CLIMATE VULNERABILITY ASSESSMENT AND ADAPTATION PLAN OF TAMIL NADU

FOREST HABITAT SUITABILITY

Under

CLIMATE STUDIO

REPORT

2024

Supported by
Department of Environment and Climate Change
Government of Tamil Nadu

Prepared by
Centre for Climate Change and Disaster Management
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PREFACE

Forests play an indispensable role in maintaining the ecological balance, supporting biodiversity and providing livelihoods for millions. Tamil Nadu forest, rich in diversity and resources are at the forefront of both conservation and climate adaptation efforts. As the state faces the challenges of a changing climate, the need for comprehensive strategies to protect these ecosystems has never been more urgent. The "Climate Risk Assessment and Adaptation Plan for Forest Habitat Suitability in Tamil Nadu" offers a crucial response to these challenges, blending science, policy and community engagement to build a resilient future.

This report is the result of extensive research and collaboration among leading experts, government departments and local communities. It offers not just an analysis of the vulnerabilities that forests face, but also a roadmap for sustainable land management; climate adaptation, and biodiversity conservation. By focusing on Good Forestry Practices, soil health, water resource management and the restoration of native species, this plan emphasizes a holistic approach to ecosystem resilience.

The involvement of local communities, who depend on these forests for their livelihood is a key element in ensuring the long-term success of the strategies outlined. Through collective action, education and awareness. these communities become active stewards of their environment, helping to safeguard the forest ability to continue providing essential services from carbon sequestration to water regulation.

This report symbolizes a forward-thinking vision for Tamil Nadu forests and is a testament to the state proactive stance in addressing the climate crisis. It not only highlights the importance of mitigating the risks posed by climate change in forest sector but also showcases the opportunities for building resilience, fostering equity and securing a sustainable future for the state forest ecosystems.

As we present this landmark report, it is our hope that the strategies and insights provided within will serve as a foundation for future efforts in forest conservation and climate resilience in Tamil Nadu and beyond.

(P.Senthilkumar)

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FOREWORD

Forests play an important role in the conservation of natural resources. Forests contribute significantly towards ecosystem services including carbon sequestration, water regulation, habitat provision, facing unique risks and opportunities in the face of climate change. As we stand on the precipice of a rapidly changing climate landscape, it becomes increasingly evident that our forest habitats must evolve to withstand and adapt to these environmental challenges.

The Government of Tamil Nadu has established Climate Studio at Centre for Climate Change and Disaster Management, Anna University to develop regional climate scenarios using regional climate models and prepare sectoral impcts and Climate Risk Assessment and Adaptation Plan for Tamil Nadu in various sectors.

The report of Climate Risk Assessment and Adaptation Plan for Forest Habitat Suitability in Tamil Nadu is not only serves as a testament to the proactive stance of Tamil Nadu in confronting climate Change but also provides a blueprint for conservation strategies and sustainable land management, offering valuable insights into the impacts of climate change and human activities on these vital ecosystems.

The Adaptation Strategies outlined in this plan offer Good Forestry Practices (GFP), emphasizing soil health, water supply improvement and erosion prevention. Growing native tree species suited to different soils is vital. Successful ecosystem restoration requires active local community involvement with awareness about forests role in carbon absorption and other crucial environmental services.

I am extremely thankful to Dr.P.Senthilkumar, I.A.S., Principal Secretary to the Government, Environment, Climate Change and Forests Department for his valuable guidance and unwavering support in the successful operationalization of the Climate Studio.

I appreciate the efforts of Dr. Kurian Joseph, Professor & Director, Centre for Climate Change and Disaster Management, Dr. A. Ramachandran, Emeritus Professor, Centre for Climate Change and Disaster Management and research team of Climate Studio for collecting, collating and analyzing scientific information from various sectors and compiling the report in the present form.

I would like to extend my appreciation to all the Government line Departments and Institutions for their valuable contributions by providing essential data and information, which played a crucial role in the successful operationalization of the Climate Studio project.

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ACKNOWLEDGEMENT

We sincerely acknowledge the support and encouragement by Dr. P. Senthilkumar, I.A.S., Principal Secretary to the Government, Environment, Climate Change and Forests Department. We express our sincere gratitude to Tmt. Supriya Sahu IAS., former Additional Chief Secretary to Government, Department of Environment, Climate Change and Forests, Government of Tamil Nadu, Thiru. A.R. Rahul Nadh IAS., Director, Department of Environment and Climate Change, Government of Tamil Nadu and Thiru. Deepak Bilgi IFS., Chief Mission Director, Tamil Nadu Coastal Restoration Mission, for the successful execution of the project "Operationalisation of Climate Studio" and in completion of the Climate Risk Assessment and Adaptation Plan for the key sectors of Tamil Nadu.

We humbly acknowledge Prof. Dr. R. Velraj, the former Honourable Vice Chancellor, Anna University, Prof. Dr. K.P. Jaya, Head of the Department, Department of Civil Engineering, Dr. K. Palanivelu, Professor, CCCDM, Dr. R. Saravanan, Professor and Director, CWR and the adjunct faculty of CCCDM, Anna University for their valuable inputs and expertise. Further, we acknowledge the support from the following departments for providing the necessary data for the completion of the Climate Risk Assessment and Adaptation Plan for the key sectors of Tamil Nadu:

- Department of Environment, Climate Change and Forests (DoE&CC), Government of Tamil Nadu
- Indian Meteorological Department (IMD), Ministry of Earth Sciences, Government of India
- Central Ground Water Board (CGWB), SECR, Ministry of Jal Shakthi, Department of Water Resources, River Development and Ganga Rejuvenation, Government of India
- State Planning Commission (SPC), Government of Tamil Nadu
- Tamil Nadu Agricultural University (TNAU)
- Department of Agriculture, Government of Tamil Nadu
- Department of Animal Husbandry, Government of Tamil Nadu
- Department of Fisheries and Fishermen Welfare, Government of Tamil Nadu
- Department of Statistics and Economics, Government of Tamil Nadu
- Department of Water Resources, Government of Tamil Nadu
- National Centre for Coastal Research (NCCR), Government of India
- Tamil Nadu Pollution Control Board (TNPCB), Government of Tamil Nadu
- Institute of Water Studies (IWS), Tharamani
- Institute of Remote Sensing (IRS), Anna University

We sincerely thank other project staff and administrative staff of CCCDM for their continuous support towards the successful execution of the project

EXECUTIVE SUMMARY

Forestry took new outlook after Kyoto Protocol 1997, focusing on Carbon Sequestration Potential in Forestry sector. Paris Agreement, 2015 and Sustainable Development Goals (SDG), accentuated and strengthened the Forestry Sector in regard to Enhancing Carbon Sink in forest floor especially reversal of land degradation and eco-restoration. The Intended Nationally Determined Contribution (INDC) of India, committed to enhance the carbon sink to 2.5 to 3 billion tonnes of Carbon equivalent in forestry sector, a prime agenda next to the Energy Sector. At this point it is imperative to study the forest cover and status of forest degradation to take up site-specific Good Forestry Practices (GFP) to enhance the carbon stock in forest.

CLIMATE STUDIO AT CCCDM

Embracing its commitment to the Nationally Determined Contribution (NDC), Tamil Nadu has emerged as a pioneer in developing adaptation strategies across sectors. Utilising the acclaimed IPCC framework on "Climate Change Risk Assessment," the Government of Tamil Nadu has established the 'Climate Studio' at the Centre for Climate Change and Disaster Management (CCCDM), Department of Civil Engineering, Anna University. This state-of-the- art facility, funded with Rs. 3.80 crores is equipped with high-performance computational resources and digital learning tools (financially supported by GIZ, Germany) to analyse global climate data at the cadastral level. The Climate Studio aims to provide updated high-resolution regional climate scenarios, assess climate change impacts on natural resources, develop multi-sectoral spatial information, and disseminate knowledge to stakeholders. Through capacity-building programs and workshops, over 250 sectoral officials and thousands of participants have been trained and sensitized, fostering a climate-resilient future for Tamil Nadu.

The present study focused on the distribution of different forest types and status of degradation at the cadastral level covering all the reserve forests in Tamil Nadu.

Analyzing, the 19 Bio-climatic variables, which are determining the forest cover are taken up and analyzed in all the hills of Western Ghats and Eastern Ghats. There are 2423 Reserve Forests in Tamil Nadu covering an area of 19841 sq. km. drawn based upon the Forest Survey of India Report. “Increasing temperature, intense rainfall and climate extremities like dry spells of post monsoon season, are detrimental on forest health which leads to gradual degradation of the forest types and species distribution”. The present study unfolds the present status of forests and probable shift of forest types due to induced bioclimatic variables as a consequence of changing climate. Current analysis of forest status in between 1985-2014 are taken as base period and the influences of bioclimatic variables in different climate scenario are analyzed up to near-century (2021-2050). The analysis reveals that the different forest types are visibly shifted to the xerophytic vegetation than that of the present condition. "It is observed that by 2050, evergreen and deciduous forest areas are projected to reduce by 32% and 18% respectively, while thorn forest suitability is expected to increase by 71%".

In the Eastern Ghats, habitat suitability for all forest types is expected to decline more, especially in Shervaroyan hills. Similarly, in the Western Ghats, there will be a decline in evergreen and deciduous forest particularly the northern portion of Western Ghats, the Nilgiris.

The thorn forests covering the degraded dry deciduous, euphorbia forest are increasing in their distribution in the foothills of both the Eastern Ghats and the Western Ghats. The accelerated degradation is primarily due to heavy temperature, altered rainfall pattern and prolonged dry spells in post monsoon season are primary components of the bioclimatic variables.

To protect and restore Thorn and Euphorbia forests from further damage, we need to use Good Forestry Practices. These practices focus on improving soil health by increasing the amount of organic matter in the soil, improving water supply, and preventing soil erosion. Some specific actions include:

Habitat Suitability of Different Forest Types in Tamil Nadu

Forest types	Baseline (1985-2014)	Near Century (2021-2050)	Area Changes (sq.km)	Changes (%)
	Area in sq.km			
Evergreen	1881	1281	600 (-)	32 (-)
Deciduous	13395	10942	2453 (-)	18 (-)
Thorn	4292	7345	3053 (+)	71 (+)

- Soil conservation and water augmentation such as contour wall check dams percolation ponds etc.,
- Protecting vulnerable and endangered tree species
- Regularly checking how well tree species can adapt to changing climate conditions
- Giving special attention to forests near rivers and streams, with measures to conserve soil
- Involving local communities in managing and monitoring forests
- Preserving wetlands in mountainous areas
- Planting trees with multi-layered canopies using local tree species in future afforestation projects
- Planting trees in a staggered pattern on hilly terrain
- Creating barriers to stop the spread of fires in fire-prone areas
- Removing non-native plants that can harm the ecosystem

It is also important to grow native tree species that are suited to different types of soil. Restoring these ecosystems can only be successful with the active involvement of local communities, through awareness programs about the role of forests in absorbing carbon dioxide and providing other important services to the environment.

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Abbreviations

AR6	Sixth Assessment Report	ISFR	India State of Forest Report
ASCII	American Standard Code for Information Interchange	MaxEnt	Maximum entropy model
AUC	Area Under curve	MC	Mid century
CO_2	Carbon dioxide	MRV	Monitoring, Reporting, and Verification
CO2e	Carbon dioxide equivalent	MSL	Mean sea level
DEM	Digital Elevation Model	NC	Near century
DF	Deciduous forest	NDC	Nationally Determined Contributions
DGPS	Differential Global Positioning Systems	NEM	Northeast Monsoon
EC	End of Century	RCP	Representative Concentration Pathways
EG	Eastern Ghats	RF	Reserve Forest
EVG	Evergreen forest	RFA	Recorded Forest Area
FSI	Forest Survey of India	ROC	Receiver Operating Characteristic
FRL	Forest Reference Level	SDM	Statistical Downscaling model
GBH	Girth Breast Height	SRTM	Shuttle Radar Topographic Mission
GHGs	Greenhouse gases	SSPs	Shared Socio-economic Pathways
GIS	Geographic information systems	SWM	Southwest Monsoon
GPS	Global Positioning System	TF	Thorn forest
GUI	Graphical User Interface	USGS	United States Geological Survey
IMD	India Meteorological Data	UNFCCC	United Nations Framework Convention on Climate Change
IPCC	Intergovernmental Panel on Climate Change	WG	Western Ghats

1. INTRODUCTION

Forests are the essential ecosystem that provides a wide range of ecological, economic, and social benefits. Also, forests are integral to the earth's climate system, acting as guardians against the adverse impacts of climate change. It acts as a natural carbon sinks, absorbing vast amounts of carbon dioxide from the atmosphere through the process of photosynthesis. Trees store carbon in their biomass and the soil, helping to regulate greenhouse gas concentrations and mitigate the impacts of climate change. The ability of forests to sequester carbon makes them indispensable in the fight against global warming.

Tamil Nadu's forests exhibit a remarkable variety, reflecting the state's diverse climatic and topographic conditions. In Tamil Nadu, the Eastern and Western Ghats are regions of immense biodiversity and are home to diverse forest types, including evergreen, deciduous, and thorn forests. In the central and northern parts, Tropical Moist Deciduous Forests dominate, showcasing deciduous trees that shed their leaves during specific seasons. The drier regions host Tropical Dry Deciduous Forests with a mix of deciduous trees adapted to seasonal changes. Tropical Dry Evergreen Forests grace the coastal regions, characterized by evergreen trees that withstand the arid conditions. The higher elevations of the Western Ghats house the unique Shola Forests, featuring stunted evergreen trees in a captivating mosaic pattern. Therefore, these forests play a crucial role in maintaining ecological balance, supporting biodiversity, and providing livelihoods to local communities. In Tamil Nadu, the overall area covered by the Western and Eastern Ghats with its three types of forest is 13,530.28 sq. km which is a Recorded Forest Area (RFA) namely, Reserve Forests (RFs) cover approximately for about 19,841 sq. km (15.20%). The evergreen forest types cover an area of 1881 sq. km (9.48%) while the deciduous forests cover 13395 sq. km (67.51%) and other forest types such as Mangroves and dry evergreen forest account for approximately 274 sq.km (1.38%) (Source: Forest Survey of India, 2021).

The Eastern Ghats of Tamil Nadu, located between 10.0° N to 13.0° N and 76.0° E to 80.5° E, runs parallel to India's east coast. This range serves as the source of many rivers and plays a vital role in the region's ecology. In Tamil Nadu, the Eastern Ghats extend from the Jawadi Hills in the north to the Alagar Hills in the south, covering 13 major hill ranges and spanning across 13 districts within Tamil Nadu, covering an expansive area of 4,100 sq. km.

The hills in this region vary in size, with areas ranging from 70 sq.km to 1,860 sq.km and altitudes between 180 meters above mean sea level (MSL) to 1,650 meters above MSL. The climate is characterized by mean minimum and maximum temperatures of 17°C and 33°C, respectively, with an average annual rainfall ranging from 800 to 1600 mm. The Eastern Ghats still harbor rich biodiversity, including over 960 species of angiosperm and gymnosperm plants. Many endemic, endangered, and medicinally important species can be found in these hills.

The Western Ghats of Tamil Nadu, situated between 8.15° N to 12.68° N and 77.52° E to 77.66° E, represent a continuous mountain range with some notable passes, including Palghat, Shencottah, Aralvaimozhi, and Achankoil. It plays a crucial role in the water resources of Tamil Nadu, with most of the rivers originating from these hills. This vast mountain range includes the Nilgiris in the north-west, to Agasthiyar Bio-reserve in the south-west. Covering approximately 9,428 sq.km in Tamil Nadu, the Western Ghats extend across 13 districts. The Western Ghats exhibit a wide range of altitudes, from around 180 meters above MSL, to an impressive 2,637 meters above MSL. The region experiences varying temperatures, with average minimum temperatures between 17°C to 20°C and maximum temperatures ranging from approximately 28°C to 35°C during the warmer months. These Western Ghats contribute significantly to the ecological diversity and natural beauty of Tamil Nadu, with their lush landscapes and unique flora and fauna. However, these forests face threats from various sources, including habitat loss, fragmentation, and degradation, largely due to human activities and climate change.

As the global climate undergoes unprecedented shifts, the importance of forests in regulating weather patterns, sequestering carbon, and supporting biodiversity becomes increasingly apparent. Conversely, deforestation and forest degradation contribute significantly to climate change. Anthropogenic activities like clearing of forests for agriculture, logging, and urbanization releases stored carbon back into the atmosphere, exacerbating the greenhouse effect. Thus, climate change is expected to significantly impact these forests, altering their habitat suitability and affecting biodiversity. Therefore, understanding the habitat suitability of these forests in the face of climate change is crucial for effective forest management and carbon sequestration in Tamil Nadu. This study focuses on assessing the habitat suitability of evergreen, deciduous, and thorn forests in the Eastern and Western Ghats of Tamil Nadu, providing valuable insights for conservation and management strategies.

The objective of the forest sector is to comprehend the changes in the habitat suitability among various forest types:

- Habitat Suitability of representative dominant species for different forest types in the Western Ghats and Eastern Ghats during the baseline and Near century under the SSP2 – 4.5 scenario
- Prioritization of vulnerable forest areas and recommend suitable adaptation actions.

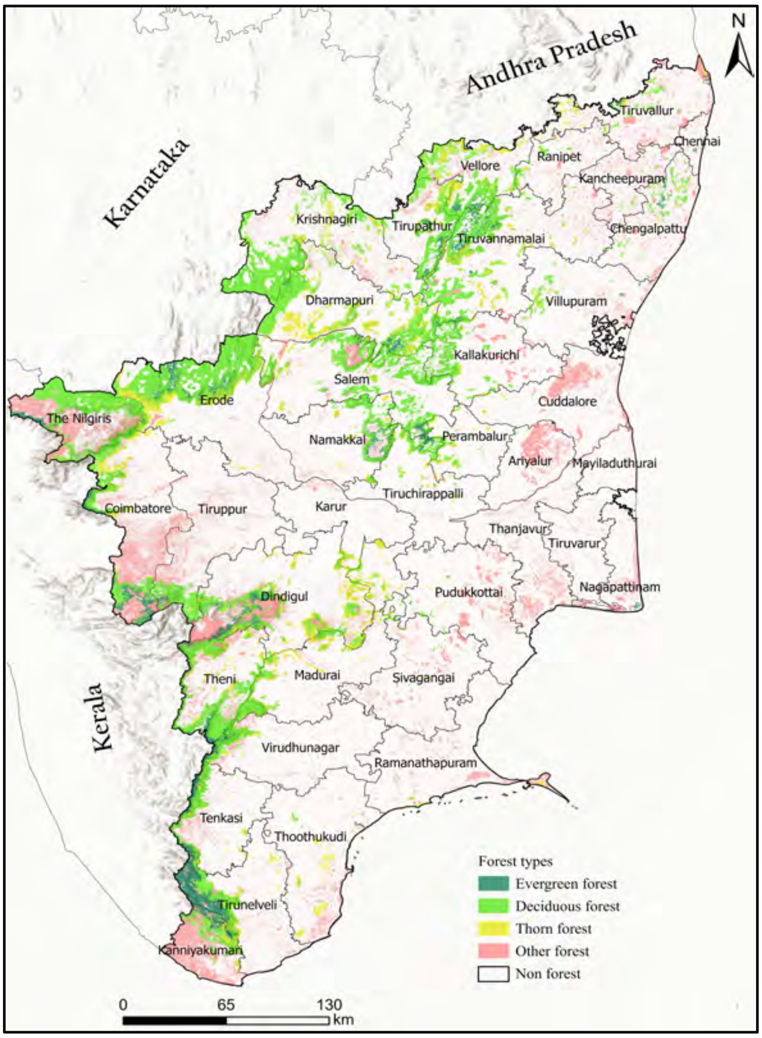

Figure 1. Spatial Extent of Forest Types in Tamil Nadu

1.1 Eastern Ghats of Tamil Nadu

The Eastern Ghats (between 10.0° N to 13.0° N and 76.0° E to 80.5° E) is a discontinuous mountain range running almost parallel to the east coast of India and constitutes the watersheds of many rivers.

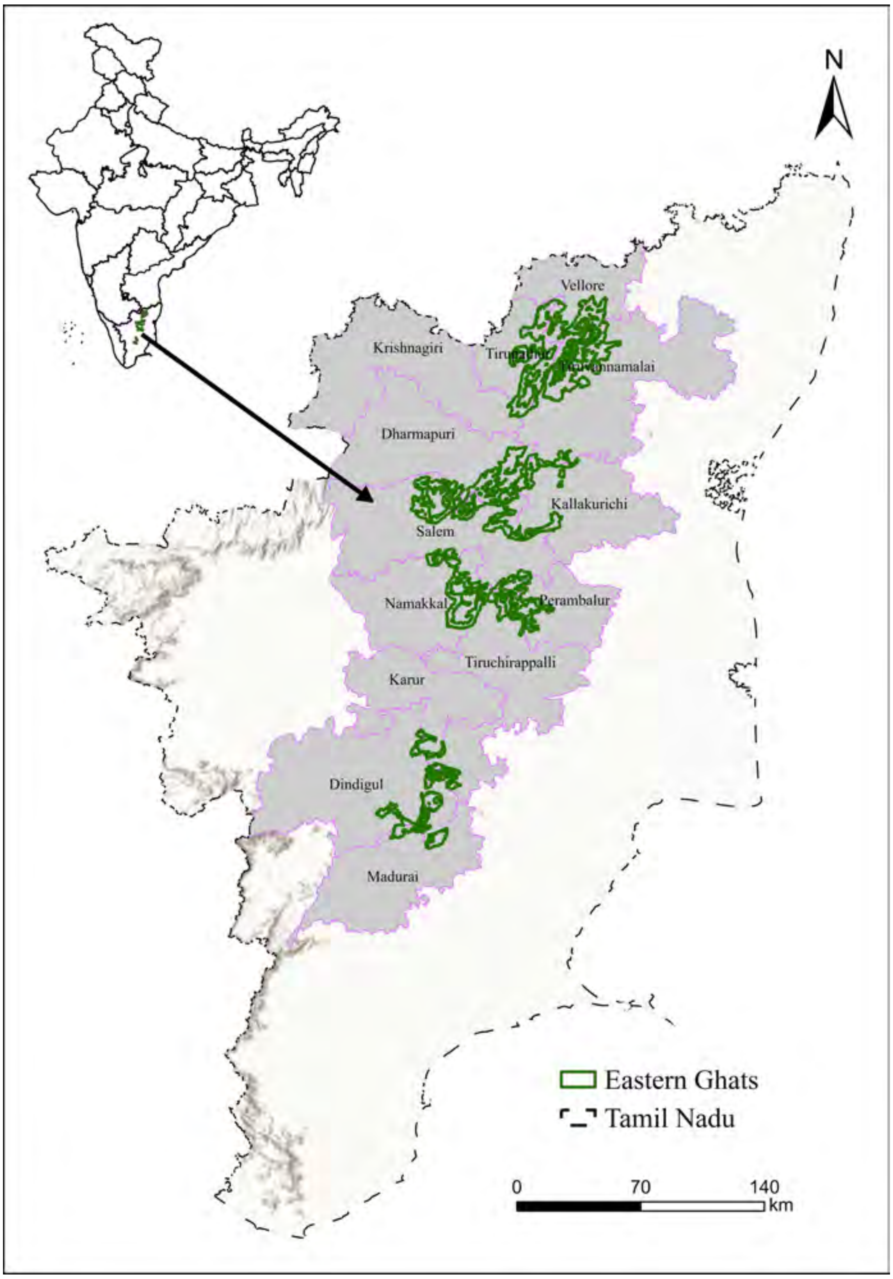

Figure 2. Geographical Location of Eastern Ghats

In Tamil Nadu, the EG start from the Jawadi Hills and extend up to the Alagar Hills (Figure 2), comprising 13 major hills (Jawadi, Elagiri, Shevaroy, Chitteri, Kalrayan, Bodamalai, Kolli, Pachaimalai, Semmalai, Aiyalur, Karandamalai, Sirumalai and Alagar) in 13 districts (Dharmapuri, Dindigul, Kallakurichi, Karur, Krishnagiri, Madurai, Namakkal, Perambalur, Salem, Tiruchirappalli, Tirupathur, Tiruvannamalai and Vellore) of Tamil Nadu.

The hills of the EG in Tamil Nadu range from 70 km^2 to 1860 km^2 in area, and the altitude in this region ranges from 180 m above mean sea level (MSL) to 1650 m above MSL. The mean minimum and maximum temperatures are 17°C and 33°C, respectively, and the average annual rainfall is 800–1600 mm. The major soil types are entisols, inceptisols, and alfisols. Geologically, the EG consist of charnockite with minor bands of pyroxin granulate and magnetite quartzite. The tributaries of many major rivers like the Pennaiyar, Palar, Vellar, Cauvery, and Vaigai originate from these hills. These hills are still rich in biodiversity, despite heavy exploitation, and they contain more than 960 species of angiosperm and gymnosperm. There are many endemic, endangered, and medicinally important species distributed within these hills (Ramachandran et al., 2016).

1.2. Western Ghats of Tamil Nadu

The Western Ghats (Longitude- 75°58′ to 77°62′ N and Latitude - 8°17′ to 11°25′ E) extend from the Niligris in the north to Marunthuvazh Malai at Swamithope in Kanyakumari district in the south (Figure 3). The hilly region along the north and the west along the whole length of the western part, at a distance from the sea varying from 80 to 160 km runs the range of Western Ghats, a steep and rugged mass averaging 1220m above MSL and rising to 2554 m at Mukurti and 2637 m at Doddabetta in Nilgiris. It has tropical evergreen, semi-evergreen and deciduous forests, as well as savannahs intermixed with cultivated lands and settled areas in the valleys. The Eastern Ghats from Andhra Pradesh cut across the State to meet the Nilgiri hils. The 'Palghat gap' of about 30 km width is the only marked break in the Western Ghats. It covers an area of about 2,500 sq.km. Though the Western Ghats is a continuous range, it has some passes. The passes are Palghat, Shencottah, Aralvaimozhi, and Achankoil. The Niligris, Anaimalai, Palani hills, Cardamom hills, Varusanadu, Andipatti and Agasthiyar hills are the major hills of Western Ghats.

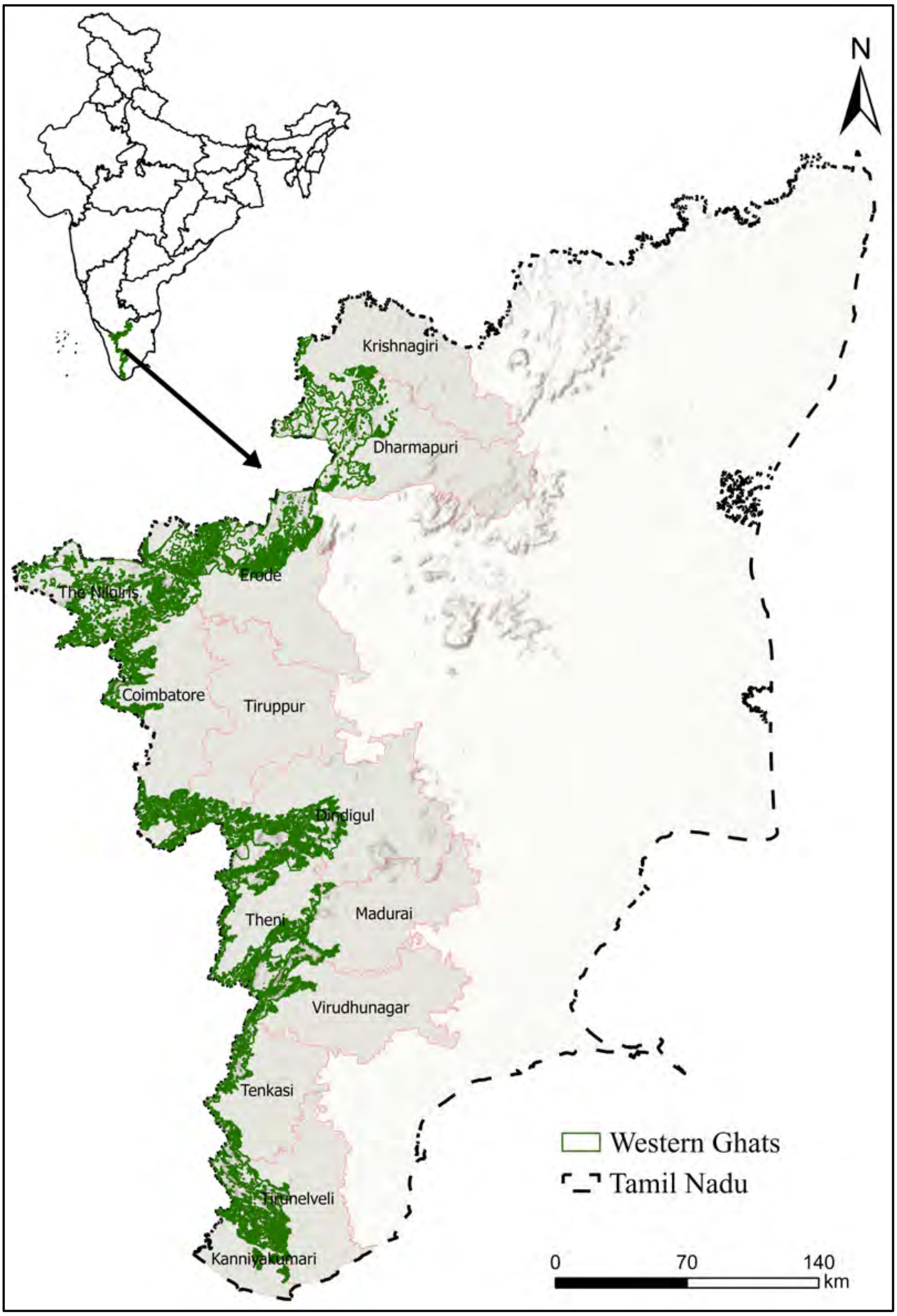

Figure 3. Geographical Location of Western Ghats

The Western Ghats effectively intercept a significant portion of rain-bearing clouds carried by the southwest monsoon, preventing their entry into the State. The northern-western and southern hilly regions boast abundant natural vegetation. The northern parts consist of a blend of hills and plains, while the eastern segments feature lush coastal lowlands. The central and south-central areas receive less rainfall due to their desert-like plains. When the monsoon falters, Tamil Nadu faces acute water scarcity and severe drought since the state relies heavily on rainfall to replenish its water reserves. Annually, the State receives an average of 989 mm of rainfall. This precipitation is sourced mainly from the northeast monsoon (48 percent) and the southwest monsoon (32 percent), enveloping a diverse array of ecosystems. The range extends from montane rain forests in the Western Ghats' southern slopes, traversing the south Deccan plateau's dry deciduous forests and Deccan thorn scrub forests, further encompassing tropical dry broadleaved forests, and culminating in the coastal realms of beaches, estuaries, salt marshes, mangroves, and coral reefs along the Bay of Bengal.

1.3 Profile of Tamil Nadu Forest Types

Diverse forest types grace the composite slopes of both the Eastern and Western Ghats in Tamil Nadu. These encompass the realms of Evergreen, Deciduous, and Thorn forests, meticulously classified according to the framework laid out by Champion & Seth (1968).

In the realm of Evergreen forests, an array of variations emerges, such as the 1A/C3 Southern hilltop tropical evergreen forest, 1A/C4 West Coast tropical evergreen forest, 2A/C2 West Coast semi-evergreen forest, 2A/C3 Tirunelveli semi-evergreen forest, 7/C1 Tropical dry evergreen forest, 7/DS1 Tropical dry evergreen scrub, and 8A/C1 Nilgiri subtropical hill forest.

Meanwhile, the Deciduous forests reveal their own captivating tapestry with the likes of the 2/E3 Moist bamboo brakes, 3B/C1a Very moist teak forest, 3B/C1b Moist teak forest, 3B/C1c Slightly moist teak forest, 3B/C2 Southern moist mixed deciduous forest, 3B/C2/2S1 Southern Secondary Moist mixed deciduous forest, 4E/RS1 Riparian fringing forest, 5A/C1a Very dry teak forest, 5A/C1b Dry teak forest, 5A/C2 Dry red sanders-bearing forest, 5A/C3 Southern dry mixed deciduous forest, 5/DS1 Dry deciduous scrub, 5/DS4 Dry grassland, 5/E9 Dry bamboo brakes, 5/1S1 Dry tropical riverain forest, 5/2S1 Secondary dry deciduous forest, and 11A/C1 Southern montane wet temperate forest.

Lastly, the Thorn forest domain boasts its own distinctive collection, including the 5/DS2 Dry savannah forest, 5/DS3 Euphorbia scrub, 6A/C1 Southern thorn forest, 6A/C2 Carnatic umbrella thorn forest, 6A/DS1 Southern thorn scrub, 6A/DS2 Southern Euphorbia scrub, 8A/DS1 South Indian sub-tropical hill savannah (woodland), 8A/E1 Reed brakes (Ochalandra), and 11A/C1/DS1 Southern montane wet scrub.

1.3.1 Evergreen forest

This forest type is referred to locally as 'shola forest' which are generally located 1000 m above MSL. The general composition includes *Memecylon edule, Neolitsea scrobiculata, Persea macrantha, Memecylon umbellatum, Elaeocarpus serratus, Syzygium cumini, Canarium strictum, Artocarpus heterophyllus, Artocarpus hirsuta,* and *Alangium salvifolium*, while the dominant shrub species are *Psychotria subintegra, Mesa indica, Glycosmis mauritiana, Phyllanthus wightianus, Tarenna asiatica, Lantana camara, and Clausena dentata,* among others.

1.3.2 Deciduous forest

This forest type is widely distributed throughout the eastern and western ghats and is found in all types of topography, such as valleys, plateaus, and foothills from 400 m up to 1000 m above MSL. The species composition in the upper and middle slopes consists of *Albizia odoratissima, Bridelia retusa, Chloroxylon swietenia, Terminalia chebula, T. bellirica, Tectona grandis, Schleichera oleosa, Sapindus emarginatus, Emblica officinalis, Pterocarpus marsupium, Dalbergia latifolia, Gyrocarpus asiaticus, and Moringa oleifera,* among others, while the dominant shrubs are *G. mauritiana, L. camara, Pterolobium hexapetalum, Ziziphus oenoplia, and Acacia pennata,* among others.

1.3.3 Thorn/Euphorbia forest

This forest type is the most affected and degraded in nature and is distributed throughout the entire lower hills and foothills at. The <400 m above MSL, as it appears near adjoining villages. The main tree species are *Acacia planifrons, Acacia leucophloea, Albizia amara, Azadirachta indica, Streblus asper, and Wrightia tinctoria,* among others, and this forest type also contains heavy impenetrable thorny species such as *Carissa carandas, Dichrostachys cineraria, Pterolobium* *hexapetalum, P. indicum, Randia dumetorum, Toddalia asiatica, Euphorbia antiquorum, and Z. oenoplia*, among others.

1.4 Challenges on Tropical Forest Ecosystem

In the 19th century, tropical deforestation emerged as a significant concern, as colonial powers relied on forest ecosystems for timber and other products. Between the 1960s and 1980s, rapid population growth led to increased deforestation for rural development, driven by government policies, particularly in developing countries (Rudel, 2005). In 1984, Mayers identified shifting cultivation as a major cause of tropical deforestation, though global concern about this issue only surfaced in the mid-20th century. According to Geist and Lambin (2002), agriculture, ranching, timber extraction, road construction, and mining are the immediate causes of deforestation. However, recent trends show a shift towards industrial-driven deforestation (Geist & Lambin, 2002; Rudel, 2005), which has accelerated the per-capita rate of forest loss and impacted conservation efforts (Wight & Muller-Landau, 2006).

The demand for energy, particularly liquid fuels, has increased with industrialization. The inventory of biofuels to meet this demand poses a threat to tropical forest systems, as the flora in the tropics are the primary feedstock for biofuels (Sunderlin et al., 2008; Laurance, 2008; Scharlemann & Laurance, 2008). In addition to these threats, emerging climate variability is also accelerating tropical forest degradation.

1.5 Climate Change Impact on Forest Ecosystem

Global consensus on climate change is now rapidly advancing and extensive. Many scientists including the IPCC has already unfolded the appropriate evidences of the reality of changing climate and its associated impacts on various sectors. Noticed increase in temperature, rainfall variations and weather extremities are the signs of climate change. Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century (IPCC 2014). The observed major changes in this century are increase in atmospheric concentrations of carbon dioxide, increased land and ocean temperatures, changes in precipitation and sea level rise. This has resulted in many impacts on various aspects of biota. However, the projected rates of change for the 21st century are faster than the 20th century (CBD 2003). This drastic change has severe impacts on various ecosystems especially forest ecosystem and its biodiversity which is concluded that forest ecosystems could be extremely impacted by future climate change. Even with a temperature increase of 1-2 °C most ecosystems and landscapes will be impacted through changes in species composition, productivity and biodiversity (Leemans & Eickhout 2004).

Table 1.Types of forest classification in Tamil Nadu

Climate factor	Cell level	Organism level	Species level	Ecosystem level
CO_2 increase	Photo synthetic rate increase Stomata conductance reduction	Growth rate increase Water use efficiency increase Seed production increase	Seed mortality decrease Recruitment increase Changes in individuals density	Biomass production increase Alteration in species competitiveness
Temperature increase	Photosynthesis increase or decrease Photosynthetic period can increase Transpiration increase	Primary production positive or negative change Seed production change	Regeneration rate changes Increase in tree mortality Negative impact on temperature sensitive species	Alteration in species competitiveness Species composition changes Increase of soil mineralization
Rainfall changes	Growth rate decrease	Seed mortality rate increase	Increase of mature individuals mortality	Alteration in species competitiveness and composition

In order to tackle these impacts, the scientific community has developed two mechanism called mitigation and adaptation. Former will reduce the emissions and the later one will concentrate on coping up with the changes or impacts. Recently scientific community has widely recognized the preventive role of forest ecosystem in mitigating climate change by carbon sequestration and prioritizing adaptation for conserving biodiversity. This dual role played by forest ecosystem brought forestry in to the main focus of International Climate Change Policy negotiations from the 13th COP of UNFCCC held in Bali in 2007 (Bass et al 2000). Generally, forests can flourish in a variety of climatic regimes, ranging from wet tropical to dry boreal regions (Sedjo & Sohngen 1998). Vegetative transition varies mainly by depending on the soil moisture and temperature availability. Any alteration in the climate regime may affect biodiversity either in a positive way or in a negative way. But the affects differ both spatially and temporally. General impacts of climate change on the forest ecosystem are given in the Table 1.

2. CLIMATE PROFILE OF TAMIL NADU

Climate Change is “a change in the State of the climate that can be identified by changes in the mean and/ or the variability of its properties and that persists for an extended period, typically decades or longer” (IPCC 2014). Anthropogenic climate change has been defined as “a change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere (e.g. increase in greenhouse gases due to fossil fuel emissions) or surface characteristics (e.g. deforestation) and which is in addition to natural climate variability observed over comparable periods”.

Climate change is already affecting every inhabited region across the globe, with human influence contributing too many observed changes in weather and climate extremes (IPCC 2021). It is reported that, in India, the mean annual temperature has increased by 0.6°C over the last century; the monsoon rainfall is declined over the last three decades of the 20th century in many parts of the country, while some parts have shown an increasing trend in the observed frequency of heavy precipitation events.

The climate of Tamil Nadu is strikingly different from the country’s general climate. Due to its topographical features and geographical area, the climate of Tamil Nadu is referred to as semi-arid and tropical monsoon. The long coastal stretch in the east, hills on the western rim, and a flat interior significantly influence the climate of the State, which is tropical with only little seasonal variation in summer and winter temperatures. Apart from a brief break during the monsoon season, the State experiences hot temperatures throughout the remaining months. Due to the proximity to the sea, the humidity remains relatively high. The summer is hot, with temperatures rising to 43℃ and extending from April to June. November to February is the coolest winter period, with temperatures around 18°C.

The State receives most of its annual rainfall during October, November, and December (post-monsoon). It is contrary to the rest of the country, where the rainy season comprises the months of June, July, August, and September. The State is frequently subjected to extreme weather conditions, such as flooding in the coastal districts and severe droughts in the interior due to monsoon failure. This has an adverse effect on agricultural production. Drought, water depletion, soil erosion, seawater incursion, forest fire, species extinction and thermal discomfort are major manifestations of climate change. Monsoon rains are the major water source for irrigation, making its linkages with the agricultural sector very critical.

Since the last decade, the State has been facing a noticeably higher incidence of cyclonic events (Vardah 2016, Ockhi 2017 and Gaja 2018) and severe floods (2015 and 2017). This warrants immediate action to analyses and understand the current and future climate trends of the State. This Chapter dwells upon Tamil Nadu's historical climatic trends based on India Meteorological Data (IMD) data for 1985 – 2014 and future projections about the climate and related uncertainties.

2.1 Temperature

The high resolution (0.25°x0.25° latitude and longitude) daily gridded rainfall datasets for 184 precipitation grids for a period of 30 years (1985– 2014) and 1.0°x1.0° latitude and longitude daily gridded temperature datasets for 23 temperature grids, spanning over 30 years (1985-2014) for maximum and minimum temperatures provided by IMD (https://www.imdpune.gov.in/lrfindex.php) have been used to calculate the spatial variability in precipitation and temperature respectively.

2.1.1 Maximum Temperature

It can be seen that the mean annual maximum temperature for Tamil Nadu is 32.5°C, with a range varying from 29.5°C to 33.4°C. It is also observed that for annual maximum temperature, the highest value is attained for the districts, viz., Chennai, Kancheepuram, Chengalpattu, Thiruvallur, Tiruvarur and Cuddalore, while the lowest value is attained for the Nilgiris district of Tamil Nadu.

2.1.2 Minimum Temperature

Mean annual minimum temperature is 22.6°C, varying from 19.4°C to 24.1°C. It is also seen that for annual minimum temperature, the highest value is attained for the district Tiruvarur, followed by Cuddalore, Mayiladuthurai and Nagapattinam, districts while the lowest value is attained for the district, Nilgiris: lying in Hilly Zone, for the period 1985-2014 (30 years). The annual average maximum and minimum temperature spatial vairation of Tamil Nadu for the baseline period is given in Figure 4

Minimum Temperature

Maximum Temperature

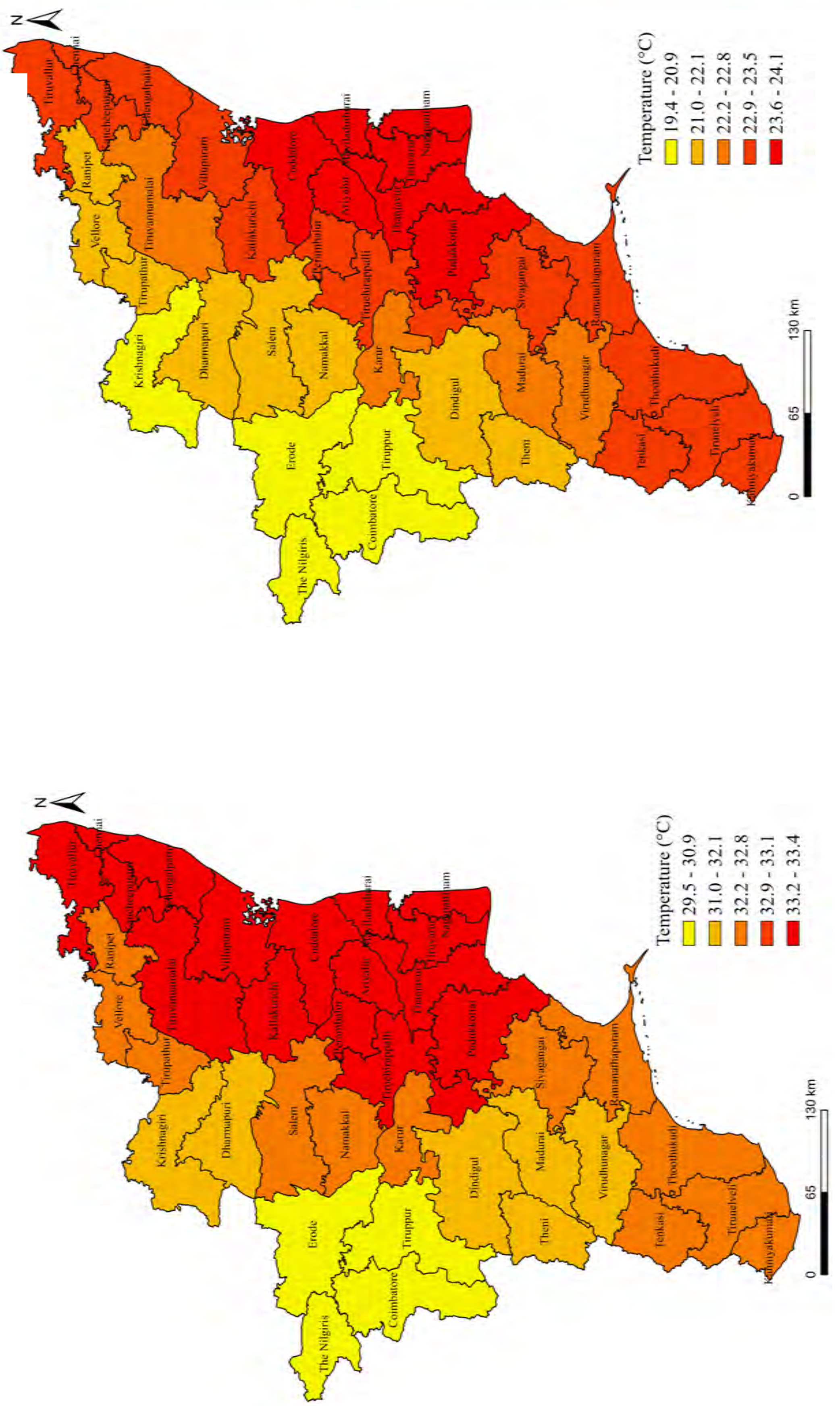

Figure 4. Observed Annual Maximum and Minimum Temperature of Tamil Nadu (1985-2014)

2.2 Rainfall

The average annual rainfall of Tamil Nadu is 989 mm within the district values ranging from 763 mm to 1432 mm over 30 years (1985-2014). As depicted in Figure 5, among all districts, The Nilgiris, Thiruvallur, Chennai, Kancheepuram, Chengalpattu, Cuddalore, Tiruvarur, Mayiladuthurai and Nagapattinam receive the maximum average annual rainfall. In contrast, Erode, Tiruppur, Karur, Tenkasi, Thoothukudi and Tirunelveli receives the lowest annual average rainfall.

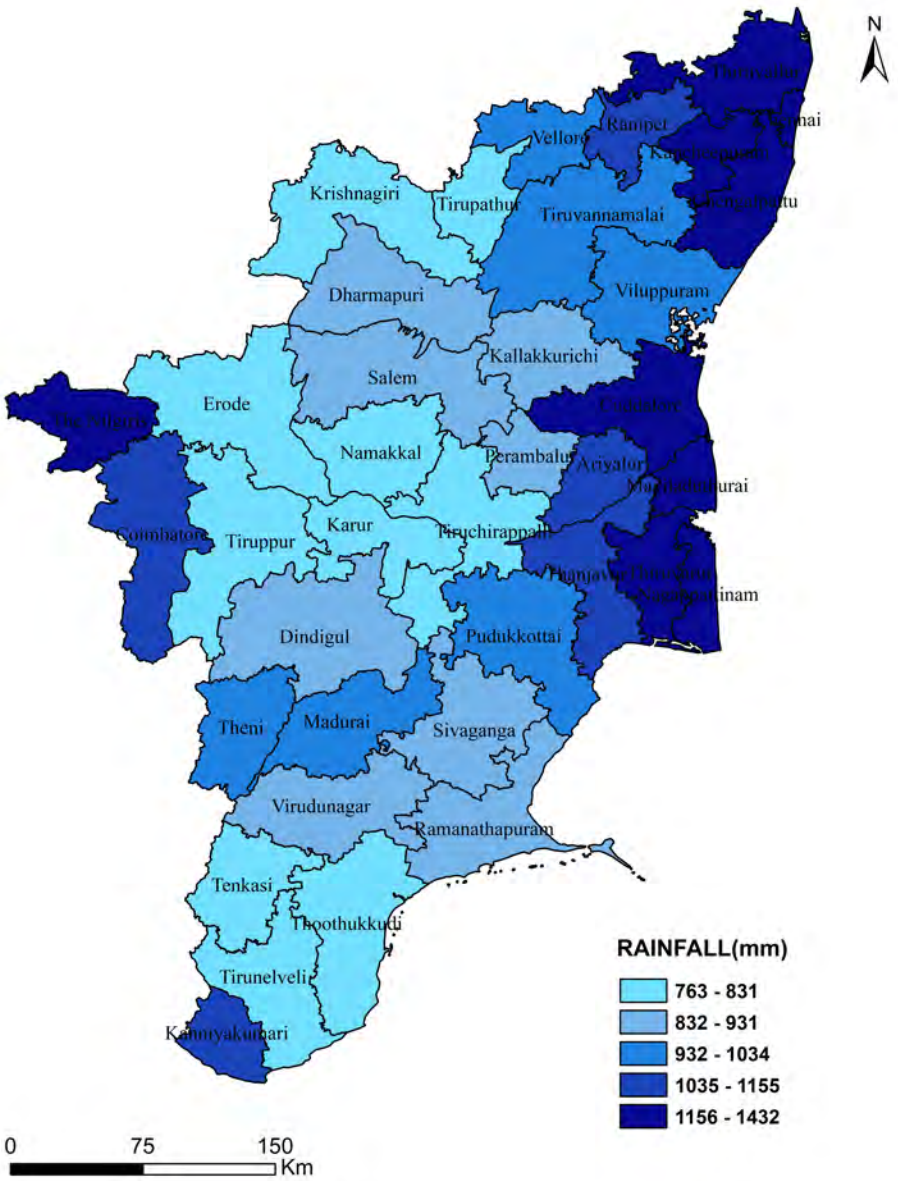

Figure 5. Spatial Variation in Observed Annual Rainfall of Tamil Nadu (1985-2014)

2.3 Climate Change Scenario

Climate change is the long-term alteration in Earth's climate patterns, primarily caused by human activities. It is driven by releasing greenhouse gases (GHGs) into the atmosphere by burning fossil fuels. This process, known as global warming, leads to changes in temperature, precipitation, wind patterns, and other factors that affect the planet's climate system. The consequences of climate change are wide-ranging, impacting ecosystems, agriculture, water resources, and human health. Addressing climate change requires global cooperation, mitigation of GHG emissions, and adaptation measures to minimize its adverse effects. The temperature anomaly of Tamil Nadu is shown in Figure 6.

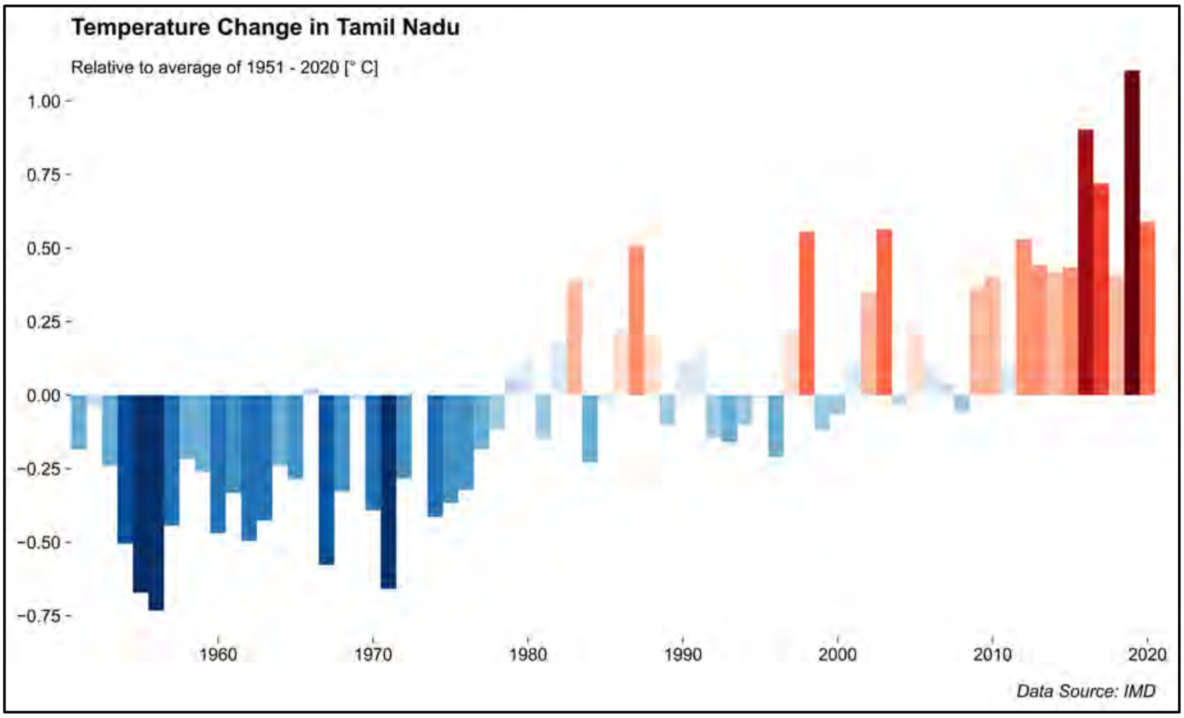

Figure 6. Temperature Change in Tamil Nadu since 1951

2.3.1 Causes and Impacts of Climate Change

Climate change is primarily caused by human activities, including burning fossil fuels and deforestation, which release GHGs and alter the planet's carbon balance. The increased concentration of GHGs leads to the enhanced greenhouse effect, resulting in rising temperatures, changing precipitation patterns, extreme weather events, sea-level rise, loss of biodiversity, and negative impacts on human health, agriculture, and water resources. These interconnected impacts highlight the urgent need to reduce GHG emissions and implement adaptation strategies.

2.3.2 Climate Change Projections and Scenarios

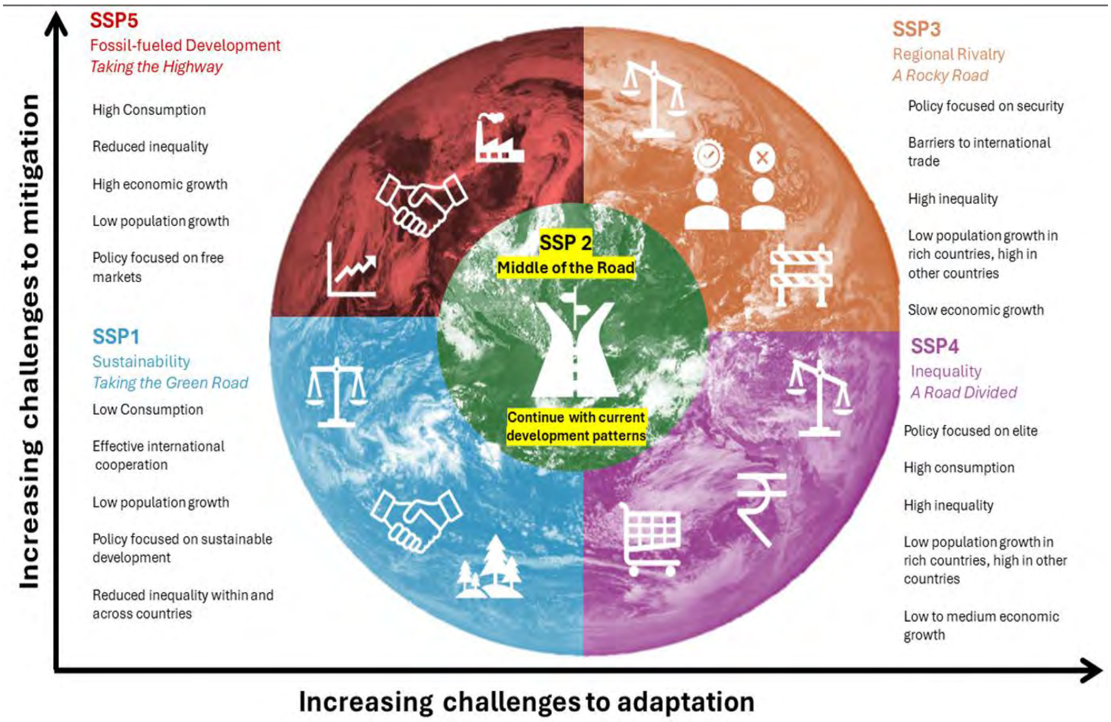

Figure 7 SSPs mapped in the challenges to mitigation/adaptation space

Climate change projections and scenarios provide insights into future climate conditions. Climate models simulate the Earth's climate, considering factors such as GHG emissions, atmospheric composition, solar radiation, and land surface characteristics. These models generate projections of future climate conditions.

Scenarios like the Shared Socio-economic Pathways (SSPs) explore different future trajectories based on socio-economic factors. The SSPs categorise scenarios into SSP 1 - sustainability, SSP 2 - middle-of-the-road, SSP 3 - regional rivalry, SSP 4 - inequality, and SSP 5 - fossil-fueled development, representing different socio-economic and emission pathways. Figure 7 shows an SSP matrix that defines five possible SSPs in terms of different degrees of "challenges to adaptation" (or ability to deal with climate change that has already occurred) and "challenges to mitigation" (or ability to restrain the extent to which climate change will occur) as well as other features of socio-economic development.

2.3.3 Importance of Climate Change Projections and Scenarios

Climate change projections and scenarios help policymakers, scientists, and the public understand potential impacts and plan for adaptation and mitigation. They assist in assessing risks and developing strategies based on socio-economic choices. The recently released Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) incorporates the SSPs to explore different socio-economic development pathways and their associated climate change consequences. These scenarios enhance our understanding of the complex interactions between human activities and climate change, guiding decision-making processes for climate mitigation and adaptation.

Climate change is a global challenge requiring collective action to mitigate its effects and build resilience. Human activities, primarily burning fossil fuels, are the main drivers of climate change. The impacts of climate change are wide-ranging, affecting ecosystems, agriculture, water resources, and human well-being. Climate change projections and scenarios provide valuable insights into future climate conditions and assist in developing adaptation and mitigation strategies. The IPCC AR6 and the SSPs offer a range of scenarios representing different socio-economic and emission pathways, highlighting the importance of sustainable development and urgent actions to transition to a low-carbon economy. By understanding the causes, impacts, and potential future climate change conditions, we can make informed decisions to protect our planet and future generations.

The EC-Earth3 model is statistically downscaled using PyClim-SDM (Statistical Downscaling model) from 100×100 km spatial resolution to 25×25 km spatial resolution for Tamil Nadu for the Shared Socio-economic Pathway scenario SSP2-4.5(Mid Pathways) and SSP5-8.5(Business as Usual) of IPCC AR6 and are projected for temperature and precipitation from 2021-2100.

Figure 8 and Figure 9 indicate the projected changes in annual maximum temperature by near, mid and end term under SSP2-4.5 and SSP5-8.5, respectively.

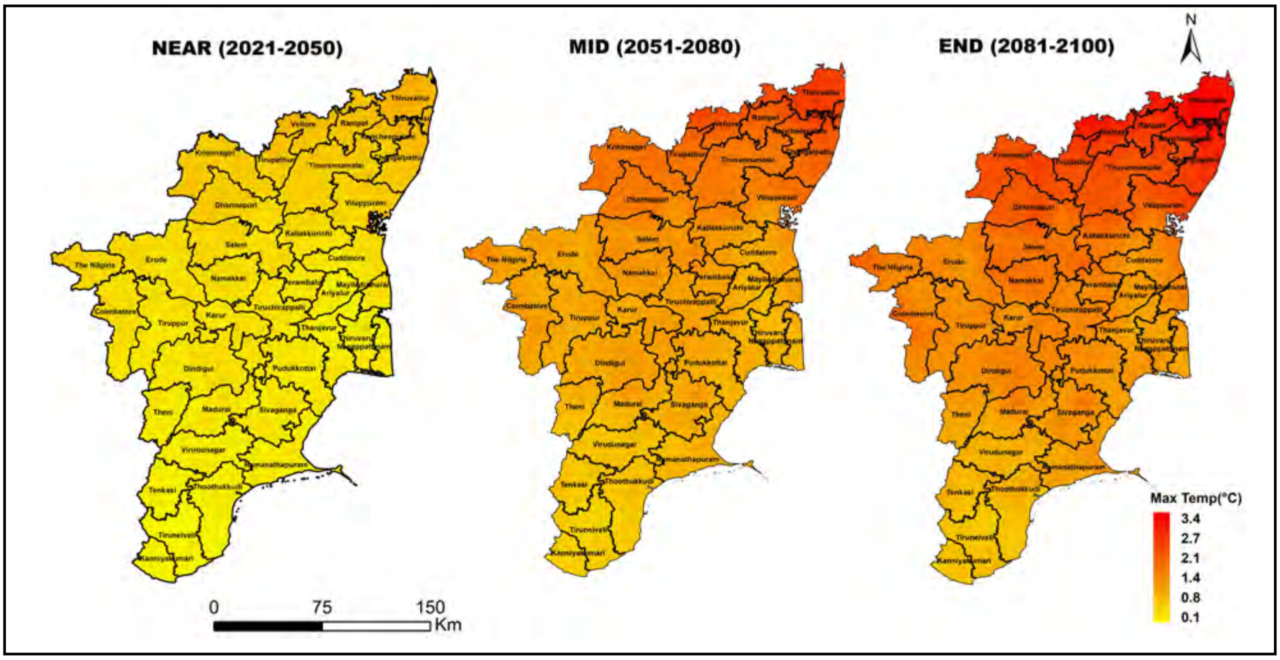

Figure 8. Projected Changes in Annual Maximum Temperature under SSP2-4.5

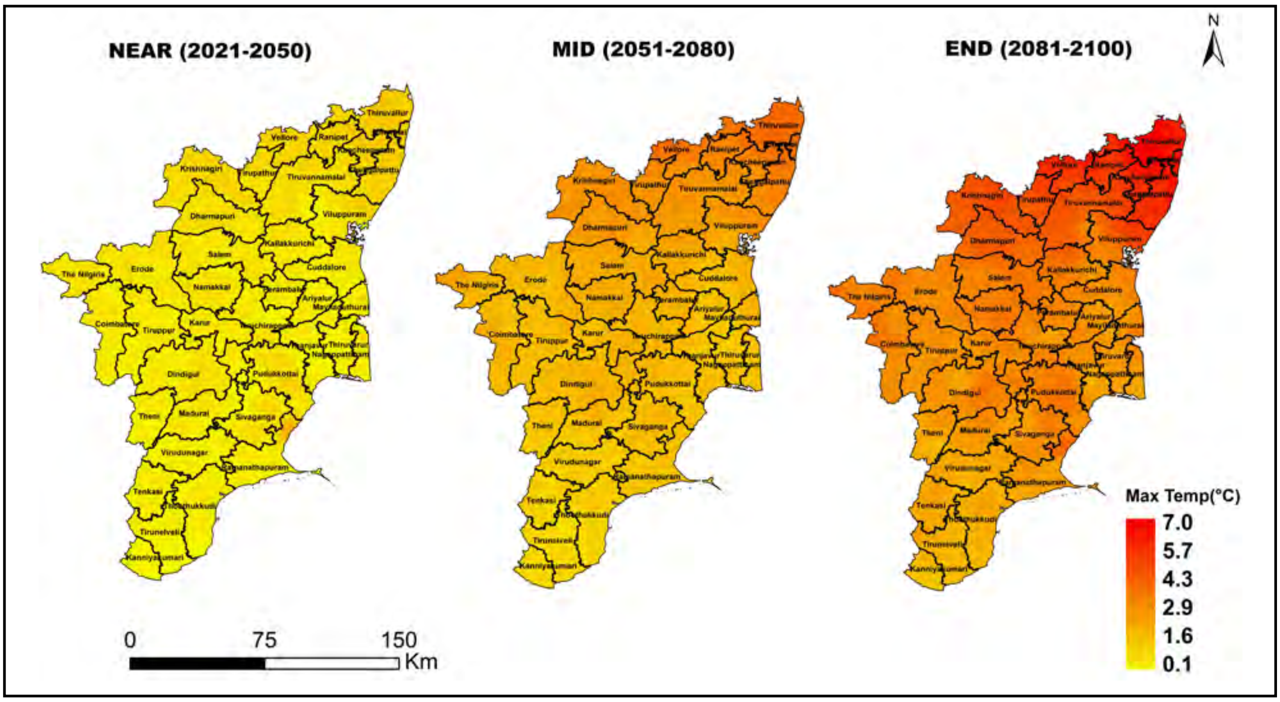

Figure 9. Projected Changes in Annual Maximum Temperature under SSP5-8.5

Table 2 indicates that the annual mean maximum temperature in the State may rise by up to 0.4 ℃, 1.3℃ and 1.7 ℃ in near-century, mid-century and by end-century, respectively, under SSP2-4.5 scenario and with respect to the SSP5-8.5 scenario, the maximum temperature may rise by 0.6℃, 1.7℃

and 3.5°C by near-century, mid-century and end-century respectively. The northern districts such as Chennai, Nagapattinam, Kanyakumari, and Mayiladuthurai are projected to have a maximum increase in temperature by the end of the century.

Table 2. Change in Annual Average Maximum Temperature

Projection Period	Increase in Annual Maximum Temperature with Reference to Baseline (°C)	
	SSP2-4.5 Scenario	SSP5-8.5 Scenario
Near Century (2021-2050)	0.4	0.6
Mid Century (2051-2080)	1.3	1.7
End Century (2081-2100)	1.7	3.5

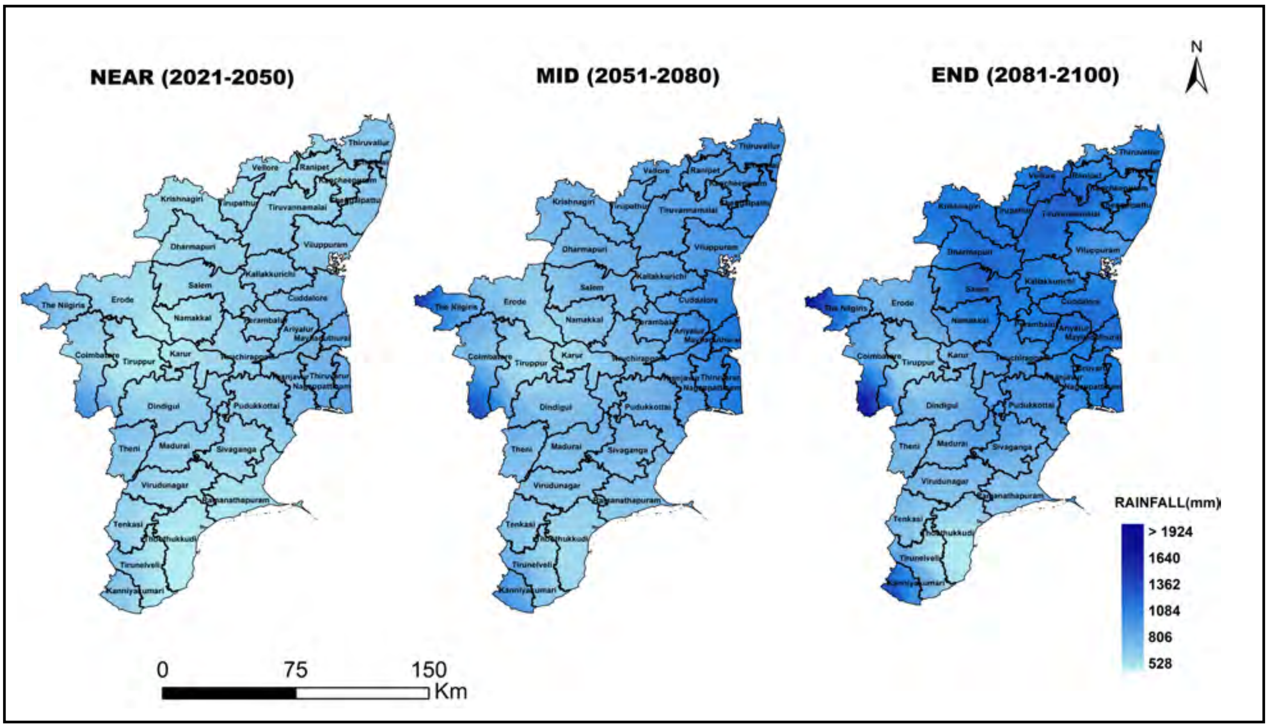

Figure 10. Projected Average Annual Rainfall by under SSP2-4.5

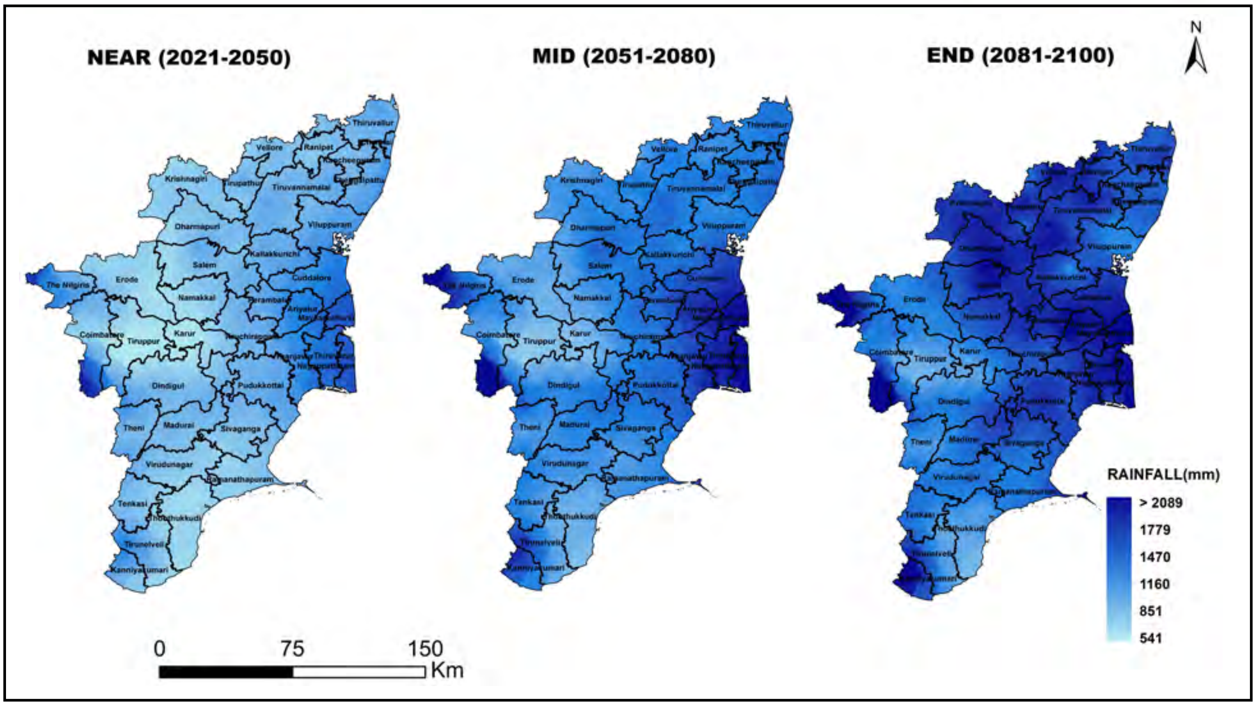

Figure 11. Projected Average Annual Rainfall under SSP5-8.5

Table 3 indicates that the Average rainfall in Tamil Nadu State may increase marginally, by 4% towards the near century, 11% by the mid-century, and about 16% towards the end-century under the SSP2-4.5 scenario (Figure 10). Under the SSP5-8.5 scenario, the increase in rainfall is by 7% towards the near century, 18% in the mid-century, and 26% towards the end century (Figure 11).

Table 3. Percentage Change in Annual Average Rainfall

Projection Period	Increase in Annual Rainfall (%)	
	SSP2-4.5 Scenario	SSP5-8.5 Scenario
Near Century (2021-2050)	4	7
Mid Century (2051-2080)	11	18
End Century (2081-2100)	16	26

The coastal districts such as Cuddalore, Nagapattinam, Kanyakumari, and Mayiladuthurai are projected to have a maximum increase in rainfall by the end of the century

3. METHODOLOGY

The Overall methodology for this is study is depicted in Figure 12.

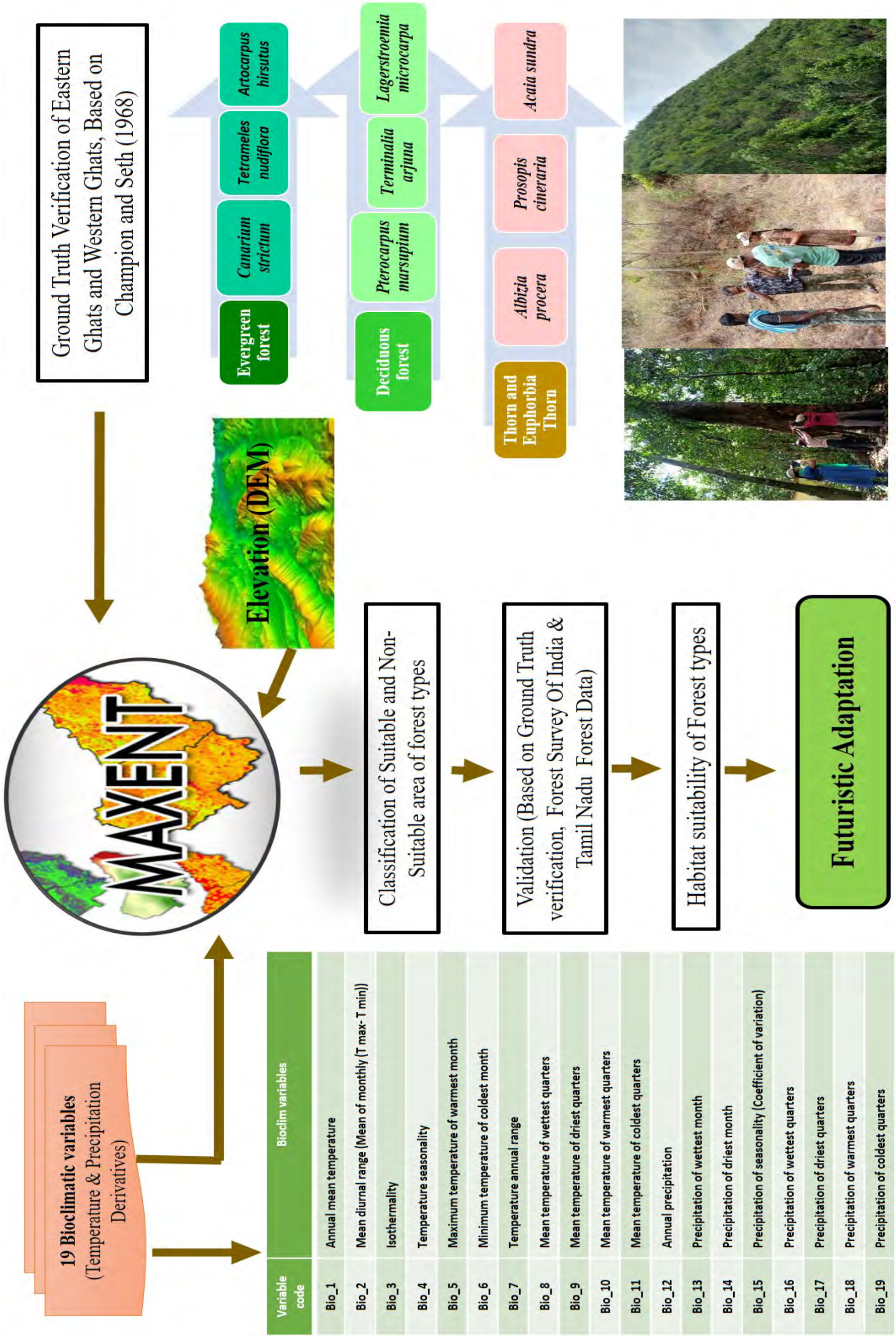

Figure 12. Methodology flow chart

3.1 Floristic Survey

Phytosociology is the study, which encompasses the structural attribute of plant community and this can be divided into qualitative and quantitative characters. In order to conduct study based on stratified random sample plots, vegetation type map of the study area was used. Floristic survey was carried out following the same methodology adopted by Ramachandran (2006) and Jayakumar (2000).

Geographic co-ordinates of each sample point was generated and overlaid on the topographic sheet and exported to Trimble Juno 3B Global Positioning System (GPS). Quadrate of 20m×20m was laid in each sample location. According to NRSA (2000), for any biodiversity study a minimum of 0.001 percent of the area to be sampled. In this study the total area sampled was 0.01% of the total area. Girth of stems >30cm girth at breast height (GBH) was considered as tree (Ramacahndran 2006). Measurements of both girth and height (using a clinometer) were measured for all tree species within the quadrats. Plant specimens were collected and identified using flora of Madras (Gamble & Fischer 1935-1936)

3.2 Temporal Climate Variability Analysis

Relationship between climate and vegetation structure, productivity, distribution and climate elements have constituted one of the classical themes in geo botanical literatures (Woodward & Williams 1987). Recent climate variability is transforming ecosystems on an alarming scale. Each species in an ecosystem responds to its changing environment and these changes may either give a positive response or a negative response. Climate change is happening on a global scale but the ecological impacts are often local and vary from place to place. This research intends to assess the existing climatic variability by analysing temporal changes in rainfall and temperature in the study area of Eastern Ghats and Western Ghats

3.3 Habitat Suitability Distribution Modeling

Climate variables have substantial influence on the distribution, structure and ecology of a forest ecosystem (Kirschbaum et al 1996). Projections from most of the global models suggest that, changes in temperature and rainfall may result in a shift of existing forest type. Hence, it is reasonable to project the habitat suitability of a forest ecosystem in the light of changing climate. Thus this research used bioclimatic envelop model called MaxEnt, in order to project current as well as the future habitat suitability of the existing forest type in the study area. It is a machine learning program that estimates the probability distribution for a species occurrence based on environmental constraints (Phillips et al 2006).

3.3.1 Species Occurrence Data Collection

The occurrence locations of Evergreen, Deciduous and Thorn Forest tree species were collected during a field survey Eastern and Western Ghats of Tamil Nadu (Figure 12). We recorded and geographical locations of tree species using Global Positioning System (GPS) in the Eastern and Western Ghats. Environmental (categorical) layers slope were generated from the Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) having 90 m spatial resolution, downloaded from the USGS website (www.srtm.usgs.gov). Using nearest neighbor re-sampling technique, the categorical layers were resampled into 1 km spatial resolution in Arc GIS.

3.3.2 Preparation of Bioclimatic Variables

Bioclimatic variables are derived from the monthly temperature and rainfall values in order to generate more biologically meaningful variables. These are often used in species distribution modeling and related ecological modeling techniques. The bioclimatic variables represent annual trends (e.g., mean annual temperature, annual precipitation) seasonality (e.g., annual range in temperature and precipitation) and extreme or limiting environmental factors (e.g., temperature of the coldest and warmest month, and precipitation of the wet and dry quarters). A quarter is a period of three months (1/4 of the year).

In addition to the environmental layers, 19 bioclimatic variables (Table 4) current period and projection derived from the EC-Earth3 model is statistically downscaled using PyClim-SDM (Statistical Downscaling model) from 100×100 km spatial resolution to 25×25 km spatial resolution for Tamil Nadu for the Shared Socio-economic Pathway scenario SSP2-4.5(Mid Pathways) of IPCC AR6. They were extracted for the study area and converted to ASCII files using Arc GIS 10.8.2.

Table 4. Bioclimatic Variables Used for Habitat Suitability Distribution Modelling

Variable code	Bioclimatic Variables	
bio_1	Annual mean temperature	The climate inputs are averaged across the year to acquire the annual mean temperature
bio_2	Mean diurnal range (Mean of monthly (Tmax-Tmin))	The mean of the monthly temperature ranges (monthly maximum minus monthly minimum)
bio_3	Isothermality	Isothermally quantifies how large the day to-night temperatures oscillate relative to the summer to-winter (annual) oscillations
bio_4	Temperature seasonality	The amount of temperature variation over a given year (or averaged years) based on the standard deviation (variation) of monthly temperature averages
bio_5	Maximum temperature of warmest month	The maximum monthly temperature occurrence over a given year (time-series) or averaged span of years (normal)
bio_6	Minimum temperature of coldest month	The minimum monthly temperature occurrence over a given year (time-series) or averaged span of years (normal)
bio_7	Temperature annual range	A measure of temperature variation over a given period
bio_8	Mean temperature of wettest quarter	This quarterly index approximates mean temperatures that prevail during the wettest season
bio_9	Mean temperature of driest quarter	This quarterly index approximates mean temperatures that prevail during the driest quarter
bio_10	Mean temperature warmest quarter	This quarterly index approximates mean temperatures that prevail during the wettest season
bio_11	Mean temperature of coldest quarter	This quarterly index approximates mean temperatures that prevail during the coldest quarter
bio_12	Annual precipitation	This is the sum of all total monthly precipitation values
bio_13	Precipitation of wettest month	This index identifies the total precipitation that prevails during the wettest month
bio_14	Precipitation of driest month	This index identifies the total precipitation that prevails during the driest month
bio_15	Precipitation of seasonality (Coefficient of variation)	This is a measure of the variation in monthly precipitation totals over the course of the year
bio_16	Precipitation of wettest quarter	This quarterly index approximates total precipitation that prevails during the wettest quarter
bio_17	Precipitation of driest quarter	This quarterly index approximates total precipitation that prevails during the driest quarter
bio_18	Precipitation of warmest quarter	This quarterly index approximates total precipitation that prevails during the warmest quarter
bio_19	Precipitation of coldest quarter	This quarterly index approximates total precipitation that prevails during the coldest quarter

3.3.3 Modeling Procedure

This study used a unique modeling method called MaxEnt model (Figure 13), which performed best among many other species distribution models (Elith et al 2006; Ortega-Huerta & Peterson 2008). It requires presence data of the modeling species and its related environmental (Categorical) and climatic variables. MaxEnt model version 3.4.4 was downloaded (https://biodiversityinformatics.amnh.org/open_source/maxent/) and used for the habitat suitability modeling of three forest types in the study area. Of the presence locations, 70% were used for the model training and 30% were used as test data.

Cross validation was maintained in the replicate run, and iterations were fixed as 500. To avoid the over fitting of the test data, we used 0.1 as the regularization number (Phillips et al 2004).

Area under the receiver-operating curve was used for the model evaluation that ranges from 0.5 (random) to 1.0 (perfect discrimination). In addition to this, Jackknife method was used to assess the importance of variables in the final model (Phillips et al 2006). The model was trained using the current bioclimatic variables and projected using future bioclimatic variables. To visualize the bioclimatic suitability range shift in the future projection, this study used a clamping module while running the model.

Further analysis, we imported the results of the MaxEnt models predicting the presence of Different forest types of tree species in to into ArcGIS. With a reference to the classification proposed by two classes of potential habitat suitability were regrouped: unsuitable habitat and suitable habitat; the model was trained using the current bioclimatic variables and projected using future bioclimatic variables.

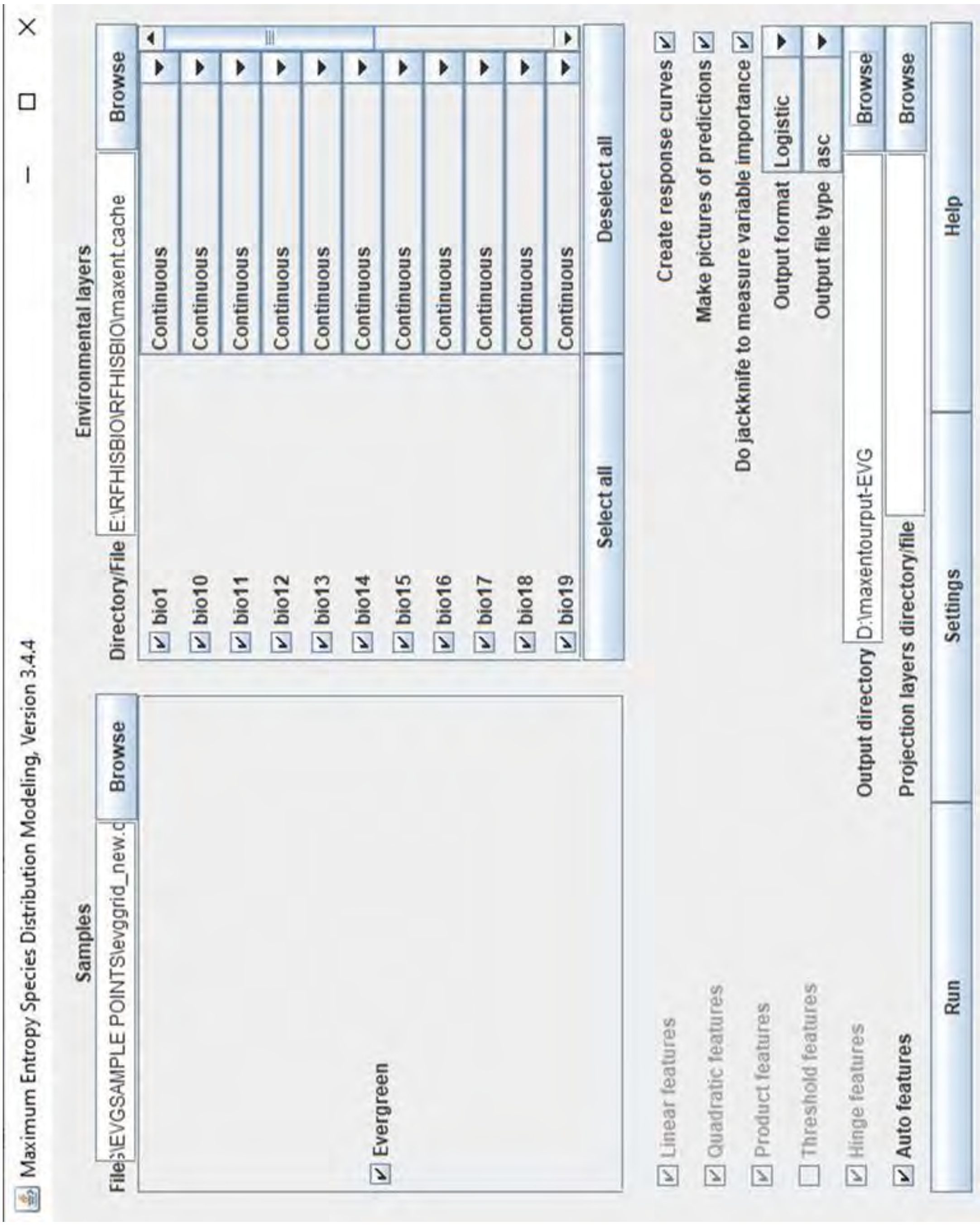

Figure 13. MaxEnt model interface

To visualize the bioclimatic suitability range, shift in the future projection we did clamping while running the model. Final outputs of the model predictions were exported to ArcGIS for prediction of habitat suitability of different forest type tree species for the current and future climate change scenarios.

4. HABITAT SUITABILITY OF DIFFERENT FOREST TYPES IN TAMIL NADU

The baseline assessment of habitat suitability revealed that 1881 sq.km, 13395 sq.km and 4292 sq.km of the total forest area is suitable for Evergreen forest, Deciduous forest and Thorn forest type respectively (Figure 14 and Table 5, Annexure Table A2, A3&A4). Projection for the year 2050 exhibited that, the habitat suitability for Evergreen forests reduced to 1281 sq.km (32%) and for Deciduous forest type reduced to 10942 sq.km (18%). Whereas the habitat suitability of Thorn forests increased by 71% amounting to 7345 sq.km (Figure 14 and Table 5).

Table 5. Habitat Suitability of Different Forest Types in Tamil Nadu

Forest type	Baseline (1985-2014)	Near Century (2021-2050)	Area Changes (sq.km)	Changes (%)
	Area in sq.km			
Evergreen	1881	1281	600 (-)	32 (-)
Deciduous	13395	10942	2453 (-)	18 (-)
Thorn	4292	7345	3053 (+)	71 (+)

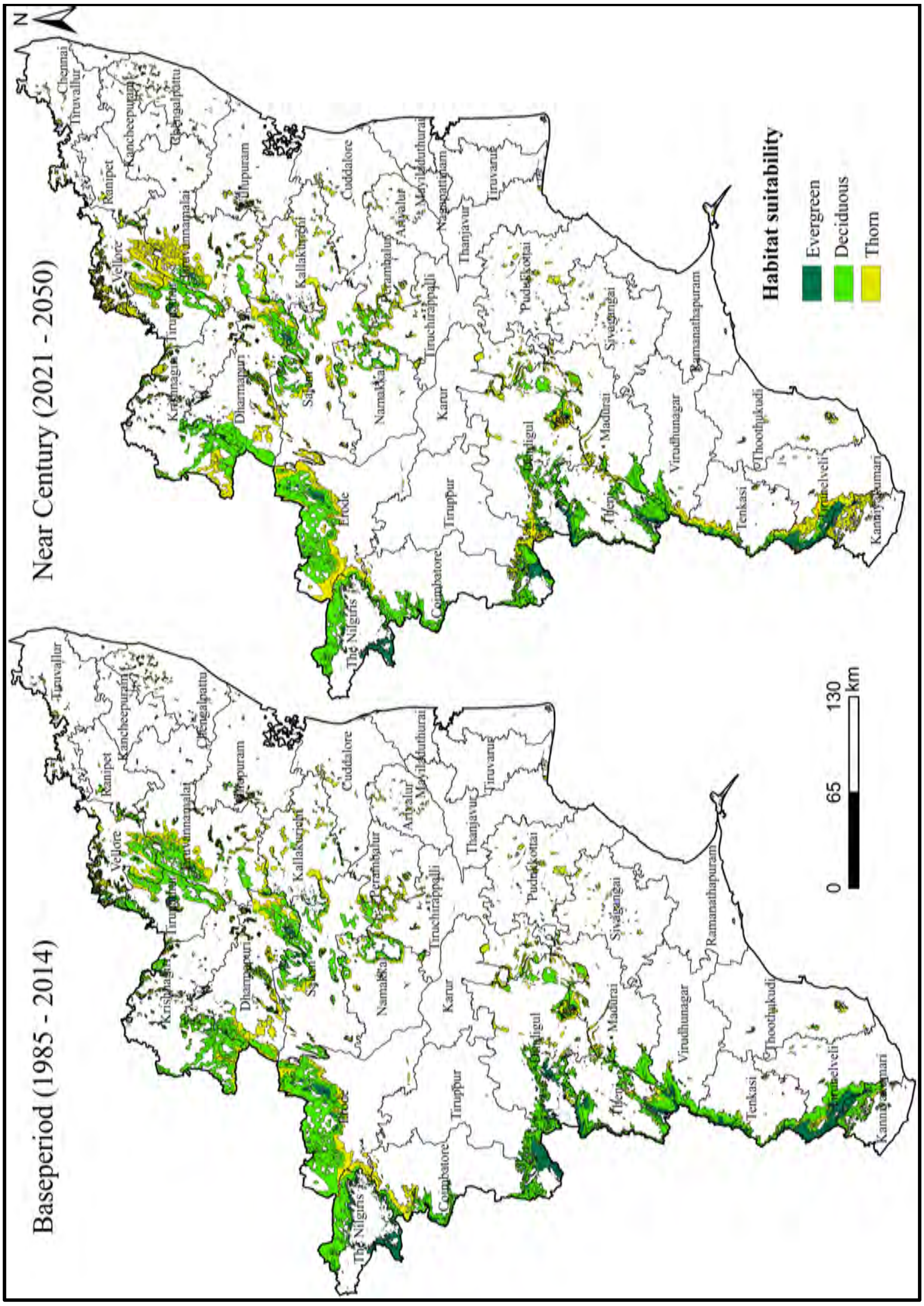

Figure 14. Habitat Suitability of Different Forest Types of Tamil Nadu

4.1 Current and Projected Habitat Suitability in Eastern Ghats

In the Eastern Ghats of Tamil Nadu, the habitat suitability was as follows: 189 sq.km for the Evergreen forest type, 2,285 sq.km for the Deciduous forest type, and 1,627 sq.km for the Thorn forest type, out of a total area of 4,101 sq.km (Figure 15 &Table 6). Based on the model's forecasts for 2050, there emerges a discernible decline in the habitat suitability distribution for Evergreen forest and Deciduous forest, showcasing reductions of 29% and 31% respectively. Conversely, the Thorn forest demonstrates a substantial increase, with its habitat suitability expanding by 47% in the Eastern Ghats (Figure 15 &Table 6).

Table 6. Habitat Suitability of Different Forest Types in Eastern Ghats

Forest type	Baseline (1985-2014)	Near Century (2021-2050)	Area Changes (sq.km)	Changes (%)
	Area in sq.km			
Evergreen	189	135	54 (-)	29 (-)
Deciduous	2285	1569	716 (-)	31 (-)
Thorn	1627	2394	767 (+)	47 (+)

Tamil Nadu Climate Change Mission.

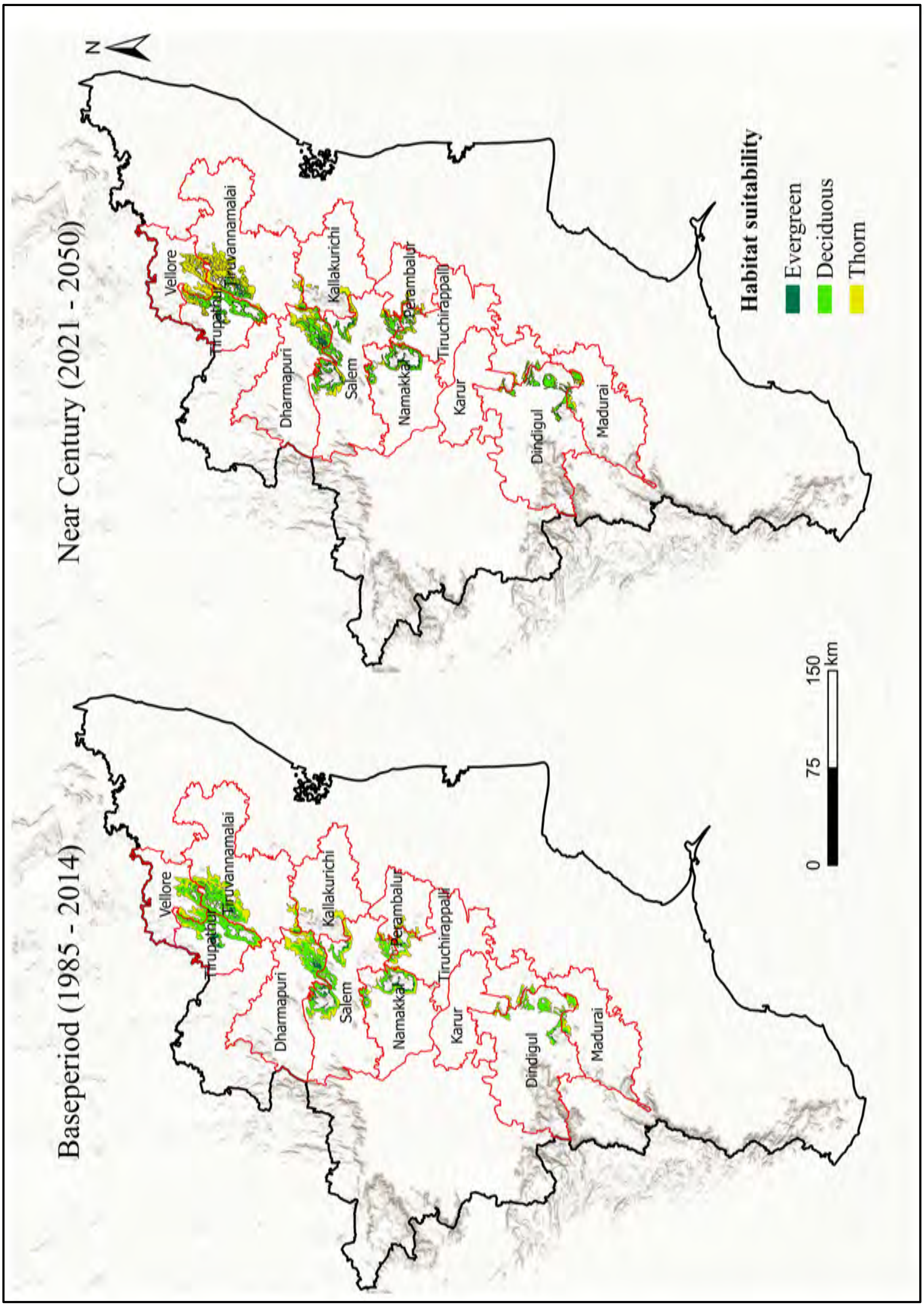

Figure 15. Habitat Suitability of Different Forest Types in Eastern Ghats

4.2 Current and Projected Habitat Suitability in Western Ghats

Similarly, the habitat suitability of Evergreen forest and deciduous forest is projected to reduce by 17% and 11% by the 2050 from the baseline of 1465 sq.km and 6346 sq.km, in the Western Ghats of Tamil Nadu (Figure 16 & Table 7). Whereas the habitat suitability of Thorn forest types is projected increase from 1618 sq.km to 2587 sq.km in the Western Ghats in Tamil Nadu (Table 7).

Table 7. Habitat Suitability of Different Forest Types in Western Ghats

Forest types	Baseline period (1985-2014)	Near Century (2021-2050)	Area Changes (sq.km)	Changes (%)
	Area in sq.km			
Evergreen	1465	1216	249 (-)	17 (-)
Deciduous	6346	5626	720 (-)	11 (-)
Thorn	1618	2587	969 (+)	60 (+)

In summary, the model anticipates substantial adjustments in habitat suitability distribution for these forest types by 2050. The suitability of Evergreen and Deciduous forests is predicted to decrease, while the Thorn forest is poised to witness a significant upswing in its habitat suitability.

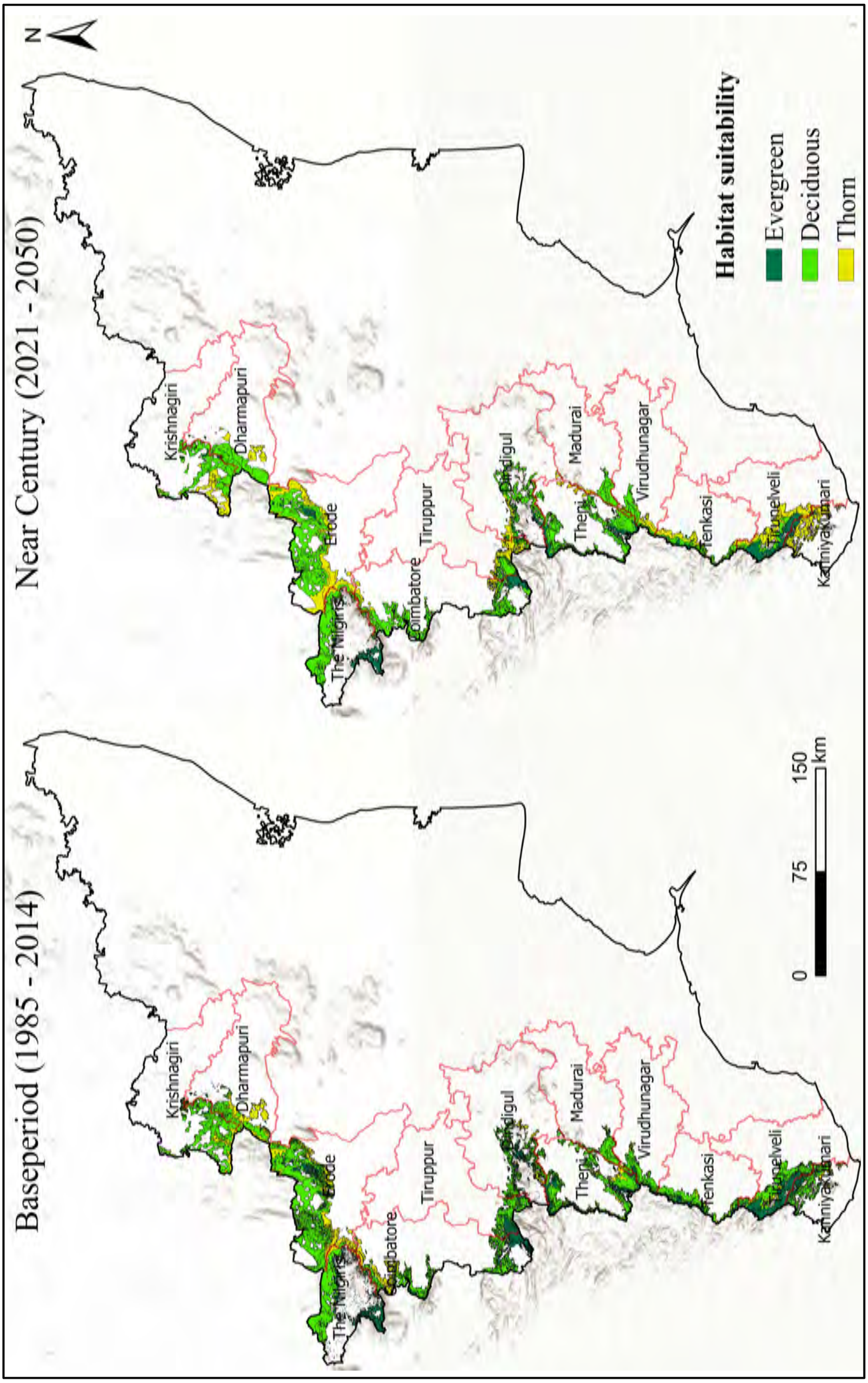

Figure 16. Habitat Suitability of Different Forest Types of Western Ghats

4.3 Districts and Reserve Forest wise Analysis of Habitat Suitability

The Eastern and Western Ghats of Tamil Nadu collectively cover approximately 4,100 sq. km and 9,428 sq. km respectively. Each of these Ghats spans across 13 districts in the region. The Eastern Ghats encompass the districts of Dharmapuri, Dindigul, Kallakurichi, Karur, Krishnagiri, Madurai, Namakkal, Perambalur, Salem, Tirupathur, Tiruvannamalai, Vellore, and Tiruchirappalli. On the other hand, the Western Ghats cover Coimbatore, Dindigul, Erode, Kanniyakumari, Krishnagiri, Madurai, Tenkasi, The Nilgiris, Theni, Tirunelveli, Dharmapuri, Tiruppur, and Virudhunagar districts. An in-depth analysis of habitat suitability at different forest types has been conducted at the district and reserve forest levels for both Eastern and Western Ghats.

4.3.1 Districts wise Habitat Suitability in Eastern and Western Ghats of Tamil Nadu

The current findings of the analysis and comparison of each thirteen districts in Eastern Ghats and Western Ghats of Tamil Nadu. The district level vulnerability assessment was compared for the Eastern and Western Ghats. This is then followed by the future vulnerability with respect to two different scenarios - base period (1985-2014) and near century (2021-2050). After determining the vulnerability indices for each of the Eastern and Western Ghats districts, a comparison analysis was done. After a vulnerability-based spatial profile for Western and Eastern Ghats of Tamil Nadu was created. The vulnerability of the districts under the current and future climatic scenarios are displayed on a map.

The district wise habitat suitability analysis indicated that Salem district is most vulnerable to climate change due to the reduction in habitat suitability of evergreen forests in the near future. It was found that the habitat suitability of deciduous forests in Tiruvannamalai and the Vellore district was reduced much when compared to the current distribution in base period whereas the habitat suitability of thorn forests was higher in both of these districts (Table 8). The change in habitat suitability for different forest types varies significantly across regions. For example, areas like Kallakurichi (0.01 sq.km), Tiruchirappalli (2.29 sq.km), and Madurai (3.64 sq.km) are currently only suitable for evergreen forest types, but are projected to become unsuitable in the Near Century due to climate change

Table 8. District Wise Habitat Suitability in Eastern Ghats

District	Evergreen Forest			Deciduous Forest			Thorn Forest		
	Base Period	Near Century	Area change (sq.km)	Base Period	Near Century	Area change (sq.km)	Base Period	Near Century	Area change (sq.km)
Dharmapuri	29.35	28.18	1.17 (-)	312.59	279.69	32.90 (-)	201.90	235.90	34.00 (+)
Dindigul	6.61	5.85	0.76 (-)	208.37	183.41	24.96 (-)	110.47	135.97	25.50 (+)
Kallakurichi	0.01	Nil	0.01 (-)	9.52	8.28	1.24 (-)	73.19	74.44	1.25 (+)
Karur	Nil	Nil	Nil	5.60	4.03	1.57 (-)	12.05	13.62	1.57 (+)
Krishnagiri	Nil	Nil	Nil	0.06	0.01	0.05 (-)	1.47	1.54	0.07 (+)
Madurai	3.64	3.64	0.00	28.61	28.30	0.31 (-)	39.12	39.43	0.31 (+)
Namakkal	39.42	21.46	17.96 (-)	171.21	156.24	14.97 (-)	115.30	148.27	32.97 (+)
Perambalur	Nil	Nil	Nil	9.24	5.88	3.36 (-)	64.20	67.56	3.36 (+)
Salem	**53.02**	**34.78**	**18.24 (-)**	396.70	354.56	42.14 (-)	237.07	294.14	57.07 (+)
Tiruchirappalli	2.29	0.15	2.14 (-)	92.33	88.67	3.36 (-)	152.99	158.77	5.78 (+)
Tirupathur	31.98	22.14	9.84 (-)	416.02	306.19	109.83 (-)	98.55	219.16	120.61 (+)
Tiruvannamalai	22.31	19.14	3.17 (-)	**416.87**	**138.13**	**278.74 (-)**	355.25	637.16	281.91 (+)
Vellore	Nil	Nil	Nil	**218.24**	**15.41**	**202.83 (-)**	165.57	368.40	202.83 (+)
Grand Total	**188.63**	**135.33**	-	**2285.37**	**1568.80**	-	**1627.12**	**2394.35**	-

Base Period (1985-2014); Near Century (2021-2050)

In the Western Ghats, the Nilgiris and Coimbatore districts are projected to be more vulnerable to changing climates, with a reduction in habitat suitability for evergreen forest types in the near future. Other districts showing the subsequent reduction suitability for evergreen forest types include Dindigul, Tiruppur, Kanyakumari, and Tirunelveli. Erode and Theni are the districts with the least reduction in habitat suitability for evergreen forest types. Additionally, more than 50 sq.km reduction in habitat suitability for deciduous forest types is projected in Erode, Krishnagiri, Dindigul, Dharmapuri, Tirunelveli, and Tiruppur (Table 9). In districts like Virudhunagar, located in the Western Ghats, the habitat suitability of evergreen forest type is currently limited to 10 sq.km, which is further projected to decrease to 3 sq.km in the Near Century. However, the habitat suitability for thorn forests is expected to increase. This warrants urgency to preserve the existing area and protect from further degradation from any other external source

4.3.2 High Vulnerable Reserve Forest of Eastern Ghats and Western Ghats

At the reserve forest level, the analysis reveals that Mangalam Reserve forest (RF), located in Tirupahur district, faces substantial vulnerability concerning the potential loss of habitat suitability for evergreen tree species. In terms of deciduous and thorn forest tree species habitat suitability, the Patrakad Reserve Forest in Thiruvannamalai district exhibits higher vulnerability (Table 10). Similarly, in Western Ghats reserve forest level identified that the Kanniyakumari District Virapuli and Coimbatore district Anaimalai Reserve Forest faces significant vulnerability with regard to the probable loss of habitat suitable for evergreen tree species (Table 11). The Talamalai Reserve Forest in Erode district shows greater susceptibility in terms of deciduous and thorn forest tree species habitat appropriateness (Table 11).

Table 9. District Wise Habitat Suitability in Western Ghats

District name	Evergreen Forest			Deciduous Forest			Thorn Forest		
	Base Period	Near Century	Area change (sq.km)	Base Period	Near Century	Area change (sq.km)	Base Period	Near Century	Area change (sq.km)
Coimbatore	**200.92**	**150.51**	**-50.41**	544.21	520.16	-24.05	218.41	292.87	74.46
Dharmapuri	-	-	-	276.31	211.02	-65.29	279.95	345.24	65.29
Dindigul	110.17	76.61	-33.56	411.70	357.31	-54.39	93.45	181.40	87.95
Erode	102.68	101.05	-1.63	**1527.29**	**1344.46**	**-182.83**	**507.25**	**691.70**	**184.45**
Kanniyakumari	89.00	60.25	-28.74	271.06	226.17	-44.90	49.37	123.01	73.64
Krishnagiri	-	-	-	736.31	646.98	-89.33	126.20	215.53	89.33
Madurai	-	-	-	214.85	200.68	-14.17	23.30	37.47	14.17
Tenkasi	78.79	70.12	-8.67	243.04	206.70	-36.34	31.91	76.92	45.01
Nilgiris	**270.20**	**219.53**	**-50.67**	626.07	601.82	-24.25	47.75	122.67	74.92
Theni	183.39	178.22	-5.17	638.87	635.91	-2.96	117.82	125.95	8.13
Tirunelveli	317.28	290.71	-26.57	**372.58**	**278.54**	**-94.04**	**71.59**	**192.19**	**120.61**
Tiruppur	102.28	65.14	-37.14	277.70	215.05	-62.65	0.06	99.85	99.79
Virudhunagar	10.01	3.85	-6.16	206.21	181.19	-25.01	51.11	82.28	31.17
Grand Total	**1464.72**	**1216.00**	-	**6346.21**	**5626.00**	-	**1618.16**	**2587.09**	-

Base Period (1985-2014); Near Century (2021-2050)

Table 10. Reserve Forest Wise Habitat Suitability in Eastern Ghats

S.No	District	Reserve Forest	Evergreen	Deciduous	Thorn
1	Dharmapuri	Pallipatti extn	0.62 (-)	-	-
		Northernchedu Extn		8.82 (-)	8.82 (+)
2	Dindigul	Sirumalai northwest slope	0.76 (-)		
		Alagarmalai	-	9.87 (-)	9.87 (+)
3	Kallakurichi	Tagarai	-	1.25 (-)	1.25 (+)
4	Karur	Sembianatham	-	1.23 (-)	-
		Palaviduthi	-	-	1.95 (+)
5	Krishnagiri	Govindapuram	-	0.62 (-)	0.5 (+)
6	Madurai	Alagarmalai	-	0.31 (-)	0.31 (+)
7	Namakkal	Selur	4.25 (-)		5.54 (+)
		Bailnadu	-	6.59 (-)	7.43 (+)
8	Perambalur	Pulambadi bit ii	-	1.96 (-)	1.96 (+)
9	Salem	Manjavadi ghat	3.62 (-)	16.27 (-)	19.89 (+)
10	Tiruchirappalli	Manmalai(try)	0.88 (+)	-	-
		Velamalai		1.68 (-)	1.68 (+)
11	Tirupathur	Mangalam	8.59 (+)	-	-
		Inner javadi	-	30.63 (-)	30.74 (+)
12	Tiruvannamalai	Valasamalai	2.15 (-)	-	-
		Patrakad		73.04 (-)	73.14 (+)
13	Vellore	Arasampattu	-	70.64 (-)	70.64 (+)

Table 11. Reserve Forest Wise Habitat Suitability in Western Ghats

S.No	District	Reserve Forest	Evergreen	Deciduous	Thorn
1	Coimbatore	Anaimalai	19.52 (-)	21.66 (-)	41.19 (+)
2	Dharmapuri	Badanavadi	-	44.32 (-)	44.32 (+)
3	Dindigul	Andipatty	0.58 (-)	34.08 (-)	34.66 (+)
		Kallar (DGL)	10.52 (-)	10.52 (+)	-
4	Erode	Talamalai	-	130.72 (-)	130.72 (+)
5	Kanniyakumari	Virapuli	22.18 (-)	33.18 (-)	55.36 (+)
6	Krishnagiri	Anchetty	-	22.51 (-)	22.51 (+)
7	Madurai	Saptur	-	7.17 (-)	7.02 (+)
8	Tenkasi	Sivagiri	3.62 (-)	21.64 (-)	25.26 (+)
9	Nilgiris	Mudumalai & Kumbarakolli	14.49 (-)	14.49 (+)	-
		Bennie & Bennie ADDN I-V	0.28 (-)	3.17 (-)	3.46 (+)
10	Theni	Bodi North Hill	2.58 (-)	1.02 (-)	3.65 (+)
11	Tirunelveli	Kalakkadu	4.50 (-)	23.85 (-)	28.35 (+)
12	Tiruppur	Amaravathi	11.53 (-)	34.09	45.62 (+)
13	Virudhunagar	Seithur	3.20 (-)	10.97 (-)	14.17 (+)

4.4 Model Performance

The performance of Maxent model for reflecting the bioclimatic and environmental variables was good, with Area Under Curve (AUC) of 0.95 for the evergreen and 0.80 for deciduous and fair for the thorn tree species with 0.76 (Philips et al., 2006) (Figure 17,18&19). The Receiver Operating Characteristic (ROC) generally for a precise model fit the ROC appears at the top left appearing (Chitale and Behera, 2012) and at the bottom right triangle is considered as worst model fit than the random (Fawcett, 2006). Hence, for the present study the model with all key variables were selected as the final model for explaining potential habitat suitability distribution of the different forest type tree species in Eastern and Western Ghats of Tamil Nadu.

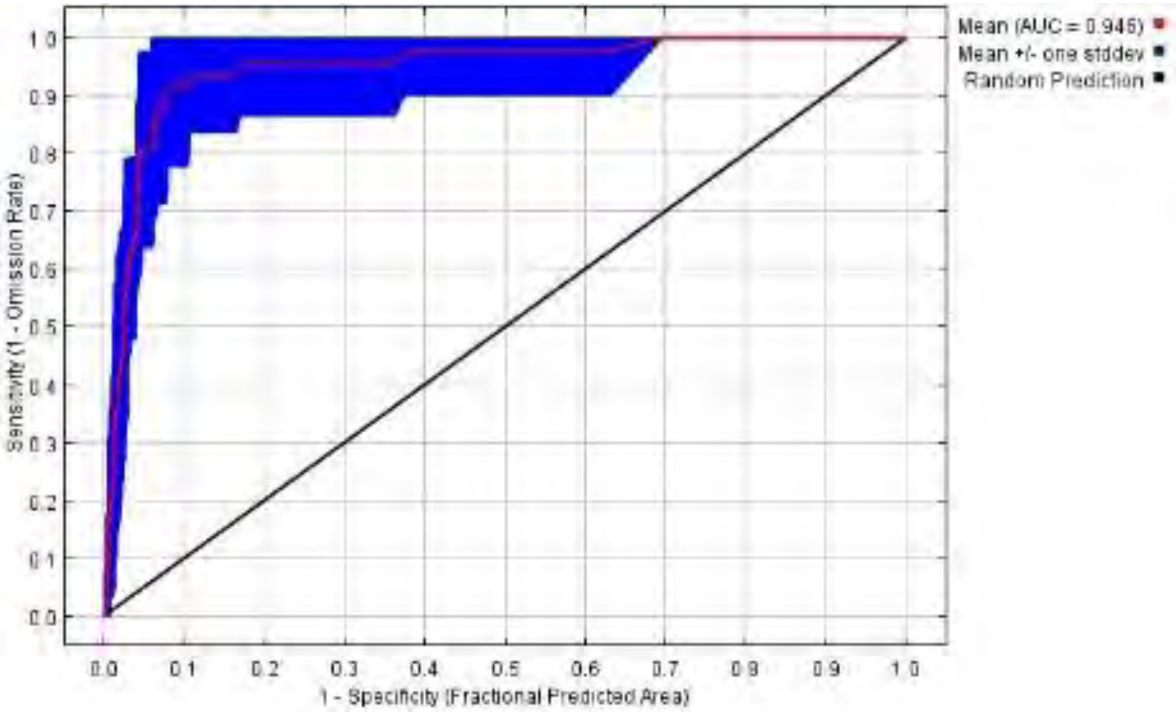

Figure 17. Area Under Curve (AUC) for Evergreen Tree Species

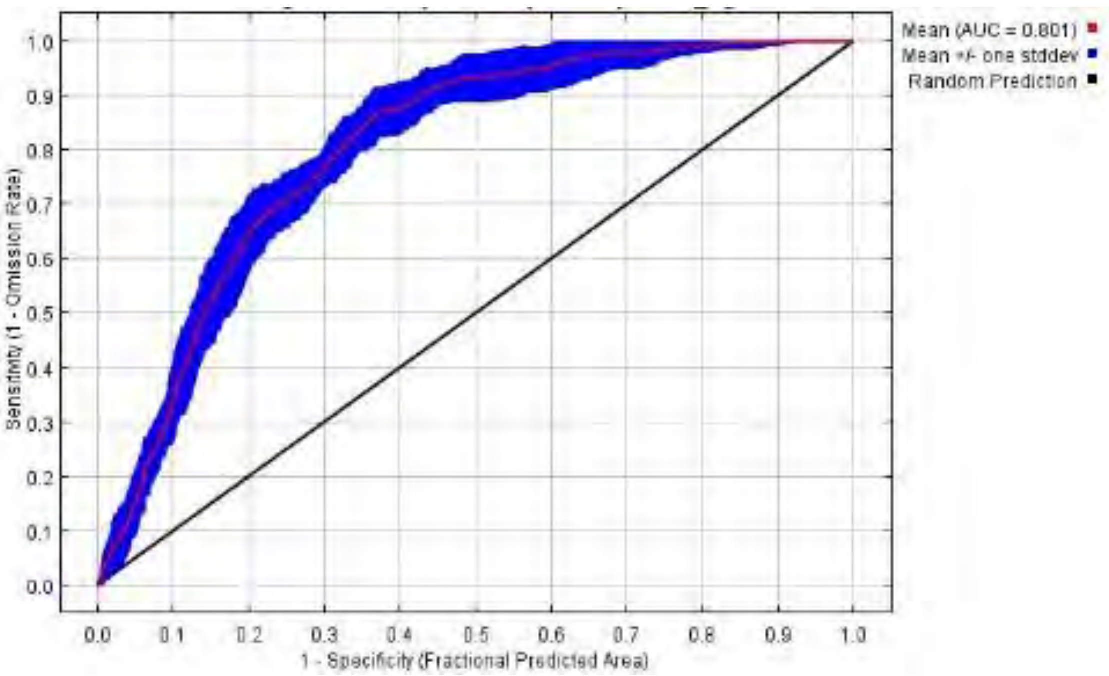

Figure 18. Area Under Curve (AUC) for Deciduous Tree Species

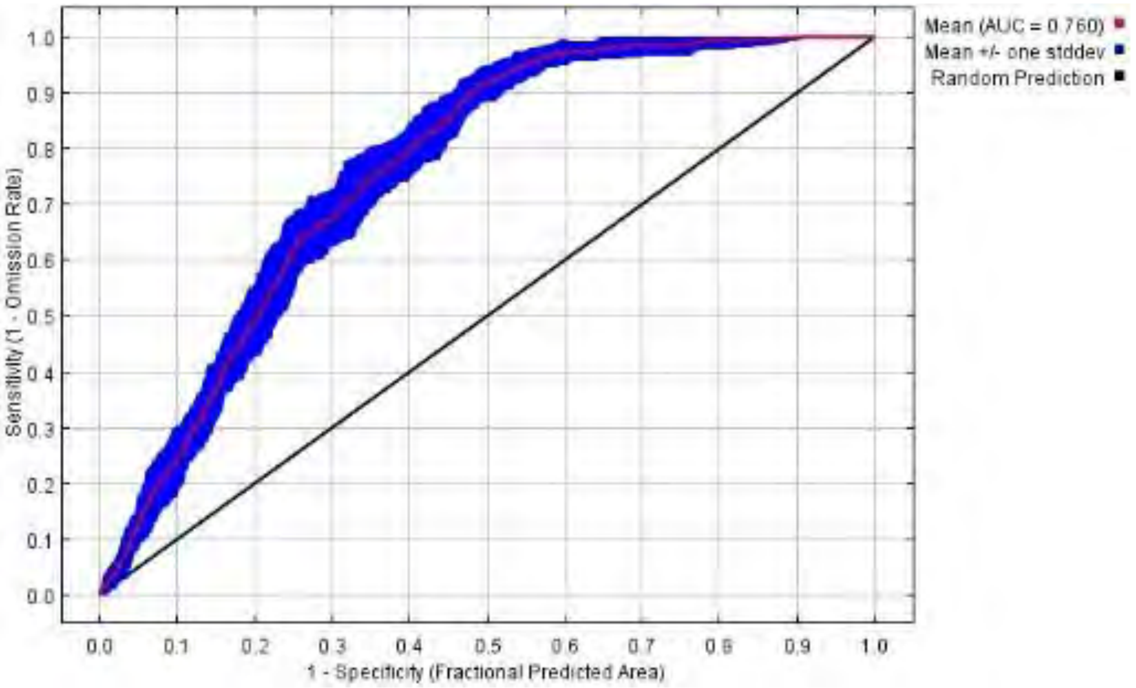

Figure 19. Area Under Curve (AUC) for Thorn Tree Species

4.5 Variable Contribution and Response

The Jackknife variable contribution test revealed that environmental parameter that is, elevation plays a major role in influencing the habitat suitability of different forest types in the Eastern and Western Ghats of Tamil Nadu (Fig.20,21&22). From the analysis of variable contribution, it is observed that Bio1: Average annual temperature, Bio 14: precipitation of driest month and Bio 19: precipitation of the coldest quarter together contributes 91% of the total variable contribution for the tree species representing evergreen forest type. Bio 2: Diurnal range of temperature (5%), Bio 18: precipitation of warmest quarter (3%) and Bio 7: Temperature annual range (0.7%) also had influence on the potential habitat suitability distribution of evergreen tree species. It was observed that during the base period, the annual mean temperature was 20.79±3 °C and the precipitation of driest month was 24±17 mm (Table 12).

Table 12. Key Bio Climatic Variables Impacting the Different Forest Types

Bioclimatic Variables	Temporal Scale	Evergreen	Deciduous	Thorn
Bio1 (°C)	Annual	20.79±3°C	24.83±2°C	27.15±2°C
Bio2 (°C)	Variation	8.79±1°C	9.51±0.8°C	9.59±1°C
Bio3 (°C)		60.24±3°C	58.39±3°C	59.48±4°C
Bio7 (°C)	Annual	14.69±2°C	16.38±2°C	16.23±2°C
Bio12 (mm)	Annual	1529±612mm	1011±343 mm	972±246 mm
Bio14 (mm)	Month	24±17mm	12±10 mm	11±7 mm
Bio15 (mm)	Variation	69±12 mm	76±11 mm	78±11 mm
Bio18 (mm)	Quarter	260±88 mm	187±43 mm	164±42mm
Bio19 (mm)	Quarter	303±126 mm	209±97 mm	229±83 mm
Elevation (m)		1262±535m	644±281m	291±270m

From the five primary contributing bioclimatic variables, the Bio1, Bio14, Bio19 variable had the maximum percent contribution for habitat suitability of evergreen forest types which was respectively 51.45 %, 22.15 % and 17.23 % (Table 13). Similarly, other studies also report the significant contribution elevation as the environmental variable (Remya et al., 2015; Gosh et al., 2021 and Kalarikal et al., 2022).

With respect to the Deciduous forest type, the distribution of representative tree species was influenced by Bio1, Bio 14 and Bio 19 which together contributed 81% of the total variable contribution.

It was observed that during the base period, the annual mean temperature was 24.83±2 °C and the precipitation of driest month was 12±10 mm (Table 13).

In contrast to the evergreen and deciduous forest types, the thorn forest type tree species distribution is influenced predominantly by Bio 15: precipitation of seasonality (32.82%) which along with Bio 1 (22.78%) and Bio 7 (11.97%) contributes 68% of the total variable contribution. Similar to our observation it is found that precipitation seasonality significantly affect the distribution of thorn tree species in arid zones of India (Singh et al., 2021). Bioclimatic variables especially temperature and precipitation during the critical periods of plant physiology determine the distribution of evergreen and deciduous tree species. Phonological changes of evergreen and deciduous tree species are significantly correlated to temperature and rainfall regimes. Temperature on the other hand could also lead to heat-tolerant species (Zomer et al.,2014; Krpnick 2013; Nictora et al., 2010), which was also observed in the present study.

Table 13. Primary contribution of the bioclimatic variables [%]

Representative species	Contribution (%)				
	Bio1	Bio7	Bio14	Bio15	Bio19
Evergreen	51.45	0.67	22.15	0	17.23
Deciduous	35.44	10.55	24.89	1.27	20.25
Thorn	22.78	11.97	7.34	32.82	8.88

(Bold: The most, second and third influential variable for representative tree species)

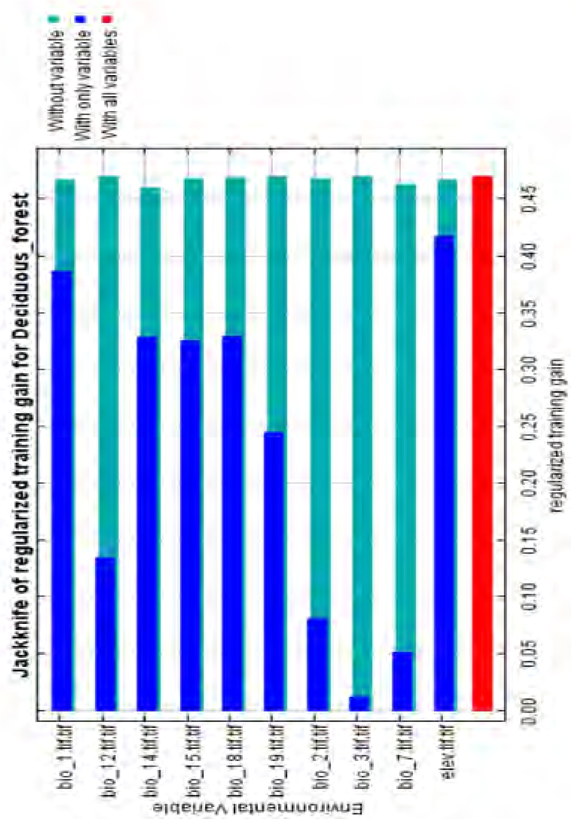

Figure 20. Variable Importance - Jackknife Test Deciduous Forest

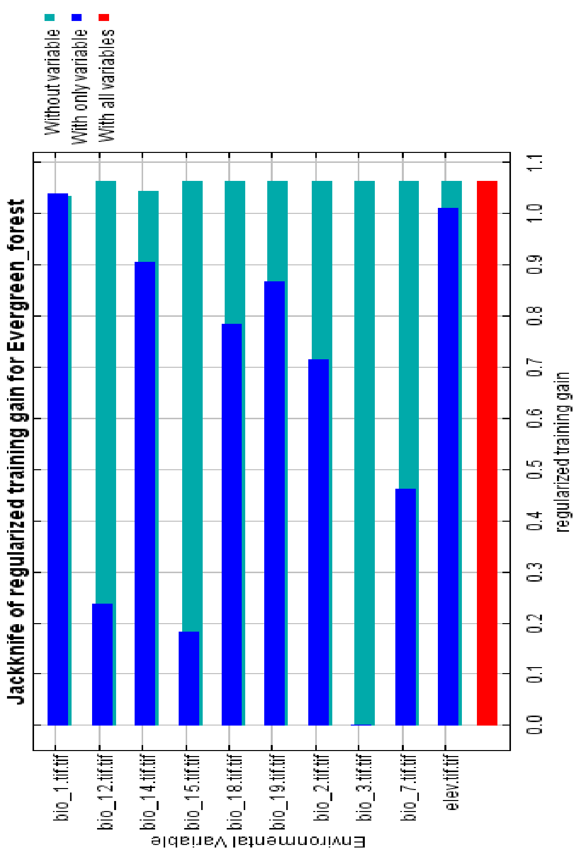

Figure 21. Variable Importance - Jackknife Test of Evergreen Forest

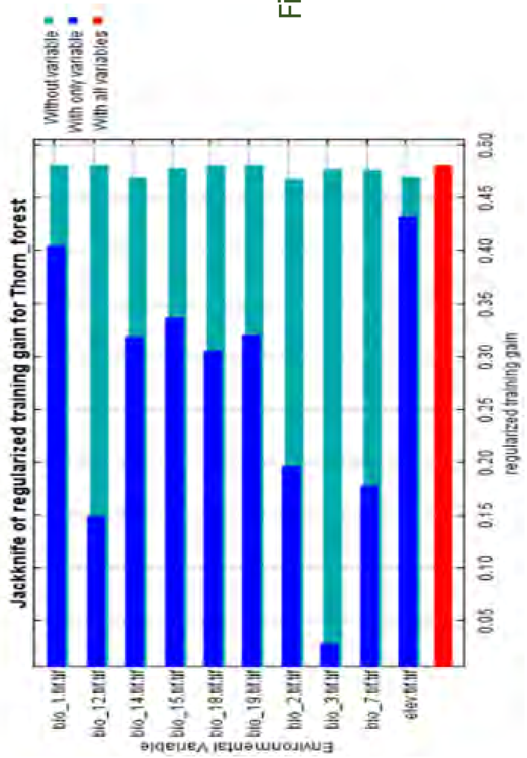

Figure 22. Variable Importance - Jackknife Test Thorn Forest

5. FUTURISTIC ADAPTATION STRATEGIES

It is found that the changes in habitat suitability of different forest types in the Eastern and Western Ghats of Tamil Nadu is driven by climate change. Land use change, socio economic pressures, and forest policies are also the confounding factors of changes in the state of forests. Being impacted by climate change, forest ecosystems take the longest response time to adjust, for example, through migration and regrowth. Additionally, the development and effective implementation of adaptation methods in the forest sector take a lot of time. Therefore, it is necessary to create and take urgent actions by applying suitable adaptation techniques. Adaptation practices are likely to vary for different forest types and regions, depending on the current status of the forests and knowledge of the projected impacts.

The Alluvial plot (Figure 23) reveal the climate resilient actions across three forest types: deciduous, evergreen, and thorn forests, with each type facing distinct challenges. Actions must address the two primary groups of climate risks i.e., climate extremes and habitat impact. In deciduous forests, where the risk of climate extremes such as intensive rainfall is prevalent, actions focus on soil conservation measures and community participation. These actions include special attention to Riparian forest, with adequate soil conservation measures and ensuring community participation in management enforcement and monitoring. In contrast, for evergreen forests, actions primarily target habitat impact reduction, emphasizing afforestation programs and biodiversity conservation. Notable actions include futuristic afforestation programmes encouraging multi-storey canopies with indigenous species and continuous observation of adaptability to tree species to changing climate Table 14.

Increase in the habitat suitability to thorn forest types necessitates the need to prevent the impact of hazards on xerophytic species. For instance, in thorn forests, actions predominantly need to focus on habitat impact mitigation and soil conservation. Creating fire breaks in fire prone areas and Soil conservation and water augmentation such as contour wall check dams, percolation ponds etc., highlight efforts to protect against wildfires and soil erosion, which are prevalent challenges in arid ecosystems. Overall, by recognizing the unique vulnerabilities and resilience mechanisms inherent to each forest type, policymakers and conservationists can develop effective strategies to enhance climate resilience and ecosystem sustainability.

Table 14. List of Adaptation Actions

S.No	List of Actions
1	Soil conservation and water augmentation such as contour wall check dams percolation ponds etc.,
2	Conserve vulnerable and endangered tree species
3	Regular monitoring of tree species adaptability to the changing climate
4	Riparian forest should have special attention with adequate soil conservation measures
5	Ensure community participation in management enforcement and monitoring
6	Conservation of mountain wetlands in mountainous ecosystem
7	Future afforestation programme should encourage multi storey canopies with indigenous species
8	Practice staggered contour planting in sloppy hills
9	Create fire breaks in fire prone area
10	Removal of alien/invasive species

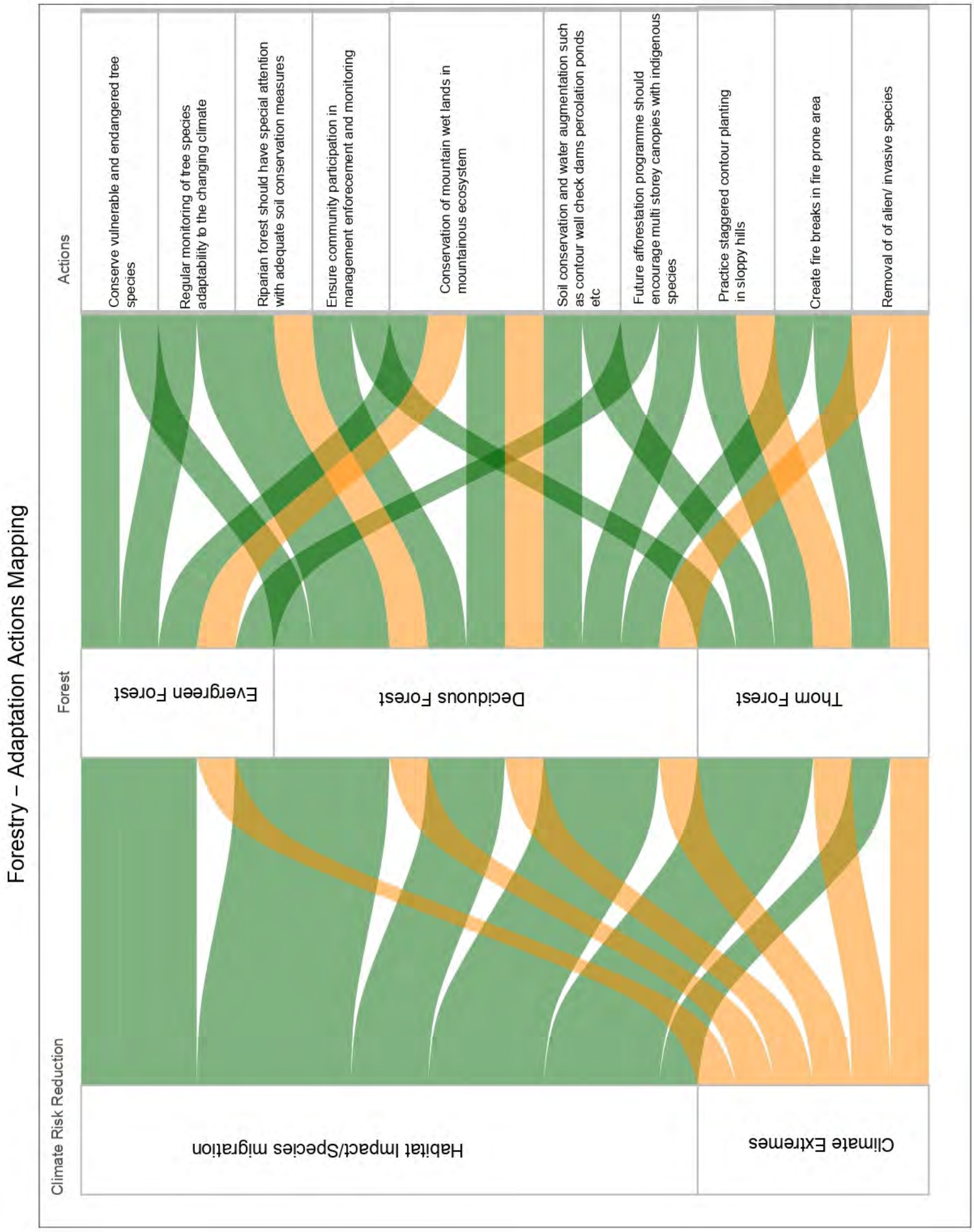

Figure 23. Forest Adaptation Action Map

SUMMARY

The present study examines the distribution and degradation status of different forest types in Tamil Nadu at the cadastral level, encompassing all reserve forests. Analysis of 19 bioclimatic variables determining forest cover was conducted across "the hills of Western Ghats and Eastern Ghats, where Tamil Nadu has 2423 Reserve Forests covering 19,841 sq. km.," as per the Forest Survey of India Report. Factors such as increasing temperature, intense rainfall, and climate extremes, like dry spells post-monsoon, adversely affect forest health, leading to gradual degradation of forest types and species distribution. The study reveals the current forest status between 1985-2014 as the base period and projects the impact of bioclimatic variables in different climate scenarios up to near-century (2021-2050). "It was projected that by 2050, evergreen and deciduous forest areas will reduce by 32% and 18%, respectively, while thorn forest suitability will increase by 71%". In the Eastern Ghats, habitat suitability for all forest types is expected to decline, particularly in Shervaroyan Hills, while in the Western Ghats, a decline in evergreen and deciduous forests is foreseen, especially in the northern portion such as the Nilgiris. Thorn forests, including degraded dry deciduous and euphorbia forests, are expanding in distribution in the foothills of both the Eastern Ghats and the Western Ghats due to factors like high temperature, altered rainfall patterns, and prolonged dry spells post-monsoon. To prevent further degradation and restore the thorn and euphorbia forests, it is crucial to adopt Good Forestry Practices, focusing on soil health by increasing soil organic carbon content, water augmentation, and soil conservation. Additionally, promoting indigenous species suitable for different soil types and involving local communities through awareness programs are essential to restore the ecosystem and its services, including carbon sequestration.

KNOWLEDGE DISSEMINATION

As part of this project aimed to disseminate knowledge on forest habitat suitability assessment in Tamil Nadu, focusing on raising awareness among policymakers about the impacts of climate change on forest ecosystems. The training programme engaged key stakeholders and policy makers of Government officials including the District Conservator of Forests, Rangers, and Foresters from the Tamil Nadu Forest Department.

A series of capacity-building sessions were conducted, comprising three two-day sessions for district-level officials and an additional one-day session for Principle Chief Conservators of Forests. A total of 63 government officials, representing all 38 districts of Tamil Nadu, participated in these sessions, gaining insights into forest habitat suitability at the Reserve Forest (RF) level.

The training programme facilitated a comprehensive understanding of various aspects of climate change and its specific impacts on different forest types prevalent in Tamil Nadu, spanning the Eastern and Western Ghats. Attendees were briefed on the shifting dynamics of forest habitat suitability, empowering them with the necessary framework and tools to assess the vulnerability and readiness of their districts and Reserve Forests.

Key priorities identified during the sessions emphasized the importance of preventing further degradation and restoring thorn and euphorbia forests. Participants were encouraged to adopt sustainable forestry practices, with a focus on enhancing soil health through measures such as increasing soil organic carbon content, water augmentation, and soil conservation strategies. Additionally, the promotion of indigenous species suited to different soil types, coupled with community engagement through awareness programs, and emerged as essential strategies for ecosystem restoration and services, including carbon sequestration.

These capacity-building initiatives laid the groundwork for the formulation of a comprehensive Forest Climate Action Plan. Participants were equipped with the knowledge and skills necessary to address the challenges posed by climate change in the Eastern and Western Ghats of Tamil Nadu, setting the stage for sustainable and climate-resilient forest management practices.

CLIMATE CHANGE VULNERABILITY AND ADAPTATION PLANTAMIL NADU - FOREST ECOSYSTEM. Capacity Building Programme-Supported by Department of Environment and Climate Change, Government of Tamil Nadu, Organized by Centre for Climate Change and Disaster Management (CCCDM) Anna University, Chennai – 600025

WAY FORWARD

The research way forward to prioritize the afforestation programme based on risks and vulnerability of changing climate with site-specific and species-specific conservation efforts. To start with, Tamil Nadu needs to take the Forest Reference Level (FRL) i.e., the present growing stock in terms of carbon dioxide equivalent. This will lead to mobilizing the local and global finances to demonstrate the projects in afforestation programme in terms of sequestered carbon, which requires in-built Monitoring, Reporting and Verification (MRV) mechanism.

- Forest Reference Level (FRL) Assessment: Evaluate the present growing stock in terms of carbon dioxide equivalent (CO_2e) to establish the Forest Reference Level (FRL) for Tamil Nadu.
- Risk and Vulnerability Assessment: Conduct a comprehensive assessment of climate change risks and vulnerabilities in Tamil Nadu, focusing on factors such as temperature trends, precipitation patterns, and ecosystem resilience.
- Site-Specific Conservation Strategies: Develop site-specific conservation strategies based on the identified risks and vulnerabilities, considering factors such as soil quality, vegetation cover, and topography.
- Financial Mobilization: Explore opportunities for mobilizing local and global finances to support afforestation projects in Tamil Nadu, leveraging the potential for carbon sequestration and ecosystem services.
- Monitoring, Reporting, and Verification (MRV): Establish an MRV mechanism to monitor the progress and effectiveness of afforestation projects, ensuring transparency and accountability in carbon sequestration efforts.

ANNEXURE

Table A1. Types of Forest Classification in Tamil Nadu

Class Name	Forest types	Area sq. km
Evergreen/Semi-evergreen Forest		
1A/C3 Southern hilltop tropical evergreen forest	Evergreen	108.815
1A/C4 West Coast tropical evergreen forest	Evergreen	680.617
2A/C2 West Coast semi-evergreen forest	Evergreen	411.057
2A/C3 Tirunelveli semi-evergreen forest	Evergreen	120.100
7/C1 Tropical dry evergreen forest	Evergreen	310.478
7/DS1 Tropical dry evergreen scrub	Evergreen	76.172
8A/C1 Nilgiri subtropical hill forest	Evergreen	173.489
	Total Evergreen/Semi-evergreen Forest	1880.728
Deciduous forest types		
2/E3 Moist bamboo brakes	Deciduous	323.638
3B/C1a Very moist teak forest	Deciduous	58.787
3B/C1b Moist teak forest	Deciduous	174.202
3B/C1c Slightly moist teak forest	Deciduous	51.346
3B/C2 Southern moist mixed deciduous forest	Deciduous	1252.743
3B/C2/2S1 Southern Secondary Moist mixed deciduous forest	Deciduous	261.465
4E/RS1 Riparian fringing forest	Deciduous	37.236
5A/C1a Very dry teak forest	Deciduous	0.904
5A/C1b Dry teak forest	Deciduous	157.374
5A/C2 Dry red sanders-bearing forest	Deciduous	10.427
5A/C3 Southern dry mixed deciduous forest	Deciduous	6207.627
5/DS1 Dry deciduous scrub	Deciduous	943.259
5/DS4 Dry grassland	Deciduous	284.191
5/E4 Hardwickia forest	Deciduous	439.772

Class Name	Forest types	Area sq. km
5/E9 Dry bamboo brakes	Deciduous	151.338
5/1S1 Dry tropical riverain forest	Deciduous	113.010
5/2S1 Secondary dry deciduous forest	Deciduous	2740.674
11A/C1 Southern montane wet temperate forest	Deciduous	186.744
Total Deciduous forest		13394.738
Thorn forest types		
5/DS2 Dry savannah forest	Thorn	367.098
5/DS3 Euphorbia scrub	Thorn	3.287
6A/C1 Southern thorn forest	Thorn	1862.607
6A/C2 Carnatic umbrella thorn forest	Thorn	1472.674
6A/DS1 Southern thorn scrub	Thorn	515.802
6A/DS2 Southern Euphorbia scrub	Thorn	43.606
8A/DS1 South Indian sub-tropical hill savannah (woodland)	Thorn	19.121
8A/E1 Reed brakes (Ochalandra)	Thorn	3.481
11A/C1/DS1 Southern montane wet scrub	Thorn	4.173
Total Thorn forest		4291.848
11A/C1/DS2 Southern montane wet grassland	Other forest	211.545
4A/L1 Littoral forest	Other forest	7.984
4B/TS1 Mangrove scrub	Other forest	32.276
4B/TS2 Mangrove forest	Other forest	20.672
4C/FS2 Submontane hill valley swamp forest	Other forest	2.131
Total other forest		273.685
Total forest area		19841
TOF/Plantation		7843.427
Water		1853.471
Non-Forest		100984.738

Table A2. List of Dominant Plant Species Distribution in the Evergreen Forest Type

S.No	Evergreen Species	Common Name
1	*Canarium strictum* Roxb.	Black dammar
2	*Elaeocarpus recurvatus* Coner	Rudraksh
3	*Artocarpus hirsutus* Lam.	Ayani
4	*Syzygium cumini* (L.) Skeels	Jamuna
5	*Mesua Ferrea* L.	Nag Kesar
6	*Myristica dactyloides* Gaertn.	Jaadhikai
7	*Dendrocalamus hamiltonii* Nees & Arn. ex Munro	Tama Bamboo
8	*Dipterocarpus macrocarpus* Vesque	Garjan oil tree
9	*Hopea parviflora* Bedd.	Ironwood
10	*Vateria indica* L.	White Dammar
11	*Pterospermum diversifolium* Blume	Muchukunda
12	*Dalbergia latifolia* Roxb.	Black Rosewood
13	*Memecylon edule* Roxb.	Iron wood
14	*Persea macrantha* (Nees) Kosterm.	Bay Tree
15	*Tetrameles nudiflora* R. Br.	Chini
16	*Vernonia arborea* Welw. ex O.Hoffm.	karana
17	*Prunus ceylanica* (Wight) Miq.	Attanrikongu
18	*Nothopegia colebrookiana* (Wight) Blume	Naicheru
19	*Memecylon umbellatum* Burm. f.	Iron wood
20	*Cinnamomum macrocarpum* Hook. fil.	Illavangappattai

Tamil Nadu Climate Change Mission.

Table A3. List of Dominant Plant Species Distribution in the Deciduous Forest Type

S.No	Deciduous Species	Common Name
1	*Pterocarpus marsupium* Roxb.	Venkai
2	*Terminalia bellirica (Gaertn.) Roxb*	Thandri
3	*Lagerstroemia lanceolata* Wall.	Ventheak
4	*Adina cordifolia* (Roxb.) Benth. & Hook.f. ex B.D.Jacks.	Manjakkatamp
5	*Grewia tiliifolia* Vahl	Una
6	*Terminalia bellirica* (Gaertn.) Roxb.	Thaandri kaai
7	*Mitragyna parvifolia* (Roxb.) Korth.	Nira Kadamba
8	*Alstonia Scholaris* (L.) R. Br.	Elilaippalai
9	*Terminalia paniculata* Roth	Pillai Maruth
10	*Anogeissus pendula* Edgew.	Button tree
11	*Boswellia serrata* Roxb. ex Colebr.	kumancam
12	*Hardwickia binata* Roxb.	Aacha
13	*Acacia arabica* (Lam.) Willd.	Karu-velamaram
14	*Butea monosperma* (Lam.) Taub.	kincukam
15	*Aegle marmelos* (L.) Correa	Vilvam
16	*Phoenix sylvestris* (L.) Roxb.	Inthupaana
17	*Terminalia chebula* Retz.	Kadukkai
18	*Gyrocarpus americanus* Jacq.	Tanakku
19	*Polyalthia cerasoides* (Roxb.) Bedd.	Irumpuli
20	*Melia azedarach* L.	Kattu Vembhu

Table A4. List of Dominant Plant Species Distribution in the Thorn Forest Type

S.No	Thorn Species	Common Name
1	*Chloroxylon swietenia* (Roxb.) DC.	Porasu
2	*Albizia amara* (Roxb.)B.Boivin	Usilai
3	*Acacia chundra* (Rottler)Willd.	Karangali
4	*Acacia ferruginea* DC.	Karivelam
5	*Azadirachta indica* A.Juss.	Neem
6	*Canthium dicoccum (Gaertn.)* Merr.	*Nanjul*
7	*Erythroxylum monogynum* Roxb.	Sembulichan
8	*Ziziphus rugosa* Lam.	Elandhi
9	*Ziziphus xylopyrus* (Retz.) Willd.	Kath Ber
10	*Cleistanthus collinus* (Roxb.) Benth. ex Hook.f.	Oduvan
11	*Dichrostachys cinerea* (L.) Wight & Arn.	vetuttalam
12	*Atalantia monophylla* DC.	Wild lime
13	*Acacia planifrons* Wight & Arn.	Kuṭai mu
14	*Strychnos nux-vomica* L.	Etti
15	*Dichrostachys cinerea* (L.) Wight & Arn.	Sickle Bush
16	*Commiphora berryi* (Arn.) Engl	Mulkiluvai
17	*Alangium glandulosum* Thwaites	Alngil
18	*Tamarindus indica* L.	Tamarind
19	*Pongamia pinnata* (L.) Pierre	Pongam
20	*Prosopis juliflora sensu* auct.	Algaroba

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