved Specimen |
| 13     | India   | Kerala    | Vazhachal                          | 10.29871 | 76.58547  | N Sasidharan          | 5401          | 1989 | Preserved Specimen |

|    |       |        |                                                                |          |          |                     |              |      |                    |
|----|-------|--------|----------------------------------------------------------------|----------|----------|---------------------|--------------|------|--------------------|
| 14 | India | Kerala | Pooyamkutty                                                    | 10.15779 | 76.78560 | E.S. Santhosh Kumar | 18370 (TBGT) | 1993 | Preserved Specimen |
| 15 | India | Kerala | Peppara                                                        | 8.62988  | 77.12845 | Mohanan and Henry   |              | 1994 | Preserved Specimen |
| 16 | India | Kerala | Pampa-Ponnambalamedu                                           | 9.41661  | 77.06488 | A. Nazarudeen       | 19572 (TBGT) | 1994 | Preserved Specimen |
| 17 | India | Kerala | Damsite, Periyar Tiger Reseve                                  | 9.52908  | 77.12976 | Jomy Augustin       | JA 15115     | 1994 | Preserved Specimen |
| 18 | India | Kerala | Attathodu, Periyar Tiger Reseve                                | 9.40358  | 77.02449 | Jomy Augustin       | 12754        | 1998 | Preserved Specimen |
| 19 | India | Kerala | Vavalala, Periyar Tiger Reseve                                 | 9.40799  | 77.03381 | Jomy Augustin       | JA 14434     | 1998 | Preserved Specimen |
| 20 | India | Kerala | Thenkudippara                                                  | 10.40327 | 76.69691 | Sujanapal           | PS19328      | 2002 | Preserved Specimen |
| 21 | India | Kerala | Ittiyani, Vazhachal                                            | 10.29624 | 76.56894 | Amitha Bachan       |              | 2003 | Preserved Specimen |
| 22 | India | Kerala | Pampavalley                                                    | 9.41980  | 76.93419 | Anilkumar N         | 1665         | 2005 | Preserved Specimen |
| 23 | India | Kerala | Kanamala                                                       | 9.41954  | 76.94085 | Joby & George       | 956          | 2009 | Preserved Specimen |
| 24 | India | Kerala | Pathanamthitta District, Edakadathi                            | 9.42225  | 76.90789 | Joby & Sajith       | 1545         | 2010 | Preserved Specimen |
| 25 | India | Kerala | Athirappilly                                                   | 10.28867 | 76.51430 | Amitha Bachan       | AH25205      | 2010 | Preserved Specimen |
| 26 | India | Kerala | Vazhachal, riparian evergreen forest, banks of Chalakudy river | 10.29877 | 76.58548 | Amitha Bachan       | 72030        | 2010 | Preserved Specimen |
| 27 | India | Kerala | Orukombankutty                                                 | 10.39365 | 76.66985 | Amitha Bachan       |              | 2010 | Preserved Specimen |
| 28 | India | Kerala | Athirapilly                                                    | 10.28454 | 76.56303 | Snehalatha V R      | 9            | 2019 | Preserved Specimen |

|    |       |            |                                   |          |          |                                   |          |      |                    |
|----|-------|------------|-----------------------------------|----------|----------|-----------------------------------|----------|------|--------------------|
| 29 | India | Kerala     | Charpa                            | 10.30266 | 76.57987 | Devika MA & Amitha Bachan KH      | AH25231  | 2022 | Preserved Specimen |
| 30 | India | Tamil Nadu | Chittar river, Thiruvananthapuram | 8.7800   | 76.915   | Anoosh Varghese and A.K. Sreekala | 2017     |      | Preserved Specimen |
| 31 | India | Kerala     | Travancore                        | 9.39466  | 77.08026 | RH Bourdillon                     | 550      |      | Preserved Specimen |
| 32 | India | Kerala     | Pampa                             | 9.41481  | 76.89754 | Devika MA & Amitha Bachan KH      | CU216138 | 2025 | Preserved Specimen |
| 33 | India | Kerala     | Devikulam, Idukki                 | 10.14560 | 76.90110 | S, Aravajy; P.V, Karunakaran      |          | 2005 | Preserved Specimen |
| 34 | India | Kerala     | Athirapilly                       | 10.28329 | 76.55484 | Devika MA & Amitha Bachan KH      | CU216128 | 2022 | Preserved Specimen |
| 35 | India | Kerala     | Vazhachal                         | 10.30086 | 76.58447 | Devika MA & Amitha Bachan KH      | CU216126 | 2022 | Preserved Specimen |

**23. *Syzygium palghatense* Gamble, Bull. Misc. Inform. Kew 1918(7): 240 (1918).**

| SL No. | Country | State      | Location                   | Latitude | Longitude | Recorded By            | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|----------------------------|----------|-----------|------------------------|---------------|------|--------------------|
| 1      | India   | Tamil Nadu | Parambikulam               | 10.49803 | 76.83368  | Sasidharan & Sujanapal | 30527         | 2021 | Preserved Specimen |
| 2      | India   | Kerala     | Pandaravarai, Parambikulam | 10.49900 | 76.83038  | Sujanapal              | 30379, 30527  | 2000 | Preserved Specimen |
| 3      | India   | Tamil Nadu | Palaghat hills             | 10.50000 | 76.83439  | Beddomei               | 254           | 1872 | Preserved Specimen |

|    |       |            |                            |          |          |                              |                  |      |                    |
|----|-------|------------|----------------------------|----------|----------|------------------------------|------------------|------|--------------------|
| 4  | India | Kerala     | Parambikulam               | 10.49562 | 76.82634 | K Yasodhavan                 | 8509, 8510, 8511 | 2005 | Preserved Specimen |
| 5  | India | Tamil Nadu | Prambikulam tiger reserve  | 10.50000 | 76.83431 | Rajanvi Ray & Vishu Mukhri   | HJCB0297         | 2014 | Preserved Specimen |
| 6  | India | Kerala     | Nelliyampathi, Nenmmara FD | 10.53500 | 76.72100 | V.R. Snehalatha & A.R. Rasmi | 7054             | 2014 | Preserved Specimen |
| 7  | India | Kerala     | Nelliyampathi              | 10.53995 | 76.71707 | Snehalatha V R               | 1                | 2018 | Preserved Specimen |
| 8  | India | Kerala     | Way to Minnampara          | 10.53780 | 76.71681 | Devika MA & Amitha Bachan KH | AH25260          | 2024 | Preserved Specimen |
| 9  | India | Kerala     | Way to Minnampara          | 10.53791 | 76.71704 | Devika MA & Amitha Bachan KH | CU216142         | 2024 | Preserved Specimen |
| 10 | India | Kerala     | Way to Minnampara          | 10.53810 | 76.71663 | Devika MA & Amitha Bachan KH | CU216141         | 2024 | Preserved Specimen |
| 11 | India | Kerala     | Way to Minnampara          | 10.53995 | 76.71708 | Devika MA & Amitha Bachan KH | CU216130         | 2024 | Preserved Specimen |

**24. *Syzygium parameswaranii* M.Mohanani & A.N.Henry, J. Bombay Nat. Hist. Soc. 84(2): 409 (1988).**

| SL No. | Country | State      | Location                          | Latitude | Longitude | Recorded By                  | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|-----------------------------------|----------|-----------|------------------------------|---------------|------|--------------------|
| 1      | India   | Tamil Nadu | Western slopes of Agasthyamalai   | 8.61425  | 77.24406  | N. Mohanan                   | 66051         | 1980 | Preserved Specimen |
| 2      | India   | Tamil Nadu | Pongalapara, Thiruvananthapuram   | 8.63311  | 77.23590  | N. Mohanan                   | 9734          | 1988 | Preserved Specimen |
| 3      | India   | Tamil Nadu | Hospital valley, High Wavy Estate | 9.63950  | 77.36116  | K. Ravikumar & V. Lakshmanan | 89029         | 1988 | Preserved Specimen |
| 4      | India   | Tamil Nadu | Agasthyamala top                  | 8.58711  | 77.26537  | N. Mohanan                   | 5148          | 1989 | Preserved Specimen |

|    |       |               |                                                                                                                 |         |          |                  |       |      |                       |
|----|-------|---------------|-----------------------------------------------------------------------------------------------------------------|---------|----------|------------------|-------|------|-----------------------|
| 5  | India | Kerala        | Pongalapara,<br>Thiruvananthapuram                                                                              | 8.62787 | 77.23474 | N. Mohanan       | 5149  | 1989 | Preserved<br>Specimen |
| 6  | India | Tamil<br>Nadu | Pongalapara,<br>Thiruvananthapuram                                                                              | 8.63030 | 77.23956 | N. Mohanan       | 5148  | 1989 | Preserved<br>Specimen |
| 7  | India | Tamil<br>Nadu | Theni District, Upper<br>Manalaru to<br>Vellimalai way                                                          | 9.58159 | 77.33963 | Lakshmanan       | 91066 | 1989 | Preserved<br>Specimen |
| 8  | India | Tamil<br>Nadu | near Brook's peak, on<br>the way to Upper<br>Manalaru to<br>Vattaparai, field No.<br>2", Pachakumatchi<br>hills | 9.58354 | 77.33303 | V.<br>Lakshmanan | 89178 | 1989 | Preserved<br>Specimen |
| 9  | India | Tamil<br>Nadu | Suruli river down,<br>High Wavy's Estate                                                                        | 9.64325 | 77.36098 | V.<br>Lakshmanan | 89194 | 1989 | Preserved<br>Specimen |
| 10 | India | Tamil<br>Nadu | Hospital valley, High<br>Wavy's Estate                                                                          | 9.64353 | 77.36299 | V.<br>Lakshmanan | 93622 | 1990 | Preserved<br>Specimen |
| 11 | India | Tamil<br>Nadu | Kardana Estate river<br>side, Megamalai                                                                         | 9.69002 | 77.39763 | V.<br>Lakshmanan | 95202 | 1990 | Preserved<br>Specimen |
| 12 | India | Tamil<br>Nadu | Pongalapara,<br>Thiruvananthapuram                                                                              | 8.62964 | 77.23611 | N. Mohanan       | 10943 | 1991 | Preserved<br>Specimen |
| 13 | India | Tamil<br>Nadu | Vathalakundu<br>Chettiyar Kaadu,<br>Karnadana Estate,                                                           | 9.68424 | 77.39924 | V.<br>Lakshmanan | 97202 | 1991 | Preserved<br>Specimen |
| 14 | India | Tamil<br>Nadu | Near Brook's peak,<br>Upper Manalar Estate                                                                      | 9.61267 | 77.34132 | V.<br>Lakshmanan | 99516 | 1992 | Preserved<br>Specimen |
| 15 | India | Tamil<br>Nadu | Near Brook's peak,<br>Upper Manalar Estate                                                                      | 9.61517 | 77.34233 | V.<br>Lakshmanan | 99533 | 1992 | Preserved<br>Specimen |
| 16 | India | Kerala        | Agasthyamala south<br>west valley                                                                               | 8.58753 | 77.26068 | S. M. Shareef    | 16737 | 1993 | Preserved<br>Specimen |



|    |       |            |                                                                                   |         |          |                                        |              |      |                    |
|----|-------|------------|-----------------------------------------------------------------------------------|---------|----------|----------------------------------------|--------------|------|--------------------|
| 17 | India | Tamil Nadu | Agasthyamala                                                                      | 8.61759 | 77.24389 | S. William Decruse and A. Gnaga prasad | 15153        | 1993 | Preserved Specimen |
| 18 | India | Tamil Nadu | Agasthyamala                                                                      | 8.61759 | 77.24392 | N. Mohanan                             | 11237        | 1993 | Preserved Specimen |
| 19 | India | Tamil Nadu | Vellimala                                                                         | 9.58158 | 77.33967 | Jomy Augustine                         | JA 12939     | 1993 | Preserved Specimen |
| 20 | India | Tamil Nadu | High Wavys Estate, Madurai(Palni), Madurai, Theni (Division), Uthamapalayam taluk | 9.64681 | 77.35911 | Ramesh and Franceschi                  | HIFP R&D0674 | 1993 | Preserved Specimen |
| 21 | India | Kerala     | Melmala, Periyar Tiger Reserve                                                    | 9.54741 | 77.31473 | Jomy Augustine                         | 14468        | 1994 | Preserved Specimen |
| 22 | India | Tamil Nadu | Kottamala, Periyar                                                                | 9.52077 | 77.40171 | Jomy Augustine & KP Rajesh             | 15205        | 1995 | Preserved Specimen |
| 23 | India | Kerala     | Kottamala, Periyar                                                                | 9.72134 | 76.93128 | Jomy Augustine & KP Rajesh             | 15294        | 1995 | Preserved Specimen |
| 24 | India | Tamil Nadu | On the way to Megamalai, Kardana Estate, river side                               | 9.61188 | 77.34555 | S. Karuppusamy                         | 924          | 2010 | Preserved Specimen |
| 25 | India | Kerala     | Pongalapara, Thiruvananthapuram                                                   | 8.62555 | 77.23863 | S M. Shareef                           | 72425        | 2011 | Preserved Specimen |
| 26 | India | Tamil Nadu | High Way's, way to Manalaru Dam, road side                                        | 9.64323 | 77.35013 | S. Karuppusamy                         | 1058         | 2011 | Preserved Specimen |
| 27 | India | Tamil Nadu | Kardana Estate, above the river                                                   | 9.65766 | 77.36608 | S. Karuppusamy                         | 1921         | 2012 | Preserved Specimen |

|    |       |            |                                                             |         |          |                                        |          |      |                    |
|----|-------|------------|-------------------------------------------------------------|---------|----------|----------------------------------------|----------|------|--------------------|
| 28 | India | Tamil Nadu | Megamalai, Sombal Aruvi above                               | 9.62917 | 77.37857 | S. Karuppusamy & V. Ravichandran       | 2952     | 2013 | Preserved Specimen |
| 29 | India | Tamil Nadu | High Wavy's Estate, Filed No. 3, river side                 | 9.63932 | 77.36030 | S. Karuppusamy & V. Ravichandran       | 3174     | 2013 | Preserved Specimen |
| 30 | India | Tamil Nadu | Kardana Estate, above the river                             | 9.69002 | 77.39763 | S. Karuppusamy & V. Ravichandran       | 2064     | 2013 | Preserved Specimen |
| 31 | India | Tamil Nadu | Megamalai Wildlife Sanctuary, the way Dhannasimottai, Theni | 9.71499 | 77.40356 | Ravichandran, Naved Page, Raja K Swamy | HJCB 788 | 2017 | Preserved Specimen |
| 32 | India | Kerala     | Agasthyamala                                                | 8.62191 | 77.24825 | Devika MA & Amitha Bachan KH           | CU216179 | 2024 | Preserved Specimen |
| 33 | India | Kerala     | Pongalapara, Thiruvananthapuram                             | 8.62384 | 77.24003 | Devika MA & Amitha Bachan KH           | CU216180 | 2024 | Preserved Specimen |

**25. *Syzygium sahyadricum* Sujanapal, Robi & Sasidh., Phytotaxa 174(5): 286 (2014).**

| SL No. | Country | State      | Location   | Latitude | Longitude | Recorded By | Herbarium No. | Year | Basis of Record    |
|--------|---------|------------|------------|----------|-----------|-------------|---------------|------|--------------------|
| 1      | India   | Tamil Nadu | Anamallays | 10.34448 | 77.02352  | Beddome     | K 001004259   |      | Preserved Specimen |

|    |       |            |                                      |          |          |                                |       |      |                    |
|----|-------|------------|--------------------------------------|----------|----------|--------------------------------|-------|------|--------------------|
| 2  | India | Tamil Nadu | Kodaikanal, Kukkal shola             | 10.29335 | 77.36301 | K.M. Matthew & M. Charles      | 49029 | 1850 | Preserved Specimen |
| 3  | India | Tamil Nadu | Dindygul dist.: Kodaikanal           | 10.25444 | 77.45324 | J. Pallithanam                 | 1488  | 1956 | Preserved Specimen |
| 4  | India | Tamil Nadu | Kodaikanal, bombay shola             | 10.23003 | 77.48871 | K.M. Matthew                   | 40003 | 1984 | Preserved Specimen |
| 5  | India | Tamil Nadu | Kodaikanal, bombay shola             | 10.22699 | 77.48616 | K.M. Matthew & N. Rajendran    | 44373 | 1986 | Preserved Specimen |
| 6  | India | Tamil Nadu | Kodaikanal, bombay shola             | 10.22747 | 77.48841 | K.M. Matthew & N. Rajendran    | 44367 | 1986 | Preserved Specimen |
| 7  | India | Tamil Nadu | Kodaikanal, Kukkal shola             | 10.29219 | 77.36036 | K.M. Matthew & N. Rajendran    | 45255 | 1986 | Preserved Specimen |
| 8  | India | Tamil Nadu | Kodaikanal, bombay shola             | 10.22518 | 77.48306 | K.M. Matthew & M. Charles      | 49684 | 1987 | Preserved Specimen |
| 9  | India | Tamil Nadu | Kodaikanal, Poombarai                | 10.25112 | 77.41039 | K.M. Matthew & M. Charles      | 49574 | 1987 | Preserved Specimen |
| 10 | India | Tamil Nadu | Kodaikanal, Poombarai                | 10.25144 | 77.41088 | K.M. Matthew & M. Charles      | 49145 | 1987 | Preserved Specimen |
| 11 | India | Tamil Nadu | Kodaikanal, Pambar Falls             | 10.22129 | 77.48190 | K.M. Matthew                   | 54143 | 1990 | Preserved Specimen |
| 12 | India | Kerala     | Mannavan Shola, Coupe road           | 10.18038 | 77.18780 | K. Kishore Kumar               | 16580 | 1995 | Preserved Specimen |
| 13 | India | Kerala     | Chengalar                            | 10.19399 | 77.19324 | K. Kishore Kumar               | 17671 | 1996 | Preserved Specimen |
| 14 | India | Kerala     | Pothumala, Chinnar WIS, Idukki       | 10.29630 | 77.15256 | K. K. Sajeev                   | 17390 | 1996 | Preserved Specimen |
| 15 | India | Kerala     | Idukki district, Silentvalley-Munnar | 10.10597 | 77.06884 | A.J. Robi & P. Sujanapal 23373 |       | 2013 | Preserved Specimen |
| 16 | India | Kerala     | Munnar, Yellapetty shola             | 10.30696 | 77.15813 | A.J. Robi & K.J. Dantas        | 23365 | 2013 | Preserved Specimen |

|    |       |        |                              |          |          |                                |          |      |                    |
|----|-------|--------|------------------------------|----------|----------|--------------------------------|----------|------|--------------------|
| 17 | India | Kerala | Anamudi                      | 10.16123 | 77.07122 | Amitha Bachan & Devika M.A.    | CU216161 | 2023 | Preserved Specimen |
| 18 | India | Kerala | Anamudi shola National park  | 10.18826 | 77.18116 | Devika M.A. & Amitha Bachan KH | CU216174 | 2023 | Preserved Specimen |
| 19 | India | Kerala | Varattukulam, Idukki, Kerala | 10.22871 | 77.10220 | Devika M.A. & Amitha Bachan KH | CU216137 | 2023 | Preserved Specimen |

## APPENDIX II

### Contribution of Bioclimatic Variables

#### 1. *Aglaia malabarica*

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 53.7                 | 62.3                   |
| BIO19- Prec Coldest Quarter      | 25                   | 1.1                    |
| BIO2- Mean Diurnal Range         | 8.2                  | 20.3                   |
| Slope                            | 6.7                  | 9.9                    |
| BIO18- Prec Warmest Quarter      | 3.4                  | 2.1                    |
| BIO3- Isothermality              | 2.1                  | 0.1                    |
| BIO8- MT Wettest Quarter         | 0.4                  | 4.2                    |
| Elevation                        | 0.2                  | 0                      |
| BIO14- Prec Driest Month         | 0.2                  | 0.1                    |
| Aspect                           | 0.1                  | 0.1                    |
| BIO15- Prec Seasonality          | 0                    | 0                      |
| BIO13- Prec Wettest Month        | 0                    | 0                      |
| BIO10- MT Warmest Quarter        | 0                    | 0                      |
| BIO9- MT Driest Quarter          | 0                    | 0                      |

#### 2. *Aporosa bourdillonii*

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 33.1                 | 83.9                   |
| BIO19- Prec Coldest Quarter      | 19.1                 | 0                      |
| BIO3- Isothermality              | 17.7                 | 0                      |
| Slope                            | 14.1                 | 5.9                    |
| BIO17- Prec Driest Quarter       | 6.7                  | 1.2                    |
| BIO16- Prec Wettest Quarter      | 4.6                  | 0                      |
| BIO2- Mean Diurnal Range         | 4.3                  | 6.1                    |
| BIO15- Prec Seasonality          | 0.1                  | 0                      |
| BIO18- Prec Warmest Quarter      | 0.1                  | 0.1                    |
| Elevation                        | 0.1                  | 2.8                    |
| BIO9- MT Driest Quarter          | 0.1                  | 0                      |
| Aspect                           | 0                    | 0                      |
| BIO8- MT Wettest Quarter         | 0                    | 0                      |
| BIO10- MT Warmest Quarter        | 0                    | 0                      |

### 3. *Cryptocarya anamalayana*

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 77                   | 78.2                   |
| Slope                            | 8.3                  | 19.3                   |
| BIO3- Isothermality              | 6.2                  | 0                      |
| BIO19- Prec Coldest Quarter      | 2.6                  | 0.5                    |
| BIO18- Prec Warmest Quarter      | 2.4                  | 1                      |
| Elevation                        | 2                    | 0                      |
| BIO2- Mean Diurnal Range         | 1.2                  | 0.9                    |
| BIO17- Prec Driest Quarter       | 0.2                  | 0                      |
| BIO8- MT Wettest Quarter         | 0.1                  | 0.2                    |
| Aspect                           | 0                    | 0                      |
| BIO10- MT Warmest Quarter        | 0                    | 0                      |
| BIO9- MT Driest Quarter          | 0                    | 0                      |
| BIO16- Prec Wettest Quarter      | 0                    | 0                      |
| BIO15- Prec Seasonality          | 0                    | 0                      |

### 4. *Cryptocarya lawsonii*

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 65.9                 | 94.1                   |
| Elevation                        | 7.4                  | 0.4                    |
| BIO3- Isothermality              | 7.2                  | 0.3                    |
| Slope                            | 5.3                  | 1.9                    |
| BIO19- Prec Coldest Quarter      | 4.5                  | 1.1                    |
| BIO17- Prec Driest Quarter       | 3.9                  | 1.3                    |
| BIO18- Prec Warmest Quarter      | 1.9                  | 0.3                    |
| BIO15- Prec Seasonality          | 1.7                  | 0.2                    |
| Aspect                           | 1.3                  | 0.1                    |
| BIO16- Prec Wettest Quarter      | 0.6                  | 0.1                    |
| BIO2- Mean Diurnal Range         | 0.1                  | 0.1                    |
| BIO10- MT Warmest Quarter        | 0.1                  | 0.1                    |
| BIO8- MT Wettest Quarter         | 0                    | 0                      |
| BIO9- MT Driest Quarter          | 0                    | 0                      |

**5. *Diospyros crumenata***

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 69.6                 | 66.4                   |
| BIO13- Prec Wettest Month        | 5.5                  | 0                      |
| Slope                            | 5.5                  | 0.9                    |
| BIO3- Isothermality              | 3.7                  | 0                      |
| BIO8- MT Wettest Quarter         | 3.4                  | 11                     |
| BIO2- Mean Diurnal Range         | 3.3                  | 0.4                    |
| BIO19- Prec Coldest Quarter      | 3                    | 0                      |
| Elevation                        | 2.1                  | 20.8                   |
| BIO14- Prec Driest Month         | 1.6                  | 0.1                    |
| BIO18- Prec Warmest Quarter      | 1.1                  | 0                      |
| Aspect                           | 0.7                  | 0.2                    |
| BIO15- Prec Seasonality          | 0.5                  | 0                      |
| BIO9- MT Driest Quarter          | 0                    | 0.1                    |
| BIO10- MT Warmest Quarter        | 0                    | 0                      |

**6. *Dipterocarpus indicus***

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 51                   | 89.6                   |
| BIO19- Prec Coldest Quarter      | 22.5                 | 0.6                    |
| BIO3- Isothermality              | 9.7                  | 1.2                    |
| Slope                            | 7.8                  | 0.9                    |
| Elevation                        | 2.9                  | 1                      |
| BIO16- Prec Wettest Quarter      | 2.4                  | 0.3                    |
| BIO18- Prec Warmest Quarter      | 1.2                  | 0.9                    |
| BIO17- Prec Driest Quarter       | 1                    | 1.3                    |
| BIO2- Mean Diurnal Range         | 0.7                  | 2.3                    |
| Aspect                           | 0.5                  | 0.3                    |
| BIO15- Prec Seasonality          | 0.1                  | 0.3                    |
| BIO8- MT Wettest Quarter         | 0.1                  | 1.2                    |
| BIO10- MT Warmest Quarter        | 0                    | 0                      |
| BIO9- MT Driest Quarter          | 0                    | 0                      |

**7. *Elaeocarpus munroi***

| Variable                         | Percent contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 48.2                 | 97.8                   |
| BIO19- Prec Coldest Quarter      | 20.1                 | 0                      |
| Elevation                        | 17.6                 | 1.7                    |
| BIO3- Isothermality              | 9.6                  | 0                      |
| BIO15- Prec Seasonality          | 2.8                  | 0.1                    |
| Slope                            | 0.5                  | 0                      |
| BIO14- Prec Driest Month         | 0.5                  | 0.2                    |
| BIO18- Prec Warmest Quarter      | 0.3                  | 0                      |
| BIO2- Mean Diurnal Range         | 0.2                  | 0.1                    |
| Aspect                           | 0.1                  | 0                      |
| BIO10- MT Warmest Quarter        | 0                    | 0                      |
| BIO9- MT Driest Quarter          | 0                    | 0                      |
| BIO13- Prec Wettest Month        | 0                    | 0                      |
| BIO8- MT Wettest Quarter         | 0                    | 0                      |

**8. *Elaeocarpus recurvatus***

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 50.8                 | 76.9                   |
| Elevation                        | 23.3                 | 0.5                    |
| BIO19- Prec Coldest Quarter      | 10.8                 | 0                      |
| BIO3- Isothermality              | 7.5                  | 0.2                    |
| BIO14- Prec Driest Month         | 4.7                  | 0.2                    |
| Slope                            | 1.2                  | 10.4                   |
| BIO2- Mean Diurnal Range         | 0.6                  | 0                      |
| BIO15- Prec Seasonality          | 0.4                  | 0                      |
| Aspect                           | 0.3                  | 0                      |
| BIO8- MT Wettest Quarter         | 0.2                  | 11.7                   |
| BIO13- Prec Wettest Month        | 0.1                  | 0                      |
| BIO18- Prec Warmest Quarter      | 0.1                  | 0                      |
| BIO10- MT Warmest Quarter        | 0.1                  | 0                      |
| BIO9- MT Driest Quarter          | 0                    | 0                      |



**9. *Ficus beddomei***

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 44.8                 | 72                     |
| BIO19- Prec Coldest Quarter      | 28.6                 | 3.6                    |
| Elevation                        | 12.5                 | 16.6                   |
| BIO3- Isothermality              | 9.5                  | 1.9                    |
| BIO16- Prec Wettest Quarter      | 1.4                  | 0.4                    |
| BIO17- Prec Driest Quarter       | 0.8                  | 2.2                    |
| BIO15- Prec Seasonality          | 0.5                  | 0.1                    |
| Aspect                           | 0.5                  | 0.4                    |
| Slope                            | 0.5                  | 0.3                    |
| BIO10- MT Warmest Quarter        | 0.3                  | 1.6                    |
| BIO18- Prec Warmest Quarter      | 0.3                  | 0.2                    |
| BIO9- MT Driest Quarter          | 0.2                  | 0.6                    |
| BIO2- Mean Diurnal Range         | 0.1                  | 0.1                    |
| BIO8- MT Wettest Quarter         | 0                    | 0                      |

**10. *Garcinia wightii***

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 38.2                 | 93                     |
| BIO19- Prec Coldest Quarter      | 27.9                 | 0                      |
| Slope                            | 13                   | 0.2                    |
| BIO17- Prec Driest Quarter       | 10.9                 | 3.9                    |
| BIO3- Isothermality              | 3                    | 0.1                    |
| BIO16- Prec Wettest Quarter      | 2.3                  | 0.1                    |
| BIO18- Prec Warmest Quarter      | 2                    | 0.6                    |
| Elevation                        | 1.3                  | 0.8                    |
| BIO2- Mean Diurnal Range         | 0.9                  | 1.4                    |
| BIO15- Prec Seasonality          | 0.4                  | 0                      |
| Aspect                           | 0                    | 0                      |
| BIO8- MT Wettest Quarter         | 0                    | 0                      |
| BIO9- MT Driest Quarter          | 0                    | 0                      |
| BIO10- MT Warmest Quarter        | 0                    | 0                      |

**11. *Goniiothalamus wightii***

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO19- Prec Coldest Quarter      | 37.8                 | 0.4                    |
| BIO14- Prec Driest Month         | 22.4                 | 2                      |
| BIO4- Temperature Seasonality SD | 22.3                 | 92.6                   |
| Elevation                        | 8                    | 2.1                    |
| BIO3- Isothermality              | 6.9                  | 0.1                    |
| Slope                            | 0.6                  | 0.6                    |
| BIO2- Mean Diurnal Range         | 0.6                  | 1.3                    |
| BIO15- Prec Seasonality          | 0.4                  | 0.1                    |
| Aspect                           | 0.4                  | 0.1                    |
| BIO9- MT Driest Quarter          | 0.3                  | 0.2                    |
| BIO18- Prec Warmest Quarter      | 0.2                  | 0.4                    |
| BIO13- Prec Wettest Month        | 0.1                  | 0                      |
| BIO10- MT Warmest Quarter        | 0                    | 0                      |
| BIO8- MT Wettest Quarter         | 0                    | 0                      |

**12. *Humboldtia vahliana***

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 39.3                 | 85.7                   |
| BIO19- Prec Coldest Quarter      | 37                   | 1.5                    |
| BIO17- Prec Driest Quarter       | 7.2                  | 0.7                    |
| BIO3- Isothermality              | 6.7                  | 2.8                    |
| Slope                            | 5.4                  | 2.3                    |
| BIO18- Prec Warmest Quarter      | 1.5                  | 0.1                    |
| Elevation                        | 1.2                  | 0.7                    |
| BIO2- Mean Diurnal Range         | 0.6                  | 4.6                    |
| Aspect                           | 0.3                  | 0.2                    |
| BIO9- MT Driest Quarter          | 0.3                  | 0.5                    |
| BIO15- Prec Seasonality          | 0.2                  | 0.1                    |
| BIO16- Prec Wettest Quarter      | 0.1                  | 0.2                    |
| BIO10- MT Warmest Quarter        | 0.1                  | 0.6                    |
| BIO8- MT Wettest Quarter         | 0                    | 0                      |

**13. *Hydnocarpus pentandrus***

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 68.1                 | 39.8                   |
| BIO19- Prec Coldest Quarter      | 8.8                  | 0.5                    |
| BIO3- Isothermality              | 8.5                  | 37.3                   |
| BIO16- Prec Wettest Quarter      | 4.7                  | 5.4                    |
| Slope                            | 3.6                  | 2.3                    |
| BIO18- Prec Warmest Quarter      | 2.4                  | 1.9                    |
| BIO17- Prec Driest Quarter       | 1.5                  | 3                      |
| Aspect                           | 1.1                  | 0.9                    |
| BIO2- Mean Diurnal Range         | 0.7                  | 7.6                    |
| BIO15- Prec Seasonality          | 0.4                  | 0.3                    |
| Elevation                        | 0.3                  | 0.2                    |
| BIO9- MT Driest Quarter          | 0                    | 0.3                    |
| BIO8- MT Wettest Quarter         | 0                    | 0.5                    |
| BIO10- MT Warmest Quarter        | 0                    | 0.1                    |

**14. *Impatiens parasitica***

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 43.4                 | 97.9                   |
| BIO19- Prec Coldest Quarter      | 26.5                 | 0.1                    |
| Elevation                        | 18                   | 0.4                    |
| BIO14- Prec Driest Month         | 4.3                  | 0.2                    |
| BIO13- Prec Wettest Month        | 3                    | 0                      |
| BIO3- Isothermality              | 1.5                  | 0                      |
| Slope                            | 1.5                  | 1.2                    |
| BIO15- Prec Seasonality          | 1.4                  | 0                      |
| Aspect                           | 0.2                  | 0                      |
| BIO2- Mean Diurnal Range         | 0.1                  | 0                      |
| BIO8- MT Wettest Quarter         | 0                    | 0.1                    |
| BIO9- MT Driest Quarter          | 0                    | 0                      |
| BIO18- Prec Warmest Quarter      | 0                    | 0                      |
| BIO10- MT Warmest Quarter        | 0                    | 0                      |

**15. *Litsea oleoides***

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 49.9                 | 53.7                   |
| BIO19- Prec Coldest Quarter      | 18.6                 | 0.7                    |
| Elevation                        | 11.8                 | 9.4                    |
| BIO3- Isothermality              | 9.6                  | 23.3                   |
| BIO17- Prec Driest Quarter       | 4.2                  | 4.1                    |
| Slope                            | 4                    | 7.6                    |
| BIO16- Prec Wettest Quarter      | 0.7                  | 0.6                    |
| Aspect                           | 0.5                  | 0.2                    |
| BIO18- Prec Warmest Quarter      | 0.3                  | 0.1                    |
| BIO15- Prec Seasonality          | 0.2                  | 0.1                    |
| BIO2- Mean Diurnal Range         | 0.1                  | 0                      |
| BIO10- MT Warmest Quarter        | 0.1                  | 0                      |
| BIO8- MT Wettest Quarter         | 0                    | 0                      |
| BIO9- MT Driest Quarter          | 0                    | 0                      |

**16. *Medinilla anamalaiana***

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 77.6                 | 76.4                   |
| Slope                            | 8.6                  | 15.7                   |
| Elevation                        | 5.2                  | 4.7                    |
| BIO2- Mean Diurnal Range         | 3.9                  | 2                      |
| BIO18- Prec Warmest Quarter      | 3.3                  | 1                      |
| BIO10- MT Warmest Quarter        | 0.8                  | 0                      |
| BIO19- Prec Coldest Quarter      | 0.5                  | 0                      |
| BIO14- Prec Driest Month         | 0.2                  | 0                      |
| Aspect                           | 0                    | 0                      |
| BIO3- Isothermality              | 0                    | 0                      |
| BIO13- Prec Wettest Month        | 0                    | 0                      |
| BIO9- MT Driest Quarter          | 0                    | 0                      |
| BIO15- Prec Seasonality          | 0                    | 0                      |
| BIO8- MT Wettest Quarter         | 0                    | 0                      |

**17. *Meiogyne pannosa***

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 54                   | 91.5                   |
| BIO19- Prec Coldest Quarter      | 19.6                 | 1.8                    |
| Slope                            | 8.1                  | 1.9                    |
| Elevation                        | 7.3                  | 1                      |
| BIO3- Isothermality              | 6.6                  | 0.3                    |
| BIO15- Prec Seasonality          | 1.4                  | 0.3                    |
| BIO16- Prec Wettest Quarter      | 0.9                  | 0.2                    |
| BIO17- Prec Driest Quarter       | 0.8                  | 0.5                    |
| BIO2- Mean Diurnal Range         | 0.7                  | 2.2                    |
| BIO18- Prec Warmest Quarter      | 0.3                  | 0.1                    |
| BIO10- MT Warmest Quarter        | 0.1                  | 0                      |
| Aspect                           | 0.1                  | 0                      |
| BIO9- MT Driest Quarter          | 0                    | 0                      |
| BIO8- MT Wettest Quarter         | 0                    | 0                      |

**18. *Ochna gamblei***

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 79.2                 | 73.8                   |
| BIO18- Prec Warmest Quarter      | 6                    | 8.4                    |
| BIO15- Prec Seasonality          | 3.2                  | 5                      |
| BIO17- Prec Driest Quarter       | 3.1                  | 1.6                    |
| BIO3- Isothermality              | 3                    | 0.5                    |
| BIO9- MT Driest Quarter          | 1.6                  | 1.8                    |
| BIO2- Mean Diurnal Range         | 1.3                  | 5.1                    |
| Elevation                        | 1.1                  | 3.4                    |
| BIO16- Prec Wettest Quarter      | 0.9                  | 0.2                    |
| Slope                            | 0.5                  | 0.2                    |
| BIO19- Prec Coldest Quarter      | 0                    | 0                      |
| BIO8- MT Wettest Quarter         | 0                    | 0                      |
| Aspect                           | 0                    | 0                      |
| BIO10- MT Warmest Quarter        | 0                    | 0                      |

**19. *Prioria pinnata***

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO19- Prec Coldest Quarter      | 51.4                 | 7.4                    |
| BIO4- Temperature Seasonality SD | 26.1                 | 45.9                   |
| BIO3- Isothermality              | 9.6                  | 6.8                    |
| Elevation                        | 6                    | 10.3                   |
| BIO18- Prec Warmest Quarter      | 2.2                  | 0.6                    |
| BIO17- Prec Driest Quarter       | 1.1                  | 3.1                    |
| BIO2- Mean Diurnal Range         | 1                    | 20.2                   |
| Aspect                           | 0.7                  | 0.7                    |
| BIO16- Prec Wettest Quarter      | 0.7                  | 2.2                    |
| Slope                            | 0.6                  | 0.5                    |
| BIO9- MT Driest Quarter          | 0.3                  | 1.8                    |
| BIO15- Prec Seasonality          | 0.2                  | 0.7                    |
| BIO10- MT Warmest Quarter        | 0                    | 0                      |
| BIO8- MT Wettest Quarter         | 0                    | 0                      |

**20. *Strobilanthes kunthiana***

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 49.8                 | 83.9                   |
| Elevation                        | 26.4                 | 13                     |
| BIO19- Prec Coldest Quarter      | 11.4                 | 0.3                    |
| BIO3- Isothermality              | 10.2                 | 0.3                    |
| BIO14- Prec Driest Month         | 0.8                  | 0.1                    |
| BIO15- Prec Seasonality          | 0.4                  | 0                      |
| BIO2- Mean Diurnal Range         | 0.3                  | 0.1                    |
| Aspect                           | 0.3                  | 0.1                    |
| BIO13- Prec Wettest Month        | 0.2                  | 0.1                    |
| Slope                            | 0.1                  | 0                      |
| BIO8- MT Wettest Quarter         | 0.1                  | 0                      |
| BIO18- Prec Warmest Quarter      | 0.1                  | 0.1                    |
| BIO9- MT Driest Quarter          | 0                    | 2                      |
| BIO10- MT Warmest Quarter        | 0                    | 0                      |

## 21. *Syzygium densiflorum*

| Variable                         | Percent Contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO4- Temperature Seasonality SD | 43.2                 | 95.9                   |
| BIO19- Prec Coldest Quarter      | 18.9                 | 0                      |
| Elevation                        | 17.6                 | 2.4                    |
| BIO3- Isothermality              | 9.3                  | 0                      |
| BIO14- Prec Driest Month         | 9.1                  | 0.7                    |
| BIO13- Prec Wettest Month        | 1                    | 0.1                    |
| BIO18- Prec Warmest Quarter      | 0.2                  | 0                      |
| Aspect                           | 0.2                  | 0                      |
| Slope                            | 0.2                  | 0.7                    |
| BIO2- Mean Diurnal Range         | 0.1                  | 0                      |
| BIO10- MT Warmest Quarter        | 0                    | 0                      |
| BIO15- Prec Seasonality          | 0                    | 0                      |
| BIO9- MT Driest Quarter          | 0                    | 0                      |
| BIO8- MT Wettest Quarter         | 0                    | 0                      |

## 22. *Syzygium occidentale*

| Variable                         | Percent contribution | Permutation Importance |
|----------------------------------|----------------------|------------------------|
| BIO19- Prec Coldest Quarter      | 44.8                 | 8.3                    |
| BIO4- Temperature Seasonality SD | 28                   | 61.2                   |
| BIO17- Prec Driest Quarter       | 6.3                  | 8.1                    |
| BIO18- Prec Warmest Quarter      | 4.8                  | 7.9                    |
| Slope                            | 4.5                  | 3.7                    |
| BIO3- Isothermality              | 4.2                  | 1.9                    |
| BIO16- Prec Wettest Quarter      | 3.8                  | 4.4                    |
| Elevation                        | 2.3                  | 3.9                    |
| Aspect                           | 0.8                  | 0.4                    |
| BIO2- Mean Diurnal Range         | 0.4                  | 0.1                    |
| BIO9- MT Driest Quarter          | 0                    | 0                      |
| BIO8- MT Wettest Quarter         | 0                    | 0                      |
| BIO15- Prec Seasonality          | 0                    | 0                      |
| BIO10- MT Warmest Quarter        | 0                    | 0                      |

**23. *Syzygium palghatense***

| <b>Variable</b>                  | <b>Percent Contribution</b> | <b>Permutation Importance</b> |
|----------------------------------|-----------------------------|-------------------------------|
| BIO4- Temperature Seasonality SD | 69                          | 51.5                          |
| Slope                            | 13.4                        | 18.8                          |
| BIO2- Mean Diurnal Range         | 6.7                         | 6.5                           |
| BIO14- Prec Driest Month         | 1.9                         | 0.5                           |
| BIO18- Prec Warmest Quarter      | 1.8                         | 2.2                           |
| BIO19- Prec Coldest Quarter      | 1.6                         | 0.4                           |
| Aspect                           | 1.4                         | 1.2                           |
| Elevation                        | 1.3                         | 0                             |
| BIO10- MT Warmest Quarter        | 1.3                         | 0                             |
| BIO15- Prec Seasonality          | 0.7                         | 0.4                           |
| BIO3- Isothermality              | 0.6                         | 0.8                           |
| BIO8- MT Wettest Quarter         | 0.3                         | 17.8                          |
| BIO13- Prec Wettest Month        | 0                           | 0                             |
| BIO9- MT Driest Quarter          | 0                           | 0                             |

**24. *Syzygium parameswaranii***

| <b>Variable</b>                  | <b>Percent Contribution</b> | <b>Permutation Importance</b> |
|----------------------------------|-----------------------------|-------------------------------|
| BIO4- Temperature Seasonality SD | 37.9                        | 58.9                          |
| BIO14- Prec Driest Month         | 20.9                        | 0.1                           |
| BIO15- Prec Seasonality          | 16.8                        | 17.3                          |
| Slope                            | 10.4                        | 16                            |
| BIO10- MT Warmest Quarter        | 4.2                         | 0                             |
| BIO3- Isothermality              | 3.7                         | 0                             |
| BIO18- Prec Warmest Quarter      | 1.3                         | 0.4                           |
| BIO2- Mean Diurnal Range         | 1.3                         | 5.8                           |
| Elevation                        | 1.2                         | 0.8                           |
| BIO9- MT Driest Quarter          | 1.2                         | 0.3                           |
| Aspect                           | 0.5                         | 0                             |
| BIO8- MT Wettest Quarter         | 0.4                         | 0.4                           |
| BIO19- Prec Coldest Quarter      | 0.1                         | 0                             |
| BIO13- Prec Wettest Month        | 0                           | 0                             |



**25. *Syzygium sahyadricum***

| <b>Variable</b>                  | <b>Percent contribution</b> | <b>Permutation Importance</b> |
|----------------------------------|-----------------------------|-------------------------------|
| BIO4- Temperature Seasonality SD | 55.4                        | 81.5                          |
| BIO15- Prec Seasonality          | 16.2                        | 0.4                           |
| Elevation                        | 14.9                        | 8.8                           |
| Slope                            | 8.4                         | 9                             |
| BIO18- Prec Warmest Quarter      | 3.2                         | 0.1                           |
| BIO14- Prec Driest Month         | 1.9                         | 0.1                           |
| BIO9- MT Driest Quarter          | 0                           | 0                             |
| BIO19- Prec Coldest Quarter      | 0                           | 0                             |
| Aspect                           | 0                           | 0                             |
| BIO3- Isothermality              | 0                           | 0                             |
| BIO8- MT Wettest Quarter         | 0                           | 0                             |
| BIO13- Prec Wettest Month        | 0                           | 0                             |
| BIO10- MT Warmest Quarter        | 0                           | 0                             |
| BIO2- Mean Diurnal Range         | 0                           | 0                             |

**APPENDIX III**  
**Phytosociological Data**

**Cluster 1: Montane Grassland**

| SL. No. | Scientific Name               | RD   | RF  | RBA | IVI  |
|---------|-------------------------------|------|-----|-----|------|
| 1       | <i>Ageratina adenophora</i>   | 0.3  | 0.7 | 0.0 | 1.0  |
| 2       | <i>Anaphalis leptophylla</i>  | 1.8  | 2.1 | 0.0 | 3.9  |
| 3       | <i>Anaphalis meeboldii</i>    | 1.4  | 2.1 | 0.0 | 3.4  |
| 4       | <i>Arundinella fuscata</i>    | 0.4  | 1.4 | 0.0 | 1.8  |
| 5       | <i>Arundinella mesophylla</i> | 0.8  | 0.7 | 0.0 | 1.5  |
| 6       | <i>Arundinella vaginata</i>   | 0.5  | 0.7 | 0.0 | 1.2  |
| 7       | <i>Brchycorythis iantha</i>   | 1.4  | 4.9 | 0.0 | 6.2  |
| 8       | <i>Carex brunnea</i>          | 10.9 | 7.6 | 1.7 | 20.2 |
| 9       | <i>Chrysopogon zeylanicus</i> | 12.6 | 8.3 | 2.2 | 23.1 |
| 10      | <i>Crotalaria fysonii</i>     | 3.0  | 6.9 | 0.0 | 9.9  |
| 11      | <i>Cyanotis papilionacea</i>  | 1.0  | 1.4 | 0.0 | 2.4  |
| 12      | <i>Cymbopogon martini</i>     | 1.3  | 0.7 | 0.0 | 2.0  |
| 13      | <i>Dichanthium polytychum</i> | 4.3  | 2.1 | 0.0 | 6.3  |
| 14      | <i>Digitaria wallichiana</i>  | 1.7  | 2.1 | 0.0 | 3.8  |
| 15      | <i>Erigeron karvinskianus</i> | 1.4  | 1.4 | 0.0 | 2.8  |
| 16      | <i>Eriocaulon collinum</i>    | 0.3  | 1.4 | 0.0 | 1.7  |
| 17      | <i>Eriocaulon robustum</i>    | 1.1  | 2.8 | 0.0 | 3.9  |
| 18      | <i>Eulalia phaeothrix</i>     | 1.5  | 1.4 | 0.0 | 2.9  |

|    |                                 |       |       |       |       |
|----|---------------------------------|-------|-------|-------|-------|
| 19 | <i>Exacum anamallayanum</i>     | 0.7   | 2.1   | 0.0   | 2.8   |
| 20 | <i>Fibristylis dichotoma</i>    | 1.0   | 0.7   | 0.0   | 1.7   |
| 21 | <i>Helichrysum buddlejoides</i> | 5.5   | 4.2   | 0.0   | 9.6   |
| 22 | <i>Hypericum mysorense</i>      | 2.4   | 2.1   | 0.0   | 4.5   |
| 23 | <i>Ischaemum nilagiricum</i>    | 2.4   | 1.4   | 0.0   | 3.8   |
| 24 | <i>Kyllingia brevifolia</i>     | 0.3   | 0.7   | 0.0   | 1.0   |
| 25 | <i>Leucas angularis</i>         | 0.3   | 0.7   | 0.0   | 1.0   |
| 26 | <i>Leucas sp</i>                | 2.5   | 2.1   | 0.0   | 4.6   |
| 27 | <i>Osbeckia leschenaultiana</i> | 0.6   | 2.8   | 0.0   | 3.4   |
| 28 | <i>Osbeckia reticulata</i>      | 0.9   | 2.8   | 0.0   | 3.7   |
| 29 | <i>Polygala japonica</i>        | 0.9   | 2.8   | 0.0   | 3.7   |
| 30 | <i>Pteridium aquilinum</i>      | 5.2   | 4.2   | 0.0   | 9.4   |
| 31 | <i>Pycneus pumilus</i>          | 2.5   | 3.5   | 0.0   | 5.9   |
| 32 | <i>Satyrium nepalens</i>        | 0.9   | 2.1   | 0.0   | 3.0   |
| 33 | <i>Sehima nervosum</i>          | 2.7   | 4.2   | 0.0   | 6.9   |
| 34 | <i>Smithia blanda</i>           | 0.2   | 0.7   | 0.0   | 0.9   |
| 35 | <i>Strobilanthes kunthiana</i>  | 20.1  | 8.3   | 96.1  | 124.6 |
| 36 | <i>Swertia corymbosa</i>        | 3.0   | 2.8   | 0.0   | 5.8   |
| 37 | <i>Tripogon bromoides</i>       | 1.9   | 2.1   | 0.0   | 4.0   |
| 38 | <i>Wahlenbergia hookeri</i>     | 0.3   | 1.4   | 0.0   | 1.6   |
|    | Total                           | 100.0 | 100.0 | 100.0 | 300.0 |

## Cluster 2: Montane Shola Forest

| SL. No. | Scientific Name                    | Height Class | RD  | RF  | RBA  | IVI  |
|---------|------------------------------------|--------------|-----|-----|------|------|
| 1       | <i>Acronychia pedunculata</i>      | MT           | 0.6 | 1.4 | 0.0  | 2.1  |
| 2       | <i>Actinodaphnae bedommei</i>      | MT           | 1.3 | 2.9 | 0.1  | 4.2  |
| 3       | <i>Actinodaphne bourdillonii</i>   | MT           | 0.8 | 1.4 | 0.2  | 2.5  |
| 4       | <i>Alseodaphne semecarpifolia</i>  | MT           | 0.8 | 1.9 | 0.0  | 2.8  |
| 5       | <i>Beilschmiedia wightii</i>       | MT           | 1.9 | 3.3 | 0.9  | 6.1  |
| 6       | <i>Chionanthus mala-elengi</i>     | MT           | 2.1 | 3.3 | 0.2  | 5.7  |
| 7       | <i>Cinnamomum macrocarpum</i>      | ET           | 1.9 | 1.4 | 1.0  | 4.3  |
| 8       | <i>Cinnamomum sulphuratum</i>      | MT           | 0.2 | 0.5 | 0.0  | 0.7  |
| 9       | <i>Cinnamomum wightii</i>          | MT           | 0.4 | 1.0 | 0.1  | 1.4  |
| 10      | <i>Cryptocarya beddomei</i>        | ET           | 0.8 | 1.9 | 0.1  | 2.8  |
| 11      | <i>Daphniphyllum neilgherrense</i> | MT           | 2.1 | 3.3 | 0.3  | 5.7  |
| 12      | <i>Elaeagnus kologa</i>            | ST           | 1.7 | 1.9 | 0.2  | 3.8  |
| 13      | <i>Elaeocarpus munori</i>          | MT           | 1.9 | 2.4 | 0.5  | 4.8  |
| 14      | <i>Elaeocarpus recurvatus</i>      | ET           | 8.9 | 6.2 | 11.7 | 26.8 |
| 15      | <i>Elaeocarpus variabilis</i>      | MT           | 0.6 | 1.4 | 0.1  | 2.1  |
| 16      | <i>Eugenia calcadensis</i>         | MT           | 1.3 | 1.4 | 0.0  | 2.7  |
| 17      | <i>Glochidion nilgriensis</i>      | MT           | 9.3 | 4.8 | 5.8  | 19.9 |
| 18      | <i>Isonandra perrottetiana</i>     | MT           | 0.4 | 1.0 | 0.0  | 1.4  |
| 19      | <i>Ixora notoniana</i>             | MT           | 0.4 | 1.0 | 0.0  | 1.4  |
| 20      | <i>Litsea wightiana</i>            | MT           | 5.3 | 6.2 | 4.5  | 16.0 |
| 21      | <i>Macaranga indica</i>            | ET           | 0.2 | 0.5 | 0.0  | 0.7  |

|    |                                  |      |       |       |       |      |
|----|----------------------------------|------|-------|-------|-------|------|
| 22 | <i>Mastixia arborea</i>          | LT   | 0.8   | 1.9   | 0.1   | 2.8  |
| 23 | <i>Microtropis ramiflora</i>     | MT   | 0.8   | 1.0   | 0.1   | 1.9  |
| 24 | <i>Myrsine wightiana</i>         | MT   | 0.8   | 1.9   | 0.1   | 2.8  |
| 25 | <i>Neolitsea cassia</i>          | MT   | 0.8   | 1.9   | 0.0   | 2.8  |
| 26 | <i>Neolitsea fischeri</i>        | MT   | 5.3   | 1.4   | 4.7   | 11.4 |
| 27 | <i>Neolitsea scrobiculata</i>    | MT   | 0.4   | 1.0   | 0.1   | 1.4  |
| 28 | <i>Ochlandra sp</i>              | ST   | 1.3   | 1.4   | 0.0   | 2.7  |
| 29 | <i>Persea macrantha</i>          | ET   | 1.9   | 1.4   | 0.7   | 4.0  |
| 30 | <i>Phoebe wightii</i>            | ET   | 1.1   | 1.4   | 0.1   | 2.5  |
| 31 | <i>Photinia integrifolia</i>     | MT   | 0.8   | 1.9   | 0.0   | 2.8  |
| 32 | <i>Rhododendron arboreum</i>     | MT   | 6.5   | 5.7   | 6.4   | 18.7 |
| 33 | <i>Rhodomyrtus tomentosa</i>     | ST   | 1.7   | 1.9   | 0.1   | 3.7  |
| 34 | <i>Strobilanthes homotropa</i>   | ST   | 0.6   | 1.4   | 0.0   | 2.1  |
| 35 | <i>Symplocos cochinchinensis</i> | MT   | 0.2   | 0.5   | 0.0   | 0.7  |
| 36 | <i>Symplocos pendula</i>         | MT   | 0.4   | 1.0   | 0.0   | 1.4  |
| 37 | <i>Syzygium densiflorum</i>      | MT   | 11.6  | 7.7   | 31.9  | 51.1 |
| 38 | <i>Syzygium hemisphericum</i>    | MT   | 1.1   | 1.4   | 0.4   | 2.8  |
| 39 | <i>Syzygium sahyadricum</i>      | MT   | 9.3   | 3.8   | 21.4  | 34.5 |
| 40 | <i>Ternstroemia japonica</i>     | MT   | 2.5   | 1.9   | 0.8   | 5.3  |
| 41 | <i>Turpinia cochinchinensis</i>  | MT   | 6.8   | 5.3   | 7.3   | 19.3 |
| 42 | <i>Vaccinium leschenaultii</i>   | ST   | 1.5   | 3.3   | 0.2   | 5.0  |
| 43 | <i>Viburnum coriaceum</i>        | ST   | 0.6   | 1.4   | 0.0   | 2.1  |
|    | Total                            | 29.6 | 100.0 | 100.0 | 300.0 | 29.6 |

## Cluster 3: Sub-montane Shola Forest (Southern Guild)

| SL. No. | Scientific Name               | Height Class | RD    | RF   | RBA  | IVI   |
|---------|-------------------------------|--------------|-------|------|------|-------|
| 1       | <i>Cinnamomum wightii</i>     | MT           | 5.41  | 7.69 | 5.32 | 18.42 |
| 2       | <i>Elaeocarpus munroi</i>     | LT           | 1.80  | 3.85 | 0.48 | 6.13  |
| 3       | <i>Eugenia bracteata</i>      | MT           | 0.90  | 1.92 | 0.05 | 2.87  |
| 4       | <i>Eurya nitida</i>           | ST           | 0.90  | 1.92 | 0.16 | 2.99  |
| 5       | <i>Fagraea ceilanica</i>      | MT           | 6.31  | 5.77 | 1.54 | 13.61 |
| 6       | <i>Garcinia ethinocarpa</i>   | ST           | 0.90  | 1.92 | 0.16 | 2.99  |
| 7       | <i>Garcinia gummi-gutta</i>   | MT           | 0.90  | 1.92 | 0.30 | 3.12  |
| 8       | <i>Garcinia travancorica</i>  | MT           | 0.90  | 1.92 | 0.12 | 2.94  |
| 9       | <i>Glochidion nilgriensis</i> | MT           | 2.70  | 5.77 | 1.38 | 9.85  |
| 10      | <i>Glycosmis angustifolia</i> | VST          | 0.90  | 1.92 | 0.09 | 2.92  |
| 11      | <i>Glycosmis macrocarpa</i>   | VST          | 0.90  | 1.92 | 0.09 | 2.92  |
| 12      | <i>Leptonychia caudata</i>    | ST           | 1.80  | 1.92 | 0.28 | 4.00  |
| 13      | <i>Ligustrum robustum</i>     | ST           | 6.31  | 7.69 | 3.62 | 17.62 |
| 14      | <i>Litsea ligustrina</i>      | MT           | 3.60  | 3.85 | 1.47 | 8.92  |
| 15      | <i>Litsea wightiana</i>       | MT           | 5.41  | 5.77 | 2.70 | 13.87 |
| 16      | <i>Memecylon talboltianum</i> | MT           | 6.31  | 5.77 | 3.62 | 15.70 |
| 17      | <i>Monoon coffeoides</i>      | MT           | 0.90  | 1.92 | 0.11 | 2.93  |
| 18      | <i>Ochlandra sp</i>           | VST          | 12.61 | 1.92 | 0.28 | 14.82 |
| 19      | <i>Orophea erythrocarpa</i>   | ST           | 1.80  | 1.92 | 0.27 | 3.99  |
| 20      | <i>Pavatta sp</i>             | ST           | 1.80  | 1.92 | 0.09 | 3.82  |
| 21      | <i>Sterculia villosa</i>      | MT           | 2.70  | 3.85 | 1.12 | 7.67  |
| 22      | <i>Symplocos racemosa</i>     | MT           | 4.50  | 5.77 | 2.63 | 12.90 |

|    |                                 |    |        |        |        |        |
|----|---------------------------------|----|--------|--------|--------|--------|
| 23 | <i>Syzygium munronii</i>        | MT | 0.90   | 1.92   | 0.20   | 3.02   |
| 24 | <i>Syzygium parameswaranii</i>  | MT | 18.02  | 7.69   | 50.71  | 76.42  |
| 25 | <i>Syzygium sasidharanii</i>    | MT | 3.60   | 3.85   | 0.91   | 8.35   |
| 26 | <i>Vernonia travancorica</i>    | MT | 6.31   | 5.77   | 22.15  | 34.23  |
| 27 | <i>Xanthophyllum flavescens</i> | MT | 0.90   | 1.92   | 0.16   | 2.99   |
|    | Total                           |    | 100.00 | 100.00 | 100.00 | 300.00 |

**Cluster 4: Sub-montane Shola Forest (Northern Guild)**

| SL. No. | Scientific Name                | Height Class | RD  | RF  | RBA  | IVI  |
|---------|--------------------------------|--------------|-----|-----|------|------|
| 1       | <i>Aphanamixis polystachya</i> | MT           | 2.0 | 3.1 | 0.6  | 5.7  |
| 2       | <i>Beilschmiedia wightii</i>   | MT           | 5.9 | 3.1 | 7.0  | 16.0 |
| 3       | <i>Bridelia retusa</i>         | MT           | 2.0 | 3.1 | 1.8  | 6.9  |
| 4       | <i>Capparis moonii</i>         | VST          | 2.0 | 3.1 | 0.1  | 5.2  |
| 5       | <i>Cassine albens</i>          | LT           | 2.0 | 3.1 | 0.2  | 5.3  |
| 6       | <i>Cinnamomum sulphuratum</i>  | MT           | 7.8 | 6.2 | 10.1 | 24.2 |
| 8       | <i>Cinnamomum wightii</i>      | MT           | 2.0 | 3.1 | 0.7  | 5.8  |
| 13      | <i>Clausena indica</i>         | ST           | 2.0 | 3.1 | 2.1  | 7.2  |
| 14      | <i>Cordia monoica</i>          | ST           | 2.0 | 3.1 | 0.5  | 5.5  |
| 15      | <i>Derris brevipes</i>         | LI           | 2.0 | 3.1 | 0.3  | 5.3  |

|    |                                  |     |       |       |       |       |
|----|----------------------------------|-----|-------|-------|-------|-------|
| 18 | <i>Epiprinus mallotiformis</i>   | ST  | 2.0   | 3.1   | 0.5   | 5.6   |
| 20 | <i>Euginea indica</i>            | MT  | 9.8   | 6.2   | 9.1   | 25.1  |
| 26 | <i>Ficus talbotii</i>            | ET  | 2.0   | 3.1   | 3.3   | 8.4   |
| 30 | <i>Glochidion heyneanum</i>      | MT  | 2.0   | 3.1   | 0.9   | 6.0   |
| 36 | <i>Heritiera papilio</i>         | ET  | 9.8   | 3.1   | 14.0  | 26.9  |
| 38 | <i>Ligustrum perrottetii</i>     | ST  | 3.9   | 3.1   | 1.0   | 8.0   |
| 45 | <i>Litsea stocksii</i>           | MT  | 3.9   | 3.1   | 1.0   | 8.0   |
| 46 | <i>Litsea wightiana</i>          | MT  | 5.9   | 3.1   | 4.8   | 13.8  |
| 50 | <i>Maesa indica</i>              | VST | 2.0   | 3.1   | 0.3   | 5.3   |
| 51 | <i>Mallotus tetracoccus</i>      | ST  | 3.9   | 6.2   | 7.9   | 18.1  |
| 56 | <i>Neolitsea scrobiculata</i>    | MT  | 2.0   | 3.1   | 1.1   | 6.2   |
| 60 | <i>Phoebe lanceolata</i>         | MT  | 2.0   | 3.1   | 0.5   | 5.5   |
| 61 | <i>Phoebe wightii</i>            | MT  | 3.9   | 3.1   | 3.5   | 10.6  |
| 66 | <i>Symplocos cochinchinensis</i> | MT  | 3.9   | 6.2   | 1.6   | 11.8  |
| 72 | <i>Syzygium palghatense</i>      | MT  | 11.8  | 9.4   | 27.0  | 48.2  |
| 86 | <i>Xantolis tomentosa</i>        | MT  | 2.0   | 3.1   | 0.3   | 5.4   |
|    | Total                            |     | 100.0 | 100.0 | 100.0 | 300.0 |



## Cluster 5: Medium Elevation Sub Montane Wet Evergreen Forest

| SL. No. | Scientific Name                  | Height Class | RD   | RF   | RBA  | IVI  |
|---------|----------------------------------|--------------|------|------|------|------|
| 1       | <i>Actinodaphne malabarica</i>   | LT           | 0.76 | 0.78 | 0.09 | 1.63 |
| 2       | <i>Aglaia barberi</i>            | LT           | 0.76 | 1.56 | 0.02 | 2.33 |
| 3       | <i>Aglaia beddomei</i>           | MT           | 0.57 | 0.39 | 0.07 | 1.03 |
| 4       | <i>Aglaia binectifer</i>         | MT           | 0.57 | 1.17 | 0.03 | 1.76 |
| 5       | <i>Aglaia perviridis</i>         | MT           | 1.14 | 1.17 | 0.39 | 2.70 |
| 6       | <i>Ailanthus triphysa</i>        | LT           | 0.57 | 1.17 | 0.04 | 1.78 |
| 7       | <i>Antidesma montanum</i>        | ST           | 0.57 | 1.17 | 0.09 | 1.82 |
| 8       | <i>Artocarpus hirsutus</i>       | LT           | 1.14 | 2.33 | 0.34 | 3.81 |
| 9       | <i>Bischofia javanica</i>        | MT           | 0.19 | 0.39 | 0.01 | 0.59 |
| 10      | <i>Bridelia retusa</i>           | MT           | 0.57 | 1.17 | 0.15 | 1.89 |
| 11      | <i>Calophyllum austroindicum</i> | LT           | 0.57 | 1.17 | 0.42 | 2.16 |
| 12      | <i>Canarium strictum</i>         | ET           | 0.19 | 0.39 | 0.00 | 0.58 |
| 13      | <i>Capparis moonii</i>           | VST          | 0.76 | 1.56 | 0.01 | 2.33 |
| 14      | <i>Capparis zeylanica</i>        | VST          | 0.38 | 0.39 | 0.00 | 0.77 |
| 15      | <i>Caryota urens</i>             | LT           | 0.38 | 0.39 | 0.00 | 0.77 |
| 16      | <i>Casearia thwaitesii</i>       | MT           | 0.57 | 1.17 | 0.01 | 1.75 |
| 17      | <i>Cinnamomum malabattrum</i>    | MT           | 2.08 | 1.95 | 0.75 | 4.78 |
| 18      | <i>Cinnamomum sulphuratum</i>    | LT           | 0.57 | 1.17 | 0.09 | 1.83 |
| 19      | <i>Cinnamomum wightii</i>        | LT           | 1.70 | 1.17 | 0.19 | 3.06 |
| 20      | <i>Clausena anisata</i>          | ST           | 1.70 | 1.17 | 0.08 | 2.95 |
| 21      | <i>Cryptocarya lawsonii</i>      | MT           | 1.89 | 3.11 | 0.27 | 5.28 |
| 22      | <i>Dalbergia latifolia</i>       | LT           | 0.38 | 0.39 | 0.01 | 0.78 |

|    |                                |    |       |      |       |       |
|----|--------------------------------|----|-------|------|-------|-------|
| 23 | <i>Dillenia bracteata</i>      | MT | 0.57  | 1.17 | 0.24  | 1.97  |
| 24 | <i>Dillenia indica</i>         | LT | 0.57  | 1.17 | 0.47  | 2.21  |
| 25 | <i>Dimocarpus longan</i>       | LT | 3.98  | 1.17 | 1.81  | 6.95  |
| 26 | <i>Diopsypyros paniculata</i>  | MT | 0.19  | 0.39 | 0.00  | 0.58  |
| 27 | <i>Diospyros montana</i>       | MT | 0.57  | 1.17 | 0.21  | 1.95  |
| 28 | <i>Elaeocarpus munroi</i>      | LT | 1.89  | 2.72 | 1.22  | 5.84  |
| 29 | <i>Elaeocarpus variabilis</i>  | MT | 1.14  | 2.33 | 0.32  | 3.79  |
| 30 | <i>Erythrina variegata</i>     | ST | 0.19  | 0.39 | 0.03  | 0.60  |
| 31 | <i>Eugenia indica</i>          | ST | 0.57  | 1.17 | 0.06  | 1.79  |
| 32 | <i>Eugenia thwaitesii</i>      | ST | 0.19  | 0.39 | 0.00  | 0.58  |
| 33 | <i>Ficus beddomei</i>          | ET | 1.33  | 1.56 | 4.07  | 6.95  |
| 34 | <i>Ficus exasperata</i>        | MT | 0.57  | 1.17 | 0.04  | 1.78  |
| 35 | <i>Ficus nervosa</i>           | LT | 0.38  | 0.78 | 0.04  | 1.19  |
| 36 | <i>Ficus virens</i>            | ET | 0.38  | 0.78 | 0.13  | 1.28  |
| 37 | <i>Glochidion candolleanum</i> | MT | 1.14  | 1.17 | 0.60  | 2.90  |
| 38 | <i>Glochidion ellipticum</i>   | MT | 0.19  | 0.39 | 0.01  | 0.59  |
| 39 | <i>Grewia abutilifolia</i>     | ST | 0.19  | 0.39 | 0.00  | 0.58  |
| 40 | <i>Heritiera papilio</i>       | ET | 12.88 | 3.89 | 63.12 | 79.89 |
| 41 | <i>Holigarna arnottiana</i>    | LT | 1.14  | 1.17 | 0.62  | 2.92  |
| 42 | <i>Holigarna grahamii</i>      | ET | 1.70  | 1.17 | 1.07  | 3.94  |
| 43 | <i>Hydnocarpus macrocarpa</i>  | LT | 1.14  | 1.17 | 0.13  | 2.43  |
| 44 | <i>Hydnocarpus pentandarus</i> | MT | 0.19  | 0.39 | 0.01  | 0.59  |
| 45 | <i>Clausena indica</i>         | ST | 0.76  | 0.39 | 0.02  | 1.17  |
| 46 | <i>Lepianthes umbellata</i>    | MT | 0.19  | 0.39 | 0.01  | 0.59  |
| 47 | <i>Lepisanthes tetraphylla</i> | MT | 0.57  | 0.39 | 0.03  | 0.99  |

|    |                                  |    |      |      |      |       |
|----|----------------------------------|----|------|------|------|-------|
| 48 | <i>Litsea deccanensis</i>        | MT | 0.95 | 1.56 | 0.04 | 2.55  |
| 49 | <i>Litsea floribunda</i>         | MT | 3.60 | 1.56 | 0.93 | 6.09  |
| 50 | <i>Litsea oleoides</i>           | LT | 3.98 | 3.11 | 5.62 | 12.71 |
| 51 | <i>Litsea quinqueflora</i>       | MT | 2.46 | 1.56 | 0.25 | 4.27  |
| 52 | <i>Litsea stocksii</i>           | MT | 4.92 | 3.50 | 2.16 | 10.58 |
| 53 | <i>Litsea venulosa</i>           | MT | 2.84 | 1.17 | 1.33 | 5.34  |
| 54 | <i>Macaranga peltata</i>         | ET | 1.14 | 2.33 | 0.14 | 3.62  |
| 55 | <i>Mallotus philippensis</i>     | MT | 0.19 | 0.39 | 0.01 | 0.59  |
| 56 | <i>Meliosma simplicifolia</i>    | ST | 1.14 | 1.17 | 0.16 | 2.46  |
| 57 | <i>Memecylon deccanense</i>      | ST | 0.57 | 1.17 | 0.08 | 1.81  |
| 58 | <i>Memecylon talbotianum</i>     | ST | 0.57 | 1.17 | 0.01 | 1.75  |
| 59 | <i>Mesua ferrea</i>              | LT | 0.57 | 1.17 | 0.08 | 1.82  |
| 60 | <i>Miliusa nilagirica</i>        | MT | 0.57 | 1.17 | 0.02 | 1.76  |
| 61 | <i>Mussaenda frondosa</i>        | ST | 1.14 | 0.39 | 0.16 | 1.69  |
| 62 | <i>Myristica beddomei</i>        | LT | 0.95 | 1.95 | 0.10 | 3.00  |
| 63 | <i>Nothapodytes nimmoniana</i>   | MT | 0.38 | 0.39 | 0.03 | 0.79  |
| 64 | <i>Persea macrantha</i>          | LT | 3.79 | 3.50 | 1.75 | 9.04  |
| 65 | <i>Phoebe lanceolata</i>         | MT | 2.84 | 2.33 | 0.95 | 6.13  |
| 66 | <i>Monoon cerasoides</i>         | MT | 0.57 | 1.17 | 0.04 | 1.78  |
| 67 | <i>Monoon fragrans</i>           | LT | 0.57 | 0.39 | 0.02 | 0.98  |
| 68 | <i>Schleichera oleosa</i>        | MT | 2.46 | 1.56 | 0.83 | 4.84  |
| 69 | <i>Symplocos cochinchinensis</i> | ST | 0.57 | 1.17 | 0.01 | 1.75  |
| 70 | <i>Symplocos paniculata</i>      | ST | 2.08 | 1.95 | 0.21 | 4.24  |
| 71 | <i>Syzygium densiflorum</i>      | MT | 1.14 | 1.17 | 0.33 | 2.63  |
| 72 | <i>Syzygium gardneri</i>         | ET | 3.60 | 3.11 | 5.20 | 11.91 |

|    |                                     |     |        |        |        |        |
|----|-------------------------------------|-----|--------|--------|--------|--------|
| 73 | <i>Syzygium hemisphericum</i>       | MT  | 2.27   | 2.33   | 0.96   | 5.57   |
| 74 | <i>Syzygium laetum</i>              | ST  | 0.38   | 0.78   | 0.08   | 1.24   |
| 75 | <i>Syzygium lanceolatum</i>         | MT  | 2.27   | 2.33   | 1.13   | 5.73   |
| 76 | <i>Syzygium salicifolium</i>        | MT  | 0.57   | 1.17   | 0.04   | 1.78   |
| 77 | <i>Tabernaemontana alternifolia</i> | VST | 0.19   | 0.39   | 0.00   | 0.58   |
| 78 | <i>Xanthophyllum flavescens</i>     | ST  | 0.19   | 0.39   | 0.00   | 0.58   |
|    | Total                               |     | 100.00 | 100.00 | 100.00 | 300.00 |

**Cluster 6: Medium Elevation Wet Evergreen Forest**

| SL. No. | Scientific Name                   | Height Class | RD  | RF  | RBA | IVI |
|---------|-----------------------------------|--------------|-----|-----|-----|-----|
| 1       | <i>Actinodaphne bourdillonii</i>  | LT           | 0.6 | 0.4 | 0.1 | 1.1 |
| 2       | <i>Actinodaphne malabarica</i>    | LT           | 0.6 | 0.8 | 0.1 | 1.5 |
| 3       | <i>Actinodaphne wightiana</i>     | LT           | 0.3 | 0.4 | 0.0 | 0.7 |
| 4       | <i>Aglaia barberi</i>             | LT           | 1.3 | 0.8 | 0.3 | 2.4 |
| 5       | <i>Aglaia lawii</i>               | MT           | 1.4 | 1.5 | 0.3 | 3.1 |
| 6       | <i>Aglaia malabarica</i>          | MT           | 0.7 | 1.3 | 0.2 | 2.2 |
| 7       | <i>Agrostistachys borneensis</i>  | MT           | 0.8 | 0.8 | 0.1 | 1.6 |
| 8       | <i>Ailanthus excelsa</i>          | LT           | 0.1 | 0.2 | 0.0 | 0.3 |
| 9       | <i>Alseodaphne semecarpifolia</i> | LT           | 1.1 | 1.1 | 0.5 | 2.6 |
| 10      | <i>Alstonia scholaris</i>         | ET           | 0.2 | 0.6 | 0.0 | 0.8 |
| 11      | <i>Antidesma montanum</i>         | MT           | 1.7 | 1.5 | 0.4 | 3.6 |
| 12      | <i>Aporosa acuminata</i>          | ST           | 2.2 | 1.5 | 0.3 | 4.0 |
| 13      | <i>Aporosa cardiosperma</i>       | ST           | 0.1 | 0.2 | 0.0 | 0.3 |
| 14      | <i>Baccaurea courtallensis</i>    | ST           | 0.8 | 0.6 | 0.1 | 1.5 |

|    |                                    |     |     |     |      |      |
|----|------------------------------------|-----|-----|-----|------|------|
| 15 | <i>Bischofia javanica</i>          | MT  | 0.1 | 0.2 | 0.0  | 0.3  |
| 16 | <i>Buchanania lanzan</i>           | MT  | 0.2 | 0.4 | 0.0  | 0.5  |
| 17 | <i>Calophyllum polyanthum</i>      | ET  | 1.5 | 1.7 | 1.4  | 4.6  |
| 18 | <i>Canarium strictum</i>           | ET  | 0.2 | 0.4 | 0.0  | 0.6  |
| 19 | <i>Capparis moonii</i>             | VST | 0.5 | 0.4 | 0.0  | 0.8  |
| 20 | <i>Capparis rheedei</i>            | VST | 0.1 | 0.2 | 0.0  | 0.3  |
| 21 | <i>Chilocarpus denudatus</i>       | MT  | 0.2 | 0.4 | 0.0  | 0.5  |
| 22 | <i>Chrysophyllum roxburghii</i>    | MT  | 0.1 | 0.2 | 0.0  | 0.3  |
| 23 | <i>Chukrasia tabularis</i>         | LT  | 0.1 | 0.2 | 0.0  | 0.3  |
| 24 | <i>Cinnamomum malabattrum</i>      | MT  | 0.5 | 0.6 | 0.1  | 1.1  |
| 25 | <i>Cinnamomum sulphuratum</i>      | MT  | 0.2 | 0.4 | 0.1  | 0.6  |
| 26 | <i>Cinnamomum verum</i>            | MT  | 0.2 | 0.4 | 0.0  | 0.5  |
| 27 | <i>Cinnanom sp</i>                 | LT  | 0.2 | 0.4 | 0.1  | 0.6  |
| 28 | <i>Cryptocarya anamalayana</i>     | LT  | 0.8 | 0.6 | 0.1  | 1.5  |
| 29 | <i>Cryptocarya lawsonii</i>        | LT  | 2.7 | 1.5 | 1.1  | 5.3  |
| 30 | <i>Cryptocarya sheikelmudiyana</i> | LT  | 0.4 | 0.6 | 0.1  | 1.1  |
| 31 | <i>Cullenia exarillata</i>         | ET  | 6.8 | 3.8 | 39.6 | 50.1 |
| 32 | <i>Cyathocalyx zeylanica</i>       | MT  | 0.2 | 0.2 | 0.0  | 0.4  |
| 33 | <i>Cydraxdium sp</i>               | MT  | 0.2 | 0.4 | 0.0  | 0.5  |
| 34 | <i>Dendrocide sinuata</i>          | ST  | 0.4 | 0.2 | 0.0  | 0.6  |
| 35 | <i>Dimocarpus longan</i>           | LT  | 0.5 | 0.4 | 0.1  | 0.9  |
| 36 | <i>Diospyros candolleana</i>       | LT  | 0.1 | 0.2 | 0.0  | 0.3  |
| 37 | <i>Diospyros montana</i>           | MT  | 0.8 | 1.9 | 0.2  | 2.8  |
| 38 | <i>Diospyros paniculata</i>        | MT  | 0.8 | 0.2 | 0.1  | 1.1  |

|    |                                 |     |     |     |     |     |
|----|---------------------------------|-----|-----|-----|-----|-----|
| 39 | <i>Diospyros sylvatica</i>      | LT  | 0.5 | 0.6 | 0.1 | 1.1 |
| 40 | <i>Dipterocarpus indicus</i>    | ET  | 0.9 | 0.4 | 1.9 | 3.2 |
| 41 | <i>Drypetes confertiflora</i>   | LT  | 2.0 | 1.3 | 0.8 | 4.1 |
| 42 | <i>Drypetes malabarica</i>      | MT  | 0.2 | 0.2 | 0.0 | 0.3 |
| 43 | <i>Drypetes oblongifolia</i>    | MT  | 0.4 | 0.4 | 0.1 | 0.8 |
| 44 | <i>Drypetes venusta</i>         | MT  | 1.4 | 1.3 | 0.4 | 3.0 |
| 45 | <i>Dysoxylum malabaricum</i>    | LT  | 0.5 | 0.8 | 0.3 | 1.5 |
| 46 | <i>Elaeocarpus tuberculatus</i> | ET  | 1.3 | 2.1 | 1.5 | 4.9 |
| 47 | <i>Elaeocarpus glandulosus</i>  | LT  | 0.2 | 0.4 | 0.0 | 0.5 |
| 48 | <i>Elaeocarpus munroi</i>       | LT  | 0.2 | 0.4 | 0.0 | 0.5 |
| 49 | <i>Ficus beddomei</i>           | ET  | 0.3 | 0.8 | 1.4 | 2.4 |
| 50 | <i>Ficus bengalensis</i>        | LT  | 0.1 | 0.2 | 0.2 | 0.4 |
| 51 | <i>Ficus mysorensis</i>         | MT  | 0.2 | 0.4 | 0.2 | 0.7 |
| 52 | <i>Flacourtia jangomas</i>      | ST  | 0.1 | 0.2 | 0.0 | 0.3 |
| 53 | <i>Flacourtia montana</i>       | LT  | 0.2 | 0.4 | 0.0 | 0.5 |
| 54 | <i>Garcinia cowa</i>            | LT  | 0.6 | 0.8 | 0.0 | 1.4 |
| 55 | <i>Garcinia gummi-gutta</i>     | VST | 0.2 | 0.4 | 0.0 | 0.5 |
| 56 | <i>Gentum edule</i>             | MT  | 0.1 | 0.2 | 0.0 | 0.3 |
| 57 | <i>Glochidion ellipticum</i>    | MT  | 0.5 | 0.8 | 0.0 | 1.2 |
| 58 | <i>Glochidion zeylanicum</i>    | LT  | 1.0 | 0.8 | 0.4 | 2.1 |
| 59 | <i>Gmelina arborea</i>          | MT  | 0.1 | 0.2 | 0.0 | 0.3 |
| 60 | <i>Gnetum edule</i>             | LI  | 0.1 | 0.2 | 0.0 | 0.3 |
| 61 | <i>Goniothalamus wightii</i>    | ET  | 1.1 | 0.8 | 0.1 | 2.0 |
| 62 | <i>Gymnacranthera canarica</i>  | LT  | 1.2 | 0.8 | 0.2 | 2.1 |

|    |                                |    |     |     |     |      |
|----|--------------------------------|----|-----|-----|-----|------|
| 63 | <i>Heritiera papilio</i>       | ET | 0.1 | 0.2 | 0.0 | 0.3  |
| 64 | <i>Heynea trijuga</i>          | LT | 0.5 | 1.3 | 0.1 | 1.9  |
| 65 | <i>Holigarna arnottiana</i>    | LT | 0.8 | 1.5 | 0.1 | 2.4  |
| 66 | <i>Holigarna ferruginea</i>    | ET | 0.1 | 0.2 | 0.0 | 0.3  |
| 67 | <i>Holigarna grahamii</i>      | ET | 0.7 | 1.7 | 0.1 | 2.4  |
| 68 | <i>Holigarna sp</i>            | LT | 0.2 | 0.4 | 0.0 | 0.5  |
| 69 | <i>Hopea parviflora</i>        | ET | 0.2 | 0.8 | 0.3 | 1.3  |
| 70 | <i>Hopea ponga</i>             | LT | 0.1 | 0.2 | 0.0 | 0.3  |
| 71 | <i>Hopea racophloea</i>        | LT | 0.1 | 0.2 | 0.0 | 0.3  |
| 72 | <i>Hydnocarpus macrocarpa</i>  | LT | 0.2 | 0.4 | 0.0 | 0.5  |
| 73 | <i>Hydnocarpus pentandarus</i> | MT | 0.2 | 0.4 | 0.0 | 0.5  |
| 74 | <i>Ixora brachiata</i>         | MT | 0.1 | 0.2 | 0.0 | 0.3  |
| 75 | <i>Knema attenuata</i>         | MT | 0.8 | 1.3 | 0.3 | 2.4  |
| 76 | <i>Lepisanthes tetraphylla</i> | MT | 0.9 | 0.8 | 0.3 | 2.0  |
| 77 | <i>Litsea beddomei</i>         | MT | 0.8 | 0.9 | 0.1 | 1.8  |
| 78 | <i>Litsea bourdillonii</i>     | MT | 0.7 | 0.4 | 0.1 | 1.1  |
| 79 | <i>Litsea floribunda</i>       | MT | 4.9 | 2.4 | 4.1 | 11.4 |
| 80 | <i>Litsea ligustrina</i>       | MT | 0.9 | 0.9 | 0.2 | 2.0  |
| 81 | <i>Litsea oleoides</i>         | LT | 1.2 | 0.9 | 1.4 | 3.6  |
| 82 | <i>Litsea stocksii</i>         | MT | 0.6 | 0.8 | 0.0 | 1.4  |
| 83 | <i>Litsea wightiana</i>        | ST | 0.5 | 0.4 | 0.0 | 0.9  |
| 84 | <i>Lophopetalum wightianum</i> | ET | 0.1 | 0.2 | 0.0 | 0.3  |
| 85 | <i>Macaranga indica</i>        | LT | 0.1 | 0.2 | 0.0 | 0.3  |
| 86 | <i>Macaranga peltata</i>       | ET | 1.5 | 2.8 | 0.8 | 5.1  |

|     |                                        |    |     |     |      |      |
|-----|----------------------------------------|----|-----|-----|------|------|
| 87  | <i>Mallotus philippensis</i>           | MT | 0.2 | 0.4 | 0.0  | 0.5  |
| 88  | <i>Mastixia arborea</i>                | MT | 0.1 | 0.2 | 0.0  | 0.3  |
| 89  | <i>Meiogyne pannosa</i>                | ST | 0.3 | 0.8 | 0.0  | 1.1  |
| 90  | <i>Melicope lunu-ankenda</i>           | ET | 2.0 | 1.9 | 0.9  | 4.8  |
| 91  | <i>Mesua ferrea</i>                    | LT | 1.5 | 1.9 | 1.2  | 4.6  |
| 92  | <i>Mesua thwaitesii</i>                | MT | 0.2 | 0.2 | 0.0  | 0.3  |
| 93  | <i>Monoon coffeoides</i>               | MT | 0.1 | 0.2 | 0.0  | 0.3  |
| 94  | <i>Monoon fragrans</i>                 | LT | 1.1 | 0.8 | 0.3  | 2.1  |
| 95  | <i>Myristica beddoemi</i>              | LT | 2.0 | 2.4 | 1.6  | 6.1  |
| 96  | <i>Myristica malabarica</i>            | MT | 0.3 | 0.8 | 0.0  | 1.1  |
| 97  | <i>Narangavalli</i>                    | LI | 0.2 | 0.4 | 0.0  | 0.5  |
| 98  | <i>Neolitsea fischeri</i>              | LT | 2.4 | 0.8 | 1.1  | 4.3  |
| 99  | <i>Neolitsea scrobiculata</i>          | LT | 0.2 | 0.4 | 0.0  | 0.5  |
| 100 | <i>Neolitsea sp</i>                    | MT | 0.2 | 0.6 | 0.0  | 0.8  |
| 101 | <i>Olea dioeca</i>                     | ST | 0.1 | 0.2 | 0.0  | 0.3  |
| 102 | <i>Oreocnide integrifolia</i>          | ST | 5.2 | 1.3 | 3.1  | 9.7  |
| 103 | <i>Ormosia travancorica</i>            | LT | 0.1 | 0.2 | 0.0  | 0.3  |
| 104 | <i>Otonephelium stipulaceum</i>        | MT | 1.6 | 1.9 | 0.6  | 4.0  |
| 105 | <i>Palaquium ellipticum</i>            | LT | 4.7 | 2.4 | 13.5 | 20.6 |
| 106 | <i>Paracroton pendulus</i>             | LT | 0.2 | 0.2 | 0.0  | 0.4  |
| 107 | <i>Persea macrantha</i>                | LT | 4.7 | 1.3 | 9.2  | 15.1 |
| 108 | <i>Phoebe lanceolata</i>               | ST | 0.4 | 0.6 | 0.0  | 1.0  |
| 109 | <i>Poeciloneuron indicum</i>           | LT | 0.1 | 0.2 | 0.0  | 0.3  |
| 110 | <i>Reinwardtiodendron anamalaiense</i> | MT | 2.6 | 3.4 | 1.2  | 7.2  |



|     |                                 |    |       |       |       |       |
|-----|---------------------------------|----|-------|-------|-------|-------|
| 111 | <i>Schleichera oleosa</i>       | MT | 2.4   | 2.4   | 2.8   | 7.7   |
| 112 | <i>Semecarpus travancorica</i>  | MT | 0.5   | 0.4   | 0.1   | 0.9   |
| 113 | <i>Spondias pinnata</i>         | MT | 0.2   | 0.6   | 0.0   | 0.8   |
| 114 | <i>Sterculia guttata</i>        | MT | 0.1   | 0.2   | 0.0   | 0.3   |
| 115 | <i>Strobocalyx arborea</i>      | MT | 0.2   | 0.4   | 0.0   | 0.5   |
| 116 | <i>Symplocos oligandra</i>      | ST | 0.2   | 0.6   | 0.0   | 0.8   |
| 117 | <i>Syzygium cumini</i>          | MT | 0.3   | 0.6   | 0.1   | 0.9   |
| 118 | <i>Syzygium gardneri</i>        | LT | 0.3   | 0.8   | 0.2   | 1.2   |
| 119 | <i>Syzygium hemisphericum</i>   | MT | 0.5   | 0.8   | 0.0   | 1.2   |
| 120 | <i>Syzygium laetum</i>          | MT | 2.8   | 2.6   | 1.1   | 6.5   |
| 121 | <i>Syzygium mundagam</i>        | ST | 0.9   | 1.3   | 0.1   | 2.3   |
| 122 | <i>Syzygium rubicundum</i>      | MT | 0.2   | 0.6   | 0.0   | 0.8   |
| 123 | <i>Syzygium zeylanicum</i>      | LT | 0.5   | 0.6   | 0.0   | 1.1   |
| 124 | <i>Terminalia bellirica</i>     | ET | 0.2   | 0.2   | 0.0   | 0.4   |
| 125 | <i>Terminalia chebula</i>       | MT | 0.1   | 0.2   | 0.0   | 0.3   |
| 126 | <i>Tetrapilus dioicus</i>       | LT | 0.2   | 0.4   | 0.0   | 0.5   |
| 127 | <i>Trichilia connaroides</i>    | LT | 0.2   | 0.4   | 0.0   | 0.5   |
| 128 | <i>Turpinia malabarica</i>      | MT | 0.8   | 1.1   | 0.5   | 2.4   |
| 129 | <i>Vateria indica</i>           | LT | 1.1   | 0.9   | 1.1   | 3.1   |
| 130 | <i>Vepris bilocularis</i>       | LT | 0.4   | 0.2   | 0.2   | 0.7   |
| 131 | <i>Vernonia arborea</i>         | LT | 0.2   | 0.4   | 0.0   | 0.5   |
| 132 | <i>Vitex altissima</i>          | MT | 0.1   | 0.2   | 0.0   | 0.3   |
| 133 | <i>Xanthophyllum flavescens</i> | ST | 0.5   | 0.6   | 0.0   | 1.1   |
|     | Total                           |    | 100.0 | 100.0 | 100.2 | 300.2 |

## Cluster 7: Low Elevation Evergreen Forest

| SL. No. | Scientific Name                | Height Class | RD   | RF   | RBA   | IVI   |
|---------|--------------------------------|--------------|------|------|-------|-------|
| 1       | <i>Actinodaphne malabarica</i> | MT           | 0.99 | 1.47 | 0.16  | 2.63  |
| 2       | <i>Aglaia lawii</i>            | MT           | 1.09 | 1.47 | 0.21  | 2.77  |
| 3       | <i>Ailanthus triphysa</i>      | ET           | 0.50 | 0.92 | 0.05  | 1.46  |
| 4       | <i>Albizia chinensis</i>       | ET           | 0.30 | 0.37 | 0.05  | 0.71  |
| 5       | <i>Alstonia scholaris</i>      | ET           | 1.19 | 1.66 | 1.69  | 4.53  |
| 6       | <i>Aporosa bourdillonii</i>    | ST           | 0.40 | 0.74 | 0.01  | 1.14  |
| 7       | <i>Aporosa cardiosperma</i>    | ST           | 1.69 | 2.21 | 0.27  | 4.16  |
| 8       | <i>Aporosa lindleyana</i>      | ST           | 0.20 | 0.18 | 0.01  | 0.39  |
| 9       | <i>Archidendron bigeminum</i>  | MT           | 0.40 | 0.74 | 0.01  | 1.14  |
| 10      | <i>Artabotrys zeylanicus</i>   | LI           | 0.50 | 0.92 | 0.01  | 1.42  |
| 11      | <i>Artocarpus hirsutus</i>     | LT           | 0.30 | 0.55 | 0.03  | 0.88  |
| 12      | <i>Atuna travancorica</i>      | MT           | 4.66 | 1.66 | 2.73  | 9.05  |
| 13      | <i>Baccaurea courtallensis</i> | ST           | 2.78 | 2.58 | 0.46  | 5.82  |
| 14      | <i>Bignonia scholaris</i>      | MT           | 0.10 | 0.18 | 0.00  | 0.28  |
| 15      | <i>Bischofia javanica</i>      | MT           | 0.40 | 0.37 | 0.05  | 0.82  |
| 16      | <i>Callicarpa tomentosa</i>    | VST          | 0.10 | 0.18 | 0.00  | 0.28  |
| 17      | <i>Calophyllum polyanthum</i>  | ET           | 0.79 | 1.47 | 0.79  | 3.05  |
| 18      | <i>Capparis rheedei</i>        | VST          | 0.40 | 0.55 | 0.01  | 0.96  |
| 19      | <i>Capparis sp</i>             | VST          | 0.79 | 0.74 | 0.05  | 1.58  |
| 20      | <i>Carallia brachiata</i>      | MT           | 0.50 | 0.92 | 0.01  | 1.43  |
| 21      | <i>Chukrasia tabularis</i>     | LT           | 2.98 | 1.84 | 10.50 | 15.32 |
| 22      | <i>Cinnamomum malabattrum</i>  | MT           | 0.10 | 0.18 | 0.00  | 0.28  |
| 23      | <i>Clausena anisata</i>        | VST          | 0.30 | 0.55 | 0.00  | 0.85  |

|    |                                 |       |      |      |      |       |
|----|---------------------------------|-------|------|------|------|-------|
| 24 | <i>Cyathocalyx zeylanica</i>    | MT    | 1.88 | 2.21 | 0.40 | 4.50  |
| 25 | <i>Derris brevipes</i>          | Liana | 0.40 | 0.74 | 0.01 | 1.14  |
| 26 | <i>Diospyros candolleana</i>    | LT    | 0.20 | 0.37 | 0.01 | 0.57  |
| 27 | <i>Diospyros crumenata</i>      | LT    | 2.38 | 2.39 | 7.53 | 12.30 |
| 28 | <i>Diospyros montana</i>        | LT    | 1.49 | 0.55 | 0.39 | 2.43  |
| 29 | <i>Diospyros sylvatica</i>      | MT    | 0.69 | 0.92 | 0.03 | 1.64  |
| 30 | <i>Dipterocarpus indicus</i>    | ET    | 0.69 | 0.92 | 0.24 | 1.86  |
| 31 | <i>Drypetes venusta</i>         | LT    | 1.79 | 0.55 | 0.85 | 3.19  |
| 32 | <i>Dysoxylum malabaricum</i>    | LT    | 0.30 | 0.55 | 0.06 | 0.91  |
| 33 | <i>Elaeocarpus serratus</i>     | MT    | 0.40 | 0.74 | 0.03 | 1.16  |
| 34 | <i>Elaeocarpus tuberculatus</i> | ET    | 0.30 | 0.55 | 0.03 | 0.88  |
| 35 | <i>Entada rheedei</i>           | LI    | 0.79 | 0.74 | 0.02 | 1.55  |
| 36 | <i>Ficus beddomei</i>           | ET    | 0.40 | 0.74 | 0.56 | 1.70  |
| 37 | <i>Ficus callosa</i>            | LT    | 0.10 | 0.18 | 0.00 | 0.29  |
| 38 | <i>Ficus glomerata</i>          | ST    | 0.20 | 0.37 | 0.00 | 0.57  |
| 39 | <i>Ficus microcarpa</i>         | MT    | 0.30 | 0.55 | 0.07 | 0.92  |
| 40 | <i>Ficus nervosa</i>            | LT    | 0.40 | 0.74 | 0.06 | 1.19  |
| 41 | <i>Ficus rigida</i>             | LT    | 0.10 | 0.18 | 0.00 | 0.28  |
| 42 | <i>Flacourtia montana</i>       | ST    | 0.20 | 0.37 | 0.01 | 0.57  |
| 43 | <i>Garcinia gummi-gutta</i>     | MT    | 0.10 | 0.18 | 0.00 | 0.28  |
| 44 | <i>Garcinia wightii</i>         | ST    | 1.19 | 1.66 | 0.15 | 3.00  |
| 45 | <i>Glochidion zeylanicum</i>    | MT    | 0.40 | 0.74 | 0.01 | 1.15  |
| 46 | <i>Gmelina arborea</i>          | MT    | 0.69 | 1.29 | 0.28 | 2.27  |
| 47 | <i>Gnetum edule</i>             | LI    | 0.99 | 0.92 | 0.09 | 2.00  |
| 48 | <i>Haldina cordifolia</i>       | MT    | 0.79 | 0.74 | 0.18 | 1.71  |
| 49 | <i>Harpullia arborea</i>        | MT    | 0.30 | 0.55 | 0.00 | 0.85  |

|    |                                 |     |      |      |      |       |
|----|---------------------------------|-----|------|------|------|-------|
| 50 | <i>Holigarna arnottiana</i>     | MT  | 0.79 | 0.74 | 0.69 | 2.22  |
| 51 | <i>Holigarna ferruginea</i>     | ET  | 0.10 | 0.18 | 0.00 | 0.28  |
| 52 | <i>Hopea parviflora</i>         | ET  | 1.19 | 1.47 | 0.96 | 3.62  |
| 53 | <i>Hopea ponga</i>              | ET  | 0.20 | 0.37 | 0.01 | 0.58  |
| 54 | <i>Humboldtia brunonis</i>      | MT  | 0.20 | 0.37 | 0.01 | 0.58  |
| 55 | <i>Humboldtia vahliana</i>      | MT  | 1.98 | 1.66 | 6.38 | 10.02 |
| 56 | <i>Hydnocarpus alpinus</i>      | MT  | 2.48 | 1.66 | 2.78 | 6.91  |
| 57 | <i>Hydnocarpus pentandrus</i>   | MT  | 3.47 | 2.76 | 2.81 | 9.05  |
| 58 | <i>Ixora brachiata</i>          | ST  | 0.50 | 0.92 | 0.02 | 1.44  |
| 59 | <i>Lagerstroemia microcarpa</i> | LT  | 3.27 | 0.92 | 7.94 | 12.14 |
| 60 | <i>Leea indica</i>              | VST | 0.20 | 0.37 | 0.00 | 0.57  |
| 61 | <i>Litsea stocksii</i>          | MT  | 0.50 | 0.92 | 0.05 | 1.46  |
| 62 | <i>Lophopetalum wightianum</i>  | ET  | 1.19 | 1.66 | 2.45 | 5.30  |
| 63 | <i>Macaranga peltata</i>        | ET  | 2.78 | 2.76 | 2.87 | 8.41  |
| 64 | <i>Mallotus atrovirens</i>      | ST  | 0.40 | 0.37 | 0.02 | 0.78  |
| 65 | <i>Mallotus aureo-punctatus</i> | ST  | 1.69 | 0.92 | 0.23 | 2.83  |
| 66 | <i>Mallotus pihppensis</i>      | MT  | 1.29 | 1.84 | 0.17 | 3.30  |
| 67 | <i>Mallotus resinusus</i>       | MT  | 0.10 | 0.18 | 0.00 | 0.29  |
| 68 | <i>Mangifera indica</i>         | LT  | 0.20 | 0.37 | 0.01 | 0.57  |
| 69 | <i>Melicope lunu-ankenda</i>    | ET  | 0.10 | 0.18 | 0.01 | 0.29  |
| 70 | <i>Memecylon terminale</i>      | ST  | 0.20 | 0.37 | 0.00 | 0.57  |
| 71 | <i>Mesua ferrea</i>             | ET  | 0.30 | 0.55 | 0.01 | 0.86  |
| 72 | <i>Mitragyna parvifolia</i>     | LT  | 0.30 | 0.55 | 0.01 | 0.86  |
| 73 | <i>Monoon fragrans</i>          | MT  | 1.39 | 1.84 | 1.21 | 4.44  |
| 74 | <i>Myristica beddomei</i>       | LT  | 2.28 | 3.50 | 1.00 | 6.78  |
| 75 | <i>Neolamarckia cadamba</i>     | LT  | 0.10 | 0.18 | 0.00 | 0.28  |

|     |                                        |     |      |      |       |       |
|-----|----------------------------------------|-----|------|------|-------|-------|
| 76  | <i>Neolitsea foleosa</i>               | MT  | 0.20 | 0.37 | 0.00  | 0.57  |
| 77  | <i>Nothopegia racemosa</i>             | MT  | 0.20 | 0.37 | 0.01  | 0.57  |
| 78  | <i>Ochlandra scriptoria</i>            | ST  | 1.59 | 1.29 | 12.47 | 15.35 |
| 79  | <i>Ochlandra travancortca</i>          | ST  | 0.20 | 0.37 | 0.00  | 0.57  |
| 80  | <i>Olea dioica</i>                     | MT  | 0.79 | 0.74 | 0.08  | 1.61  |
| 81  | <i>Orophea erythrocarpa</i>            | ST  | 0.40 | 0.18 | 0.01  | 0.59  |
| 82  | <i>Otonephelium stipulaceum</i>        | MT  | 2.38 | 0.92 | 0.66  | 3.96  |
| 83  | <i>Palaquium ellipticum</i>            | LT  | 0.30 | 0.55 | 0.00  | 0.85  |
| 84  | <i>Paracroton pendulus</i>             | MT  | 1.19 | 1.47 | 0.46  | 3.12  |
| 85  | <i>Persea macrantha</i>                | MT  | 0.60 | 1.10 | 0.63  | 2.33  |
| 86  | <i>Prioria pinnata</i>                 | LT  | 1.49 | 0.92 | 1.27  | 3.68  |
| 87  | <i>Psychotria anamallayana</i>         | VST | 0.50 | 0.92 | 0.01  | 1.42  |
| 88  | <i>Pterocarpus marsupium</i>           | LT  | 0.20 | 0.18 | 0.02  | 0.40  |
| 89  | <i>Pterospermum reticulatum</i>        | MT  | 0.10 | 0.18 | 0.01  | 0.29  |
| 90  | <i>Reinwardtiodendron anamalaiense</i> | MT  | 2.08 | 1.66 | 0.64  | 4.38  |
| 91  | <i>Sarcostigma kleinii</i>             | LI  | 0.30 | 0.55 | 0.00  | 0.85  |
| 92  | <i>Schleichera oleosa</i>              | MT  | 4.46 | 1.29 | 6.55  | 12.30 |
| 93  | <i>Spondias pinnata</i>                | MT  | 0.79 | 1.29 | 0.10  | 2.19  |
| 94  | <i>Stereospermum tetragonum</i>        | MT  | 0.60 | 0.55 | 0.03  | 1.18  |
| 95  | <i>Strychnos wallichiana</i>           | MT  | 1.29 | 1.29 | 0.07  | 2.65  |
| 96  | <i>Syzygium gardneri</i>               | LT  | 0.69 | 1.29 | 0.37  | 2.35  |
| 97  | <i>Syzygium laetum</i>                 | ST  | 0.99 | 1.29 | 0.08  | 2.36  |
| 98  | <i>Syzygium munronii</i>               | VST | 0.30 | 0.55 | 0.02  | 0.87  |
| 99  | <i>Syzygium occidentale</i>            | VST | 0.60 | 0.55 | 0.02  | 1.17  |
| 100 | <i>Terminaha chebula</i>               | MT  | 0.20 | 0.37 | 0.02  | 0.58  |
| 101 | <i>Terminalia bellirica</i>            | ET  | 1.49 | 1.47 | 0.28  | 3.24  |

|     |                                 |    |      |      |       |         |
|-----|---------------------------------|----|------|------|-------|---------|
| 102 | <i>Tetrameles nudiflora</i>     | ET | 1.88 | 0.92 | 6.12  | 8.92    |
| 103 | <i>Turpinia malabarica</i>      | MT | 0.89 | 0.74 | 0.07  | 1.70    |
| 104 | <i>Vateria indica</i>           | LT | 3.87 | 2.03 | 10.91 | 16.81   |
| 105 | <i>Vepris bilocularis</i>       | MT | 0.79 | 0.74 | 0.73  | 2.26    |
| 106 | <i>Vitex altissima</i>          | ST | 0.60 | 1.10 | 0.37  | 2.07    |
| 107 | <i>Xanthophyllum flavescens</i> | ST | 1.98 | 2.21 | 0.43  | 4.62    |
|     | Total                           |    | 100  | 100  | 100.2 | 300.152 |

**Cluster 8: Very Low Elevation Evergreen Forest**

| SL. No. | Scientific Name                  | Height Class | RD   | RF   | RBA  | IVI  |
|---------|----------------------------------|--------------|------|------|------|------|
| 1       | <i>Agalaia perviridis</i>        | LT           | 0.45 | 1.06 | 0.05 | 1.55 |
| 2       | <i>Agalaia simplicifolia</i>     | LT           | 0.45 | 1.06 | 0.02 | 1.53 |
| 3       | <i>Aglaia barberi</i>            | LT           | 2.70 | 1.59 | 0.56 | 4.85 |
| 4       | <i>Aglaia edulis</i>             | MT           | 1.12 | 0.53 | 0.09 | 1.74 |
| 5       | <i>Aglaia lawii</i>              | MT           | 0.67 | 1.59 | 0.01 | 2.27 |
| 6       | <i>Aglaia malabarica</i>         | MT           | 0.45 | 1.06 | 0.11 | 1.62 |
| 7       | <i>Agrostistachys borneensis</i> | MT           | 0.22 | 0.53 | 0.00 | 0.76 |
| 8       | <i>Alstonia scholaris</i>        | ET           | 0.67 | 1.59 | 0.18 | 2.44 |
| 9       | <i>Anacolosa densiflora</i>      | LT           | 1.35 | 1.06 | 0.06 | 2.47 |
| 10      | <i>Antiaris toxicaria</i>        | ET           | 0.22 | 0.53 | 0.02 | 0.77 |
| 11      | <i>Aphananthe cuspidata</i>      | MT           | 0.45 | 1.06 | 0.03 | 1.53 |
| 12      | <i>Aporosa cardiosperma</i>      | ST           | 0.22 | 0.53 | 0.00 | 0.76 |
| 13      | <i>Baccaurea courtallensis</i>   | ST           | 1.35 | 1.06 | 0.05 | 2.46 |
| 14      | <i>Beilschmiedia wightii</i>     | LT           | 0.22 | 0.53 | 0.01 | 0.77 |
| 15      | <i>Bombax ceiba</i>              | ET           | 0.90 | 1.06 | 0.56 | 2.52 |
| 16      | <i>Calamus thwaitesii</i>        | LI           | 0.22 | 0.53 | 0.00 | 0.75 |

|    |                                 |    |      |      |       |       |
|----|---------------------------------|----|------|------|-------|-------|
| 17 | <i>Chionanthus mala-elengi</i>  | MT | 0.90 | 1.06 | 10.67 | 12.62 |
| 18 | <i>Debregeasia orientalis</i>   | ST | 0.22 | 0.53 | 0.00  | 0.75  |
| 19 | <i>Dimocarpus longan</i>        | LT | 1.35 | 1.06 | 0.05  | 2.45  |
| 20 | <i>Diospyros foliosa</i>        | MT | 0.67 | 1.59 | 0.04  | 2.30  |
| 21 | <i>Diospyros paniculata</i>     | MT | 4.94 | 2.12 | 1.26  | 8.32  |
| 22 | <i>Diospyros sylvatica</i>      | LT | 1.80 | 2.12 | 0.17  | 4.08  |
| 23 | <i>Dipterocarpus indicus</i>    | ET | 9.89 | 4.76 | 53.86 | 68.51 |
| 24 | <i>Dolichandrone atrovirens</i> | MT | 1.57 | 1.06 | 0.65  | 3.28  |
| 25 | <i>Drypetes elata</i>           | MT | 0.22 | 0.53 | 0.01  | 0.77  |
| 26 | <i>Drypetes oblongifolia</i>    | MT | 0.22 | 0.53 | 0.00  | 0.75  |
| 27 | <i>Drypetes venusta</i>         | MT | 2.47 | 1.59 | 0.58  | 4.64  |
| 28 | <i>Ficus exasperata</i>         | MT | 0.45 | 1.06 | 0.02  | 1.53  |
| 29 | <i>Ficus glomerata</i>          | ST | 0.22 | 0.53 | 0.00  | 0.75  |
| 30 | <i>Ficus nervosa</i>            | LT | 1.12 | 1.59 | 0.12  | 2.84  |
| 31 | <i>Ficus racemosa</i>           | MT | 0.45 | 1.06 | 0.04  | 1.55  |
| 32 | <i>Flacourtia montana</i>       | ST | 1.12 | 2.12 | 0.14  | 3.38  |
| 33 | <i>Gnetum edule</i>             | LI | 0.67 | 1.59 | 0.01  | 2.28  |
| 34 | <i>Gluta travancorica</i>       | ET | 1.12 | 0.53 | 0.05  | 1.71  |
| 35 | <i>Hopea parviflora</i>         | ET | 1.57 | 1.59 | 1.78  | 4.94  |
| 36 | <i>Hopea racophloea</i>         | LT | 1.12 | 2.12 | 0.23  | 3.47  |
| 37 | <i>Hydnocarpus pentandrus</i>   | LT | 6.74 | 2.12 | 7.76  | 16.62 |
| 38 | <i>Isonandra perrottetiana</i>  | LT | 0.67 | 1.59 | 0.03  | 2.29  |
| 39 | <i>Ixora brachiata</i>          | ST | 1.12 | 2.65 | 0.05  | 3.82  |
| 40 | <i>Knema attenuata</i>          | LT | 1.80 | 2.12 | 0.29  | 4.20  |
| 41 | <i>Lagerstroemia microcarpa</i> | LT | 1.80 | 0.53 | 3.10  | 5.42  |
| 42 | <i>Lannea coromandelica</i>     | ST | 0.45 | 1.06 | 0.00  | 1.51  |
| 43 | <i>Lepisanthes tetraphylla</i>  | ST | 0.22 | 0.53 | 0.00  | 0.76  |

|    |                                        |    |      |      |      |       |
|----|----------------------------------------|----|------|------|------|-------|
| 44 | <i>Litsea coriacea</i>                 | MT | 0.22 | 0.53 | 0.00 | 0.76  |
| 45 | <i>Litsea travancorica</i>             | MT | 0.45 | 1.06 | 0.02 | 1.53  |
| 46 | <i>Macranga peltata</i>                | ET | 0.45 | 1.06 | 0.01 | 1.52  |
| 47 | <i>Mallotus nudiflorus</i>             | ST | 0.90 | 1.59 | 0.07 | 2.55  |
| 48 | <i>Mallotus tetracoccus</i>            | ST | 5.84 | 2.12 | 1.13 | 9.09  |
| 49 | <i>Meiogyne pannosa</i>                | ST | 0.90 | 1.06 | 0.01 | 1.97  |
| 50 | <i>Mesua ferea</i>                     | ET | 1.57 | 2.12 | 0.52 | 4.20  |
| 51 | <i>Monoon fragrans</i>                 | LT | 1.12 | 2.12 | 0.16 | 3.40  |
| 52 | <i>Myristica beddomei</i>              | MT | 2.25 | 2.65 | 0.48 | 5.37  |
| 53 | <i>Otonephelium stipulaceum</i>        | MT | 0.90 | 1.06 | 0.13 | 2.09  |
| 54 | <i>Palaquium ellipticum</i>            | LT | 0.67 | 1.59 | 0.14 | 2.40  |
| 55 | <i>Paracroton pendulus</i>             | MT | 0.45 | 0.53 | 0.02 | 0.99  |
| 56 | <i>Poeciloneuron indicum</i>           | LT | 0.45 | 1.06 | 0.00 | 1.51  |
| 57 | <i>Prioria pinnata</i>                 | ET | 4.49 | 3.17 | 2.80 | 10.47 |
| 58 | <i>Reinwardtiadendron anamalaiense</i> | MT | 1.57 | 1.06 | 0.17 | 2.80  |
| 59 | <i>Sapindus trifoliatus</i>            | MT | 0.45 | 1.06 | 0.02 | 1.53  |
| 60 | <i>Schleichera oleosa</i>              | MT | 1.57 | 1.06 | 0.28 | 2.91  |
| 61 | <i>Syzygium cumini</i>                 | LT | 1.57 | 1.59 | 0.51 | 3.67  |
| 62 | <i>Syzygium gardneri</i>               | ET | 1.12 | 1.59 | 0.16 | 2.88  |
| 63 | <i>Syzygium hemisphericum</i>          | MT | 1.80 | 1.06 | 0.17 | 3.02  |
| 64 | <i>Syzygium jambos</i>                 | MT | 0.45 | 1.06 | 0.01 | 1.52  |
| 65 | <i>Syzygium laetum</i>                 | MT | 0.90 | 2.12 | 0.04 | 3.05  |
| 66 | <i>Syzygium mundagam</i>               | ST | 2.47 | 1.59 | 0.18 | 4.24  |
| 67 | <i>Syzygium rubicundam</i>             | MT | 0.45 | 1.06 | 0.00 | 1.51  |
| 68 | <i>Terminalia bellarica</i>            | ET | 1.80 | 2.12 | 0.31 | 4.23  |
| 69 | <i>Terminalia paniculata</i>           | MT | 0.45 | 1.06 | 0.07 | 1.58  |
| 70 | <i>Tetrameles nudiflora</i>            | ET | 1.80 | 2.65 | 8.08 | 12.52 |



|    |                                  |    |        |       |        |        |
|----|----------------------------------|----|--------|-------|--------|--------|
| 71 | <i>Valeria indica</i>            | LT | 0.67   | 0.53  | 0.17   | 1.37   |
| 72 | <i>Vepris bilocularis</i>        | LT | 2.02   | 1.59  | 1.39   | 5.00   |
| 73 | <i>Xanthophyllum flavascence</i> | ST | 3.60   | 2.12  | 0.29   | 6.00   |
|    | Total                            |    | 100.00 | 99.99 | 100.00 | 300.00 |

**Cluster 9: Low Elevation Riparian Evergreen Forest**

| SL. No. | Scientific Name                 | Height Class | RD  | RF  | RBA | IVI |
|---------|---------------------------------|--------------|-----|-----|-----|-----|
| 1       | <i>Acacia indica</i>            | LT           | 0.3 | 0.7 | 0.0 | 1.0 |
| 2       | <i>Aporosa bourdillonii</i>     | VST          | 0.8 | 2.1 | 0.0 | 2.9 |
| 3       | <i>Aporosa cardiosperma</i>     | ST           | 1.6 | 4.3 | 0.0 | 5.9 |
| 4       | <i>Artocarpus hirsutus</i>      | LT           | 0.5 | 1.4 | 0.0 | 2.0 |
| 5       | <i>Bambusa bambos</i>           | ST           | 0.3 | 0.7 | 0.0 | 1.0 |
| 6       | <i>Barringtonia acutangula</i>  | ST           | 1.3 | 2.1 | 0.0 | 3.5 |
| 7       | <i>Calophyllum calaba</i>       | ET           | 2.1 | 4.3 | 0.3 | 6.7 |
| 8       | <i>Calophyllum inophyllum</i>   | LT           | 0.5 | 1.4 | 0.0 | 2.0 |
| 9       | <i>Carallia brachiata</i>       | MT           | 0.8 | 2.1 | 0.0 | 3.0 |
| 10      | <i>Chionanthus mala-elengi</i>  | LT           | 0.5 | 1.4 | 0.0 | 2.0 |
| 11      | <i>Cinnamomum malabattrum</i>   | MT           | 0.5 | 1.4 | 0.0 | 2.0 |
| 12      | <i>Diospyros buxifolia</i>      | MT           | 0.8 | 2.1 | 0.2 | 3.1 |
| 13      | <i>Diospyros malabarica</i>     | MT           | 0.5 | 1.4 | 0.0 | 2.0 |
| 14      | <i>Elaeocarpus tuberculatus</i> | ET           | 0.5 | 1.4 | 0.0 | 2.0 |
| 15      | <i>Entada scandens</i>          | LI           | 0.8 | 2.1 | 0.0 | 2.9 |
| 16      | <i>Falcourtia montana</i>       | ST           | 0.8 | 2.1 | 0.0 | 2.9 |
| 17      | <i>Ficus hispida</i>            | ST           | 1.1 | 1.4 | 0.1 | 2.5 |

|    |                                |    |      |     |      |       |
|----|--------------------------------|----|------|-----|------|-------|
| 18 | <i>Ficus microcarpa</i>        | MT | 0.8  | 2.1 | 0.1  | 3.1   |
| 19 | <i>Garcinia gummi-gutta</i>    | MT | 0.5  | 1.4 | 0.0  | 2.0   |
| 20 | <i>Garcinia wightii</i>        | ST | 9.6  | 5.7 | 2.8  | 18.1  |
| 21 | <i>Gnetum edule</i>            | LI | 0.3  | 0.7 | 0.0  | 1.0   |
| 22 | <i>Holigarna grahamii</i>      | LT | 1.6  | 2.1 | 0.1  | 3.8   |
| 23 | <i>Hopea parviflora</i>        | ET | 2.4  | 4.3 | 8.0  | 14.6  |
| 24 | <i>Hopea ponga</i>             | LT | 1.6  | 2.8 | 0.2  | 4.6   |
| 25 | <i>Humboldtia vahliana</i>     | MT | 33.5 | 4.3 | 82.0 | 119.7 |
| 26 | <i>Hydnocarpus alpinus</i>     | MT | 0.5  | 1.4 | 0.0  | 2.0   |
| 27 | <i>Hydnocarpus pentandrus</i>  | MT | 0.5  | 0.7 | 0.0  | 1.2   |
| 28 | <i>Lagerstroemia speciosa</i>  | MT | 0.5  | 1.4 | 0.0  | 2.0   |
| 29 | <i>Madhuca neriifolia</i>      | ST | 6.9  | 5.7 | 1.9  | 14.4  |
| 30 | <i>Mallotus resinusus</i>      | ST | 4.8  | 4.3 | 0.4  | 9.5   |
| 31 | <i>Neolamarckia cadamba</i>    | LT | 1.6  | 1.4 | 0.1  | 3.1   |
| 32 | <i>Ochlandra scriptoria</i>    | ST | 1.6  | 4.3 | 0.5  | 6.3   |
| 33 | <i>Ochlandra travancorica</i>  | ST | 0.3  | 0.7 | 0.0  | 1.0   |
| 34 | <i>Ochreinauclea missionis</i> | LT | 2.1  | 1.4 | 0.2  | 3.8   |
| 35 | <i>Pandanus furcatus</i>       | ST | 1.1  | 0.7 | 0.0  | 1.8   |
| 36 | <i>Pongamia pinnata</i>        | MT | 4.8  | 6.4 | 1.6  | 12.7  |
| 37 | <i>Sterculia guttata</i>       | MT | 0.3  | 0.7 | 0.0  | 1.0   |
| 38 | <i>Syzygium cumini</i>         | MT | 0.8  | 2.1 | 0.3  | 3.2   |
| 39 | <i>Syzygium occidentale</i>    | LT | 2.7  | 3.5 | 0.1  | 6.3   |
| 40 | <i>Syzygium salicifolium</i>   | MT | 0.5  | 2.1 | 0.0  | 2.7   |

|    |                             |     |       |       |       |       |
|----|-----------------------------|-----|-------|-------|-------|-------|
| 41 | <i>Terminalia arjuna</i>    | LT  | 2.7   | 0.7   | 0.5   | 3.9   |
| 42 | <i>Terminalia tomentosa</i> | LT  | 0.3   | 0.7   | 0.0   | 1.0   |
| 43 | <i>Vateria indica</i>       | ET  | 2.4   | 3.5   | 0.2   | 6.2   |
| 44 | <i>Vitex altissima</i>      | VST | 1.6   | 2.1   | 0.3   | 4.0   |
|    | Total                       |     | 100.0 | 100.0 | 100.0 | 300.0 |

**Cluster 10: Low Elevation Coastal Evergreen Forest**

| SL. No. | Scientific Name                 | Height Class | RD  | RF  | RBA | IVI  |
|---------|---------------------------------|--------------|-----|-----|-----|------|
| 1       | <i>Acacia auriculiformis</i>    | LT           | 2.6 | 2.4 | 0.2 | 5.2  |
| 2       | <i>Actinodaphne malabarica</i>  | LT           | 0.9 | 1.2 | 0.0 | 2.1  |
| 3       | <i>Albizia odoratissima</i>     | ET           | 0.9 | 1.2 | 0.0 | 2.1  |
| 4       | <i>Anacardium occidentale</i>   | MT           | 1.7 | 1.2 | 0.4 | 3.3  |
| 5       | <i>Archidendron monadelphum</i> | MT           | 0.9 | 1.2 | 0.0 | 2.0  |
| 6       | <i>Artocarpus heterophyllus</i> | LT           | 1.7 | 1.2 | 0.0 | 2.9  |
| 7       | <i>Artocarpus hirsutus</i>      | LT           | 9.5 | 7.1 | 4.5 | 21.0 |
| 8       | <i>Callicarpa tomentosa</i>     | ST           | 0.9 | 1.2 | 0.0 | 2.0  |
| 9       | <i>Calophyllum calaba</i>       | LT           | 0.9 | 1.2 | 0.2 | 2.2  |
| 10      | <i>Cananga odorata</i>          | ST           | 0.9 | 1.2 | 0.0 | 2.0  |
| 11      | <i>Capparis floribunda</i>      | VST          | 0.9 | 1.2 | 0.0 | 2.0  |
| 12      | <i>Carallia brachiata</i>       | MT           | 0.9 | 1.2 | 0.0 | 2.0  |
| 13      | <i>Caryota urens</i>            | LT           | 2.6 | 3.5 | 0.1 | 6.2  |
| 14      | <i>Cinnamomum verum</i>         | MT           | 1.7 | 1.2 | 0.0 | 2.9  |
| 15      | <i>Dalbergia lanceolaria</i>    | MT           | 0.9 | 1.2 | 0.0 | 2.1  |
| 16      | <i>Dimocarpus longan</i>        | LT           | 0.9 | 1.2 | 0.0 | 2.0  |
| 17      | <i>Diospyros candolleana</i>    | LT           | 0.9 | 1.2 | 0.0 | 2.0  |

|    |                                |     |      |     |      |       |
|----|--------------------------------|-----|------|-----|------|-------|
| 18 | <i>Ficus benghalensis</i>      | ET  | 0.9  | 1.2 | 0.2  | 2.2   |
| 19 | <i>Ficus exasperata</i>        | LT  | 0.9  | 1.2 | 0.0  | 2.1   |
| 20 | <i>Ficus hispida</i>           | ST  | 0.9  | 1.2 | 0.0  | 2.1   |
| 21 | <i>Ficus microcarpa</i>        | LT  | 0.9  | 1.2 | 0.0  | 2.1   |
| 22 | <i>Ficus tsjakela</i>          | ET  | 0.9  | 1.2 | 0.0  | 2.1   |
| 23 | <i>Ficus virens</i>            | ET  | 0.9  | 1.2 | 0.0  | 2.1   |
| 24 | <i>Garcinia gummi-gutta</i>    | MT  | 4.3  | 3.5 | 0.3  | 8.2   |
| 25 | <i>Gliricidia sepium</i>       | ST  | 1.7  | 1.2 | 0.0  | 2.9   |
| 26 | <i>Gnetum edule</i>            | LI  | 2.6  | 1.2 | 0.1  | 3.8   |
| 27 | <i>Grewia nervosa</i>          | VST | 0.9  | 1.2 | 0.0  | 2.0   |
| 28 | <i>Holigarna arnottiana</i>    | LT  | 3.4  | 4.7 | 0.2  | 8.3   |
| 29 | <i>Hopea parviflora</i>        | ET  | 0.9  | 1.2 | 0.3  | 2.4   |
| 30 | <i>Hopea ponga</i>             | LT  | 2.6  | 2.4 | 0.8  | 5.8   |
| 31 | <i>Huberantha korinti</i>      | VST | 0.9  | 1.2 | 0.0  | 2.0   |
| 32 | <i>Hydnocarpus pentandrus</i>  | MT  | 3.4  | 3.5 | 0.2  | 7.2   |
| 33 | <i>Lagerstroemia speciosa</i>  | MT  | 0.9  | 1.2 | 0.0  | 2.1   |
| 34 | <i>Lannea coromandelica</i>    | ST  | 1.7  | 2.4 | 0.0  | 4.1   |
| 35 | <i>Lophopetalum wightianum</i> | ET  | 0.9  | 1.2 | 0.0  | 2.1   |
| 36 | <i>Macaranga peltata</i>       | LT  | 2.6  | 3.5 | 0.3  | 6.4   |
| 37 | <i>Mangifera indica</i>        | LT  | 2.6  | 3.5 | 0.5  | 6.6   |
| 38 | <i>Memecylon umbellatum</i>    | VMT | 0.9  | 1.2 | 0.0  | 2.1   |
| 39 | <i>Mimusops elengi</i>         | LT  | 0.9  | 1.2 | 0.0  | 2.0   |
| 40 | <i>Ochlandra travancorica</i>  | ST  | 10.3 | 1.2 | 90.6 | 102.2 |
| 41 | <i>Ochna gamblei</i>           | VST | 6.9  | 4.7 | 0.1  | 11.7  |
| 42 | <i>Olea dioica</i>             | MT  | 3.4  | 4.7 | 0.1  | 8.2   |
| 43 | <i>Opuntia elatior</i>         | VST | 0.9  | 1.2 | 0.0  | 2.0   |

|    |                                 |     |      |      |       |       |
|----|---------------------------------|-----|------|------|-------|-------|
| 44 | <i>Pongamia pinnata</i>         | MT  | 0.9  | 1.2  | 0.2   | 2.2   |
| 45 | <i>Prioria pinnata</i>          | ET  | 0.9  | 1.2  | 0.1   | 2.1   |
| 46 | <i>Psychotria viridis</i>       | VST | 0.9  | 1.2  | 0.0   | 2.0   |
| 47 | <i>Samadera indica</i>          | VST | 0.9  | 1.2  | 0.0   | 2.0   |
| 48 | <i>Sterculia balanghas</i>      | MT  | 0.9  | 1.2  | 0.0   | 2.0   |
| 49 | <i>Strophanthus wightianus</i>  | LI  | 0.9  | 1.2  | 0.0   | 2.0   |
| 50 | <i>Strychnos nux-vomica</i>     | MT  | 0.9  | 1.2  | 0.0   | 2.0   |
| 51 | <i>Syzygium caryophyllatum</i>  | MT  | 1.7  | 2.4  | 0.4   | 4.4   |
| 52 | <i>Syzygium cumini</i>          | LT  | 0.9  | 1.2  | 0.0   | 2.1   |
| 53 | <i>Tetrameles nudiflora</i>     | ET  | 0.9  | 1.2  | 0.0   | 2.1   |
| 54 | <i>Vateria indica</i>           | ET  | 0.9  | 1.2  | 0.0   | 2.1   |
| 55 | <i>Vitex altissima</i>          | MT  | 0.9  | 1.2  | 0.0   | 2.0   |
| 56 | <i>Xanthophyllum flavescens</i> | ST  | 0.9  | 1.2  | 0.0   | 2.0   |
|    | Total                           |     | 99.1 | 98.8 | 100.0 | 298.0 |

## APPENDIX IV

### 1. Schoener's D Overlap Matrix

```
## --- Schoener's D Overlap Matrix (25x25) ---
print(round(overlap_D_matrix, 3)) # Round for cleaner display

##           Aglai_mala Aporo_bour Cryp_anam Cryp_law Dios_crum
Dipte_indi
## Aglai_mala           1.000           0.550           0.669           0.478           0.709
0.637
## Aporo_bour           0.550           1.000           0.455           0.412           0.463
0.578
## Cryp_anam            0.669           0.455           1.000           0.524           0.667
0.531
## Cryp_law             0.478           0.412           0.524           1.000           0.507
0.613
## Dios_crum            0.709           0.463           0.667           0.507           1.000
0.606
## Dipte_indi           0.637           0.578           0.531           0.613           0.606
1.000
## Elaeo_mun            0.431           0.381           0.457           0.554           0.412
0.588
## Elaeo_recur          0.357           0.287           0.430           0.430           0.291
0.376
## Ficus_beddo          0.546           0.449           0.481           0.608           0.516
0.680
## Garci_wigh           0.455           0.593           0.431           0.396           0.379
0.498
## Gonio_wigh           0.354           0.358           0.409           0.396           0.287
0.414
## Humbo_vahl           0.487           0.508           0.522           0.501           0.435
0.530
## Hydno_pent           0.647           0.592           0.569           0.553           0.636
0.720
## Impati_parasi        0.288           0.323           0.349           0.389           0.233
0.377
## Litse_oleoi          0.494           0.432           0.490           0.671           0.460
0.598
## Medi_anama           0.538           0.477           0.636           0.468           0.449
0.485
## Meiog_pann           0.602           0.512           0.571           0.622           0.580
0.766
## Ochn_gamb            0.269           0.123           0.269           0.272           0.288
0.202
## Prio_pinn            0.573           0.500           0.458           0.498           0.516
0.660
## Strob_kunt           0.292           0.207           0.354           0.420           0.247
0.349
## Syzy_densi           0.345           0.366           0.395           0.482           0.295
0.450
```

|                           |           |             |             |            |       |
|---------------------------|-----------|-------------|-------------|------------|-------|
| ## Syzy_occi<br>0.554     | 0.556     | 0.607       | 0.424       | 0.365      | 0.473 |
| ## Syzy_palgh<br>0.514    | 0.627     | 0.455       | 0.717       | 0.488      | 0.591 |
| ## Syzy_param<br>0.334    | 0.337     | 0.328       | 0.394       | 0.322      | 0.233 |
| ## Syzy_sahya<br>0.372    | 0.405     | 0.349       | 0.462       | 0.379      | 0.302 |
| ##                        | Elaeo_mun | Elaeo_recur | Ficus_beddo | Garci_wigh |       |
| Gonio_wigh                |           |             |             |            |       |
| ## Aglai_mala<br>0.354    | 0.431     | 0.357       | 0.546       | 0.455      |       |
| ## Aporo_bour<br>0.358    | 0.381     | 0.287       | 0.449       | 0.593      |       |
| ## Cryp_anam<br>0.409     | 0.457     | 0.430       | 0.481       | 0.431      |       |
| ## Cryp_law<br>0.396      | 0.554     | 0.430       | 0.608       | 0.396      |       |
| ## Dios_crum<br>0.287     | 0.412     | 0.291       | 0.516       | 0.379      |       |
| ## Dipte_indi<br>0.414    | 0.588     | 0.376       | 0.680       | 0.498      |       |
| ## Elaeo_mun<br>0.502     | 1.000     | 0.590       | 0.689       | 0.427      |       |
| ## Elaeo_recur<br>0.463   | 0.590     | 1.000       | 0.471       | 0.343      |       |
| ## Ficus_beddo<br>0.549   | 0.689     | 0.471       | 1.000       | 0.519      |       |
| ## Garci_wigh<br>0.588    | 0.427     | 0.343       | 0.519       | 1.000      |       |
| ## Gonio_wigh<br>1.000    | 0.502     | 0.463       | 0.549       | 0.588      |       |
| ## Humbo_vahl<br>0.631    | 0.495     | 0.396       | 0.620       | 0.699      |       |
| ## Hydno_pent<br>0.370    | 0.444     | 0.311       | 0.566       | 0.503      |       |
| ## Impati_parasi<br>0.494 | 0.542     | 0.629       | 0.407       | 0.381      |       |
| ## Litse_oleoi<br>0.520   | 0.675     | 0.558       | 0.730       | 0.503      |       |
| ## Medi_anama<br>0.482    | 0.557     | 0.580       | 0.470       | 0.459      |       |
| ## Meiog_pann<br>0.462    | 0.693     | 0.479       | 0.725       | 0.497      |       |
| ## Ochn_gamb<br>0.182     | 0.213     | 0.178       | 0.271       | 0.148      |       |
| ## Prio_pinn<br>0.518     | 0.470     | 0.321       | 0.695       | 0.548      |       |
| ## Strob_kunt<br>0.440    | 0.586     | 0.723       | 0.473       | 0.278      |       |
| ## Syzy_densi<br>0.626    | 0.667     | 0.632       | 0.565       | 0.487      |       |

|                           |            |            |               |             |
|---------------------------|------------|------------|---------------|-------------|
| ## Syzy_occi<br>0.459     | 0.332      | 0.258      | 0.515         | 0.691       |
| ## Syzy_palgh<br>0.402    | 0.417      | 0.374      | 0.473         | 0.416       |
| ## Syzy_param<br>0.574    | 0.492      | 0.658      | 0.393         | 0.433       |
| ## Syzy_sahya<br>0.505    | 0.539      | 0.723      | 0.439         | 0.423       |
| ##                        | Humbo_vahl | Hydno_pent | Impati_parasi | Litse_oleoi |
| Medi_anama                |            |            |               |             |
| ## Aglai_mala<br>0.538    | 0.487      | 0.647      | 0.288         | 0.494       |
| ## Aporo_bour<br>0.477    | 0.508      | 0.592      | 0.323         | 0.432       |
| ## Cryp_anam<br>0.636     | 0.522      | 0.569      | 0.349         | 0.490       |
| ## Cryp_law<br>0.468      | 0.501      | 0.553      | 0.389         | 0.671       |
| ## Dios_crum<br>0.449     | 0.435      | 0.636      | 0.233         | 0.460       |
| ## Dipte_indi<br>0.485    | 0.530      | 0.720      | 0.377         | 0.598       |
| ## Elaeo_mun<br>0.557     | 0.495      | 0.444      | 0.542         | 0.675       |
| ## Elaeo_recur<br>0.580   | 0.396      | 0.311      | 0.629         | 0.558       |
| ## Ficus_beddo<br>0.470   | 0.620      | 0.566      | 0.407         | 0.730       |
| ## Garci_wigh<br>0.459    | 0.699      | 0.503      | 0.381         | 0.503       |
| ## Gonio_wigh<br>0.482    | 0.631      | 0.370      | 0.494         | 0.520       |
| ## Humbo_vahl<br>0.454    | 1.000      | 0.523      | 0.372         | 0.582       |
| ## Hydno_pent<br>0.431    | 0.523      | 1.000      | 0.320         | 0.494       |
| ## Impati_parasi<br>0.516 | 0.372      | 0.320      | 1.000         | 0.464       |
| ## Litse_oleoi<br>0.537   | 0.582      | 0.494      | 0.464         | 1.000       |
| ## Medi_anama<br>1.000    | 0.454      | 0.431      | 0.516         | 0.537       |
| ## Meiog_pann<br>0.565    | 0.565      | 0.598      | 0.428         | 0.698       |
| ## Ochn_gamb<br>0.146     | 0.292      | 0.218      | 0.089         | 0.281       |
| ## Prio_pinn<br>0.384     | 0.616      | 0.593      | 0.274         | 0.586       |
| ## Strob_kunt<br>0.440    | 0.367      | 0.274      | 0.519         | 0.530       |
| ## Syzy_densi<br>0.543    | 0.518      | 0.363      | 0.700         | 0.610       |



|                           |            |           |           |            |            |
|---------------------------|------------|-----------|-----------|------------|------------|
| ## Syzy_occi<br>0.365     | 0.595      | 0.604     | 0.254     | 0.463      |            |
| ## Syzy_palgh<br>0.577    | 0.477      | 0.541     | 0.347     | 0.444      |            |
| ## Syzy_param<br>0.627    | 0.426      | 0.270     | 0.558     | 0.450      |            |
| ## Syzy_sahya<br>0.664    | 0.439      | 0.311     | 0.537     | 0.500      |            |
| ##                        | Meiog_pann | Ochn_gamb | Prio_pinn | Strob_kunt | Syzy_densi |
| Syzy_occi                 |            |           |           |            |            |
| ## Aglai_mala<br>0.556    | 0.602      | 0.269     | 0.573     | 0.292      | 0.345      |
| ## Aporo_bour<br>0.607    | 0.512      | 0.123     | 0.500     | 0.207      | 0.366      |
| ## Cryp_anam<br>0.424     | 0.571      | 0.269     | 0.458     | 0.354      | 0.395      |
| ## Cryp_law<br>0.365      | 0.622      | 0.272     | 0.498     | 0.420      | 0.482      |
| ## Dios_crum<br>0.473     | 0.580      | 0.288     | 0.516     | 0.247      | 0.295      |
| ## Dipte_indi<br>0.554    | 0.766      | 0.202     | 0.660     | 0.349      | 0.450      |
| ## Elaeo_mun<br>0.332     | 0.693      | 0.213     | 0.470     | 0.586      | 0.667      |
| ## Elaeo_recur<br>0.258   | 0.479      | 0.178     | 0.321     | 0.723      | 0.632      |
| ## Ficus_beddo<br>0.515   | 0.725      | 0.271     | 0.695     | 0.473      | 0.565      |
| ## Garci_igh<br>0.691     | 0.497      | 0.148     | 0.548     | 0.278      | 0.487      |
| ## Gonio_igh<br>0.459     | 0.462      | 0.182     | 0.518     | 0.440      | 0.626      |
| ## Humbo_vahl<br>0.595    | 0.565      | 0.292     | 0.616     | 0.367      | 0.518      |
| ## Hydno_pent<br>0.604    | 0.598      | 0.218     | 0.593     | 0.274      | 0.363      |
| ## Impati_parasi<br>0.254 | 0.428      | 0.089     | 0.274     | 0.519      | 0.700      |
| ## Litse_oleoi<br>0.463   | 0.698      | 0.281     | 0.586     | 0.530      | 0.610      |
| ## Medi_anama<br>0.365    | 0.565      | 0.146     | 0.384     | 0.440      | 0.543      |
| ## Meiog_pann<br>0.484    | 1.000      | 0.238     | 0.622     | 0.433      | 0.530      |
| ## Ochn_gamb<br>0.177     | 0.238      | 1.000     | 0.243     | 0.224      | 0.157      |
| ## Prio_pinn<br>0.633     | 0.622      | 0.243     | 1.000     | 0.322      | 0.430      |
| ## Strob_kunt<br>0.209    | 0.433      | 0.224     | 0.322     | 1.000      | 0.589      |
| ## Syzy_densi<br>0.342    | 0.530      | 0.157     | 0.430     | 0.589      | 1.000      |

|                  |            |            |            |       |       |
|------------------|------------|------------|------------|-------|-------|
| ## Syzy_occi     | 0.484      | 0.177      | 0.633      | 0.209 | 0.342 |
| 1.000            |            |            |            |       |       |
| ## Syzy_palgh    | 0.521      | 0.251      | 0.412      | 0.325 | 0.369 |
| 0.386            |            |            |            |       |       |
| ## Syzy_param    | 0.418      | 0.101      | 0.331      | 0.524 | 0.622 |
| 0.316            |            |            |            |       |       |
| ## Syzy_sahya    | 0.463      | 0.158      | 0.372      | 0.574 | 0.612 |
| 0.337            |            |            |            |       |       |
| ##               | Syzy_palgh | Syzy_param | Syzy_sahya |       |       |
| ## Aglai_mala    | 0.627      | 0.337      | 0.405      |       |       |
| ## Aporo_bour    | 0.455      | 0.328      | 0.349      |       |       |
| ## Cryp_anam     | 0.717      | 0.394      | 0.462      |       |       |
| ## Cryp_law      | 0.488      | 0.322      | 0.379      |       |       |
| ## Dios_crum     | 0.591      | 0.233      | 0.302      |       |       |
| ## Dipte_indi    | 0.514      | 0.334      | 0.372      |       |       |
| ## Elaeo_mun     | 0.417      | 0.492      | 0.539      |       |       |
| ## Elaeo_recur   | 0.374      | 0.658      | 0.723      |       |       |
| ## Ficus_beddo   | 0.473      | 0.393      | 0.439      |       |       |
| ## Garci_wigh    | 0.416      | 0.433      | 0.423      |       |       |
| ## Gonio_wigh    | 0.402      | 0.574      | 0.505      |       |       |
| ## Humbo_vahl    | 0.477      | 0.426      | 0.439      |       |       |
| ## Hydno_pent    | 0.541      | 0.270      | 0.311      |       |       |
| ## Impati_parasi | 0.347      | 0.558      | 0.537      |       |       |
| ## Litse_oleoi   | 0.444      | 0.450      | 0.500      |       |       |
| ## Medi_anama    | 0.577      | 0.627      | 0.664      |       |       |
| ## Meiog_pann    | 0.521      | 0.418      | 0.463      |       |       |
| ## Ochn_gamb     | 0.251      | 0.101      | 0.158      |       |       |
| ## Prio_pinn     | 0.412      | 0.331      | 0.372      |       |       |
| ## Strob_kunt    | 0.325      | 0.524      | 0.574      |       |       |
| ## Syzy_densi    | 0.369      | 0.622      | 0.612      |       |       |
| ## Syzy_occi     | 0.386      | 0.316      | 0.337      |       |       |
| ## Syzy_palgh    | 1.000      | 0.357      | 0.397      |       |       |
| ## Syzy_param    | 0.357      | 1.000      | 0.754      |       |       |
| ## Syzy_sahya    | 0.397      | 0.754      | 1.000      |       |       |

## 2. Hellinger's I Overlap Matrix

```
cat("\n--- Hellinger's I Overlap Matrix (25x25) ---\n")

##
## --- Hellinger's I Overlap Matrix (25x25) ---

print(round(overlap_I_matrix, 3)) # Round for cleaner display

##
## Aglai_mala Aporo_bour Cryp_anam Cryp_law Dios_crum
Dipte_indi
## Aglai_mala 1.000 0.821 0.883 0.760 0.906
0.872
## Aporo_bour 0.821 1.000 0.721 0.701 0.754
0.825
## Cryp_anam 0.883 0.721 1.000 0.792 0.877
```

|                  |           |             |             |            |       |
|------------------|-----------|-------------|-------------|------------|-------|
| 0.769            |           |             |             |            |       |
| ## Cryp_law      | 0.760     | 0.701       | 0.792       | 1.000      | 0.783 |
| 0.856            |           |             |             |            |       |
| ## Dios_crum     | 0.906     | 0.754       | 0.877       | 0.783      | 1.000 |
| 0.858            |           |             |             |            |       |
| ## Dipte_indi    | 0.872     | 0.825       | 0.769       | 0.856      | 0.858 |
| 1.000            |           |             |             |            |       |
| ## Elaeo_mun     | 0.759     | 0.681       | 0.748       | 0.812      | 0.724 |
| 0.867            |           |             |             |            |       |
| ## Elaeo_recur   | 0.667     | 0.574       | 0.745       | 0.719      | 0.550 |
| 0.666            |           |             |             |            |       |
| ## Ficus_beddo   | 0.821     | 0.719       | 0.747       | 0.825      | 0.796 |
| 0.899            |           |             |             |            |       |
| ## Garci_wigh    | 0.764     | 0.839       | 0.716       | 0.692      | 0.690 |
| 0.787            |           |             |             |            |       |
| ## Gonio_wigh    | 0.652     | 0.620       | 0.704       | 0.688      | 0.578 |
| 0.684            |           |             |             |            |       |
| ## Humbo_vahl    | 0.795     | 0.772       | 0.809       | 0.793      | 0.753 |
| 0.807            |           |             |             |            |       |
| ## Hydno_pent    | 0.877     | 0.855       | 0.800       | 0.830      | 0.885 |
| 0.929            |           |             |             |            |       |
| ## Impati_parasi | 0.573     | 0.633       | 0.672       | 0.685      | 0.490 |
| 0.658            |           |             |             |            |       |
| ## Litse_oleoi   | 0.798     | 0.708       | 0.781       | 0.880      | 0.756 |
| 0.857            |           |             |             |            |       |
| ## Medi_anama    | 0.820     | 0.753       | 0.877       | 0.709      | 0.712 |
| 0.741            |           |             |             |            |       |
| ## Meiog_pann    | 0.880     | 0.788       | 0.813       | 0.864      | 0.849 |
| 0.946            |           |             |             |            |       |
| ## Ochn_gamb     | 0.575     | 0.360       | 0.551       | 0.570      | 0.571 |
| 0.488            |           |             |             |            |       |
| ## Prio_pinn     | 0.830     | 0.745       | 0.716       | 0.772      | 0.787 |
| 0.879            |           |             |             |            |       |
| ## Strob_kunt    | 0.605     | 0.464       | 0.657       | 0.711      | 0.500 |
| 0.647            |           |             |             |            |       |
| ## Syzy_densi    | 0.669     | 0.680       | 0.717       | 0.767      | 0.587 |
| 0.754            |           |             |             |            |       |
| ## Syzy_occi     | 0.816     | 0.814       | 0.669       | 0.661      | 0.731 |
| 0.800            |           |             |             |            |       |
| ## Syzy_palgh    | 0.850     | 0.717       | 0.906       | 0.746      | 0.835 |
| 0.758            |           |             |             |            |       |
| ## Syzy_param    | 0.642     | 0.606       | 0.713       | 0.601      | 0.482 |
| 0.607            |           |             |             |            |       |
| ## Syzy_sahya    | 0.725     | 0.632       | 0.754       | 0.649      | 0.563 |
| 0.658            |           |             |             |            |       |
| ##               | Elaeo_mun | Elaeo_recur | Ficus_beddo | Garci_wigh |       |
| Gonio_wigh       |           |             |             |            |       |
| ## Aglai_mala    | 0.759     | 0.667       | 0.821       | 0.764      |       |
| 0.652            |           |             |             |            |       |
| ## Aporo_bour    | 0.681     | 0.574       | 0.719       | 0.839      |       |
| 0.620            |           |             |             |            |       |
| ## Cryp_anam     | 0.748     | 0.745       | 0.747       | 0.716      |       |

|                  |            |            |               |             |
|------------------|------------|------------|---------------|-------------|
| 0.704            |            |            |               |             |
| ## Cryp_law      | 0.812      | 0.719      | 0.825         | 0.692       |
| 0.688            |            |            |               |             |
| ## Dios_crum     | 0.724      | 0.550      | 0.796         | 0.690       |
| 0.578            |            |            |               |             |
| ## Dipte_indi    | 0.867      | 0.666      | 0.899         | 0.787       |
| 0.684            |            |            |               |             |
| ## Elaeo_mun     | 1.000      | 0.842      | 0.911         | 0.710       |
| 0.739            |            |            |               |             |
| ## Elaeo_recur   | 0.842      | 1.000      | 0.736         | 0.630       |
| 0.737            |            |            |               |             |
| ## Ficus_beddo   | 0.911      | 0.736      | 1.000         | 0.799       |
| 0.817            |            |            |               |             |
| ## Garci_wigh    | 0.710      | 0.630      | 0.799         | 1.000       |
| 0.831            |            |            |               |             |
| ## Gonio_wigh    | 0.739      | 0.737      | 0.817         | 0.831       |
| 1.000            |            |            |               |             |
| ## Humbo_vahl    | 0.785      | 0.691      | 0.871         | 0.898       |
| 0.869            |            |            |               |             |
| ## Hydno_pent    | 0.760      | 0.605      | 0.837         | 0.801       |
| 0.650            |            |            |               |             |
| ## Impati_parasi | 0.801      | 0.875      | 0.678         | 0.677       |
| 0.752            |            |            |               |             |
| ## Litse_oleoi   | 0.892      | 0.832      | 0.924         | 0.773       |
| 0.797            |            |            |               |             |
| ## Medi_anama    | 0.773      | 0.852      | 0.710         | 0.707       |
| 0.707            |            |            |               |             |
| ## Meiog_pann    | 0.923      | 0.769      | 0.916         | 0.779       |
| 0.725            |            |            |               |             |
| ## Ochn_gamb     | 0.460      | 0.398      | 0.562         | 0.391       |
| 0.439            |            |            |               |             |
| ## Prio_pinn     | 0.790      | 0.610      | 0.930         | 0.834       |
| 0.779            |            |            |               |             |
| ## Strob_kunt    | 0.853      | 0.917      | 0.774         | 0.563       |
| 0.734            |            |            |               |             |
| ## Syzy_densi    | 0.897      | 0.885      | 0.841         | 0.793       |
| 0.849            |            |            |               |             |
| ## Syzy_occi     | 0.640      | 0.533      | 0.801         | 0.912       |
| 0.727            |            |            |               |             |
| ## Syzy_palgh    | 0.712      | 0.672      | 0.738         | 0.716       |
| 0.710            |            |            |               |             |
| ## Syzy_param    | 0.748      | 0.894      | 0.664         | 0.708       |
| 0.795            |            |            |               |             |
| ## Syzy_sahya    | 0.788      | 0.920      | 0.711         | 0.689       |
| 0.738            |            |            |               |             |
| ##               | Humbo_vahl | Hydno_pent | Impati_parasi | Litse_oleoi |
| Medi_anama       |            |            |               |             |
| ## Aglai_mala    | 0.795      | 0.877      | 0.573         | 0.798       |
| 0.820            |            |            |               |             |
| ## Aporo_bour    | 0.772      | 0.855      | 0.633         | 0.708       |
| 0.753            |            |            |               |             |
| ## Cryp_anam     | 0.809      | 0.800      | 0.672         | 0.781       |

|                  |            |           |           |            |            |
|------------------|------------|-----------|-----------|------------|------------|
| 0.877            |            |           |           |            |            |
| ## Cryp_law      | 0.793      | 0.830     | 0.685     | 0.880      |            |
| 0.709            |            |           |           |            |            |
| ## Dios_crum     | 0.753      | 0.885     | 0.490     | 0.756      |            |
| 0.712            |            |           |           |            |            |
| ## Dipte_indi    | 0.807      | 0.929     | 0.658     | 0.857      |            |
| 0.741            |            |           |           |            |            |
| ## Elaeo_mun     | 0.785      | 0.760     | 0.801     | 0.892      |            |
| 0.773            |            |           |           |            |            |
| ## Elaeo_recur   | 0.691      | 0.605     | 0.875     | 0.832      |            |
| 0.852            |            |           |           |            |            |
| ## Ficus_beddo   | 0.871      | 0.837     | 0.678     | 0.924      |            |
| 0.710            |            |           |           |            |            |
| ## Garci_wigh    | 0.898      | 0.801     | 0.677     | 0.773      |            |
| 0.707            |            |           |           |            |            |
| ## Gonio_wigh    | 0.869      | 0.650     | 0.752     | 0.797      |            |
| 0.707            |            |           |           |            |            |
| ## Humbo_vahl    | 1.000      | 0.815     | 0.681     | 0.847      |            |
| 0.711            |            |           |           |            |            |
| ## Hydno_pent    | 0.815      | 1.000     | 0.609     | 0.793      |            |
| 0.708            |            |           |           |            |            |
| ## Impati_parasi | 0.681      | 0.609     | 1.000     | 0.743      |            |
| 0.803            |            |           |           |            |            |
| ## Litse_oleoi   | 0.847      | 0.793     | 0.743     | 1.000      |            |
| 0.779            |            |           |           |            |            |
| ## Medi_anama    | 0.711      | 0.708     | 0.803     | 0.779      |            |
| 1.000            |            |           |           |            |            |
| ## Meiog_pann    | 0.823      | 0.862     | 0.718     | 0.913      |            |
| 0.813            |            |           |           |            |            |
| ## Ochn_gamb     | 0.581      | 0.517     | 0.266     | 0.574      |            |
| 0.359            |            |           |           |            |            |
| ## Prio_pinn     | 0.867      | 0.835     | 0.544     | 0.862      |            |
| 0.651            |            |           |           |            |            |
| ## Strob_kunt    | 0.673      | 0.565     | 0.783     | 0.828      |            |
| 0.708            |            |           |           |            |            |
| ## Syzy_densi    | 0.828      | 0.693     | 0.913     | 0.879      |            |
| 0.788            |            |           |           |            |            |
| ## Syzy_occi     | 0.838      | 0.826     | 0.524     | 0.756      |            |
| 0.631            |            |           |           |            |            |
| ## Syzy_palgh    | 0.779      | 0.793     | 0.647     | 0.729      |            |
| 0.810            |            |           |           |            |            |
| ## Syzy_param    | 0.709      | 0.548     | 0.833     | 0.732      |            |
| 0.878            |            |           |           |            |            |
| ## Syzy_sahya    | 0.710      | 0.602     | 0.789     | 0.783      |            |
| 0.882            |            |           |           |            |            |
| ##               | Meiog_pann | Ochn_gamb | Prio_pinn | Strob_kunt | Syzy_densi |
| Syzy_occi        |            |           |           |            |            |
| ## Aglai_mala    | 0.880      | 0.575     | 0.830     | 0.605      | 0.669      |
| 0.816            |            |           |           |            |            |
| ## Aporo_bour    | 0.788      | 0.360     | 0.745     | 0.464      | 0.680      |
| 0.814            |            |           |           |            |            |
| ## Cryp_anam     | 0.813      | 0.551     | 0.716     | 0.657      | 0.717      |

|                  |            |            |            |       |       |
|------------------|------------|------------|------------|-------|-------|
| 0.669            |            |            |            |       |       |
| ## Cryp_law      | 0.864      | 0.570      | 0.772      | 0.711 | 0.767 |
| 0.661            |            |            |            |       |       |
| ## Dios_crum     | 0.849      | 0.571      | 0.787      | 0.500 | 0.587 |
| 0.731            |            |            |            |       |       |
| ## Dipte_indi    | 0.946      | 0.488      | 0.879      | 0.647 | 0.754 |
| 0.800            |            |            |            |       |       |
| ## Elaeo_mun     | 0.923      | 0.460      | 0.790      | 0.853 | 0.897 |
| 0.640            |            |            |            |       |       |
| ## Elaeo_recur   | 0.769      | 0.398      | 0.610      | 0.917 | 0.885 |
| 0.533            |            |            |            |       |       |
| ## Ficus_beddo   | 0.916      | 0.562      | 0.930      | 0.774 | 0.841 |
| 0.801            |            |            |            |       |       |
| ## Garci_wigh    | 0.779      | 0.391      | 0.834      | 0.563 | 0.793 |
| 0.912            |            |            |            |       |       |
| ## Gonio_wigh    | 0.725      | 0.439      | 0.779      | 0.734 | 0.849 |
| 0.727            |            |            |            |       |       |
| ## Humbo_vahl    | 0.823      | 0.581      | 0.867      | 0.673 | 0.828 |
| 0.838            |            |            |            |       |       |
| ## Hydno_pent    | 0.862      | 0.517      | 0.835      | 0.565 | 0.693 |
| 0.826            |            |            |            |       |       |
| ## Impati_parasi | 0.718      | 0.266      | 0.544      | 0.783 | 0.913 |
| 0.524            |            |            |            |       |       |
| ## Litse_oleoi   | 0.913      | 0.574      | 0.862      | 0.828 | 0.879 |
| 0.756            |            |            |            |       |       |
| ## Medi_anama    | 0.813      | 0.359      | 0.651      | 0.708 | 0.788 |
| 0.631            |            |            |            |       |       |
| ## Meiog_pann    | 1.000      | 0.520      | 0.863      | 0.737 | 0.814 |
| 0.758            |            |            |            |       |       |
| ## Ochn_gamb     | 0.520      | 1.000      | 0.531      | 0.474 | 0.391 |
| 0.457            |            |            |            |       |       |
| ## Prio_pinn     | 0.863      | 0.531      | 1.000      | 0.633 | 0.739 |
| 0.868            |            |            |            |       |       |
| ## Strob_kunt    | 0.737      | 0.474      | 0.633      | 1.000 | 0.851 |
| 0.487            |            |            |            |       |       |
| ## Syzy_densi    | 0.814      | 0.391      | 0.739      | 0.851 | 1.000 |
| 0.669            |            |            |            |       |       |
| ## Syzy_occi     | 0.758      | 0.457      | 0.868      | 0.487 | 0.669 |
| 1.000            |            |            |            |       |       |
| ## Syzy_palgh    | 0.777      | 0.544      | 0.680      | 0.632 | 0.680 |
| 0.656            |            |            |            |       |       |
| ## Syzy_param    | 0.700      | 0.281      | 0.594      | 0.777 | 0.856 |
| 0.581            |            |            |            |       |       |
| ## Syzy_sahya    | 0.747      | 0.363      | 0.648      | 0.820 | 0.835 |
| 0.613            |            |            |            |       |       |
| ##               | Syzy_palgh | Syzy_param | Syzy_sahya |       |       |
| ## Aglai_mala    | 0.850      | 0.642      | 0.725      |       |       |
| ## Aporo_bour    | 0.717      | 0.606      | 0.632      |       |       |
| ## Cryp_anam     | 0.906      | 0.713      | 0.754      |       |       |
| ## Cryp_law      | 0.746      | 0.601      | 0.649      |       |       |
| ## Dios_crum     | 0.835      | 0.482      | 0.563      |       |       |
| ## Dipte_indi    | 0.758      | 0.607      | 0.658      |       |       |

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|                  |       |       |       |
|------------------|-------|-------|-------|
| ## Elaeo_mun     | 0.712 | 0.748 | 0.788 |
| ## Elaeo_recur   | 0.672 | 0.894 | 0.920 |
| ## Ficus_beddo   | 0.738 | 0.664 | 0.711 |
| ## Garci_wigh    | 0.716 | 0.708 | 0.689 |
| ## Gonio_wigh    | 0.710 | 0.795 | 0.738 |
| ## Humbo_vahl    | 0.779 | 0.709 | 0.710 |
| ## Hydno_pent    | 0.793 | 0.548 | 0.602 |
| ## Impati_parasi | 0.647 | 0.833 | 0.789 |
| ## Litse_oleoi   | 0.729 | 0.732 | 0.783 |
| ## Medi_anama    | 0.810 | 0.878 | 0.882 |
| ## Meiog_pann    | 0.777 | 0.700 | 0.747 |
| ## Ochn_gamb     | 0.544 | 0.281 | 0.363 |
| ## Prio_pinn     | 0.680 | 0.594 | 0.648 |
| ## Strob_kunt    | 0.632 | 0.777 | 0.820 |
| ## Syzy_densi    | 0.680 | 0.856 | 0.835 |
| ## Syzy_occi     | 0.656 | 0.581 | 0.613 |
| ## Syzy_palgh    | 1.000 | 0.661 | 0.685 |
| ## Syzy_param    | 0.661 | 1.000 | 0.935 |
| ## Syzy_sahya    | 0.685 | 0.935 | 1.000 |

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## **APPENDIX V**

### **List of Publications and Presentations**

#### **A. Publications in Journals**

1. Devika, M. A., & Bachan, A. K. H. (2025). Integrating niche modelling and species assemblage to assess current and future habitats of threatened *Diospyros crumenata* under climate change. *Ecological Frontiers*, 45(5), 1297–1306. <https://doi.org/10.1016/j.ecofro.2025.05.001>
2. Bachan, A. K. H., & Devika, M. A. (2025). Niche modelling with vegetation inputs for Grinnellian and Eltonian niche factors in niche specific conservation and ecorestoration planning. *Plant Ecology*, 226, 883–893. <https://doi.org/10.1007/s11258-025-01537-7>
3. Devika, M. A., & Bachan, A. K. H. (2024). Niche model-based conservation and ecorestoration area prediction of threatened *Prioria pinnata* (Fabaceae) and conservation implication on IUCN status. *Acta Ecologica Sinica*, 44(2), 381–390. <https://doi.org/10.1016/j.chnaes.2023.10.002>
4. Devika, M. A., & Bachan, A. K. H. (2023). Ecoregion-level niche specific habitat prediction of threatened *Syzygium caryophyllum* (Myrtaceae) for reintroduction and ecorestoration. *Indian Journal of Forestry*, 46(2), 78–86. <https://doi.org/10.54207/bsmps1000-2023-663HOX>
5. Afrah, M., Shifamol, T. A., Dileep, S. D., Devika, M. A., & Bachan, A. K. H. (2025). Inventory and conservation of threatened trees in the Sree Narayanapuram Grama Panchayath, Kerala, India. *Cornous Environmental Science*, 2(1), 16–27. <https://doi.org/10.37446/ces/ras/2.1.2025.16-27>
6. Fitha, T. M., Fasna, K. M., Irfana Parvin, C. A., Mubeena, P. N., Karthika, K. B., Bachan, A. K. H., & Devika, M. A. (2025). Preliminary monitoring of mangrove ecorestoration: A case study in the Sree Narayanapuram Grama Panchayath, Kerala. *Journal of Indian Association for Environmental Management*, 45(2), 25–34.
7. Bachan, A. K. H., Devika, M. A., Anitha, K. T., & Aswin, K. B. (2025). Indigenous language unlocks ecological insights on hornbills, purple frog and others: The



- Western Ghats Kadar experience. *Cornous Biology*, 3(3), 1–9.  
<https://doi.org/10.37446/corbio/ras/3.3.2025.1-9>.
8. Bachan, A. K. H., & Devika, M. A. (2023). *Cryptocarya lawsonii*. *The IUCN Red List of Threatened Species*, 2023: e.T159104035A159444007.  
<https://dx.doi.org/10.2305/IUCN.UK.2023-1.RLTS.T159104035A159444007.en>
  9. Bachan, A. K. H., & Devika, M. A. (2023). *Diospyros crumenata* (errata version published in 2024). *The IUCN Red List of Threatened Species*, 2023: e.T30864A261429932.  
<https://dx.doi.org/10.2305/IUCN.UK.2023-1.RLTS.T30864A261429932.en>
  10. Bachan, A. K. H., & Devika, M. A. (2024). *Elaeocarpus recurvatus*. *The IUCN Red List of Threatened Species*, 2024: e.T33642A117645817.  
<https://dx.doi.org/10.2305/IUCN.UK.2024-1.RLTS.T33642A117645817.en>
  11. Bachan, A. K. H., & Devika, M. A. (2023). *Ficus beddomei*. *The IUCN Red List of Threatened Species*, 2023: e.T210013452A210023277.  
<https://dx.doi.org/10.2305/IUCN.UK.2023-1.RLTS.T210013452A210023277.en>
  12. Verspagen, N., Erkens, R. H. J., Bachan, A. K. H., & Devika, M. A. (2022). *Goniothalamus wightii*. *The IUCN Red List of Threatened Species*, 2022: e.T179206765A179206767.  
<https://dx.doi.org/10.2305/IUCN.UK.2022-1.RLTS.T179206765A179206767.en>
  13. Devika, M. A., & Bachan, A. K. H. (2024). *Impatiens parasitica*. *The IUCN Red List of Threatened Species*, 2024: e.T239578975A239579834.  
<https://dx.doi.org/10.2305/IUCN.UK.2024-1.RLTS.T239578975A239579834.en>
  14. Devika, M. A., & Bachan, A. K. H. (2023). *Medinilla anamalaiana*. *The IUCN Red List of Threatened Species*, 2023: e.T239579056A239579839.  
<https://dx.doi.org/10.2305/IUCN.UK.2023-1.RLTS.T239579056A239579839.en>
  15. Verspagen, N., Erkens, R. H. J., Bachan, A. K. H., & Devika, M. A. (2022). *Meiogyne pannosa*. *The IUCN Red List of Threatened Species*, 2022: e.T179067254A179067264.  
<https://dx.doi.org/10.2305/IUCN.UK.2022-1.RLTS.T179067254A179067264.en>
  16. Bachan, A. K. H., & Devika, M. A. (2023). *Ochna gamblei*. *The IUCN Red List of Threatened Species*, 2023: e.T208974595A209009666.  
<https://dx.doi.org/10.2305/IUCN.UK.2023-1.RLTS.T208974595A209009666.en>

17. Devika, M. A., & Bachan, A. K. H. (2023). *Prioria pinnata*. *The IUCN Red List of Threatened Species*, 2023: e.T33647A201031235. <https://dx.doi.org/10.2305/IUCN.UK.2023-1.RLTS.T33647A201031235.en>
18. Bachan, A. K. H., & Devika, M. A. (2024). *Strobilanthes kunthiana*. *The IUCN Red List of Threatened Species*, 2024: e.T239578615A239579829. <https://dx.doi.org/10.2305/IUCN.UK.2024-1.RLTS.T239578615A239579829.en>
19. Devika, M. A., & Bachan, A. K. H. (2025). *Syzygium densiflorum*. *The IUCN Red List of Threatened Species*, 2025: e.T38820A115933387.
20. Bachan, A. K. H., & Devika, M. A. (2023). *Syzygium occidentale*. *The IUCN Red List of Threatened Species*, 2023: e.T31199A119040796. <https://dx.doi.org/10.2305/IUCN.UK.2023-1.RLTS.T31199A119040796.en>
21. Bachan, A. K. H., & Devika, M. A. (2023). *Syzygium palghatense*. *The IUCN Red List of Threatened Species*, 2023: e.T31200A149812631. <https://dx.doi.org/10.2305/IUCN.UK.2023-1.RLTS.T31200A149812631.en>
22. Bachan, A. K. H., & Devika, M. A. (2023). *Syzygium parameswaranii*. *The IUCN Red List of Threatened Species*, 2023: e.T38821A119040966. <https://dx.doi.org/10.2305/IUCN.UK.2023-1.RLTS.T38821A119040966.en>

## B. Publications as Book Chapters

1. Devika, M. A., & Bachan, A. K. H. (2022). Addressing the limitations of niche modelling for species distribution prediction with reference to the Western Ghats. In *Proceedings of the National Seminar "Species The Passion 7"* (pp. 41–55).
2. Bachan, A. K. H., & Devika, M. A. (2022). Niche profiling and niche modelling of endangered *Cryptocarya anamalayana* endemic to Western Ghats for conservation and restoration. In D. A. DellaSala & M. I. Goldstein (Eds.), *Imperiled: The encyclopedia of conservation* (Vol. 1, pp. 751–764). Elsevier. <https://doi.org/10.1016/B978-0-12-821139-7.00225-7>
3. Bachan, A. K. H., Pooja, S., & Devika, M. A. (2022). Riparian forest of Western Ghats, an endangered ecosystem. In D. A. DellaSala & M. I. Goldstein (Eds.), *Imperiled: The encyclopedia of conservation* (Vol. 2, pp. 100–113). Elsevier. <https://doi.org/10.1016/B978-0-12-821139-7.00207-5>

### C. Publications as Book

1. Bachan, A. K. H., Mohanan, M. S., Rehana, P. A., Devika, M., & Syamili, N. M. (2025). *Restoring the coasts: A community blueprint for ecological revival – The Sreenarayanapuram Grama Panchayat model*. Zenodo, Niche Publications, BMC Sreenarayanapuram. Pages 76. <https://doi.org/10.5281/zenodo.15425764>

### D. Paper presentations (National and International Conferences)

1. **IUCN Red List Assessment and Niche Specific Conservation Planning for Threatened Angiosperms in the Western Ghats**, in the National Seminar Species the Passion 10, held at St Thomas College (Autonomous), Thrissur, on 28<sup>th</sup> & 29<sup>th</sup> January 2025. (Received best paper presentation award with cash prize).
2. **Climate Change Impact on Future Habitat and Conservation of Epiphytes of the Submontane Pseudo-Shola Forests in the Western Ghats**, in the International Seminar on Exploring the Intersections of Biodiversity, Ecology, and Sustainable Agriculture, held at Carmel College (Autonomous), Mala, on 19<sup>th</sup> December 2024.
3. **IUCN Red List Assessment, Niche Specific Conservation Planning and Community based Ecorestoration of Threatened Angiosperms in the Western Ghats**, in the Teresian Centenary International Multidisciplinary Conclave, held at St Teresa's College (Autonomous), Ernakulam, on 16<sup>th</sup> to 18<sup>th</sup> December 2024.
4. **Role of fungal interaction and climate change in germination and niche specific ecorestoration of Critically Endangered *Diospyros crumenata* Thwaites**, in the National seminar on Biodiversity & Climate Change held at MES Asmabi College, P. Vemballur, on 18<sup>th</sup> & 19<sup>th</sup> January 2024 (Received best presentation award).
5. **Climate Change Resilience Through Niche Specific Ecosystem Restoration**, in the National Seminar Climate change & Biodiversity held at Vimala College, Thrissur, on 9<sup>th</sup> August 2023.
6. **Niche specificity of Malabar Pied Hornbill and Conservation of Endangered Low elevation riparian forest ecosystem in the Western Ghats**, in the 8th International Hornbill Conference, Happy Hornbills-Healthy Forests. Kasetsart University, Bangkok in Thailand, held on 22<sup>nd</sup> to 24<sup>th</sup> May 2023.

7. **Niche Specific Prediction and Profiling of Threatened Trees of the Western Ghats Contributing to IUCN Red List Assessment and Restoration**, in the ESPLORO 23 Annual Research Conclave & International Conference on Advancement in Research, held at M.E.S Asmabi College, P. Vemballur, on 29<sup>th</sup> & 30<sup>th</sup> March 2023 (Received best presentation award).
8. **Modified Niche Modelling of the Threatened Trees for Restoration of Rainforest Habitats**, in the International Conference on Recent Advances in Biological Science, held at University of Kerala, Kariavattom, on 17<sup>th</sup> to 19<sup>th</sup> January, 2023 (Received best presentation award).
9. **Predicting and Profiling Niches of Threatened Tree Species Contributing to IUCN Status Assessment, Ecosystem Based Conservation and Niche Specific Restoration**, in the 32nd Annual Conference of Indian Association for Angiosperm Taxonomy and National Symposium held at Karnataka Science College, Dharwad, Karnataka, on 11<sup>th</sup> to 13<sup>th</sup> November 2022.
10. **IUCN Red List Assessment, Niche Modelling and Profiling Contributing for Niche Specific Restoration of Threatened Angiosperms in the Western Ghats**, in National Seminar Biodiversity Challenges and Threats; Current Scenario held at Sree Narayana College, Kollam, on 21<sup>st</sup> & 22<sup>nd</sup> December 2022 (Received best presentation award).



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| 2. | Title of thesis / dissertation | NICHE SPECIFICITY AND OVERLAP OF THREATENED ANGIOSPERMS IN THE WESTERN GHATS AND ITS APPLICABILITY IN RED LIST ASSESSMENT, CONSERVATION AND ECORESTORATION |                                                                  |
| 3. | Name of the Supervisor         | Dr. Amitha Bachan KH                                                                                                                                       |                                                                  |
| 4. | Department/Institution         | Research Department of Botany, MES Asmabi College, P. Vemballur, Thrissur                                                                                  |                                                                  |
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