# CLIMATE RISK ASSESSMENT AND ADAPTATION PLAN OF TAMIL NADU

## SUSTAINABLE AGRICULTURE

Under

**CLIMATE STUDIO**

**REPORT**

**2024**


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Department of Environment and Climate Change
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Prepared by
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## PREFACE

The agriculture sector in Tamil Nadu stands at a critical crossroads, as climate change increasingly impacts food production systems and the livelihoods of millions. Historically, Tamil Nadu agriculture has thrived due to its diverse agro-climatic zones, enabling the cultivation of a wide array of crops. However, the rising intensity of climate change is introducing unprecedented challenges, threatening the very foundation of this essential sector.

The "Climate Risk Assessment and Adaptation Plan for Sustainable Agriculture in Tamil Nadu" is a direct response to these evolving threats. This report not only highlights the vulnerabilities of Tamil Nadu agricultural landscape to climate-induced stressors but also charts a path forward for enhancing the sector's resilience. The document brings together extensive research and field data to propose strategic interventions aimed at fostering sustainable agricultural practices that can withstand the adverse impacts of climate variability.

In preparing this report, the Climate Studio has undertaken a rigorous assessment of the complex interactions between climate parameters and crop productivity. By evaluating the sector's vulnerabilities and identifying potential adaptation strategies, this report serves as a critical tool for policymakers, researchers and farmers alike in shaping a sustainable future for Tamil Nadu agricultural community.

The recommendations and strategies presented here are a result of collaborative efforts across multiple sectors and institutions, demonstrating a united commitment to building climate resilience. The knowledge shared in this document will be instrumental in guiding Tamil Nadu agricultural sector toward a more secure, adaptive, and sustainable future.

This report is not just a technical document; it is a blueprint for action, aimed at empowering stakeholders at all levels to confront the challenges posed by climate change head-on.

( P.Senthilkumar )

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## FOREWORD

Tamil Nadu has a long and rich tradition of agriculture with diverse agro-climatic zones that support the cultivation of a wide range of crops. However, this vital sector is now facing an unprecedented challenge due to the rapidly changing global climate. Agriculture is the backbone of Tamil Nadu's economy, contributing significantly to the state's GDP and providing employment and sustenance to millions of people. It is a crucial sector that ensures food security and supports the livelihoods of rural communities. However, the adverse effects of climate change are increasingly threatening the productivity and resilience of agricultural systems in the state.

The Climate Risk Assessment and Adaptation Plan for Sustainable Agriculture in Tamil Nadu presented in this document marks a significant milestone in our endeavor to establish a climate-resilient agricultural sector for the state. This comprehensive report exemplifies Tamil Nadu's proactive approach to addressing climate change challenges and provides a roadmap for sustainable development in the region.

Through an in-depth analysis of the intricate relationship between climate variables and crop, this document offers valuable insights into the vulnerabilities and resilience of the agricultural sector, enabling informed decision-making and adaptive strategies. This report presents a comprehensive suite of adaptation strategies tailored to the unique challenges faced by our state's agricultural sector.

I extend my sincere gratitude 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.

**(A.R. Rahul Nadh)**

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- State Planning Commission (SPC), Government of Tamil Nadu
- Tamil Nadu Agricultural University (TNAU), Coimbatore
- 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
- Tamil Nadu Pollution Control Board (TNPCB), Government of Tamil Nadu
- Institute of Water Studies (IWS), Tharamani
- Institute of Remote Sensing (IRS), Anna University

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*EXECUTIVE SUMMARY*

Climate change induced by human activities poses a major threat to sustainable development as it influences the frequency and severity of extreme events such as floods, heat waves, droughts, cyclones, etc., which have direct and indirect impacts on water resources, agriculture, forestry, biodiversity, coastal ecosystems, and health. The Intergovernmental Panel on Climate Change (IPCC) Assessment Report 6 (AR6) emphasizes the role of sustainable agriculture in mitigating and adapting to climate change impacts on food production systems. Simultaneously, the Sustainable Development Goal (SDG) 2, "Zero Hunger," underscores the importance of sustainable agriculture in ending hunger, achieving food security, improving nutrition, and supporting smallholder farmers. Aligning with these global goals, the National Mission for Sustainable Agriculture (NMSA) in India aims to transform Indian agriculture into a climate-resilient and sustainable production system. At the state level, the Tamil Nadu State Action Plan on Climate Change (TNSAPCC) prioritizes sustainable agriculture practices to enhance resilience and mitigate emissions. Leveraging agriculture's potential as a climate change solution enables countries to advance environmental and socio-economic goals synergistically. Ultimately, integrating sustainable agricultural practices into policy frameworks allows nations to bolster resilience, ensure food security, and promote inclusive growth amid rapid global changes.

*Climate Studio at CCCDM*

Embracing its commitment to the Nationally Determined Contribution (NDC), Tamil Nadu has emerged as a pioneer in developing adaptation and mitigation strategies across sectors. Utilizing 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 analyze global climate data at the cadastral level. 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

### *Climate Change Impact on Major Crops*

Addressing the serious food security challenges posed by climate change, researchers globally have employed simulation models at various scales to evaluate crop yield impacts. A commonly used model is the Decision Support System for Agro technology Transfer (DSSAT), which simulates crop growth, development, and yield. Utilizing DSSAT, crop simulation models have projected significant yield reductions for major crops in Tamil Nadu under future climate conditions. These crops include rice, maize, sorghum, groundnut, and black gram across various agro-climatic zones. The model simulations compared crop yields under baseline and projected climate scenarios, while also considering different agricultural practices. The simulation of crop yield during the near century with reference to baseline (1985-2014) in Tamil Nadu is presented in the following table.

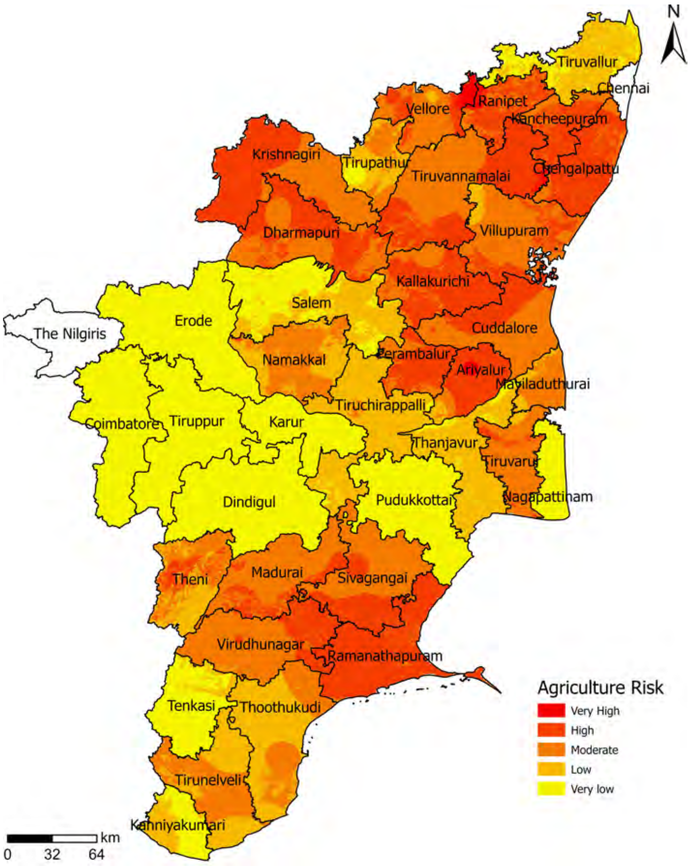
Projected Crop Yield Change during Near Century (2021-2050)

| Crop | Yield Change (%) | Very high-impact districts |
|---|---|---|
| Rice | -19.8 to -4.6 | Chengalpattu, Kancheepuram, Ranipet and Kallakuruchi |
| Maize | -23.37 to -14.5 | Chengalpattu, Kancheepuram, Villupuram, Kallakurichi, Tiruvallur, Ranipet, Tiruvannamalai and Cuddalore |
| Sorghum | -19.05 to -2.8 | Vellore, Cuddalore, Kallakurichi, Tiruvannamalai, Ranipet, Villupuram |
| Black gram | -7.09 to 14.74 | Chengalpattu and Kancheepuram |
| Groundnut | -16.5 to -2.37 | Cuddalore, Ranipet, Villupuram, Kallakurichi andTiruvannamalai |

### *Agriculture Risk Assessment*

Further, a climate risk assessment incorporating the hazards (floods and droughts), and vulnerability, including water availability, biophysical factors, and socio-economic factors. The climate risk assessment revealed that agriculture in Ranipet, Ariyalur, Perambalur, Ramanathapuram, Kallakurichi, Chengalpattu, Dharmapuri, Kancheepuram, Cuddalore, Krishnagiri, Vellore, Thiruvannamalai, Sivagangai, Madurai and Virudhunagar shows very high agriculture risks in the near century period. Villupuram, Thiruvarur, Nagappattinam and Theni would be at high risk in agriculture due to climate change. Erode and Coimbatore indicate as very low agriculture risk of Tamil Nadu

Agriculture Risk of Tamil Nadu




## *Agriculture Adaptation Actions*

The adaptation measures identified were categorized according to the broad framework outlined by the IPCC, encompassing strategies such as

- Crop Management
- Good Agriculture Practices
- Water Augmentation

Based on the comprehensive assessment of projected agricultural risks, a set of prioritized actions has been identified to address the challenges posed by climate change impacts on the agricultural sector. These actions are designed to ensure the sustainability of food production systems and promote the implementation of resilient agricultural practices. improving water resource management, promoting sustainable soil management practices, and enhancing farmer access to climate information and advisory services.

Tamil Nadu aims to safeguard its agricultural sector from the projected risks associated with climate change, ensuring food security, protecting farmer livelihoods, and maintaining the overall sustainability of the agricultural ecosystem. These actions will contribute to building a more resilient and adaptive agricultural system that can withstand the impacts of climate change while continuing to meet the food demands of the state's population.

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# Abbreviation

| | | | |
|---|---|---|---|
| AR6 | Sixth Assessment Report | NC | Near century |
| ARI | Agriculture Risk Index | NEZ | North Eastern Zone |
| AVI | Agriculture vulnerability index | NGO | Non-Governmental Organization |
| CDZ | Cauvery Delta Zone | NMSA | National Mission on Sustainable Agriculture |
| CMIP6 | Coupled Model Intercomparison Project Phase 6 | NWZ | North Western Zone |
| $CO_2$ | Carbon die oxide | PDMC | Per Drop More Crop |
| DHI | Drought Hazard Index | PMKSY | Pradhan Mantri Krishi Sinchayee Yojana |
| DRI | Drought Risk Index | RAD | Rainfed Area Development |
| DSSAT | Decision Support System for Agrotechnology Transfer | RCP | Representative Concentration Pathway |
| DVI | Drought Vulnerability Index | RKVY | Rashtriya Krishi Vikas Yojana |
| EC | End of century | SDI | Streamflow Drought Index |
| FHI | Flood Hazard Index | SDM | Statistical Downscaling model |
| FRI | Flood Risk Index | SPEI | Standardized Precipitation Evapotranspiration Index |
| GAP | Good Agricultural Practices | SPI | Standardized Precipitation Index |
| GCM | Global Circulation Models | SSP | Shared Socioeconomic Pathways |
| GDP | Gross domestic product | SW | South-West |
| GHGs | Greenhouse gases | SWAT | Soil and Water Assessment Tool |
| GIS | Geographic Information Systems | SZ | Southern Zone |
| HRZ | High Rainfall Zone | TNIAMP | Tamil Nadu Irrigated Agriculture Modernization Project |
| IMD | India Meteorological Department | TNSAPCC | Tamil Nadu State Action Plan on Climate Change |
| IPCC | Intergovernmental Panel on Climate Change | UNEP | United Nations Environment Programme |
| LULC | Land Use Land Cover | | |
| MC | Mid-century | WMO | World Meteorological Organization |
| MSL | Mean Sea Level | WZ | WZ |
| NADP | National Agriculture Development Programme | | |
| NAFCC | National Adaptation Fund for Climate Change | | |
| NBS | Nature-Based Solutions | | |

## 1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) warns that climate change severely endangers agriculture and food supplies worldwide. Higher temperatures, shifting precipitation patterns, and more frequent extreme events like droughts and floods are already diminishing agricultural productivity across many regions. Consequently, crop yields decline, livestock perish, and food distribution faces disruptions - exacerbating hunger and malnutrition risks, especially among vulnerable populations. As the global population expands, escalating food demands underscore the urgency of confronting climate change's agricultural challenges. The National Mission on Sustainable Agriculture (NMSA) is a program initiated by the Indian Government’s Ministry of Agriculture and Farmers Welfare. It aims to make agriculture in India more sustainable and resilient to climate change by promoting practices that improve soil health, conserve water, and reduce the use of chemicals in farming. The NMSA also encourages farmers to adopt integrated farming systems tailored to their specific locations, aiming to increase farm productivity and income while ensuring environmental sustainability. This mission is crucial for addressing challenges such as soil degradation, water scarcity, and climate change in Indian agriculture.

The Tamil Nadu State Action Plan on Climate Change (TNSAPCC) is a comprehensive strategy developed by the government to tackle climate change in the state. It aims to reduce greenhouse gas emissions, boost climate resilience, and foster sustainable development across sectors, notably agriculture. Regarding agriculture, the TNSAPCC focuses on advocating climate-smart farming techniques to help farmers adjust to changing climate patterns and alleviate climate change impacts. This includes promoting drought-resistant crops, enhancing water management, and improving soil health. Additionally, the TNSAPCC stresses the significance of sustainable farmer livelihoods, promoting practices that enhance both agricultural productivity and environmental conservation while fostering community development.

Agriculture is the backbone of Tamil Nadu's economy, playing a pivotal role in the state's socio-economic development and food security. With approximately 60 percent of the population engaged in agricultural and allied activities, this sector remains the primary source of livelihood for a significant portion of the state (AGRISNET 2020-21). Agriculture is a crucial sector in Tamil Nadu, contributing around 8–9% to the state's gross domestic product. In the 2021–22 crop year, the total food grain production in Tamil Nadu was around 10.5 million metric tons, with rice being the major crop, contributing over 6.5 million metric tons. Tamil Nadu is known for its diverse agro-climatic conditions, which enable the cultivation of a wide range of crops, including rice, millets, pulses, oilseeds, cotton, sugarcane, and various horticulture crops. However, the agricultural sector in Tamil Nadu faces numerous challenges, including water scarcity, soil degradation, fragmented landholdings, and the impacts of climate change.

Climate change is already manifesting its impact in Tamil Nadu, with increased temperature, frequency, and intensity of rainfall, droughts, and floods. These climatic changes directly affect crop yields, water availability, and soil fertility, threatening the sustainability of agricultural practices and farmers' livelihoods. This has severe implications for rained agriculture, which accounts for a substantial portion of the state's cultivated area. In addition, climate change also indirectly affects agriculture through the increased incidence of pests and diseases, soil degradation, and the loss of biodiversity. These factors can potentially lead to reduced crop yields, compromised food quality, and economic losses for farmers, ultimately threatening the state's food security and rural livelihoods.

There is a need to quantify the growth and yield responses of essential crops and identify suitable land use options to sustain agricultural productivity under this extensive range of climatic variations. This includes developing resilient crop varieties that can withstand extreme weather conditions, implementing efficient irrigation systems to mitigate the effects of droughts, and adopting climate-smart agricultural practices. Additionally, promoting soil conservation techniques and agroforestry can help enhance the resilience of agricultural systems to climate variability. By taking proactive measures and investing in sustainable agricultural practices, the Indian subcontinent can better adapt to the challenges posed by climate change and ensure food security for its growing population. The Decision Support System for Agro technology Transfer (DSSAT) is a research and teaching tool used to derive recommendations concerning crop management and investigate environmental and sustainability issues.

## 1.1 Tamil Nadu Agriculture at Glance

Tamil Nadu, situated at the southernmost tip of the Indian Peninsula, lies between the latitudes of 8°05' and 13°35' north and longitudes of 76°15' and 80°20' east. It shares borders with Kerala, Karnataka, Andhra Pradesh, and the union territory of Puducherry. Physiographically, it is bordered by the Eastern Ghats to the north, the Nilgiris and the Anamalai Hills to the west, the Bay of Bengal to the east, the Gulf of Mannar and the Palk Strait to the southeast, and the Indian Ocean to the south. Much of Tamil Nadu falls within the rain shadow of the Western Ghats, resulting in limited rainfall during the Southwest Monsoon. However, it receives significant rainfall during the Northeast.

Tamil Nadu is a state in southern India known for its diverse agricultural landscape, with crops ranging from rice and sugarcane to cotton and pulses. The state experiences a tropical climate with distinct wet and dry seasons, making it vulnerable to extreme weather events such as droughts and floods. The agriculture sector plays a crucial role in the state's economy, providing livelihoods for many of the population. In recent years, the state has faced water scarcity, soil degradation, and climate change challenges, highlighting the need for sustainable agricultural practices and technological interventions. In Tamil Nadu, 70% of the population is engaged in agriculture, and 22% of income is from agriculture and allied sectors. At the national level, 2.9% of the total cropped area is in Tamil Nadu (Agriculture Statistics, 2019).

The net area sown in Tamil Nadu is 47.38 lakh hectares, making up about 36.4 percent of the State's total geographical area. As per the agricultural statistics, Tamil Nadu has 73.43 lakh operational landholders, tending to 64.88 lakh hectares of cultivable land. The cropping intensity of Tamil Nadu is 125.4%, which means the ratio of net sown area and gross cropped area. Table 1 shows the spatial extent of the agriculture-related information in Tamil Nadu

**Table 1 Agriculture Profile of Tamil Nadu**

| S. No | Particulars | Unit (Lakhs) |
|---|---|---|
| 1. | Total geographical area | 130.33 |
| 2. | Total cultivable area | 61.55 |
| 3. | Net area sown | 48.33 |
| 4. | Gross Area sown | 61.56 |
| 5. | Total cultivable area of cereals | 30.17 |
| 6.. | Total cultivable area of pulses | 8.03 |
| 7 | Total cultivable area of food grains | 38.2 |

*(Sources: Agriculture statistics, 2019–20)*

Regarding agricultural land use, Tamil Nadu boasts a total cultivable area of approximately 38.2 lakh hectares dedicated to food grains and 8.03 lakh hectares allocated for pulses, as per agricultural statistics from 2019-20. This delineation of land usage highlights Tamil Nadu's significant contribution to the production of essential food crops within the country. It also underscores the need for sustainable land management practices to maximize productivity while minimizing environmental degradation.

According to 2015-16, Tamil Nadu landholdings are 62.24 lakhs of farmers that come under marginal farmers, with less than 1 ha of land. Enhancing its resilience to climate change and ensuring a stable future for its agricultural sector. The distribution of land holdings in the state varies, with 62.24 lakh marginal holdings, 11.19 lakh small holdings, 4.52 lakh semi-medium holdings, 1.28 lakh medium holdings, and 0.15 lakh large holdings (Fig.1).

**Table 2 Number and area of land holding in Tamil Nadu**

| S. No | Classification | Number of holdings (lakhs) | Area (lakhs ha) |
|---|---|---|---|
| 1 | Marginal (< 1 ha) | 62.24 | 21.69 |
| 2 | Small (1 to 2 ha) | 11.19 | 15.56 |
| 3 | Semi-medium (2 to 4 ha) | 4.52 | 12.15 |
| 4 | Medium (4 to 10 ha) | 1.28 | 7.14 |
| 5 | Large (10 ha & above) | 0.15 | 3.17 |
| Total | | 79.38 | 59.71 |

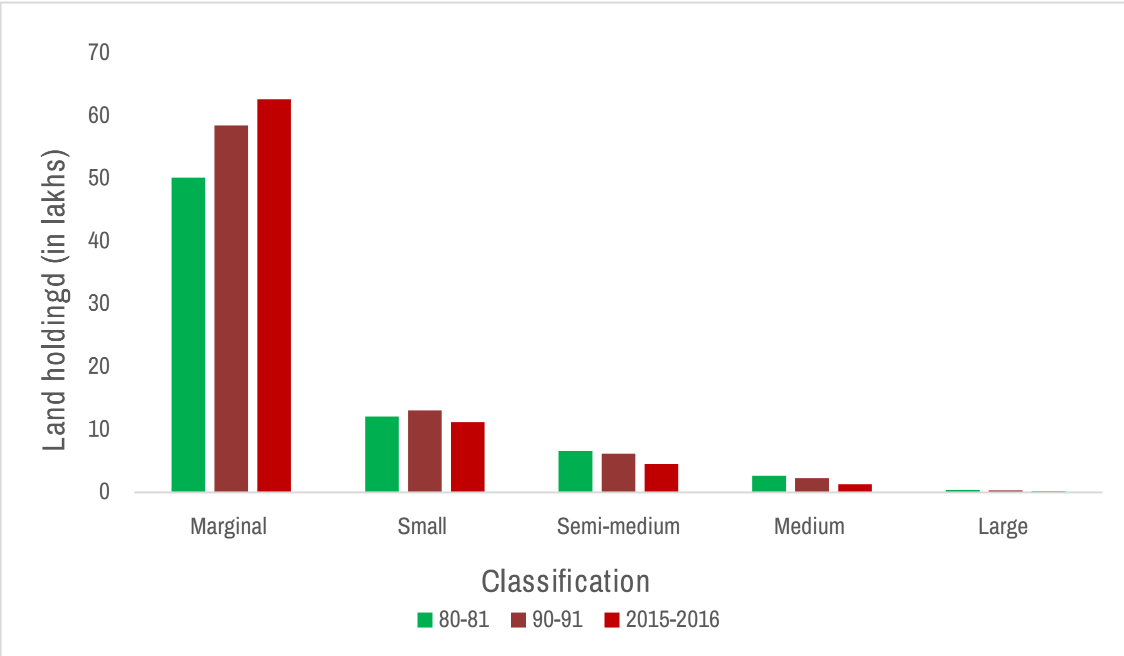


Figure 1 Number of holdings in Tamil Nadu

These statistics highlight the diverse range of land holdings in Tamil Nadu, with a significant number of marginal and small farms. It is crucial for the government to provide support and resources to these small-scale farmers to empower them to adopt modern agricultural practices and technologies. By investing in sustainable agriculture and focusing on increasing productivity, Tamil Nadu can continue to make strides towards food security and economic development in the agricultural sector.

## 1.2 Agro-Climatic Zone of Tamil Nadu

Tamil Nadu has been categorized into seven agro-climatic zones based on its diverse geographical and climatic features. The classification of agro-climatic zones in Tamil Nadu is primarily based on factors such as rainfall, soil types, elevation, and cropping patterns (Figure 2).


Figure 2 Agro Climatic Zone of Tamil Nadu

### 1.3.1 North Eastern Zone

The Northeastern Zone (NEZ) of Tamil Nadu comprises ten districts: Kancheepuram, Chengalpattu, Thiruvallur, Cuddalore, Villupuram, Kallakurichi, Vellore, Tirupathur, Ranipet, and Thiruvannamalai. (Figure.3). Chennai is excluded, it is urbanized district of NEZ. This Zone covers Red sandy loam, Clay loam, Saline coastal, and alluvium. The average annual rainfall received in this Zone is 1105 mm. Four of the ten districts are coastal: Thiruvallur, Chengalpattu, Villupuram, and Cuddalore. These coastal districts contribute to the agricultural output and have unique land use patterns influenced by their proximity to the Bay of Bengal. Chennai, the capital city of Tamil Nadu, is situated within this zone and is the most urbanized district.

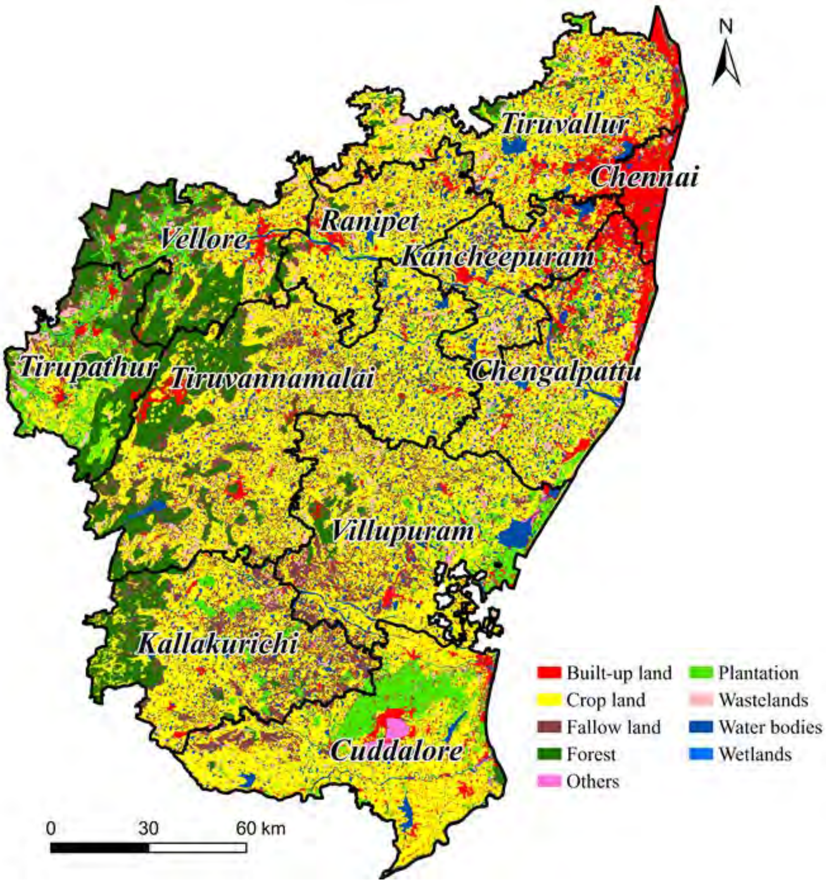


Figure 3 Landuse and Land cover of NEZ

Due to its extensive urban infrastructure, Chennai's contribution to agriculture is negligible. The Eastern Ghats bounds the western parts of the NEZ, a significant geographical feature that influences the zone's climate, water availability, and soil types. This zone is notable for its diverse land use and land cover patterns, which are significant in its agricultural and ecological dynamics. As depicted in Fig. 3, the NEZ features a variety of land uses and land covers, with approximately 60-70% of the area designated for agricultural activities. This substantial agricultural presence underscores the importance of this zone in the state's food production and rural economy. The predominant agricultural practices include the cultivation of paddy, pulses, groundnut, sugarcane, and various horticultural crops. Table 3 illustrates these districts' geographical area, cropped area, net area sown, and cropping intensity. Thiruvannamalai has a larger geographical area (631,205 ha), which often implies more potential land for agricultural activities.

Table 3 Agriculture profile of NEZ

| Districts | Geographical area (ha) | Cropped area (ha) | Net area Sown (ha) | Cropping Intensity (%) |
|---|---|---|---|---|
| Kancheepuram | 1,70,479 | 48,146 | 39,048 | 146.9 |
| Chengalpattu | 2,63,892 | 74,600 | 64,420 | 121.3 |
| Tiruvallur | 3,24,604 | 1,44,766 | 89,016 | 165.9 |
| Cuddalore | 3,67,781 | 3,09,832 | 2,12,736 | 148 |
| Villupuram | 3,91,468 | 2,58,911 | 1,94,264 | 160.1 |
| Kallakuruchi | 3,30,735 | 2,09,843 | 1,43,417 | 146.3 |
| Vellore | 2,23,264 | 57,754 | 48,940 | 126 |
| Tirupathur | 1,83,201 | 73,855 | 60,780 | 126.4 |
| Ranipet | 1,85,553 | 60,678 | 49,969 | 128.4 |
| Thiruvannamalai | 6,31,205 | 3,51,011 | 2,37,071 | 160.1 |

Thiruvannamalai also has the highest net sown area (237,071 ha). Among the ten districts, Thiruvallur has the highest cropping intensity (165.9%), followed by Villupuram (160.1%), Thiruvannamalai (160.1%), and Cuddalore (148%). This indicates that farmers in Thiruvallur, Villupuram, and Cuddalore districts efficiently use agricultural land and better utilize water resources.

### 1.3.2 North WZ

The districts covered Salem, Namakkal, Dharmapuri, and Krishnagiri. The climate in this Zone is semi-arid, with hot and limited rainfall during the monsoon season. The average annual rainfall was 875 mm. The region has predominantly red and laterite soils, less fertile than alluvial soils. The North WZ (NWZ) has a diversified land use and land cover pattern. Built-up land accounts for 812.86 hectares, with cropland covering the largest area at 9161.67 hectares (Figure 4). Fallow land, forests, plantations, wastelands, and water bodies are also significant components of the region's landscape, showing a balanced mix of urban, agricultural, and natural areas. Salem has the largest geographical area among these four districts.

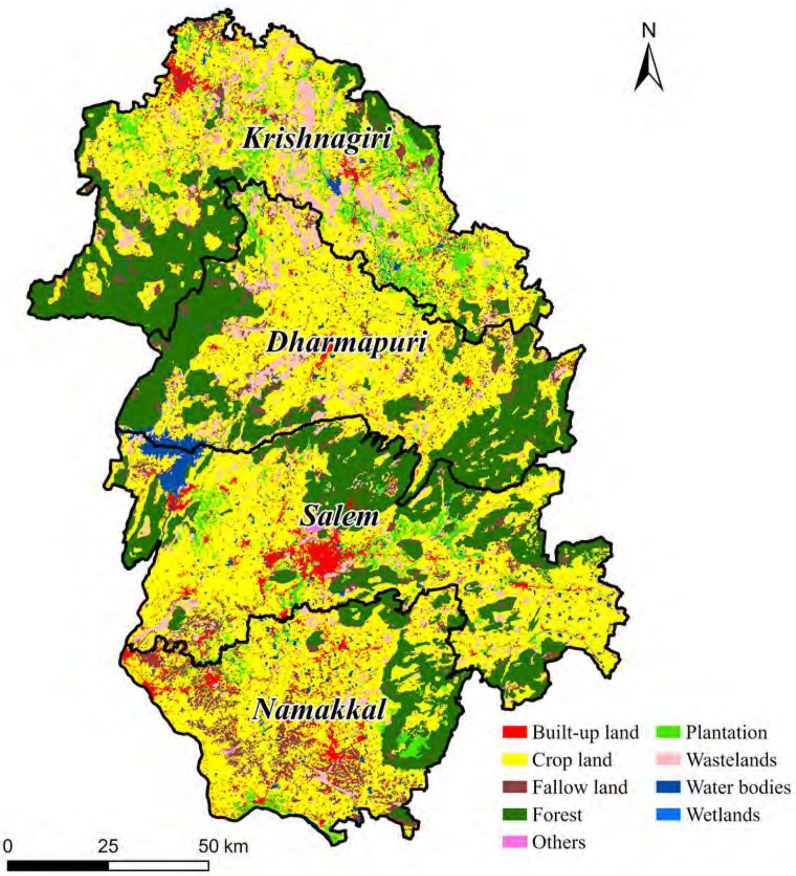


Figure 4 Land use and land cover of NWZ

Salem utilizes the largest absolute area for agriculture, followed by Dharmapuri, Krishnagiri, and Namakkal (Table 4).

*Table 4 Agriculture Profile of NWZ*

| Districts | Geographical area (ha) | Cropped area (ha) | Net area Sown (ha) | Cropping Intensity (%) |
|---|---|---|---|---|
| Salem | 5,20,530 | 2,94,964 | 2,05,085 | 150.5 |
| Namakkal | 3,36,719 | 2,12,768 | 1,55,857 | 143.3 |
| Dharmapuri | 4,49,777 | 2,41,944 | 1,6,2974 | 152.4 |
| Krishnagiri | 5,14,326 | 2,18,085 | 1,68,328 | 141.1 |

Dharmapuri leads in cropping intensity, closely followed by Salem. This indicates that these two districts practice multiple cropping or have more favorable conditions for growing seasons. Krishnagiri, given its large geographical area but lower cropping intensity, might have the most potential for agricultural expansion or intensification

### 1.3.3 Cauvery Delta Zone

The Cauvery Delta Zone (CDZ) in Tamil Nadu is an agriculturally rich region that spans several districts in the state's southeastern part. The CDZ encompasses districts like Karur, Tiruchirappalli, Ariyalur, Perambalur, Thanjavur, Thiruvarur, Nagapattinam, and Mayiladuthurai (Figure 5). It is located along the eastern coast of Tamil Nadu. This zone is characterized by its fertile alluvial soil, abundant water resources from the Cauvery River, and a tropical climate. The region experiences a tropical climate with a significant monsoon season, ensuring reliable water availability for agriculture. The Cauvery Delta is known for its fertile alluvial soil, rich in nutrients and ideal for various crops. This soil type results from sediment deposition by the Cauvery River over centuries.

The Cauvery Delta Zone (CDZ) is a diverse landscape characterized by various land uses and land cover types. Croplands dominate the region, accounting for nearly 9,873 hectares** of its total area. This extensive agricultural land demonstrates the region's significance as a food-producing hub. Built-up areas, including urban centers, industrial zones, and transportation infrastructure, cover 2,219 hectares. These areas represent the human footprint and development activities within the CDZ.

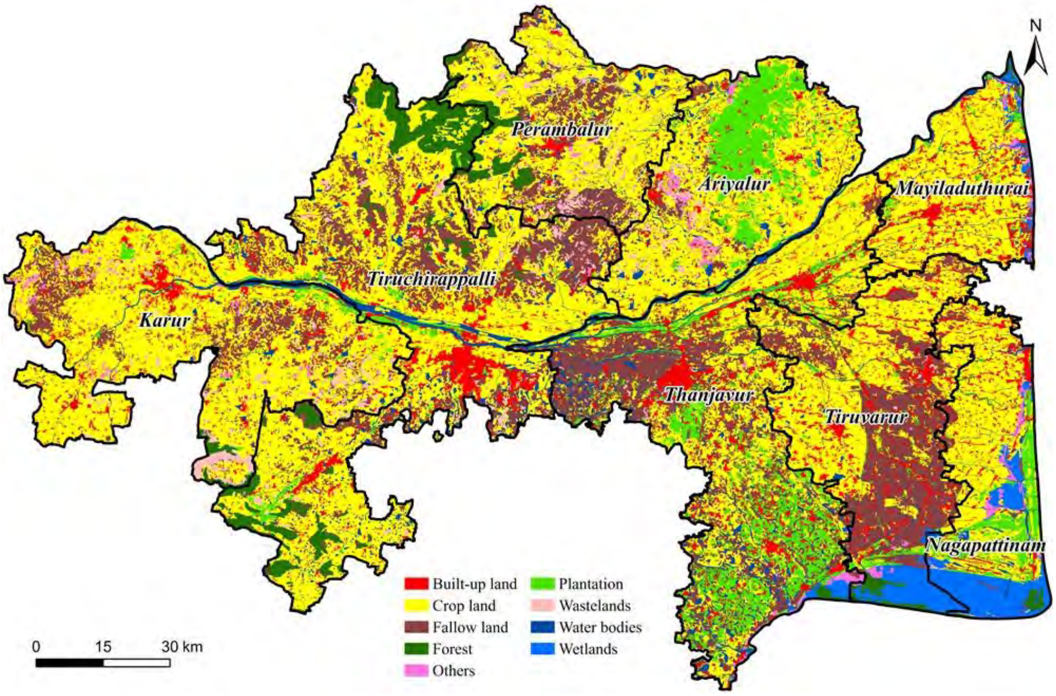


Figure 5 Land use and Land cover of CDZ

Fallow lands, those not currently cultivated, comprise 3,373 hectares. This land may be temporarily unused due to various factors, such as crop rotation, soil fertility management, or economic conditions (Table.5). Forests, though relatively smaller in extent at 641.4 hectares, play a crucial role in maintaining ecological balance, conserving biodiversity, and providing ecosystem services. The delta districts of Thanjavur, Thiruvarur, and Nagapattinam exhibit similar geographical areas, ranging from approximately 271,228 to 339,657 hectares. Thanjavur boasts the largest cultivated area, with 289,324 hectares under cultivation. Nagapattinam closely follows with 262,469 hectares. In terms of net sown area, which represents the sown with crops, Thanjavur takes the lead with 195,541 hectares, while Karur has the smallest net sown area at 74,794 hectares. This land use and land cover analysis provides valuable insights into the CDZ's agricultural activities, urbanization patterns, and natural resources. It helps to understand the region's ecological footprint, land-use dynamics, and potential challenges and opportunities for sustainable development.

**Table 5 Agriculture Profile of CDZ**

| Districts | Geographical area (ha) | Cropped area (ha) | Net area Sown (ha) | Cropping Intensity (%) |
|---|---|---|---|---|
| Thanjavur | 3,39,657 | 2,89,324 | 1,95,541 | 154.8 |
| Thiruvarur | 2,71,228 1 | 2,09,709 | 1,54,770 | 178.1 |
| Nagapatinam (inclusive of Mayiladuthurai) | 2,71,583 | 2,62,469 | 74,921 | 152.9 |
| Ariyalur | 1,93,398 | 1,07,122 | 94,726 | 118 |
| Perambalur | 1,75,739 | 1,06,015 | 1,02,601 | 106.8 |
| Tiruchirappalli | 4,40,383 | 1,69,177 | 1,53,646 | 111.8 |
| Karur | 2,89,557 | 73,665 | 74,794 | 104.1 |

Interestingly, Nagapattinam net sown area (74,921 ha) is significantly smaller than its cropped area, suggesting intense multiple cropping. Thiruvarur has the highest cropping intensity (178.1%), indicating extensive multiple cropping

### 1.3.4 Western Zone

The Western Zone (WZ), encompassing Coimbatore, Tirupur, and Erode districts, is a geographically diverse region in the Western Ghats and their foothills (Figure.6). This variation in topography significantly influences the local climate, which ranges from temperate in the mountainous areas to tropical in the lower elevations. Various soil types, including red, black, and laterite soils, characterize the WZ. These soil types have varying fertility levels and water-holding capacities, affecting agricultural productivity and land use patterns. Rainfall in the WZ averages around 715 millimeters annually. This level of rainfall, combined with the diverse topography and soil types, contributes to the region's agricultural potential and supports a mix of crops. While Erode district appears to have a higher proportion of cropland, covering approximately 59% of its area, Coimbatore and Tiruppur exhibit a more mixed land use pattern. These districts likely have significant built-up areas, including urban centers, industrial zones, and transportation infrastructure. This reflects the region's economic development and urbanization trends. Overall, the WZ presents a complex interplay of geographical factors, climate variations, soil types, and land use patterns. These factors shape the region's agricultural activities, economic development, and environmental characteristic.

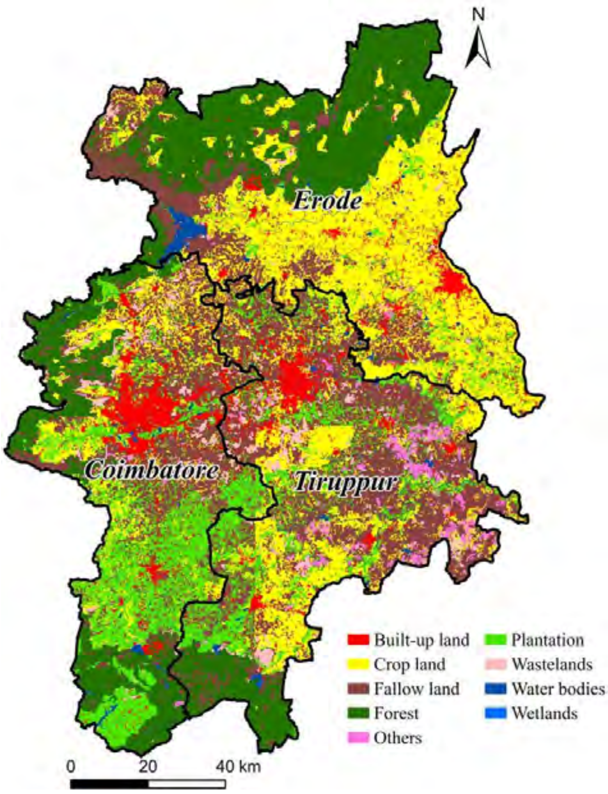


Figure 6 Landuse and Land Cover of WZ

Erode (572,264 ha) has a cropping intensity of 107.04%, with 182,556 ha cropped area and 158,862 ha net sown area, indicating moderate multiple cropping (Table 6). Coimbatore (472,322 ha) shows similar patterns with 105.2% cropping intensity (Table 6).

Table 6 Agriculture Profile of WZ

| Districts | Geographical area (ha) | Cropped area (ha) | Net area Sown (ha) | Cropping Intensity (%) |
|---|---|---|---|---|
| Coimbatore | 4,72,322 | 1,72,234 | 1,66,703 | 105.2 |
| Erode | 5,72,264 | 1,82,556 | 1,58,862 | 107.04 |
| Tiruppur | 5,19,559 | 1,74,815 | 1,82,302 | 102 |

Tiruppur (519,559 ha) has the lowest cropping intensity at 102%, despite 174,815 ha cropped area and 182,302 ha net sown area. All three districts have the potential to improve agricultural productivity through more intensive cropping practices and optimized resource use.

### 1.3.5 Southern Zone

The Southern Zone (SZ) districts covered Dindigul, Theni, Madurai, Virudhunagar, Sivagangai, Pudukkottai, Ramanathapuram, Thirunelveli, Tenkasi, and Thoothukudi (Figure.7). The climate in this Zone is semi-arid, with hot and limited rainfall during the monsoon season. The annual average rainfall was 875 mm. The region has predominantly red and laterite soils, which are less fertile than alluvial soils. The river basin is Pambar, Vaigai, Gundar, Vaippar, Tamiraparani, Nambiyar, Kallar. Crops cultivated in this zone include rice, maize, sorghum, millets (specifically cumbu and ragi), as well as pulses (comprising black gram and green gram), oilseeds (namely groundnut and gingelly), cotton, and chilies.

The land use pattern of the SZ Pudukkottai, Madurai, Virudhunagar, Tenkasi, and Thirunelveli is dominated by croplands. Thoothukudi has a concentration of built-up areas near the coast, with crop lands inland. The district of Dindigul stands out with the largest geographical area of 626,664 ha and the highest cropped area of 219,402 ha, reflecting its significant agricultural activity (Table.7). Thoothukudi also shows extensive cultivation, with 214,855 ha of cropped area, despite a smaller geographical size than Dindigul. Conversely, Tirunelveli has the smallest cropped area at 71,344 ha, indicating lower agricultural intensity relative to its geographical area.

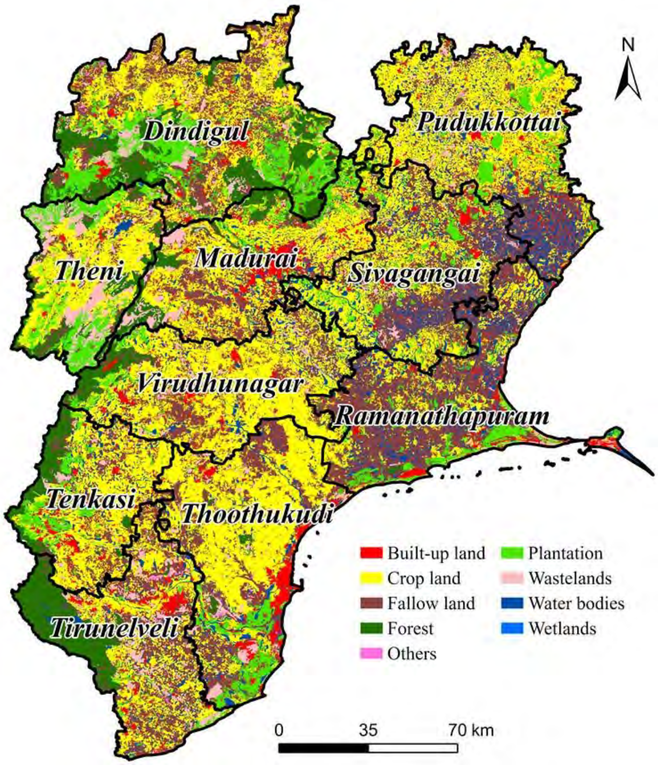


Figure 7 Land Use and Land Cover of SZ

Table 7 Agriculture Profile of SZ

| Districts | Geographical area (ha) | Cropped area (ha) | Net area Sown (ha) | Cropping Intensity (%) |
|---|---|---|---|---|
| Pudukkottai | 4,66,329 | 1,36,138 | 1,36,926 | 106.6 |
| Madurai | 3,74,173 | 1,24,213 | 1,23,496 | 102.8 |
| Theni | 3,24,230 | 1,14,360 | 1,08,732 | 106.3 |
| Dindigul | 6,26,664 | 2,19,402 | 2,17,694 | 100.0 |
| Tirunelveli | 3,87,606 | 71,344 | 66,434 | 107.4 |
| Tenkasi | 2,88,244 | 1,24,467 | 1,12,813 | 109.2 |
| Thoothukudi | 4,70,724 | 2,14,855 | 2,11,091 | 101.8 |
| Sivagangai | 4,18,900 | 1,01,641 | 1,01,205 | 100.4 |
| Viruthunagar | 4,24,323 | 1,36,650 | 1,41,380 | 104.3 |
| Ramanathapuram | 4,08,957 | 1,82,261 | 1,82,261 | 100.4 |

Dindigul has a large cropped area of 2,19,402 ha, which is significant considering its geographical area of 6,26,664 ha. The net sown area is high in Dindigul, Thoothukudi and at the same time cropping intensity low 100% and 101.8% respectively (Table.7). It indicates that the fields in those districts are not cultivated more than once a year. However, Tenkasi, Tirunelveli, Pudukkottai, and Theni exhibited the highest cropping intensity, with fields in these districts being cultivated more than once a year.

### 1.3.6 High Rainfall Zone

The High Rainfall Zone (HRZ) in Tamil Nadu includes Kanyakumari district, which experiences an annual rainfall of 2121 mm (Figure.8) This region supports cultivating various crops, including rice, banana, jackfruit, mango, tapioca, cashew nut, coconut, and clove. The agricultural land use in this zone is dominated by forested areas, which play a crucial role in maintaining ecological balance.

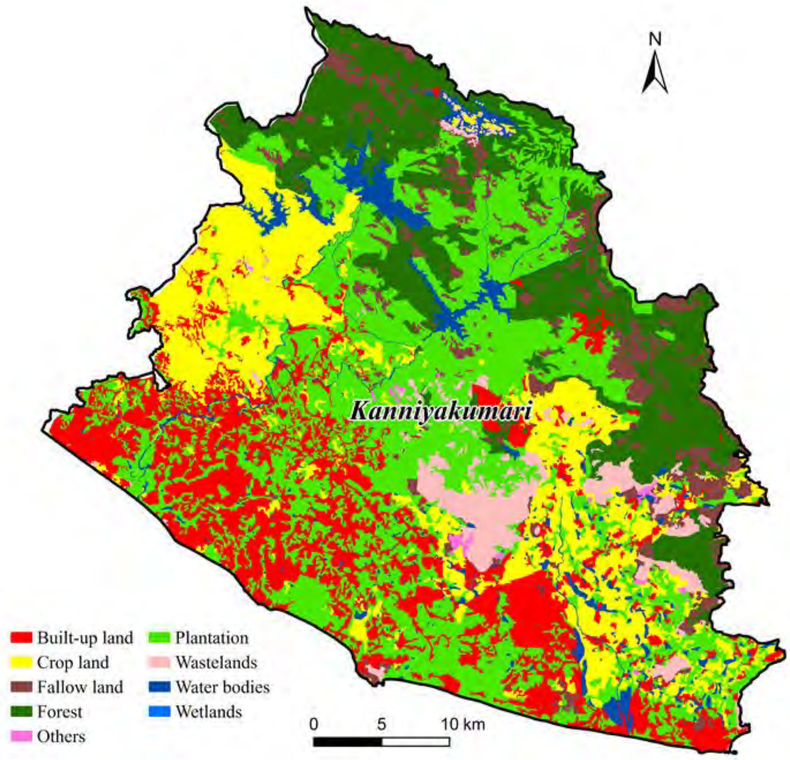


Figure 8 Landuse and Land Cover of HRZ

The geographical area of the HRZ in Kanniyakumari is 167,200 hectares, with 43% of the area designated as net sown area. The cropping intensity, which measures the frequency of cropping on the available land, is 108.6%, indicating efficient land use

### 1.3.7 High Altitude and Hilly Zone

The High Altitude and Hilly Zone of Tamil Nadu encompasses regions like the Nilgiris, Eastern Ghats, and Western Ghats, characterized by an average annual rainfall of 2124 mm (Figure.9). The predominant soils are red and laterite, while peaty soils rich in organic matter are found in forested areas. These soils, along with the favourable climate, make the zone ideal for cultivating horticultural crops such as fruits, vegetables, spices, and condiments, as well as plantation crops like tea and coffee.

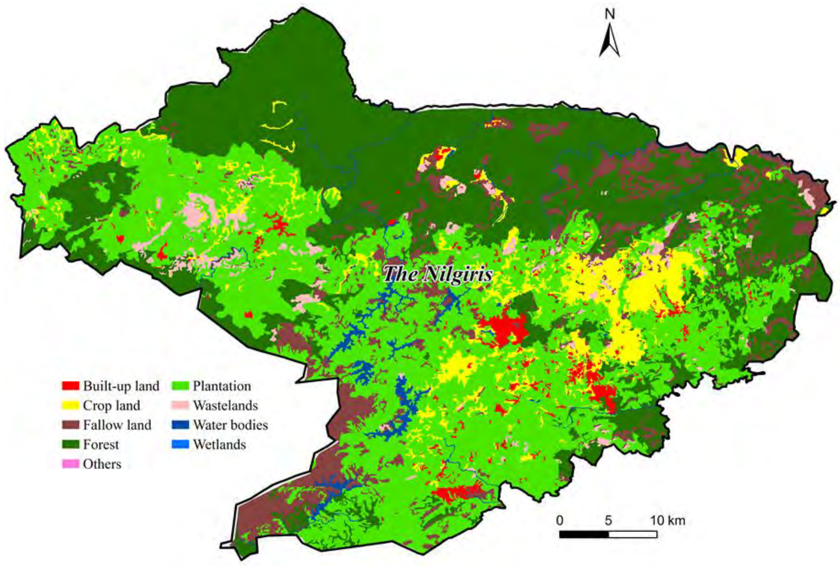


Figure 9 Land use and Landcover of High Altitude and Hilly Zone

In the Nilgiris District, a significant agricultural hub, the geographical area covers 2,54,485 hectares, with 72,238 hectares dedicated to cultivation. The region's unique environmental conditions contribute to its agricultural diversity and economic importance, supporting the growth of crops suited to high-altitude farming.

## 1.3 Current Status of Agriculture in Tamil Nadu

According to the Agricultural statistics 2021, the Rice area is around 19.07 lakh hectares followed by millets, pulses, sugarcane, oilseed and cotton (Table 8). Maize and sorghum have a relatively smaller area of cultivation but have high yields per hectare, with maize producing 2.51 million metric tons and sorghum producing 0.49 million metric tons. Pulses and oilseeds, with a total area of 1.22 million hectares, contribute 1.48 million metric tons to the agricultural production of Tamil Nadu. The food grains area, production, and productivity are around 36.92 lakh hectares, 115.02 lakh Mt, and 3115 kg/ha, respectively (Agricultural Statistics 2021).

Table 8 Current Status of Agriculture in Tamil Nadu (2021)

| S. No. | Crop | Area (lakh ha ) | Production (lakh MT) | Yield (kg/ha) |
|---|---|---|---|---|
| | | Cereals | | |
| 1 | Paddy | 22.17 | 79.06 | 3566 |
| 2 | Cholam (Jowar) | 3.97 | 3.62 | 912 |
| 3 | Cumbu (Bajra) | 0.60 | 1.46 | 2437 |
| 4 | Ragi | 0.74 | 2.27 | 3056 |
| 5 | Maize | 4.00 | 28.26 | 7066 |
| 6 | Small Millets | 0.230 | 0.298 | |
| | | **Pulses** | | |
| 7. | Bengal gram | 0.04 | 0.04 | 926 |
| 8. | Red gram | 0.48 | 0.45 | 936 |
| 9. | Green gram | 1.64 | 0.62 | 379 |
| 10. | Black gram | 4.07 | 2.69 | 660 |
| 11. | Horse gram | 0.66 | 0.447 | 681 |
| | | **Oilseeds** | | |
| 12. | Groundnut | 3.724 | 10.472 | 2812 |
| 13. | Gingelly | 0.475 | 0.279 | 587 |
| 14. | Coconut | 4.577 | 0.535 | 11692 |
| 15. | Castor | 0.641 | 0.020 | 316 |
| 16. | Sunflower | 0.558 | 0.547 | 980 |
| | | **Other crops** | | |
| 17. | Cotton | 1.479 | 3.023 | 348 |
| 18. | Sugarcane | 1.480 | 161.669 | 109000 |
| 19. | Tobacco | 0.015 | 0.023 | 1513 |
| 20. | Spices and Condiments | 0.532 | 0.264 | 496 |
| 21 | Total other crops | 3.506 | 164.979 | |

Overall, the state has a diverse range of crops being cultivated, showcasing the agricultural prowess and potential of Tamil Nadu.

## 1.4 Food grain status of Tamil Nadu

Tamil Nadu is one of the leading states in India when it comes to food grain production. The state produces a significant amount of rice, maize, sorghum, pulses, and oilseeds, contributing to the overall food grain status of the region. With high yields per hectare and a diverse range of cultivated crops, Tamil Nadu continues to display its agricultural strength and capacity within the nation. Food grain production data was collected from the Department of Economics and Statistics from 2010-11 to 2019-20. The data for each district was categorized according to the agro-climatic zones in Tamil Nadu. The cultivated land area dedicated to food grains experienced a decline from 4.2 million hectares to 2.6 million hectares between 1980-81 and 2012-13, followed by a gradual rise from 2013-14 to 2019-2020, as depicted in Figure 10. Over the period from 1950-51 to 2019-20, food grain production demonstrated a yearly increase of approximately 61,108 metric tons.

The production of food grains notably increased over time, with a rise from 4.6 million metric tons to 5.65 million metric tons between 1950-51 and 1979-80, and further escalating from 7.4 million metric tons to 11.5 million metric tons from 1980-81 to 2019-20. Despite a reduction in the cultivation area for food grains, advancements such as introducing new cultivars and enhanced fertilizer utilization contributed to the amplified production. The yield of food grains also witnessed augmentation, progressing from 1113 to 1331 metric tons per hectare during 1950-51 to 1979-80, and subsequently from 1582 to 2108 metric tons per hectare from 1980-81 to 2019-20. Rice, Maize, Sorghum, Cumbu, Ragi, Black gram, Red gram, Green gram, Horse gram, and Bengal gram, specific to each agro-climatic zone, shows rice as the leading crop in production across various zones. Rice cultivation is minimal in zones characterized by high rainfall and high altitude. It is a substantial endeavor in all agro-climatic zones, occupying a central role in terms of production. After rice, maize is the second most cultivated crop in several zones. Sorghum production has grown substantially in recent years, particularly in the NEZ, one of the top cultivated crops. In contrast,

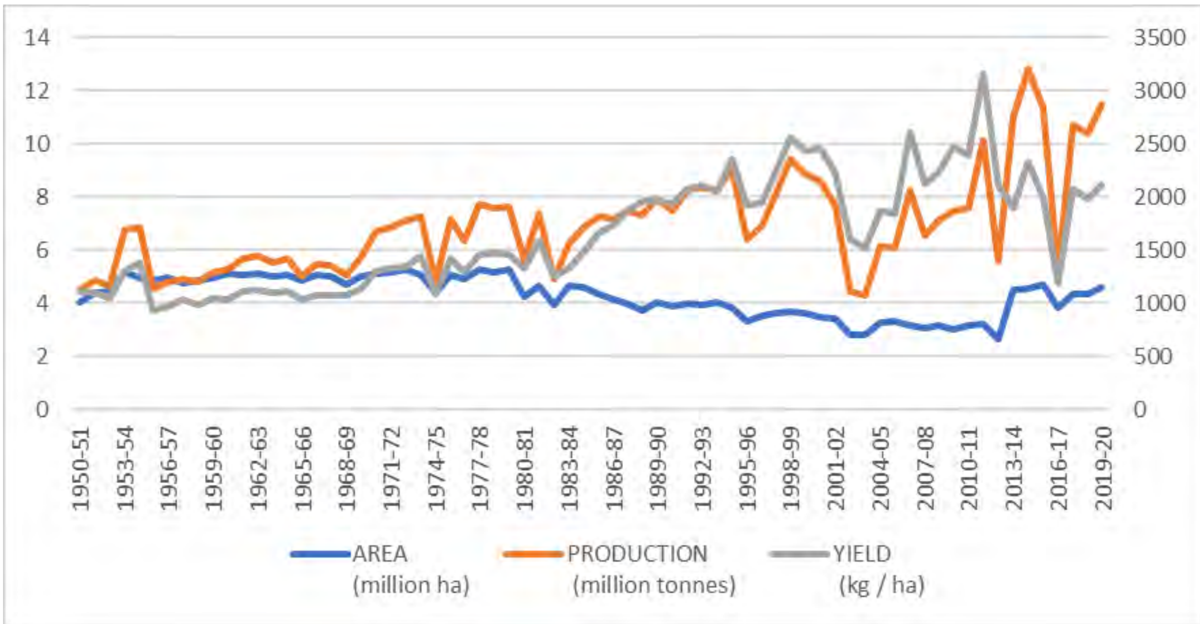


Figure 10 Trend of cultivated area, production, and yield of food grains

maize cultivation seems more concentrated in the southern and Cauvery Delta zones. Overall, the distribution of these crops across different zones underscores the diverse agricultural landscape of the region. Farmers in each zone have strategically chosen to cultivate crops that are well-suited to their respective climates and soil conditions. This diversity in crop distribution ensures a stable food supply for the region and contributes to the agricultural sector's overall economic growth. Additionally, the success of sorghum and maize cultivation in different zones serves as a testament to the adaptability and resilience of these crops in the face of changing environmental factors. This agricultural landscape showcases farmers' ingenuity and resourcefulness in maximizing their land's productivity.

## 1.5 Opportunities and Challenges

The primary difficulties faced by the agricultural sector in the region stem from its heavy reliance on rainfall for irrigation, challenges related to soil fertility, limited farm mechanization due to small land holdings, and the emerging impact of climate change. In Tamil Nadu, nearly half of the cultivated land depends on rainfed agriculture. The scarcity and contamination of irrigation water supplies adversely affect crop production, mainly due to the erratic nature of monsoon patterns. The state of the soil worsens due to depleted nutrients, diminished organic carbon content, and declining humus levels. This degradation of soil quality persists, accompanied by the spread of chemical-intensive farming practices, the emergence of sodic and alkaline soils, and the utilization of brackish water extracted from deeper aquifers through bore wells, all contributing to further complications. Agricultural land is being converted into habitats. The acreage of land under agriculture is rapidly declining.

Hence, increasing productivity is the need of the hour. It becomes imperative to develop varieties that survive well on dry land, thereby improving the productivity of such land. Developing crop varieties that survive drought and brave floods is a requirement for climatic changes. An essential challenge in achieving nutritional security is increasing the cultivation of grains, vegetables, and fruits. Consuming carbohydrates alone will only lead to fat deposits, and therefore, proteins, vitamins, fibers, minerals, and amino acids need to be balanced in one's diet to attain nutritional security. The soil remains the foundation for agriculture, and only nutrient-rich soil can increase agricultural productivity. The government is implementing various schemes to improve the quality of the soil without depleting its nutrients. By promoting organic farming and sustainable agricultural practices, the government aims to ensure that the soil remains fertile for future generations. Additionally, educating farmers on proper crop rotation and soil conservation techniques is crucial to maintaining the health of the soil.

## 1.6. Overview of the report

This report involved a comprehensive approach to data collection and analysis. Firstly, the major crop area, production, and yield data were obtained from the Agriculture Department, Government of Tamil Nadu, from 2010-11 to 2019-2020. This historical data was used to identify major crops and efficient cropping zones in the state. Additionally, a field survey was conducted at the Tamil Nadu Agricultural University (TNAU) Agriculture Research Stations (ARS) across the seven agro-climatic zones of Tamil Nadu (Figure 11). This survey aimed to gather essential information on the phenological characteristics of the ruling varieties and crop management details of Rice (*Oryza sativa*), Maize (Zea mays), Sorghum (Sorghum bicolor), Black gram (Vigna mungo), and Groundnut (Arachis hypogea), which were crucial inputs for the crop simulation model.

Based on the collected data, genetic coefficient files and crop management files were meticulously created within the Decision Support System for Agro technology Transfer (DSSAT) module. The daily climate parameters, including rainfall, solar radiation, and maximum and minimum temperature data were sourced from the EC-Earth CMIP6 data and served as inputs for the crop simulation model. Furthermore, soil data, encompassing soil texture, nutrient content, water holding capacity, and other relevant parameters, were obtained from the S-file of DSSAT. Utilizing this management information, the crop simulation model was employed to simulate crop yields for a near-century period from 2021 to 2050. The agricultural risk was assessed by integrating the simulated crop yield data with flood and drought hazards, exposure, and vulnerability factors. Vulnerability factors included sensitivity and adaptive capacity, which were considered for the period from 2021 to 2050. The adaptation strategies encompass measures aimed at enhancing crop production and bolstering the livelihoods of farmers, enabling them to adapt to the impacts of climate-related risks prevalent across the agro-climatic zones of Tamil Nadu.

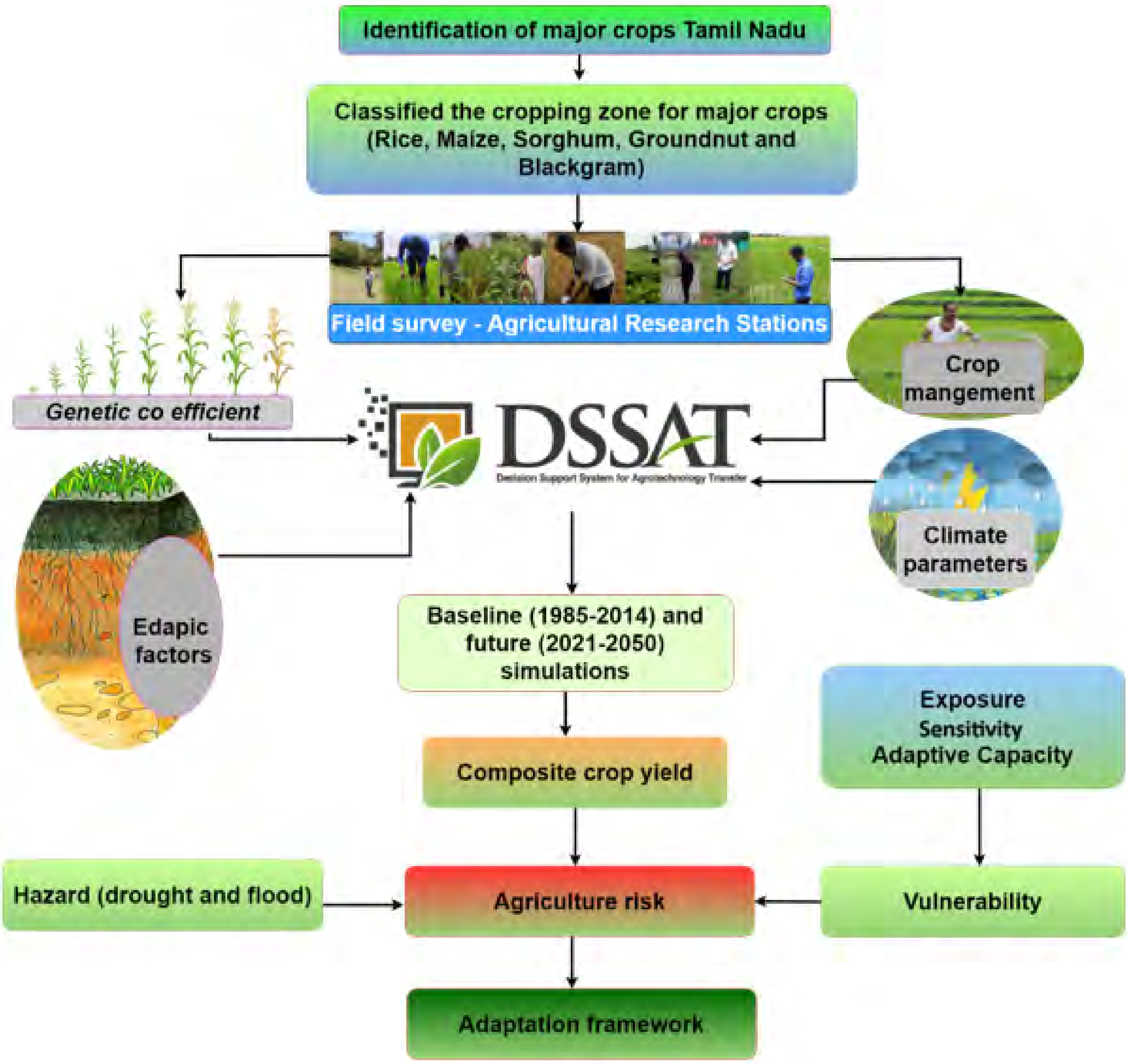


Figure 11 Overall Methodology

## 2. Tamil Nadu Climate Profile

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 (GHG) 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 to 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 has 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°C 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 (northeast 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 play a crucial role in replenishing groundwater levels, thereby aiding in groundwater recharge and irrigation and establishing essential connections with the agricultural sector.

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 (2005, 2015 and 2017, 2023). This warrants immediate action to analyze and understand the state's current and future climate trends. 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.

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 Temperature

An examination of Tamil Nadu's climatic conditions reveals significant variations in both maximum and minimum temperatures across its districts. With a mean annual maximum temperature of 32.5°C, ranging from 29.5°C to 33.4°C, certain districts such as Chennai, Kancheepuram, Chengalpattu, Thiruvallur, Thiruvarur, and Cuddalore experience higher temperatures compared to others. Conversely, the Nilgiris district stands out with the lowest annual maximum temperature. Similarly, the mean annual minimum temperature, averaging at 22.6°C and ranging from 19.4°C to 24.1°C, showcases variations across districts, with Thiruvarur recording the highest values followed by Cuddalore, Mayiladuthurai, and Nagapattinam. Conversely, the Nilgiris district, situated in the Hilly Zone, consistently registers the lowest minimum temperatures. These temperature dynamics are further illustrated in Figure 12, depicting the spatial variation of annual average maximum and minimum temperatures across Tamil Nadu during the baseline period of 1985-2014. The anomaly change shows that the average temperature change is increased by close to 1°C (Figure 13)

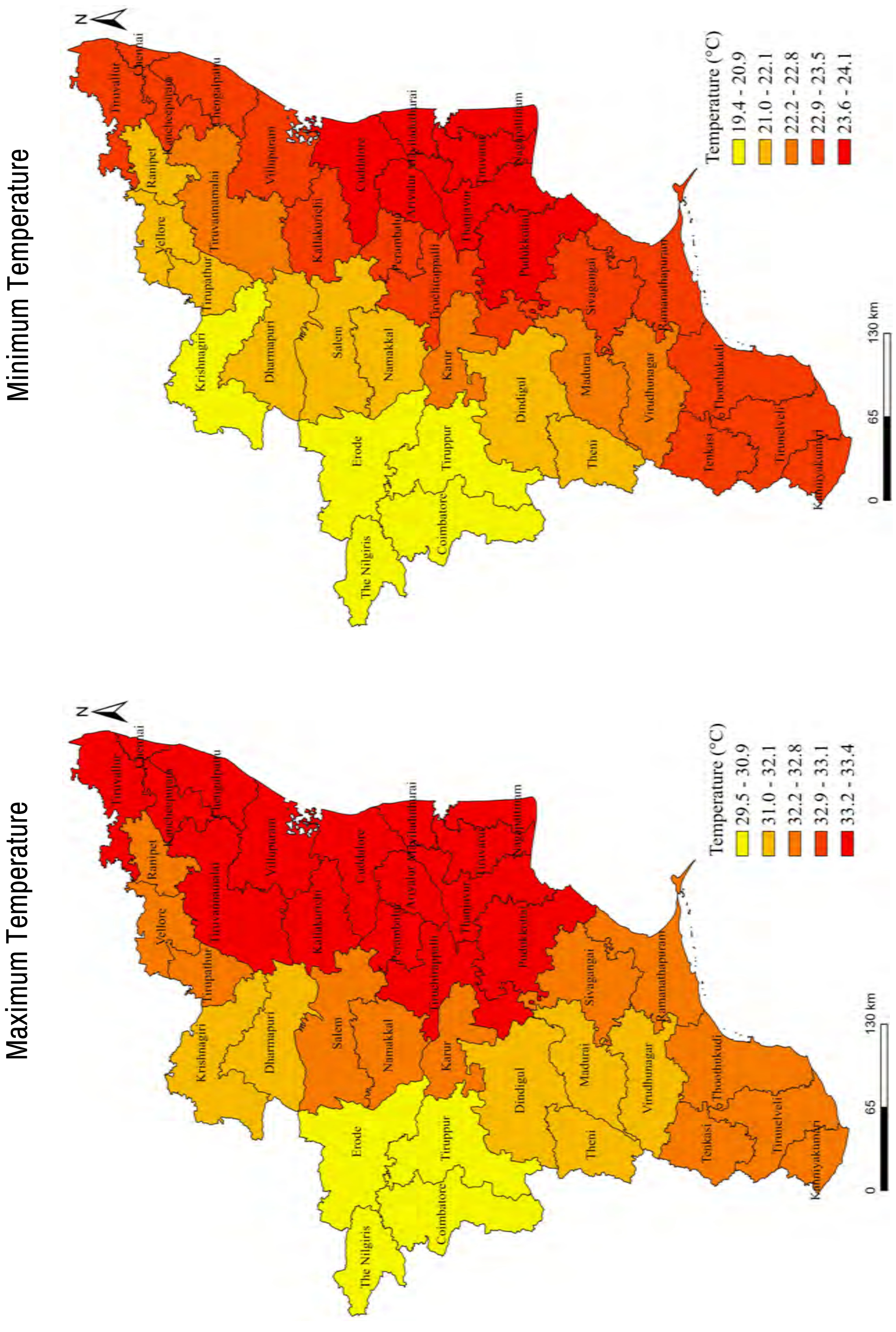


Figure 12 Observed Annual Max and Min Temp. of Tamil Nadu (1985-2014)

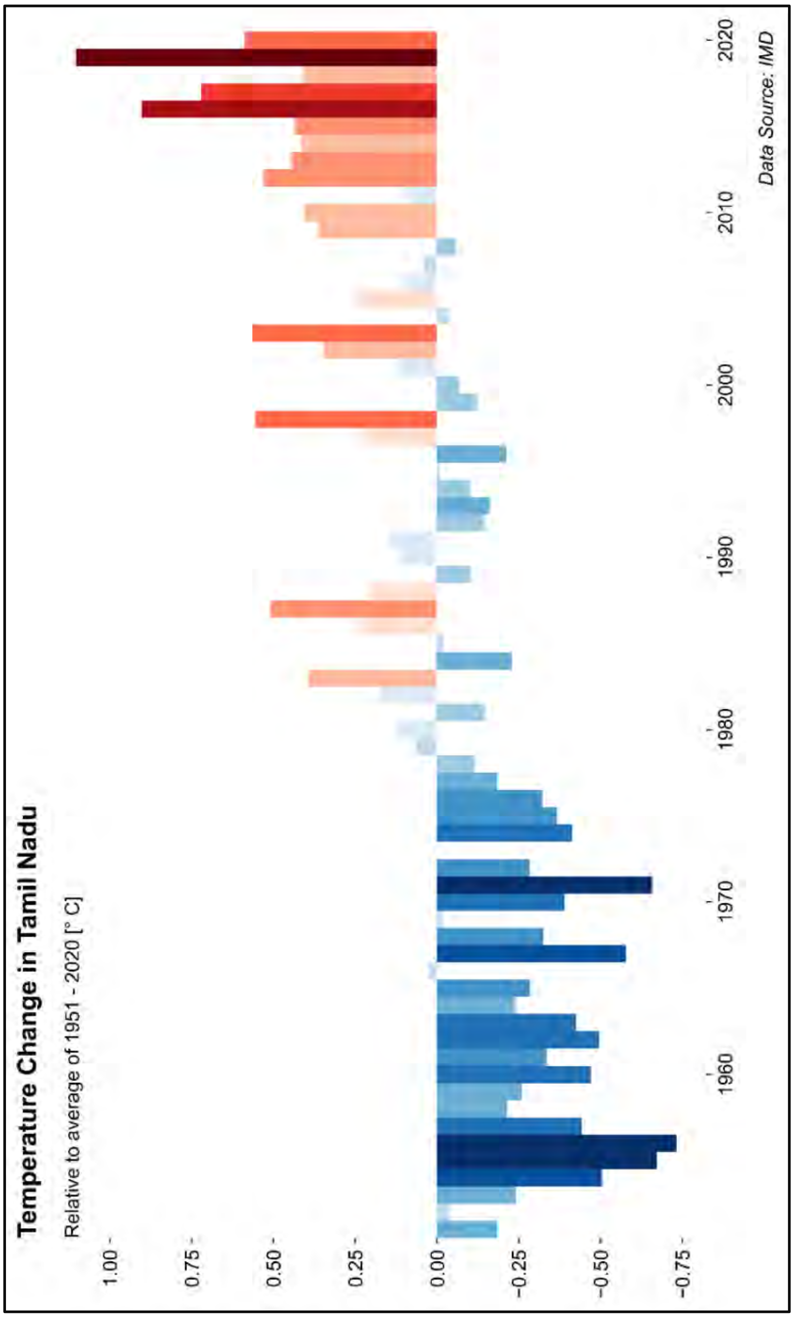


Figure 13 Temperature Change in Tamil Nadu since 1951

## 2.2 Rainfall

The average annual rainfall of Tamil Nadu is 987 mm within the district values ranging from 708 mm to 1406 mm over 30 years (1985-2014). As depicted in Figure 14, among all districts, The Nilgiris, Thiruvallur, Chennai, Kancheepuram, Chengalpattu, Cuddalore, Thiruvarur, Mayiladuthurai, and Nagapattinam receive the maximum average annual rainfall. In contrast, Erode, Tiruppur, Karur, and Thoothukudi receive the lowest annual average rainfall.

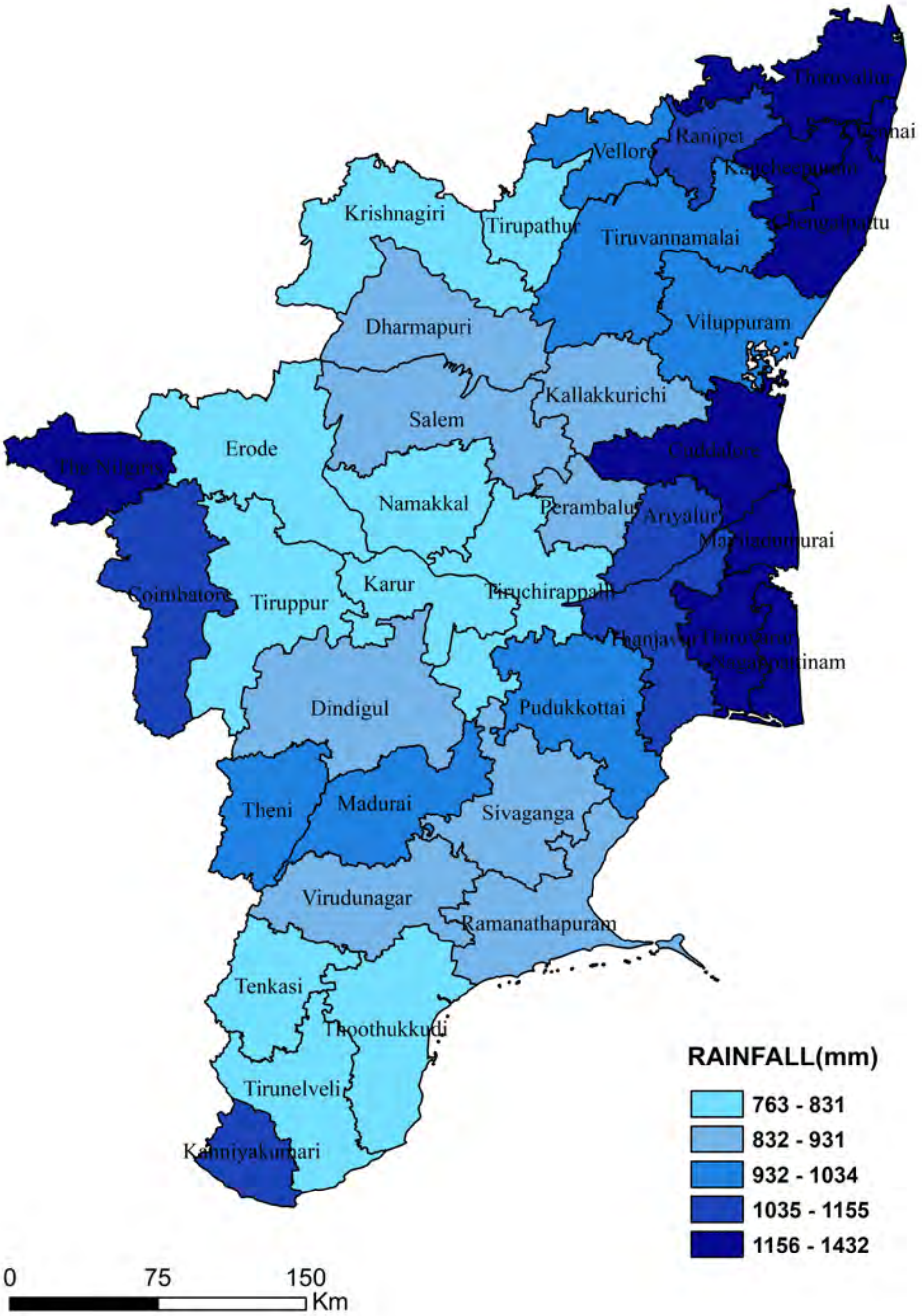


Figure 14 Observed Annual Rainfall of Tamil Nadu (1985-2014)

## 2.3. Climate Change Projections and Scenarios

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. 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. 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 (Figure 15).


Figure 15 SSPs mapped in the Challenges to mitigation/ adaptation space

The SSPs categorize scenarios into SSP 1 - sustainability, SSP 2 - middle-of-the-road, SSP 3 - regional rivalry, SSP 4 - inequality, and SSP 5 - fossil-fuelled development, representing different socio-economic and emission pathways. 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.

The EC-Earth3 model is statistically downscaled using PyClim-SDM (Statistical Downscaling Model) from 100×100 km 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 16 and Figure 17 indicate the projected changes in annual maximum and minimum temperature by near, mid, and end term under SSP2-4.5 and SSP5-8.5, respectively. Table 9 shows the change in annual maximum temperature in both scenarios.

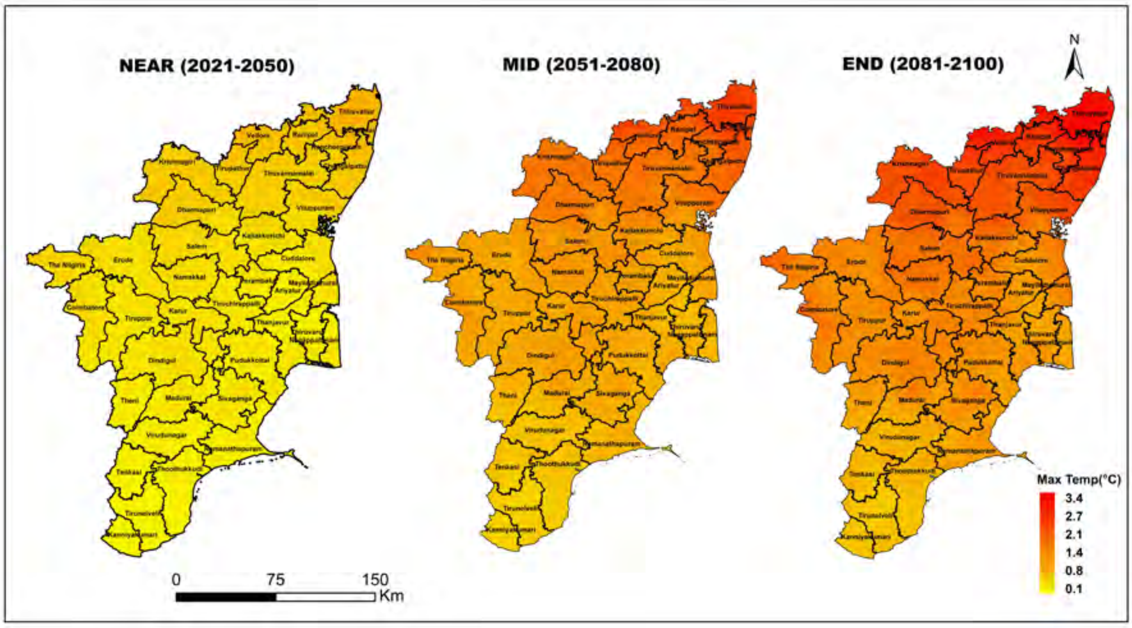


Figure 16 Projected Changes in Annual Maximum Temperature under SSP2-4.5

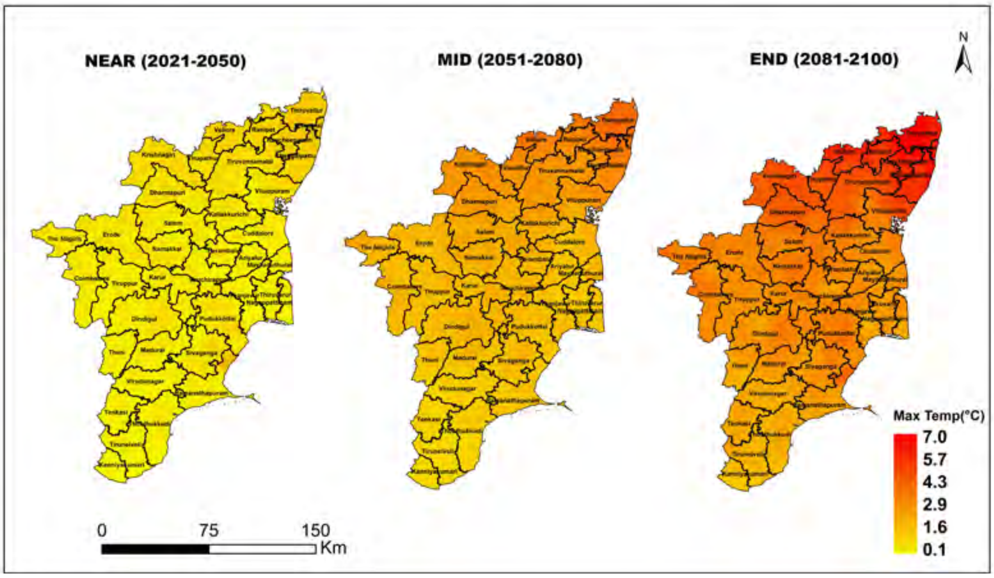


Figure 17 Projected Changes in Annual Minimum Temperature under SSP5-8.5

Table 9 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 |

Table 9 indicates that the annual mean maximum temperature in the State may rise by up to 0.4 °C, 1.3°C and 1.7°C in near-century, mid-century and end-century, respectively, under SSP2 4.5 scenario and SSP5 8.5 scenario, the maximum temperature may rise by 0.6°C, 2.0°C and 3.6°C by near-century, mid-century, and end-century. 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 10 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 of the century under the

SSP2 4.5 scenario (Figure. 18). 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 of the century (Figure.19).

Table 10 Projected Change Percentage 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.

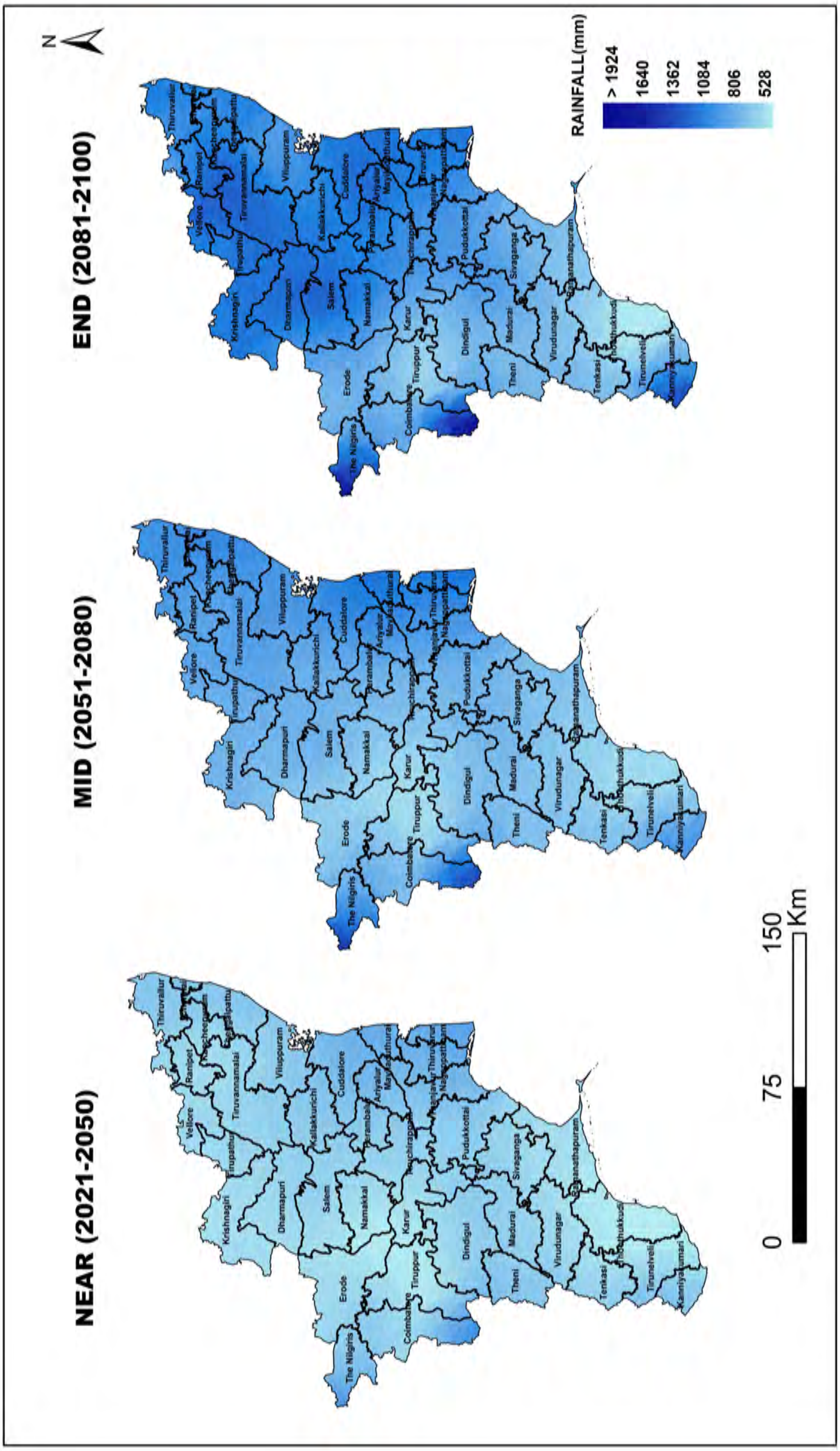


Figure 18 Projected Average Annual Rainfall under SSP2 4.5

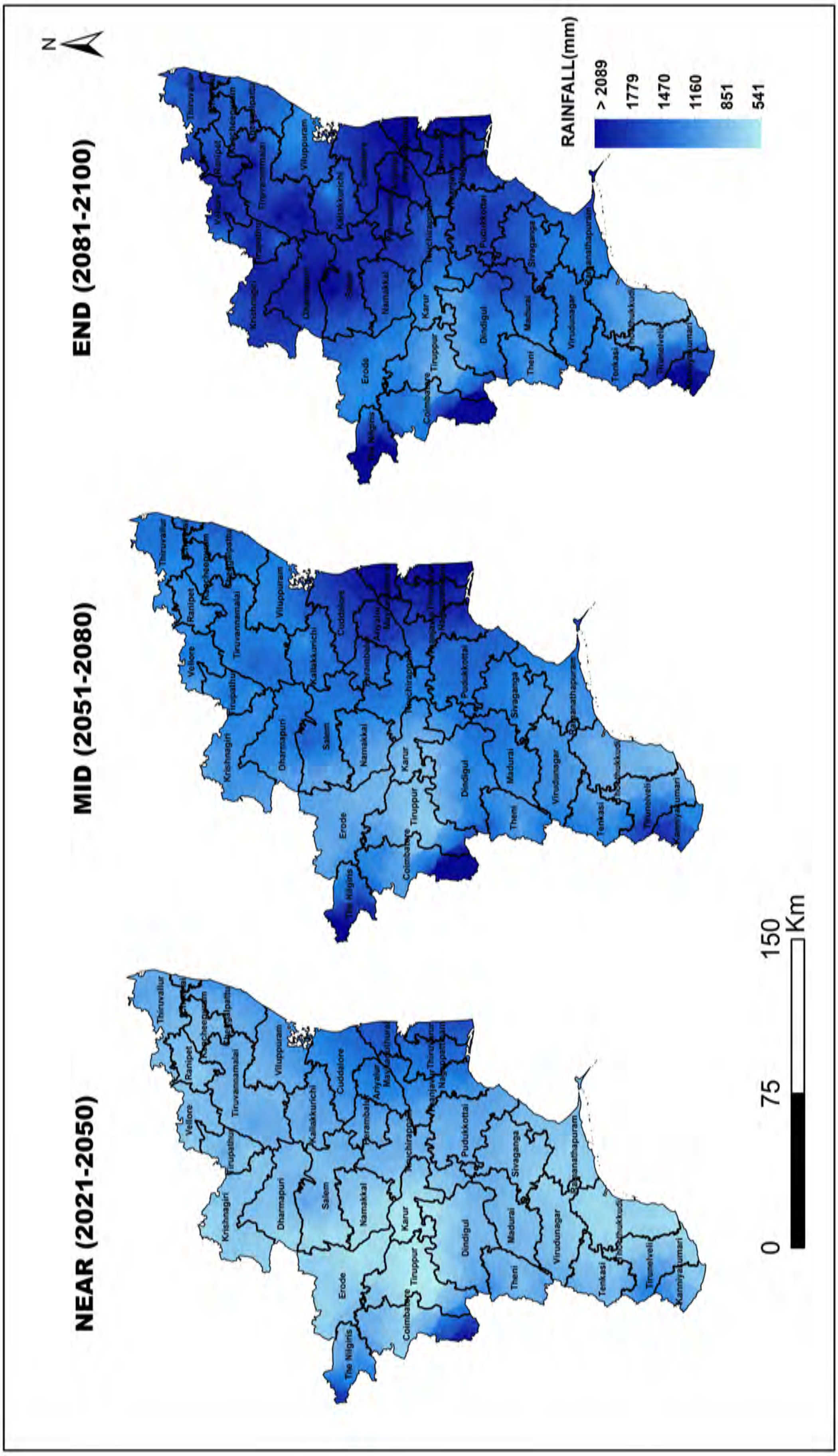


Figure 19 Projected Average Annual Rainfall under SSP5 8.5

## 3. Agriculture Impacts, Vulnerability and Risk of Climate Change

### 3.1 Identification of the Cropping Zone

The cultivable area, production, productivity, and total cultivable area of Rice, Maize, Sorghum, Black gram, and Groundnut in different districts and states were collected from 2011-12 to 2020 -2021 from the Department of Economics and Statistics, Tamil Nadu. From the data, the Relative Spread Index (RSI) and Relative Yield Index (RYI) were computed (Table 11) by

Table 11 Criteria for Efficient Cropping Zone

| RSI | RYI | Cropping Zone |
|---|---|---|
| >100 (High) | >100 (High) | Most Efficient Cropping Zone (MECZ) |
| >100 (High) | < 100 (Low) | Efficient Cropping Zone (ECZ) |
| < 100 (Low) | >100 (High) | Not Efficient Cropping Zone (NECZ) |
| < 100 (Low | < 100 (Low | Inefficient Cropping Zone |

RSI measures the variability or spread of yields across different districts of Tamil Nadu. It is calculated as the standard deviation of yields divided by the mean yield, multiplied by 100 to express it as a percentage. A higher RSI indicates greater variability in yields.

RYI is used to compare the yield performance of different districts of Tamil Nadu. It is calculated as the yield of each crop divided by the yield of the control, multiplied by 100 to express it as a percentage. An RYI greater than 100 indicates that the treatment or variety outperformed the control.

#### 3.1.1 Rice Cultivation Efficiency

Rice efficient cropping zone is identified (Figure 20) in Tamil Nadu. North East Zone, several districts stand out for their efficient rice production. Thiruvallur, Kanchipuram, Chengalpattu, Thiruvannamalai, Kallakurichi, and Villupuram exhibit high efficiency in rice cultivation. This suggests that these areas have optimal rice-growing conditions, such as favorable soil types, adequate water supply, and effective farming practices. Cuddalore also shows efficiency, contributing to the region's overall productivity.

Cauvery Delta Zone, the districts of Mayiladuthurai, Thanjavur, Thiruvarur, Nagapattinam, and Pudukkottai. While these areas are recognized for rice cultivation, they exhibit a high spread (area under cultivation) but low yield. This indicates potential inefficiencies—perhaps due to outdated farming techniques or environmental challenges that prevent optimal productivity. Tenkasi and Tirunelveli emerge as the most efficient cropping areas in the Southern Zone, showcasing high yields relative to their spread. Other districts like Ramanathapuram, Kanyakumari, Sivagangai, Madurai, Theni, and Dindigul also present an efficient zone with a combination of low spread and high yield, indicating a concentrated effort to maximize output in smaller areas. Conversely, Virudhunagar appears inefficient, exhibiting both low spread and yield, suggesting significant room for improvement in agricultural practices.

The Western Zone, encompassing districts like Nilgiris, Coimbatore, Erode, and Tiruppur, has been identified as not efficient for rice cultivation. This could stem from unsuitable climatic conditions or soil types that are not conducive to rice farming. Similarly, the Northwestern Zone (comprising Krishnagiri, Dharmapuri, Salem, and Namakkal) is noted for its inefficiency, further emphasizing the need for targeted agricultural strategies to enhance rice productivity in these areas. The rice cropping zones in Tamil Nadu highlight significant disparities in agricultural efficiency across the state. It underscores the importance of regional characteristics in determining rice production outcomes and suggests potential pathways for improving efficiency, particularly in less productive zones. Addressing these inefficiencies through better practices, resource management, and technology adoption could greatly enhance overall rice production in Tamil Nadu.

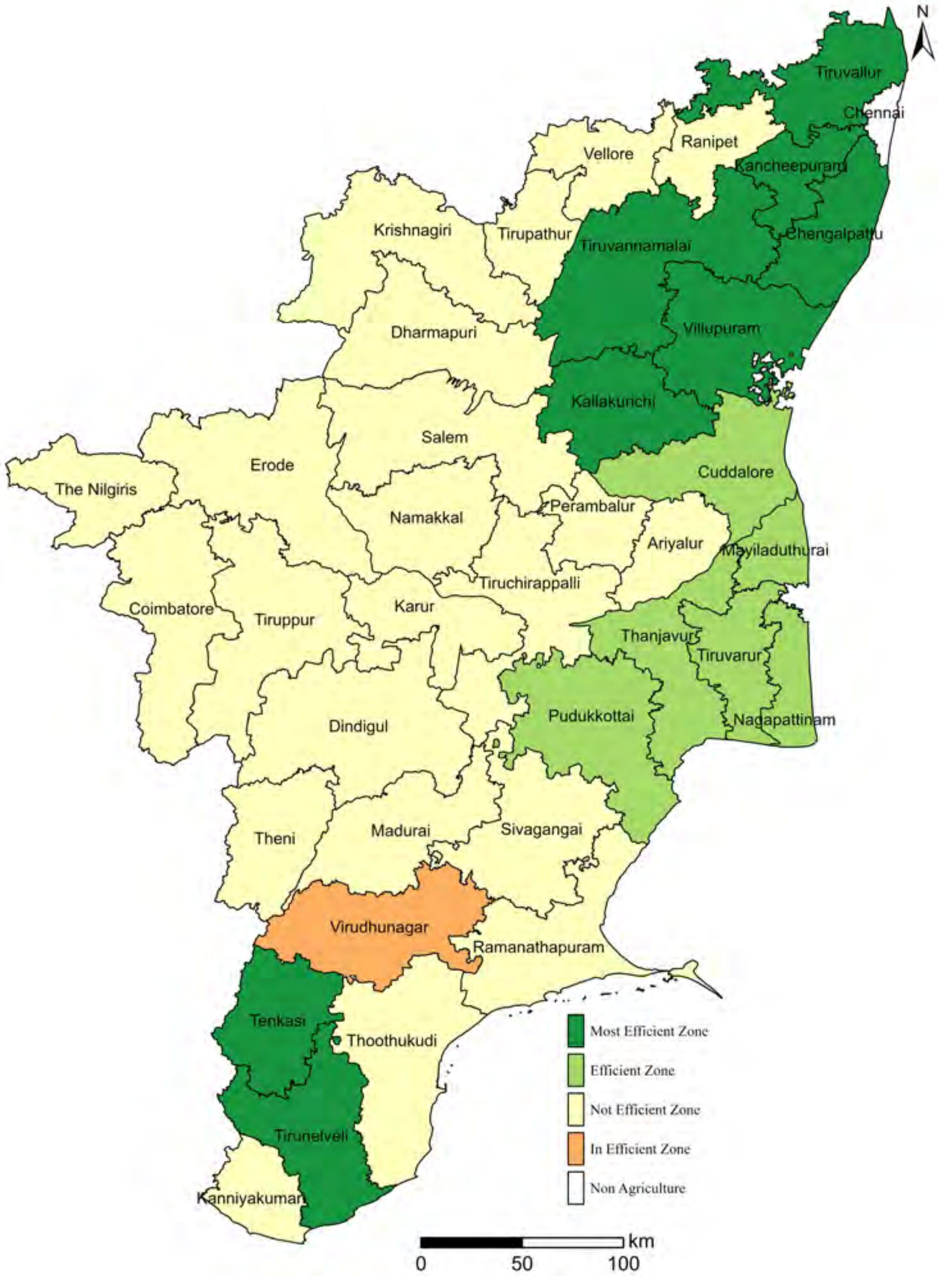


Figure 20 Rice efficient cropping zone of Tamil Nadu

### 3.1.2 Maize Cultivation Efficiency

From the data collected between 2010-11 and 2019-20, the southern districts such as Dindigul and Theni emerged as the top performers in maize cultivation, showcasing high yield and resource utilization efficiency (Figure.21). In the western part of the state, Tiruppur and Erode maintain high-efficiency levels, reinforcing their status as key agricultural. The districts such as Madurai, Virudhunagar, and Thoothukudi follow closely, demonstrating strong productivity. However, the unexpected underperformance of Coimbatore is noteworthy, suggesting potential challenges such as soil degradation, water scarcity, or suboptimal farming practices that may hinder productivity.

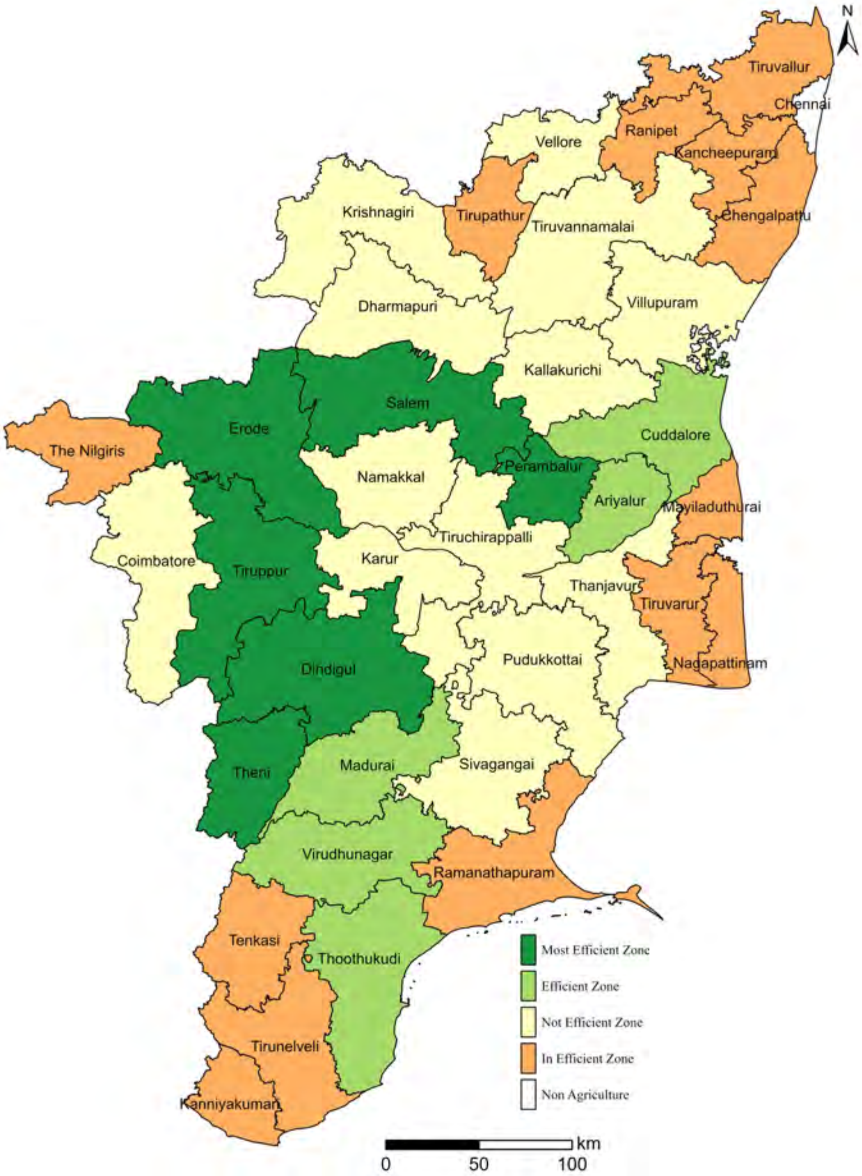


Figure 21 Maize efficient cropping zone of Tamil Nadu

The Cauvery Delta region presents a more nuanced scenario. While Perambalur excels in maize cultivation, other districts like Ariyalur and Perambalure exhibit commendable performance, indicating a favorable environment for maize. In contrast, Nagapattinam, Mayiladuthurai and Thiruvarur are the districts of CDZ inefficient to grow Maize. In thes districts is a frequent flood and salinity problem, which may adversely affect crop yields.

Only Cuddalore shows significant for maize in the northeastern zone, while most surrounding districts reveal low productivity levels. This could be attributed to inadequate irrigation infrastructure or lack of access to modern agricultural techniques. Meanwhile, the northwestern district of Salem stands out for its high efficiency, suggesting effective farming practices or favorable conditions, even as neighboring areas show potential despite limited cultivation activities.

### 3.1.3 Sorguhum cultivation Efficiency

Sorghum cultivation efficiency in Tamil Nadu exhibits a somewhat different pattern compared to maize. The southern zone continues to dominate, with Dindigul, Theni, and Virudhunagar once again leading in efficiency (Figure.22). They are followed closely by Tenkasi, Thoothukudi, and Tirunelveli, all of which demonstrate strong productivity and effective resource management.

In the Cauvery Delta, Ariyalur and Perambalur excel in sorghum cultivation, while other districts show mixed results. This suggests that while certain areas possess the necessary conditions for successful sorghum farming, others may face soil quality or climatic challenges. The western districts, Tiruppur and Erode, maintain their efficiency in sorghum just as they did with maize, indicating a robust agricultural framework that supports diverse crop cultivation (Figure.22). However, most northeastern districts face difficulties with sorghum production, which may be due to environmental constraints or insufficient farming practices. Additionally, the hilly and high-rainfall regions in Tamil Nadu are deemed unsuitable for both maize and sorghum, likely due to topographical challenges and water management issues.

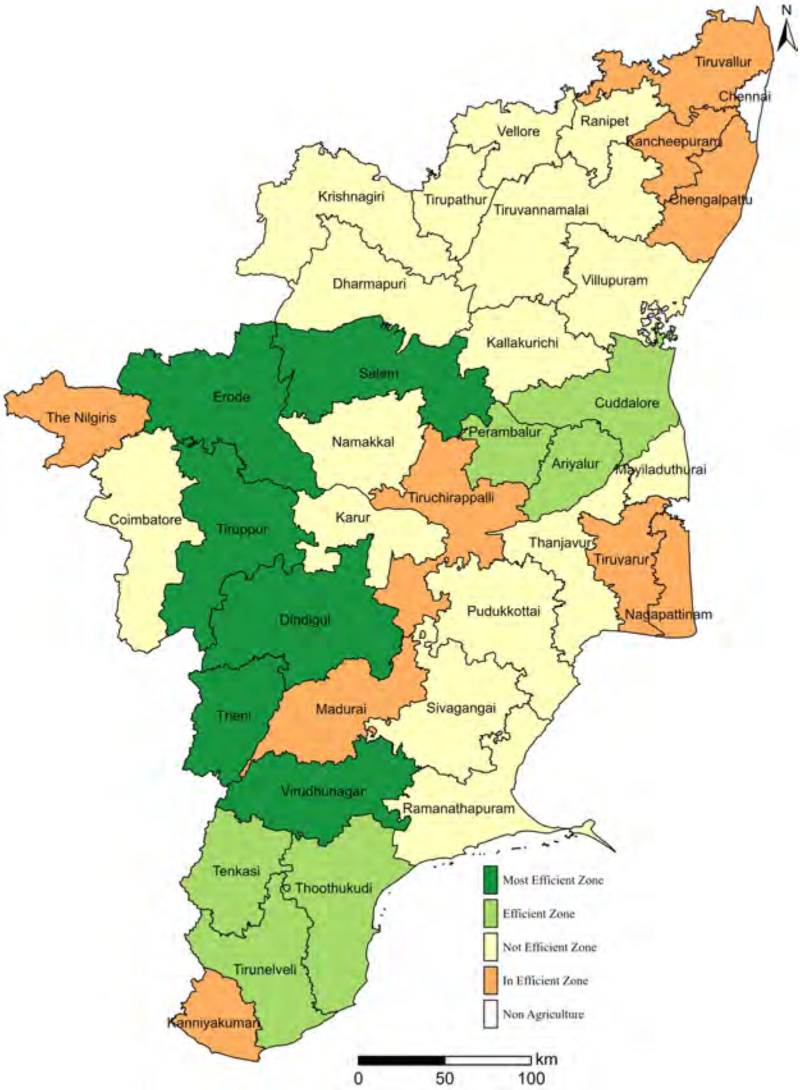


Figure 22 Sorghum efficient cropping zone of Tamil Nadu

### 3.1.4 Groundnut Cultivation Efficiency

As depicted in Figure 23, the groundnut cropping zone is the most productive in the state's northeastern region. Districts such as Villupuram and Kallakuruchi showed the highest efficiency levels. Thiruvannamalai, Vellore, Ranipet, Thiruvallur, Kancheepuram, Chengalpattu, and Thirupathur are indicated as not efficient and have less amount land to cultivate groundnut and get the highest productivity. In the northwestern zone, districts such as Dharmapuri, Salem, and Namakkal exhibit an inefficient zone for groundnut cultivation. Meanwhile, the Krishnigiri is inefficient for cultivating the groundnut (low area and productivity). However, the central dry zone reveals low efficiency, indicating challenges hindering crop success. In the southern zone, Tenkasi, Thoothukudi, and Tirunelveli show an efficient zone for groundnut cultivation. Theni, Virudhunagar, Ramanathapuram, Sivagangai, and Pudukkottai are indicated as an inefficient zone of groundnut cultivation. Additionally, the hilly and high-rainfall areas of Tamil Nadu are deemed unsuitable for Black gram cultivation efficacy.

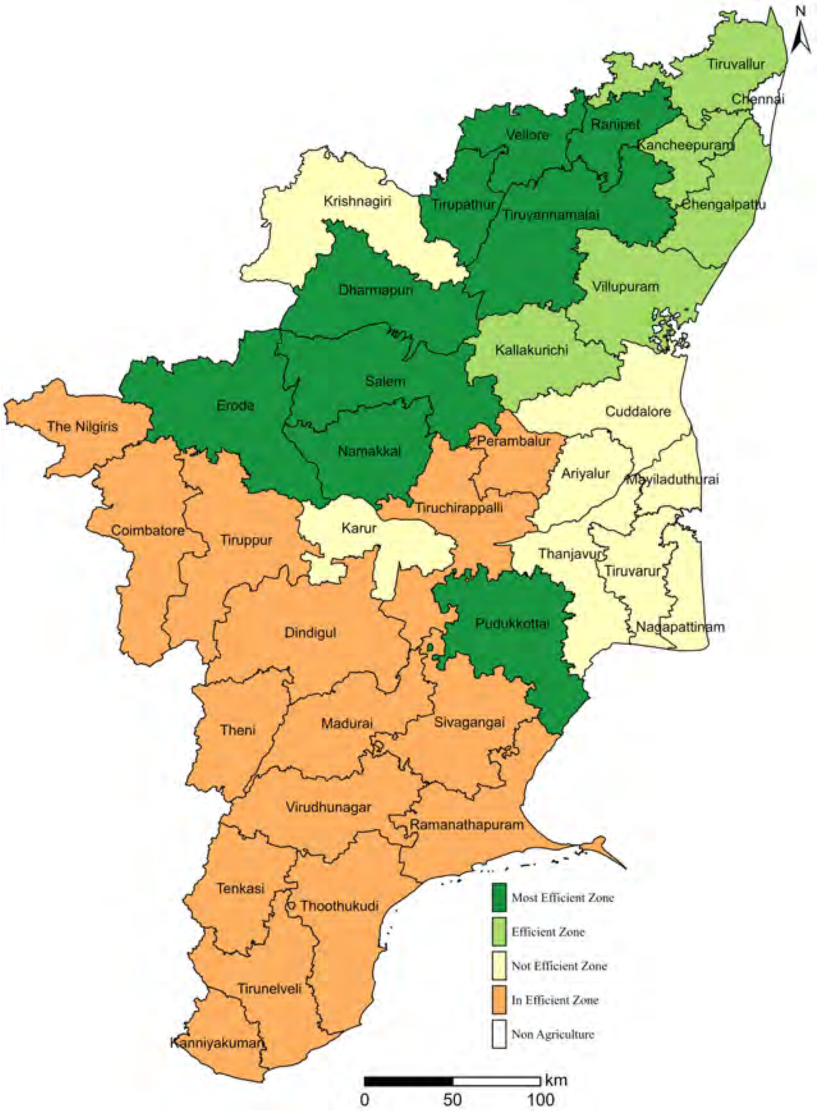


Figure 23 Groundnut Cropping Zone of Tamil Nadu

The northwestern zone, including Dharmapuri, Salem, and Namakkal, also shows promise for groundnut cultivation. However, the central dry zone exhibits low efficiency, while in the southern zone, only Pudukkottai stands out as efficient amidst generally low productivity. Hilly areas and high rainfall zones are unsuitable for groundnut farming.

### 3.1.5 Black gram cultivation efficiency

Districts such as Vellore, Ranipet, Tirupathur, and Thiruvannamalai were the most efficient in the NEZ Zone. Dharmapuri, Salem, and Namakkal in NWZ, Erode in the Western Zone, and Pudukkottai in the Southern Zone were the most efficient for black gram cultivation, as illustrated in Figure 24. Efficient districts such as Thiruvarur, Kancheepuram, Chengalpattu, Villupuram, and Kallakuruchi are also in the NEZ.

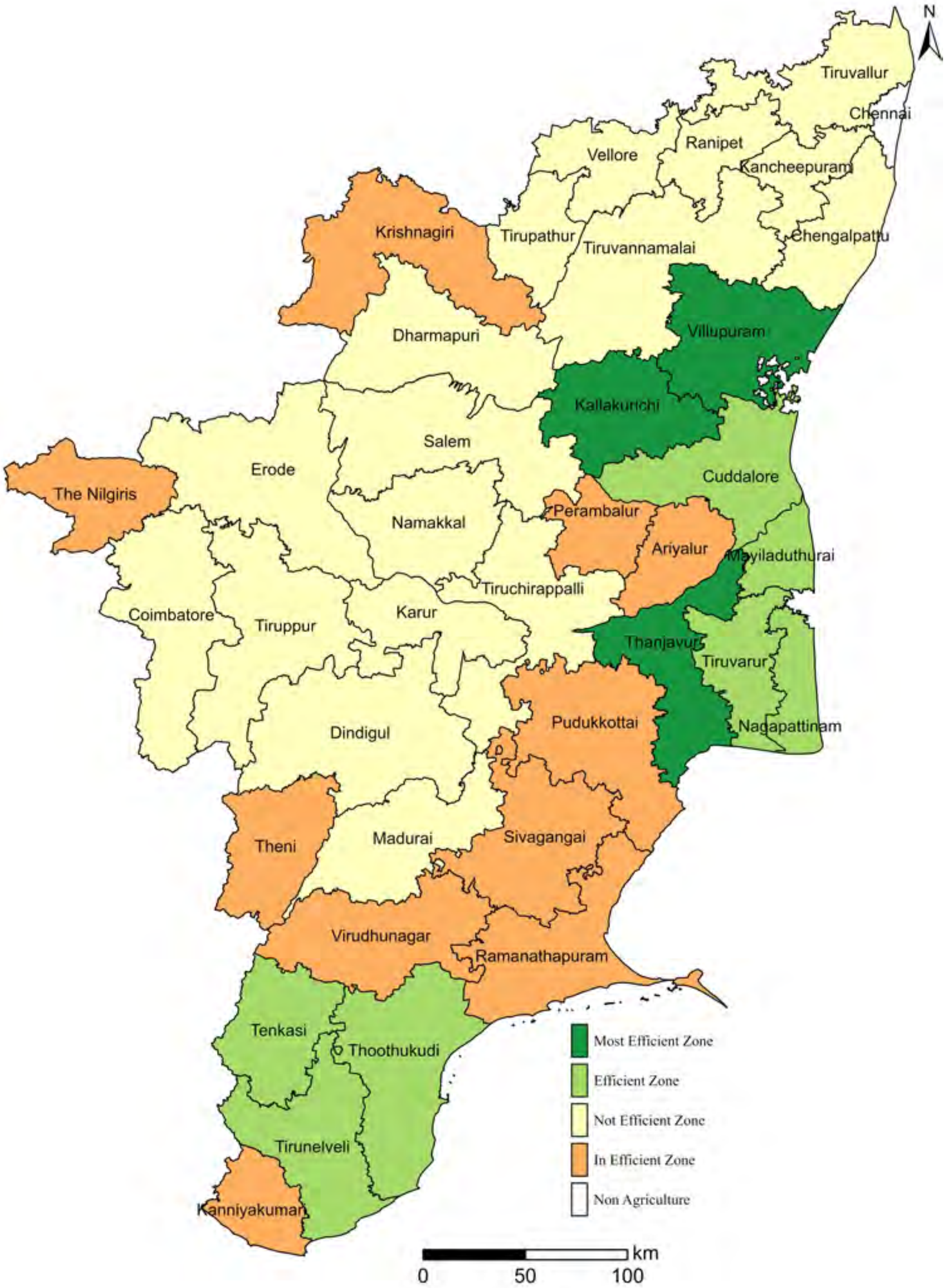


Figure 24 Black gram efficient cropping zone of Tamil Nadu

This distribution of efficient zones for both crops highlights the diverse agricultural landscape of Tamil Nadu, where factors such as soil composition, rainfall patterns, and local farming practices significantly influence crop suitability and yield potential across different regions of groundnut farming due to unfavorable soil and climatic conditions.

## 3.2 Climate Change impact on Major crops

Climate variability plays a significant role in determining the sustainability of agriculture sectoral growth. IPCC (2014) has reported that frequent drought, extreme heat stress, floods, cyclones, and monsoon uncertainty adversely affect crop production. The assessment of crop impacts was conducted using the Decision Support System for Agro Technology Transfer (DSSAT) crop simulation model. The CERES (Crop Environment Resource Synthesis) model set in DSSAT was used to assess the impact of climate change on Cereals. The CERES-RICE, CERES-MAIZE, CERES-SORGHUM, and CROPGRO modules within DSSAT are extensively utilized for simulating the yields of Rice, Maize, Sorghum, Black gram, and Groundnut, respectively. The DSSAT crop simulation model requires various input data, including weather parameters, genetic information of crop varieties, soil characteristics, and crop management practices, to effectively simulate crop yields.

The future downscaled climate data from the EC -Earth 3 is used as a projected climate input in the CROPGRO model, such as maximum temperature, minimum temperature rainfall, and solar radiation for baseline (1985-2014) and near century (2021-2050). The extracted baseline and future daily precipitation (mm), solar radiation, and maximum (°C) and minimum temperature (°C) data for the six agro-climatic come under the SSP2 4.5 scenario. for examining the biophysical impact of climate change on crop production, the baseline and future climate data were exported as weather files in the DSSAT 4.8 crop simulation model. The weather data were converted into DSSAT weather file format using the Weatherman tool available in DSSAT.

In the soil module, the different layers of soil texture and bulk density were set up in the DSSAT module's S-build based on the study area's condition. The soil database for Tamil Nadu, available at a scale of 1: 50,000 and obtained from the Department of Remote Sensing and GIS at the Tamil Nadu Agricultural University (TNAU), was utilized to generate soil files. The required profile details were extracted from this database using the ArcGIS software and then incorporated into the S Build tool within the Decision Support System for Agro technology Transfer (DSSAT) to create the soil files.

The crop management details, such as harvesting time, irrigation management, treatment of organic material, and fertilizers applied for Rice, Maize, Sorghum, Black gram, and Groundnut, were set up in experimental file X Build of DSSAT. The crop management files were developed by following the standard practices recommended in the crop production guide published by the Tamil Nadu Agricultural University (TNAU) for the specific crops under study. Details regarding the experimental conditions and field characteristics, such as the name of the weather station, soil description, planting layouts, irrigation and water management practices, and fertilizer application details, were provided through the X Build tool in the Decision Support System for Agro technology Transfer (DSSAT) software.

### 3.2.1 Climate change impact on Rice (*Oryza sativa*) yield in Tamil Nadu (2021–2050)

Different rice-leading varieties are used based on the rainfall patterns, soil, and topographical conditions of six agro-climatic zones. The spatial distribution of the projected rice yield scenario in Tamil Nadu (2021–2050) under the SSP2-4.5 scenario is illustrated in Figure 25. The projected rice yield in Tamil Nadu would reduce by - 4.6 to -19.8% in the near century (2021–2050), and the overall rice yield may decline by 10.7%. The projected rice yield in the Northeastern and Cauvery Delta zones would be reduced to 10.05 and 8.7% in the near century, respectively.

The intensity of rainfall and flash floods due to the Northeast monsoon increased during harvest. Chengalpattu, Kancheepuram, Thiruvallur, and Villupuram districts in NEZ. Thanjavur, Nagappattinam, and Mayiladuthurai in the Cauvery Delta show a very high rice yield decline during 2021–2050. Most of the districts in the two Agro-climatic zones are near the coast. The Southern, Western, Northwestern, and HRZ regions suggest that rice yields are projected to decrease by approximately 13.1%, 10.7%, 10.2%, and 10.9%, respectively. Higher temperatures accelerate water loss in rice plants, causing water stress, particularly if rainfall does not keep up. This increases irrigation demands, straining water resources. Additionally, warmer conditions can cause earlier maturation and shorter growing seasons, reducing the time for grain development, which can potentially lower yields.

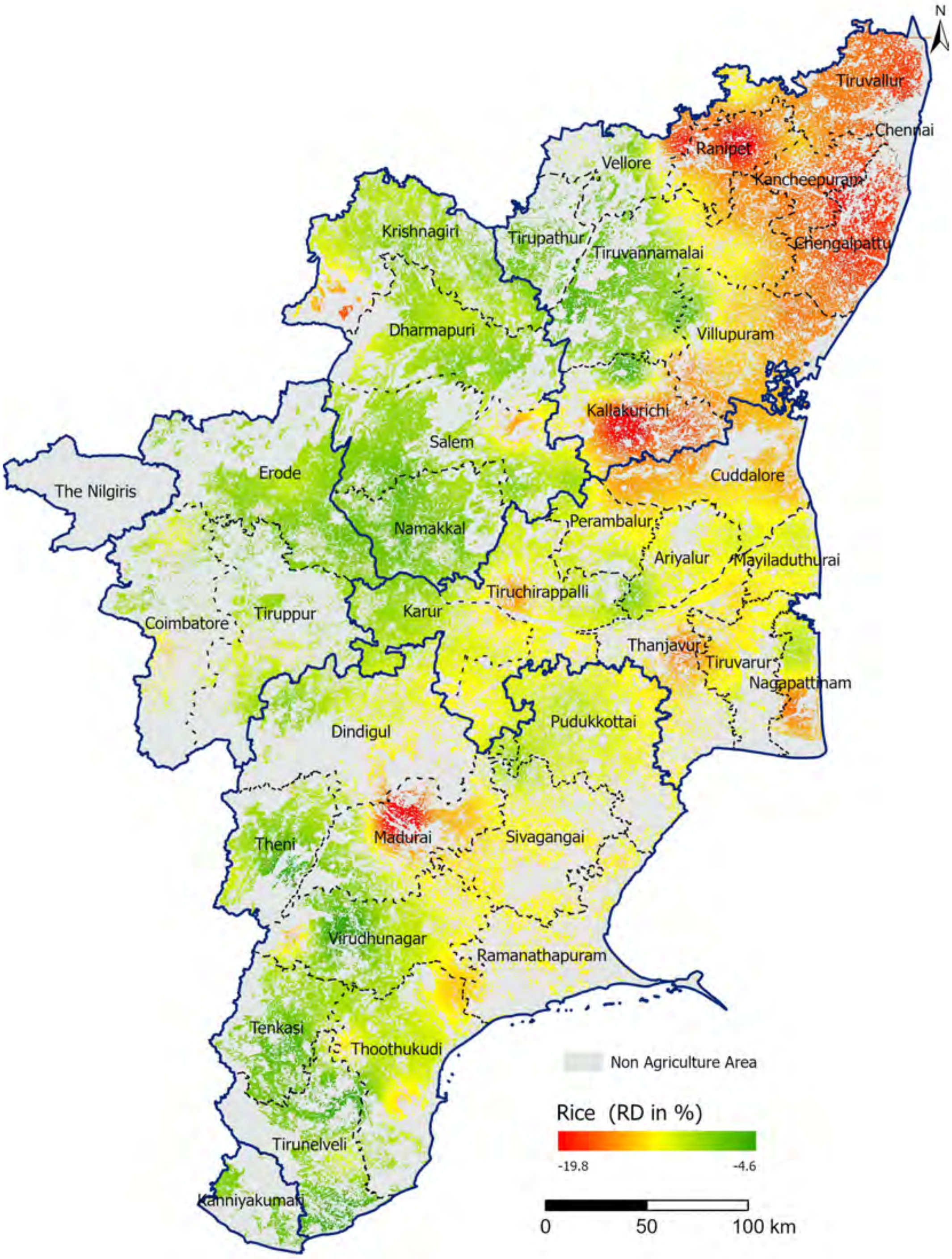


Figure 25 Spatial distribution of Rice yield for 2021 to 2050

### 3.2.2 Climate change impact on Maize (Zea mays) yield in Tamil Nadu (2021–2050)

Climate change is poised to significantly impact maize yields in Tamil Nadu, with projections indicating a concerning decline in productivity. Studies suggest that increasing temperatures and altered precipitation patterns, leading to more frequent and severe droughts, could reduce maize yields by 3.1% to 23.3% between 2021 and 2050, with some estimates reaching up to 31.3% (Figure.26).

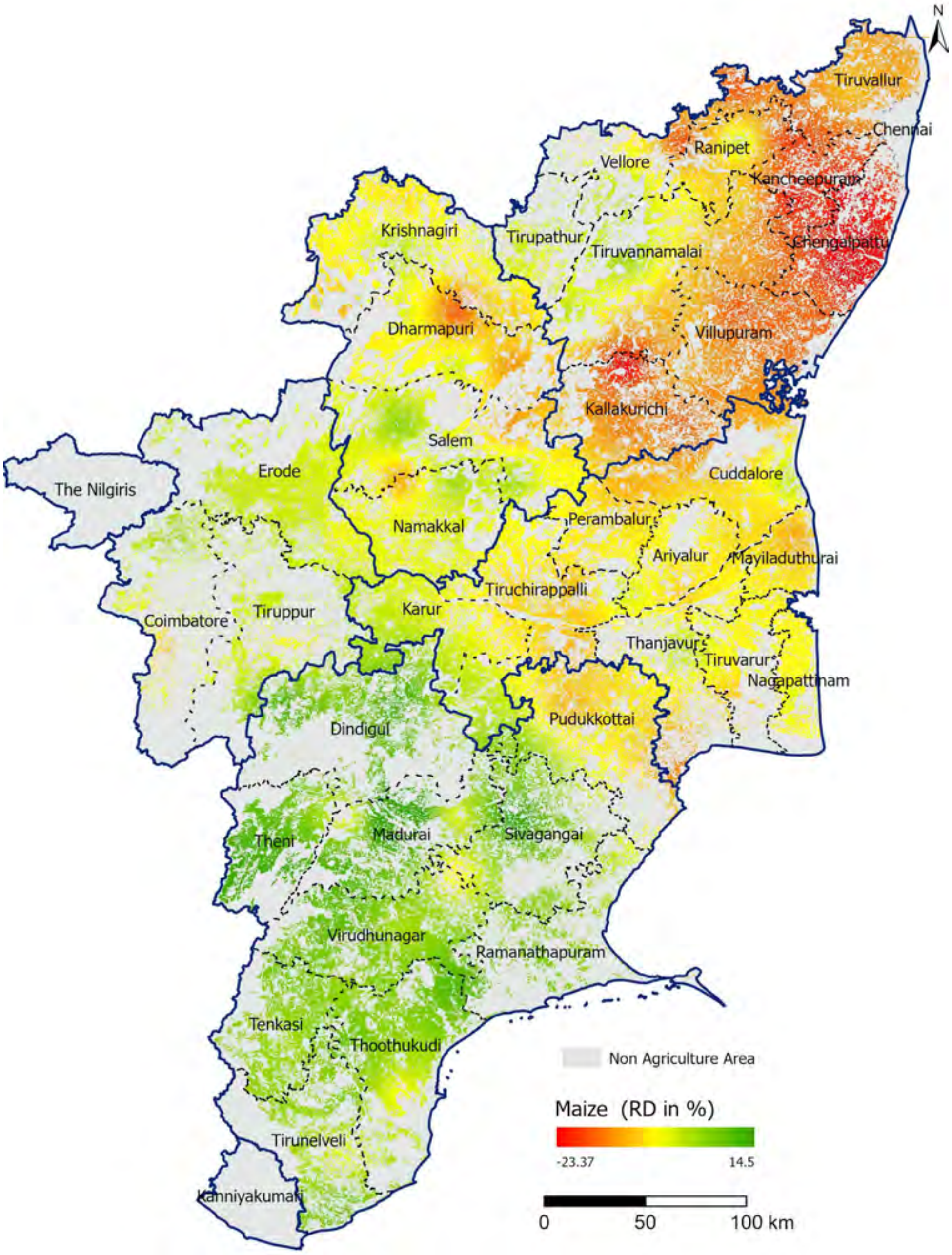


Figure 26 Maize yield scenario of Tamil Nadu (2021-2050) under SSP2-4.5 Scenario

The impact is expected to vary across the region, with the Northeastern Zone and Cauvery delta experiencing the most severe declines. Districts like Chengalpattu, Kanchipuram, and Villupuram are projected to face yield reductions of 14.44% to 19.61%. These changes significantly threaten food security and rural livelihoods in Tamil Nadu, potentially exacerbating poverty and hunger.

Research by Parthasarathy et al. (2015), Krishnan et al. (2019), and Gowtham et al. (2022) has been instrumental in understanding these projections, utilizing crop simulation models to forecast the potential impacts. To mitigate these effects, experts recommend adopting heat-tolerant and drought-resistant maize varieties, improving water management practices, and implementing climate-smart agricultural techniques. However, it's crucial to note that long-term projections carry inherent uncertainties, and ongoing research is vital to refine our understanding and develop effective adaptation strategies. The situation underscores the urgent need for policymakers and farmers in Tamil Nadu to proactively address these challenges, ensuring the resilience of maize production and safeguarding the region's agricultural future.

### 3.2.3 Climate change impact on sorghum yield in Tamil Nadu (2021–2050)

Sorghum (Sorghum bicolor) is an important crop in the dry land agriculture system. The CERES-sorghum module, in combination with the seasonal analysis program in DSSAT, was used to simulate the phenology, growth, and yield of sorghum. The spatial distribution of projected sorghum yield was simulated for the near century (2021-2050) under the SSP2 4.5 scenario (Figure. 27), which would be reduced by about 0.2 to 19.05%. Rising temperatures during critical growth stages like flowering and grain filling significantly impact sorghum yields. Studies report yield reductions of up to 20% under heat-stress conditions (Zenda et al., 2022). In NC, there is a 12.5% yield decline in Tamil Nadu.

Heat stress disrupts plant physiology, leading to smaller and fewer panicles, the structures that hold the grains. High temperatures can render sorghum flowers sterile, further reducing their yield potential. Warmer air disrupts the photosynthetic process, limiting the plant's energy production and ultimately impacting yield. Breeding programs are developing varieties with improved tolerance to heat stress and water scarcity, offering farmers more resilient options (Boyer *et al*., 2020).

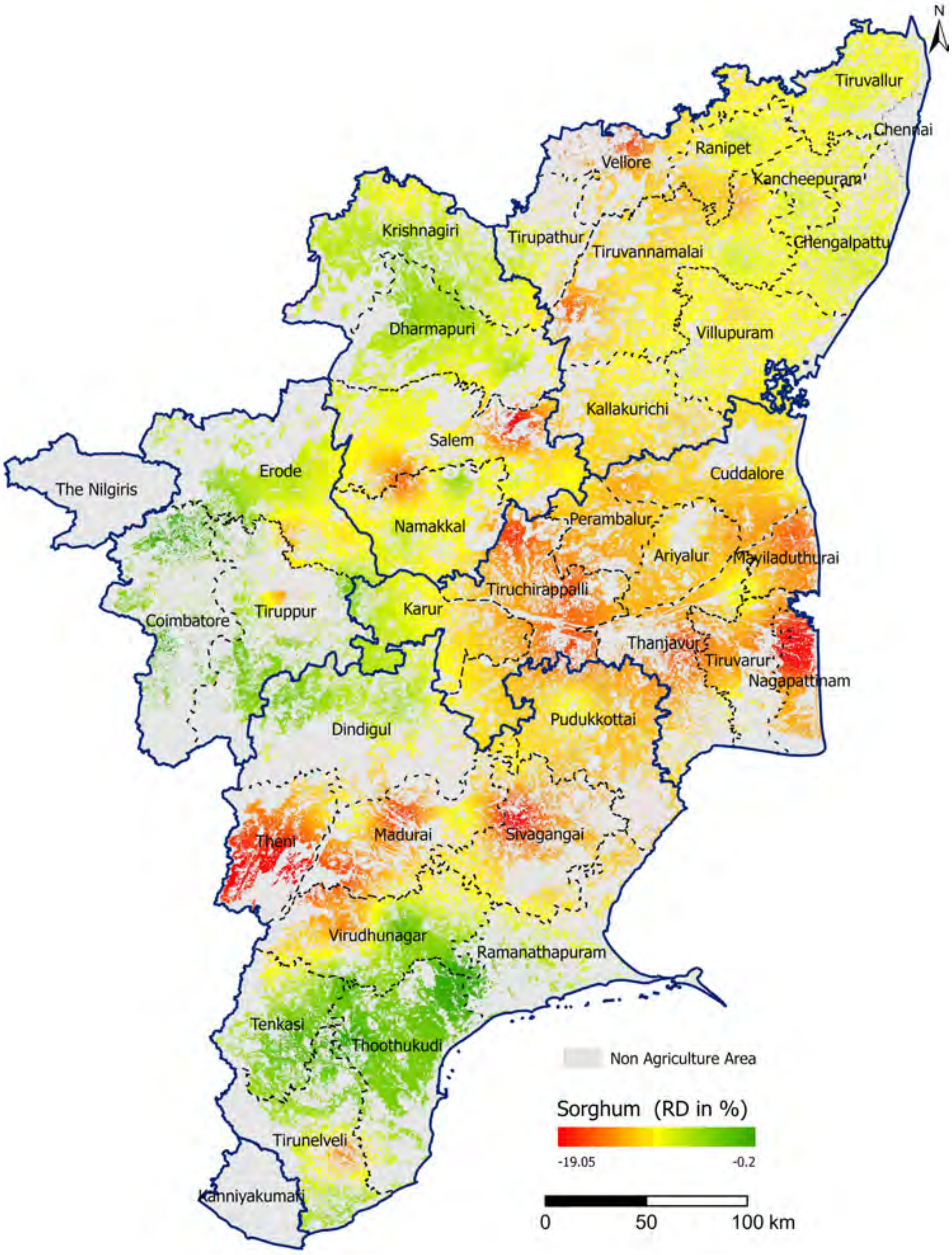


Figure 27 Sorghum yield scenario of Tamil Nadu (2021-2050) under SSP2-4.5 Scenario

Implementing efficient water management techniques like rainwater harvesting, drip irrigation, and precision agriculture can help optimize water use and reduce irrigation needs (Van der Schans *et al.*, 2017). Adopting crop rotation or intercropping practices can help spread risk, improve soil health, and enhance resilience to climate extremes (Liu et al., 2019). Building weather forecasting and early warning systems can help farmers prepare for extreme weather events and minimize losses (Midega et al., 2022).

### 3.2.4 Climate change impact on groundnut yield in Tamil Nadu (2021–2050)

Groundnut, a vital legume crop for food security and income generation in Tamil Nadu faces an increasing threat from climate change. Projections indicate a concerning decline in groundnut yield ranging from 2.37% to 16.5%, with the North Central region, Southern Coastal region, and Western Ghats region potentially experiencing a significant 14.2% reduction (Figure.28). This decline is primarily attributed to rising temperatures and changing precipitation patterns, leading to more frequent and severe drought stress. According to Patil et al. (2018), temperature increases during critical growth stages like flowering and pod filling can reduce yields by up to 20%. The impact of climate change extends beyond temperature effects, as altered rainfall patterns contribute to soil erosion and degradation, affecting soil fertility.

Moreover, these changes increase the risk of pests and diseases, compromising groundnut production. These factors severely threaten food security and livelihoods in Tamil Nadu, particularly for smallholder farmers who rely heavily on groundnut cultivation for their income. The projected decline jeopardizes the nutritional status of communities depending on this protein-rich crop. It risks economic instability in rural areas, potentially leading to increased poverty and rural-to-urban migration. Addressing these challenges will require a multifaceted approach, including the development of climate-resilient varieties, improved water management techniques, and support for farmers in adopting climate-smart agricultural practices to ensure the sustainability of groundnut cultivation.

Ramachandran *et al. (2017)* simulated that the groundnut yield is likely to be reduced by 5.1 and 9.6% for the mid- and end-century of Tamil Nadu. Climate change significantly threatens groundnut production, impacting yields and food security. However, by understanding the multifaceted impact and actively pursuing adaptation strategies, farmers and researchers can work together to build resilience and ensure the continued viability of this vital crop.

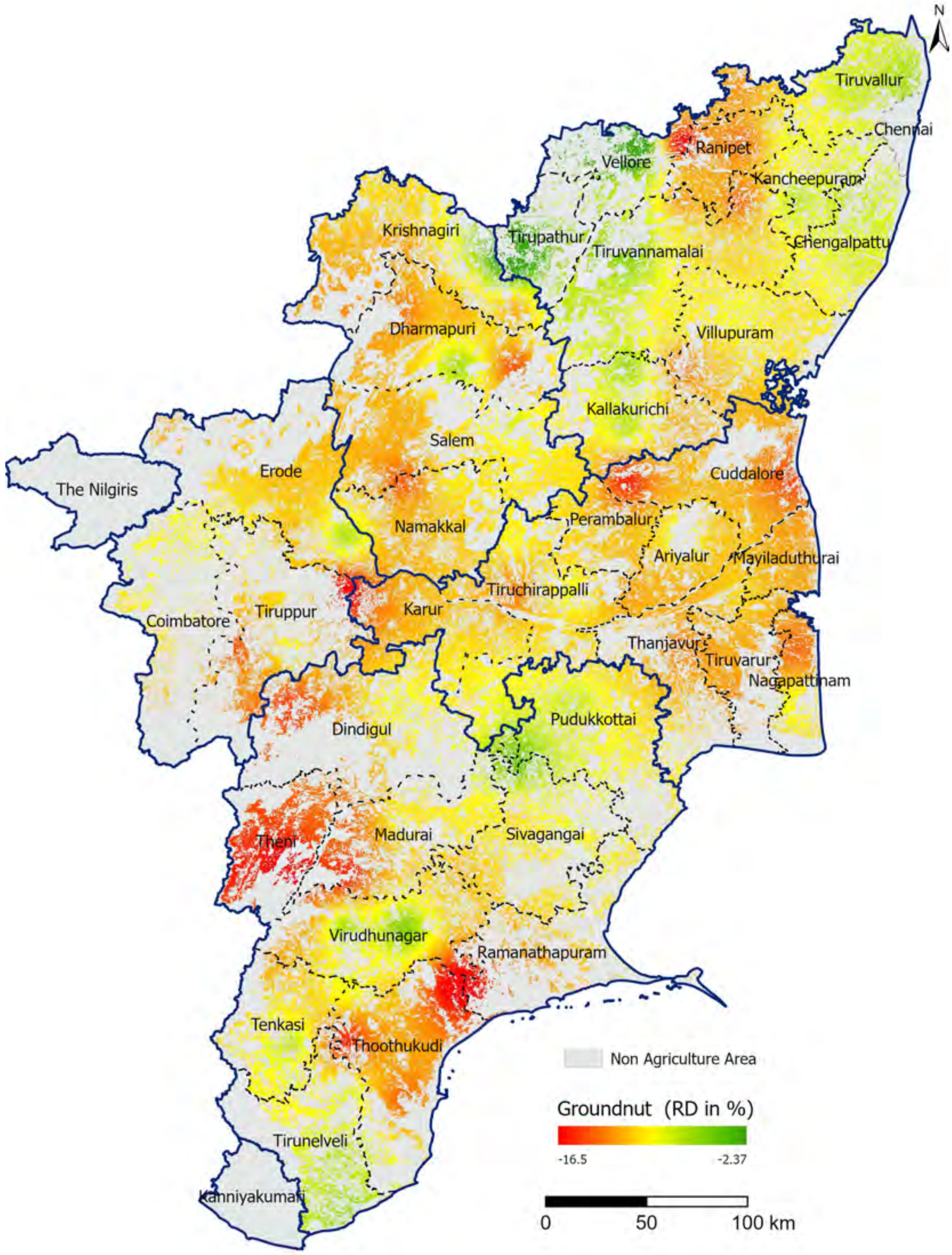


Figure 28 Groundnut yield scenario in Tamil Nadu (2021-2050) under SSP2-4.5 Scenario

### 3.2.5 Climate change impact on black gram yield in Tamil Nadu (2021–2050)

Black gram is the prime pulse in the state, accounting for more than 50% of the total pulse production. In Tamil Nadu, it is cultivated over 4.05 lakh hectares, producing 3.17 lakh tonnes and 780 kg per ha in 2019–2020 (AGRISNET, 2021). Figure. 29 illustrates the black gram yield scenario in Tamil Nadu under SSSP2- 4.5.

The black gram yield minimally declined compared to other crops, which ranged from 14.74 to -7.09%. The yield would be increased by about 3 to 14.74% in the Cauvery delta region. Increased atmospheric carbon dioxide levels can sometimes fertilize black gram, promoting growth and potentially increasing yields. In the near century, black gram yields will increase by 14.74%, with some parts of Tamil Nadu reducing yields by 7% in 2050. Some areas are expected to increase black gram yields by up to 14.74%. This positive trend aligns with recent studies, such as the one conducted by Pavithrapriya et al. (2023), which projected a 34% increase in black gram yield in the Cauvery Delta region by 2050.

However, other parts of Tamil Nadu might experience a reduction in yields by up to 7%. This variability highlights the importance of location-specific adaptation strategies. The general trend seems to be positive, with Pradipa et al. (2022) noting an overall projected increase of 18% in black gram yield across Tamil Nadu. The significant differences in projected yields across different parts of Tamil Nadu emphasize the need for localized adaptation strategies and crop planning. black gram in Tamil Nadu's pulse production, the projected increases in yield could have positive economic implications for farmers and the agricultural sector.

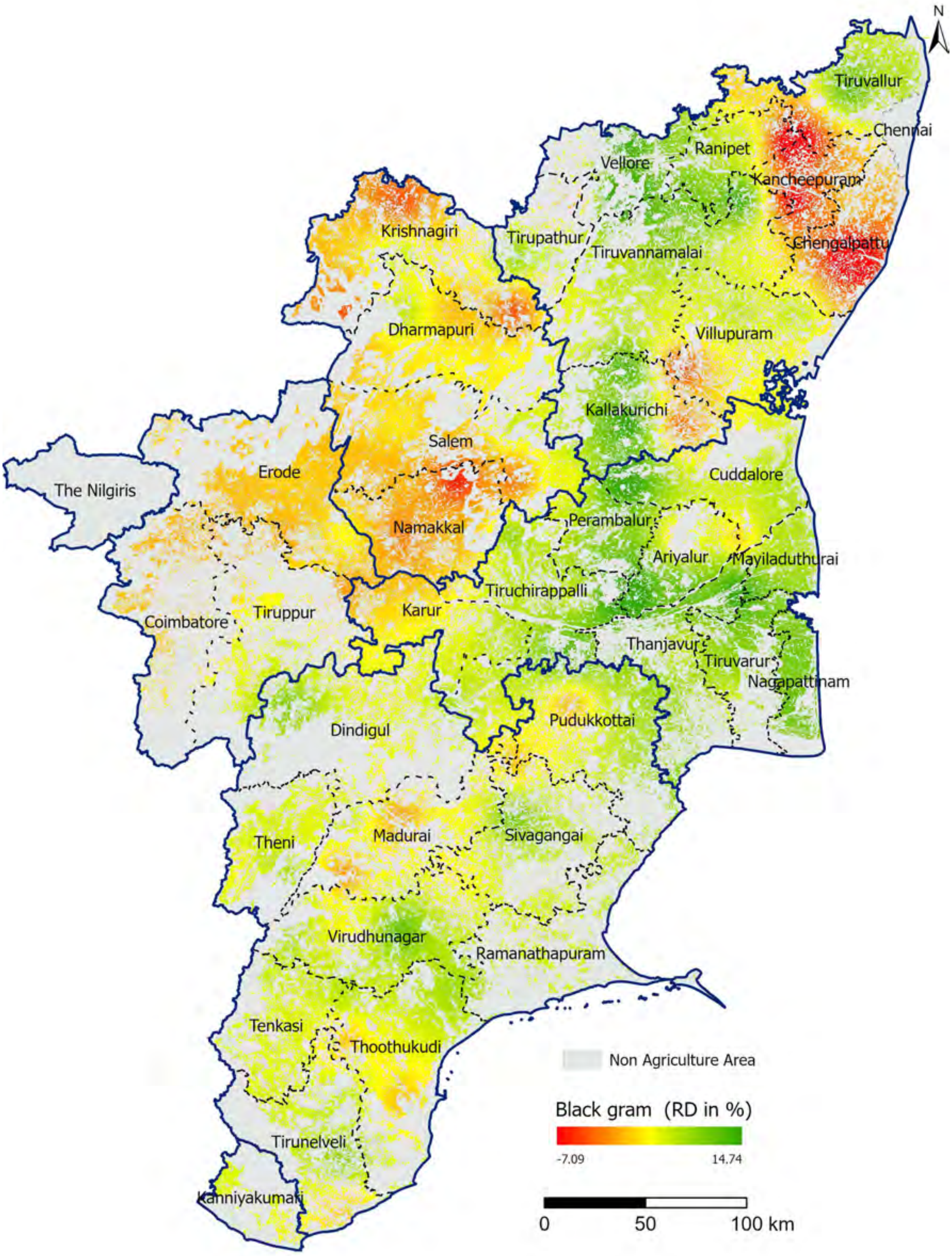


Figure 29 Black gram yield scenario in Tamil Nadu (2021-2050) under SSP2-4.5 Scenario

### 3.2.6 Composite crop yield index

The composite crop yield index provides a useful integrated measure of the performance and productivity of key crops in Tamil Nadu (Figure. 30). The index combines yields of major crops like rice, maize, sorghum, groundnut, and black gram and indicates considerable spatial variability in projected yield changes across districts in Tamil Nadu during 2021-2050 compared to the 1985-2014 baseline. The yield change has been classified into five classes: very high severity, high severity, moderate severity, low severity, and very low severity (Table.12).

Table 12 Classification of climate change impact on crop yield of Tamil Nadu

| CLassification | Districts |
|---|---|
| Very high severity | Chengalpattu, Kancheepuram, Villupuram, Cuddalore, Ranipet, Tiruvallur, and Ramanathapuram |
| High severity | Mayiladurai, Nagapattinam, Tiruvarur, Perambalur, Thanjavur, Thiruvannamalai,Tiruchirappalli, and Ariyalur |
| Moderate Severity | Pudukkottai, Krishnagiri, Sivasgangai, Dharmapuri, Salem, and Virudhunagar |
| Low Severity | Namakkal, Theni, Madurai, Karur, Coimbatore, Erode, Tiruppur, and Vellore |
| Very low severity | Thoothukudi, Dindigul, Kanyakumari, Tenkasi, Tirupathur, and Tirunelveli |

Overall, the impact of climate change on crop yields in Tamil Nadu is varied, with some districts facing high severity while others are expected to experience low severity. Policymakers and farmers in high-severity districts must implement adaptive measures to mitigate the adverse effects of climate change on agriculture. On the other hand, districts categorized as very low' severity should still be vigilant and prepared for any potential changes in climate patterns that could affect crop production in the future. Collaboration between stakeholders at both the local and state levels will be essential in developing sustainable solutions to ensure food security in Tamil Nadu.

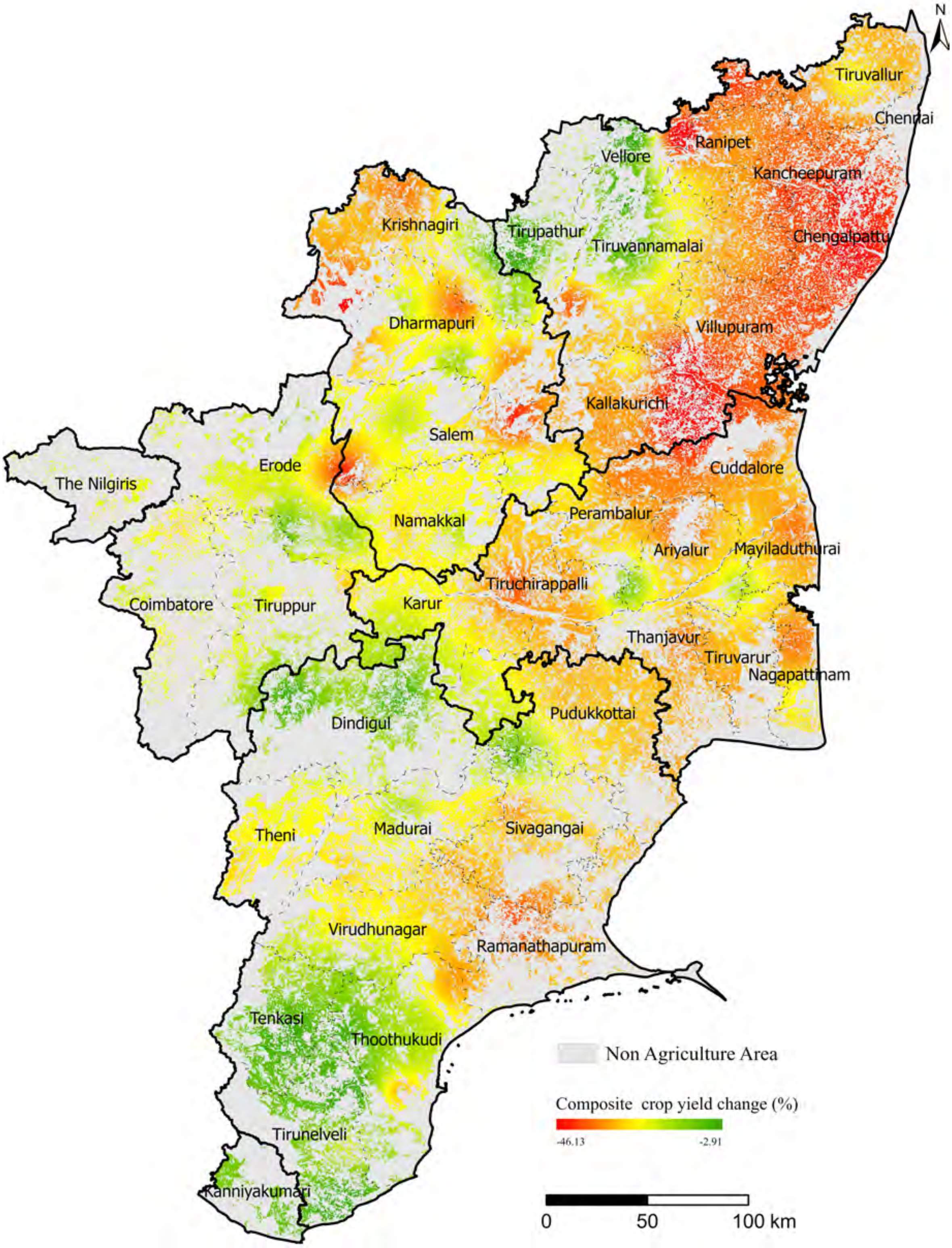


Figure 30 Composite crop yield index in Tamil Nadu (2021-2050) under SSP2-4.5 Scenario

## 3.3 Climate Risk Assessment

Since the IPCC First Assessment Report, the consequences of climate change have been explained as a function of various evolving components. Assessing the impact of climate change has been delineated through risk reduction and the latest Assessment Report of IPCC Working Group II. The concept of risk provides a framework for understanding the gradual but severe, interrelated, and often unalterable impacts of climate change on ecosystems, biodiversity, and human systems.

The potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from the potential impacts of climate change and human responses to climate change. Hazards, exposure, and vulnerability may each be subject to uncertainty in magnitude and likelihood of occurrence, and each may change over time and space due to socioeconomic changes and human decision-making. Understanding the climate change risk means understanding the sub-components that contribute to it (IPCC, 2022). The AR6 assessment assesses risk as a function of the interaction of climate hazards, vulnerability, and exposure. The risk conceptualization framework is shown in Figure. 31.


Figure 31 Conceptualization of Risk Framework - IPCC AR6

### 3.3.1 Hazard

Natural and human-induced physical events or trends can pose significant risks to human life, health, property, infrastructure, livelihoods, and the environment. These risks, particularly those related to climate change, manifest in various forms and timeframes. Some hazards develop slowly over time, while others occur suddenly and with little warning. Slow-onset hazards include gradual changes in temperature and precipitation patterns, which can lead to droughts and agricultural losses. In contrast, sudden-onset hazards encompass events like tropical storms and floods, which can cause immediate and severe damage.

Droughts and floods represent two extreme ends of the hydrological spectrum, both capable of causing widespread societal impacts. As highlighted by He et al. (2020), these events can have far-reaching consequences on communities, economies, and ecosystems. The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) scenarios suggest that India is likely to experience an increase in the frequency of extreme events compared to historical baselines (Das et al., 2022). This projection underscores the urgent need for comprehensive risk assessment and management strategies.

To better understand and predict these extreme events, researchers are employing sophisticated modeling techniques. Global climate models are being downscaled and integrated with hydrological models to capture the nuances of extremities such as droughts and floods (Brunner et al., 2021). The Soil and Water Assessment Tool (SWAT) model has been widely used in this context, providing valuable outputs for assessing hydro-climatic extreme events (Tan et al., 2020). More recently, the enhanced SWAT+ model has been employed to simulate hydrological variables under both baseline and future scenarios, offering insights into potential drought and flood hazards. Focusing on Tamil Nadu, a flood risk assessment for the near-century period under the Shared Socioeconomic Pathway 2-4.5 (SSP2-4.5) scenario has revealed concerning projections. As illustrated in Figure 32, several districts are expected to face very high flood risks. These high-risk areas include: Mayiladuthurai, Thiruvarur, Nagapattinam, Cuddalore and Chennai. This projection of increased flood risk in these districts has significant implications for urban planning, infrastructure development, and disaster preparedness in Tamil Nadu. The concentration of high-risk areas along the coast and in major urban centers like Chennai highlights the vulnerability of densely populated and economically important regions to climate-related hazards.

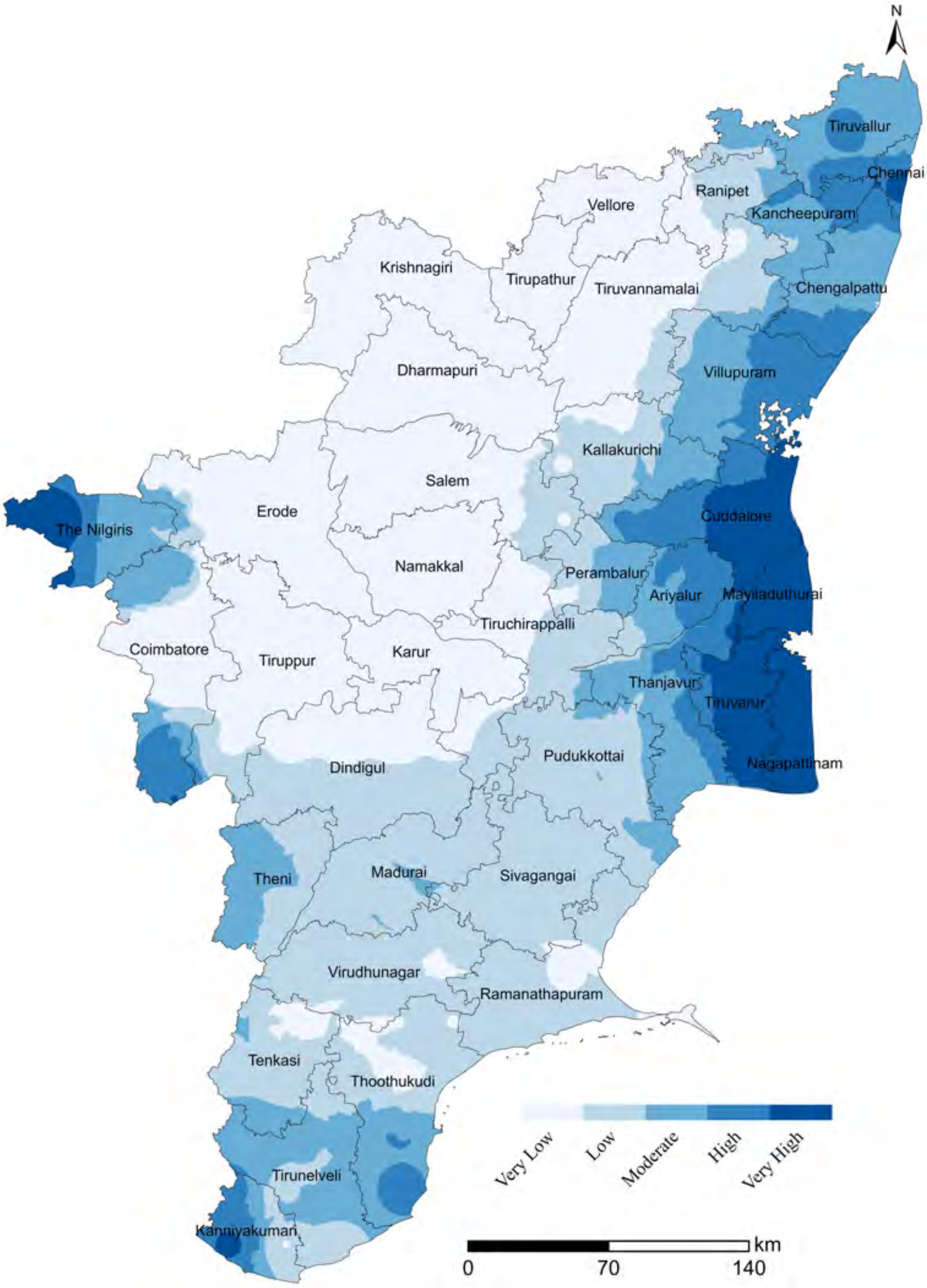


Figure 32 Projected flood hazard of Tamil Nadu in the Near Century

The drought risk spatial distribution of Tamil Nadu under the SSP2-4.5 scenario for the near century period is shown in Figure 33. Districts such as Ramanathapuram, Dharmapuri, Krishnagiri, Thiruvannamalai, Thoothukudi, and Virudhunagar are projected to have a very high drought risk in the near century period. The drought and flood layers are integrated to create a hazard layer.

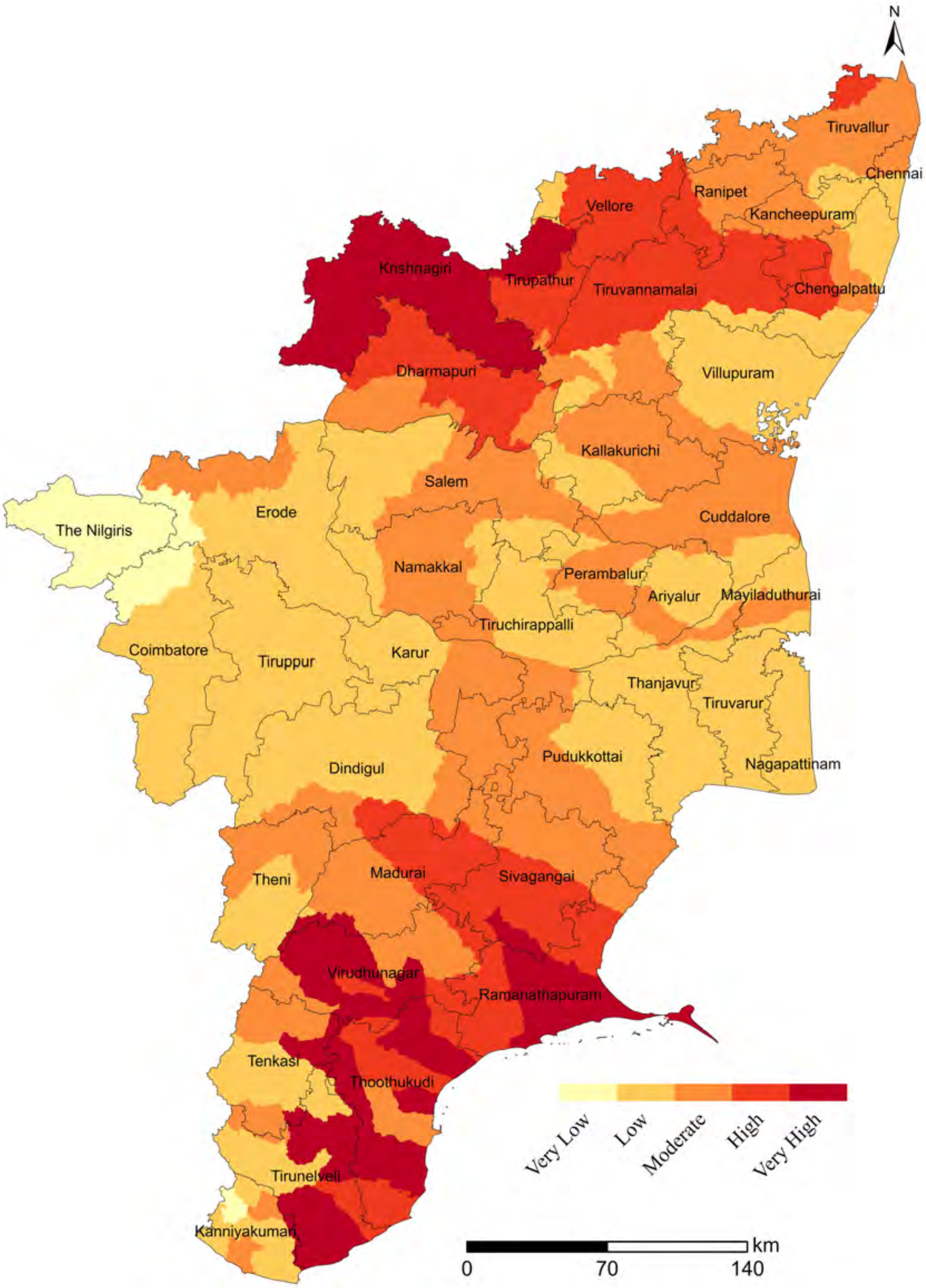


Figure 33 Projected drought hazards of Tamil Nadu in the Near Century

### 3.3.2 Agriculture Vulnerability

Vulnerability refers to the degree to which a system or population is susceptible and unable to cope with the adverse effects of climate change, including climate variability and extremes. It encompasses the characteristics and circumstances that make individuals, communities, or ecosystems more prone to harm or disruption from climate-related hazards. Various factors, including social, economic, and environmental conditions, influence vulnerability. These can include poverty, inequality, limited access to resources and services, inadequate infrastructure, and a lack of institutional capacity.

Agricultural vulnerability refers explicitly to the propensity of a system or population to suffer negative impacts when exposed to drought events. Three main factors determine this vulnerability:

1. Sensitivity: The degree to which a system is adversely or beneficially affected by climate variability or change. Sensitivity is influenced by factors such as crop type, soil quality, and water availability. For example, crops that require a lot of water are more sensitive to drought.
2. Adaptive Capacity: The ability of a system to adjust to climate change, including variability and extremes, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. Adaptive capacity is influenced by factors such as access to technology, knowledge, financial resources, and social networks. For example, farmers who have access to drought-resistant crop varieties or irrigation systems have higher adaptive capacity.
3. Exposure: The extent to which a system is exposed to climate change, including climate variability and extremes. Exposure is influenced by factors such as geographic location and climatic conditions. For example, regions that experience frequent droughts are more exposed to drought events.


Figure 34 Historical Natural Hazards impacts on Agriculture

This timeline illustrates the recurring pattern of natural disasters that have significantly impacted agriculture in Tamil Nadu, India from 1983 to 2023. It begins with a severe drought in 1983 that caused extensive crop loss, followed by another major drought in 2002 that severely affected the state's agriculture. In 2005, widespread flooding submerged or damaged over 3 lakh hectares of crops. The region was then hit by Cyclone Thane in 2011, causing widespread damage to standing crops and resulting in substantial economic losses. 2016 saw another severe drought, with rainfall decreasing by 62% and economic losses exceeding ₹20,000 crores. Cyclones Vardah (2018) and Gaja (2018) further devastated crops and coconut trees, a vital source of income for farmers. More recent events include major floods in 2021 and 2023, each affecting around 5 lakh hectares of agricultural land. The 2023 flood is estimated to have reduced paddy crop yields by 30% in affected areas. This chronology highlights the ongoing challenges faced by Tamil Nadu's agricultural sector due to various climate-related disasters, underscoring the need for robust disaster management and climate adaptation strategies.

The agriculture vulnerability has been assessed for Tamil Nadu state, Chennai and Nilgris were excluded from the agriculture vulnerability assessment of Tamil Nadu, Chennai is fully urbanized and a metropolitan city and Nilgris is also negligible due to less amount of field crops cultivated. Small and marginal farmers, net sown area, percentage of rainfed agriculture, and cropping intensity are agriculture indicators. Number of farm ponds, groundwater exploitation, and surface water availability as water indicators. Road connectivity, the number of regulatory markets, and agro-advisories as institutional & infrastructure. The percentage of crop insurance, multi-poverty dimensional index, livestock population, and percentage of rural population are socio-economic indicators. Integrating the agriculture index, water index, institutional & infrastructure index, and socioeconomic index assesses the agriculture vulnerability. These indicators are normalized to a common scale to compute the agriculture vulnerability index (AVI). Agricultural vulnerability in Tamil Nadu was assessed using biophysical, socioeconomic, institutional, and infrastructure indexes. The rural-based indicators were used to categorize districts into very high, high, moderate, low, and very low vulnerability. The primary drivers influencing agricultural vulnerability are led by water resources, followed by institutional and infrastructure factors, socio-economic conditions, and agricultural practices (Figure. 35).

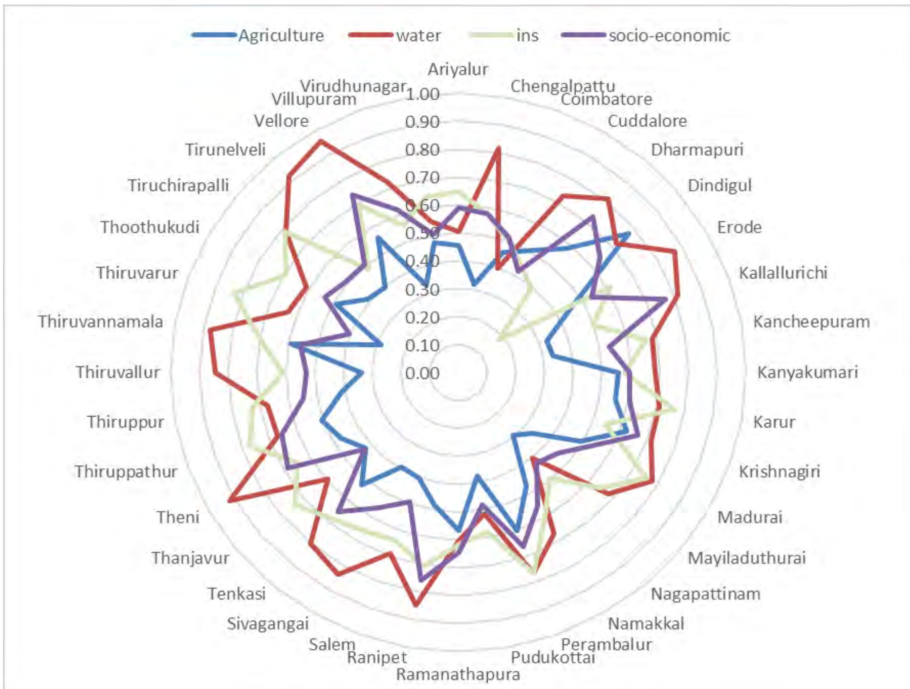


Figure 35 Major Drivers influencing the Agricultural vulnerability

Surface water availability is a critical factor in agricultural production, particularly in regions where water resources are limited. It plays a pivotal role in shaping the agricultural vulnerability index, with cropping intensity emerging as a major determinant. Cropping intensity refers to the frequency with which crops are grown on a given piece of land during a year, and its relationship with water availability directly affects agricultural resilience. Other significant factors influencing agricultural vulnerability include the prevalence of rainfed agriculture, the extent of the net sown area, and the high proportion of small and marginal farmers who are more susceptible to changes in water availability and agricultural productivity.

In the context of Tamil Nadu, Dindigul district stands out for exhibiting very high vulnerability in the agriculture vulnerability index. This high level of vulnerability is likely driven by the district's dependence on rainfed agriculture, limited surface water resources, and the significant presence of small-scale farmers who have limited capacity to invest in irrigation infrastructure or cope with climate variability. Other districts such as Vellore, Thiruvannamalai, Tenkasi, Ramanathapuram, Perambalur, Krishnagiri, Karur, Kanyakumari, and Dharmapuri also exhibit high vulnerability, particularly concerning the challenges faced by small and marginal farmers. These farmers are especially vulnerable due to their limited access to water resources, smaller land holdings, and reliance on traditional farming methods that may not be resilient to climatic changes. In contrast, the remaining districts across Tamil Nadu display moderate agricultural vulnerability, indicating a relatively better capacity to cope with water scarcity and other agricultural stressors. However, even in these districts, surface water availability remains a key factor influencing agricultural outcomes.

When focusing specifically on water resources, surface water availability is again a key determinant of vulnerability within the water index for agriculture. In addition to surface water, factors such as the presence of farm ponds and groundwater availability significantly contribute to a district's overall vulnerability. Districts that lack adequate surface water or groundwater reserves are more likely to face water-related challenges that exacerbate agricultural vulnerability. Several districts exhibit high vulnerability in the water index, including Vellore, Theni, Thirunelveli, Thiruvannamalai, Erode, Ranipet, Thiruvallur, Sivagangai, Chengalpattu, Dharmapuri, Kallakurichi, Tenkasi, Tiruchirappalli, and Madurai (Fig.37). These regions face significant challenges in maintaining sufficient water resources for agriculture, largely due to limited surface water availability and the strain on groundwater supplies.

On the other hand, districts such as Nagapattinam, Coimbatore, Pudukkottai, and Cuddalore demonstrate the lowest levels of vulnerability in the water index. These areas may benefit from better water resource management practices, more reliable access to surface water, or more sustainable groundwater extraction, allowing them to maintain a more resilient agricultural system. These regional disparities in water resource availability and agricultural vulnerability highlight the need for targeted water management strategies and support for vulnerable farmers, particularly in districts with high vulnerability. The socio-economic indicators considered in the assessment include livestock population, rural population, and the Multidimensional Poverty Index (MDPI). Based on these factors, districts such as Kallakurichi and Ranipet demonstrated a very high level of vulnerability in the socio-economic index (Figure 38).

Agro-advisory services emerged as crucial components of the infrastructure and institutional index, followed closely by market accessibility and road connectivity (Figure 39). Districts such as

Thiruvarur, Tiruchirappalli, Thiruppathur, Perambalur, Karur, Madurai, and Thanjavur exhibited exceptionally high vulnerability in this category. Moreover, several other districts, including Thiruppur, Ranipet, Thiruvannamalai, Thoothukudi, Vellore, Tenkasi, Kancheepuram, Sivagangai, Ariyalur, Theni, Mayiladuthurai, Salem, Virudhunagar, Ramanathapuram, Erode, Thiruvallur, Namakkal, Pudukottai, Kanyakumari, Chengalpattu, Villupuram, Krishnagiri, Coimbatore, Kallakurichi, Nagapattinam, Thirunelveli, Cuddalore, and Dharmapuri, also displayed high levels of vulnerability concerning the infrastructure and institutional index (Figure 39). These findings highlight the significant disparities in socio-economic and infrastructural resilience across districts, emphasizing the need for targeted interventions to reduce vulnerability.

Districts such as Thiruvannamalai, Vellore, and Perambalur have been identified as having very high agricultural vulnerability (refer to Fig. 40). This heightened vulnerability is shaped by several critical factors. One of the most significant is the availability of farm ponds, which play a crucial role in water storage for irrigation, particularly in regions where surface water is scarce.

The presence or absence of such water conservation measures directly impacts a district's ability to sustain agricultural activities, especially during dry spells or periods of inconsistent rainfall. Surface water availability is another key determinant of agricultural vulnerability. Districts that rely heavily on rainfed agriculture, where crops depend solely on rainfall rather than irrigation, are particularly susceptible to fluctuations in water availability. The reliance on rainfed systems increases the risk of crop failure during droughts or periods of irregular rainfall, making these regions more vulnerable.

Cropping intensity, or the frequency with which crops are cultivated within a given agricultural cycle, further compounds vulnerability. Regions with higher cropping intensity are more dependent on continuous water availability and are thus more susceptible to water shortages or climatic changes that disrupt the growing season.

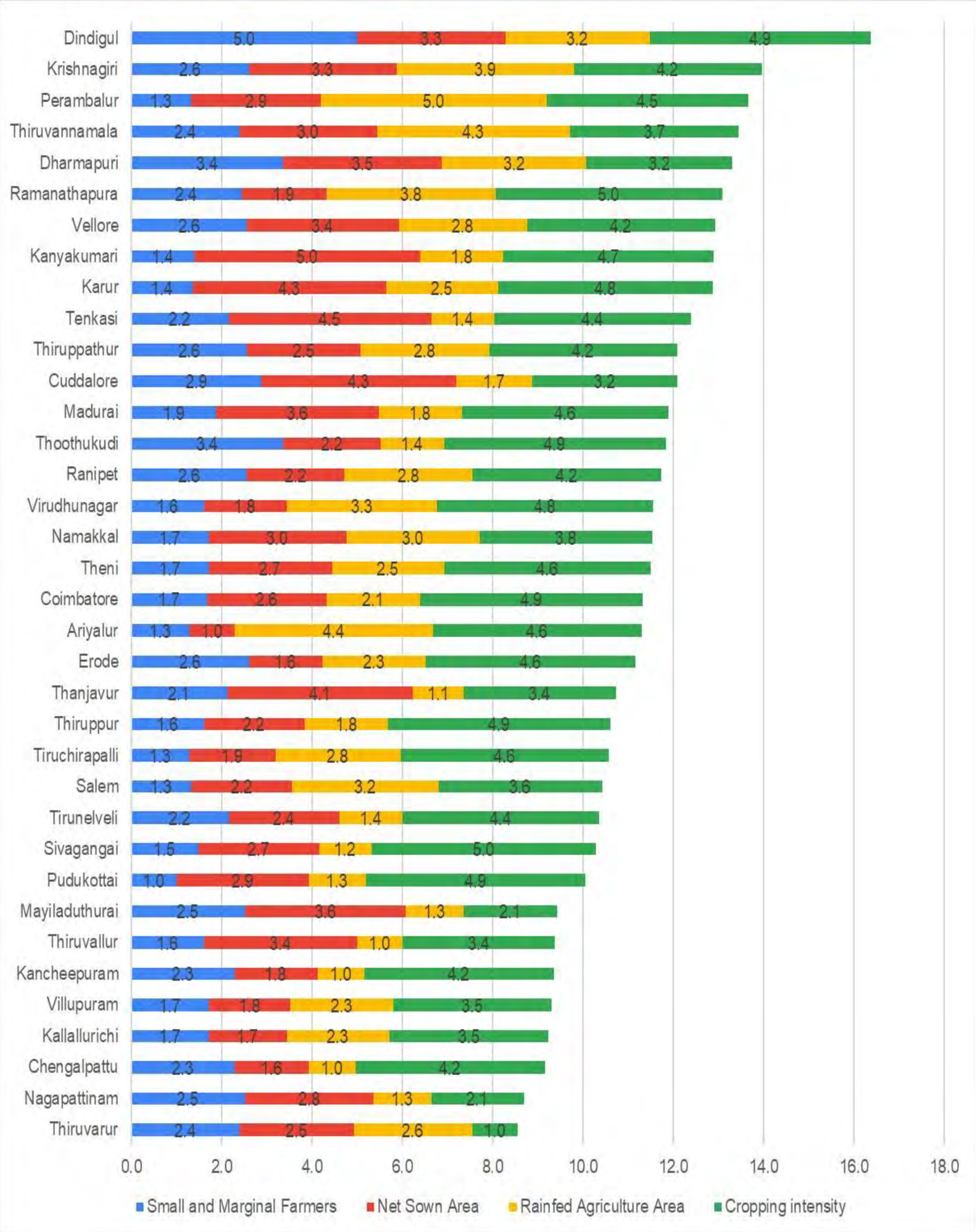


Figure 36 Districts level drivers influence the agricutlure vulnerability

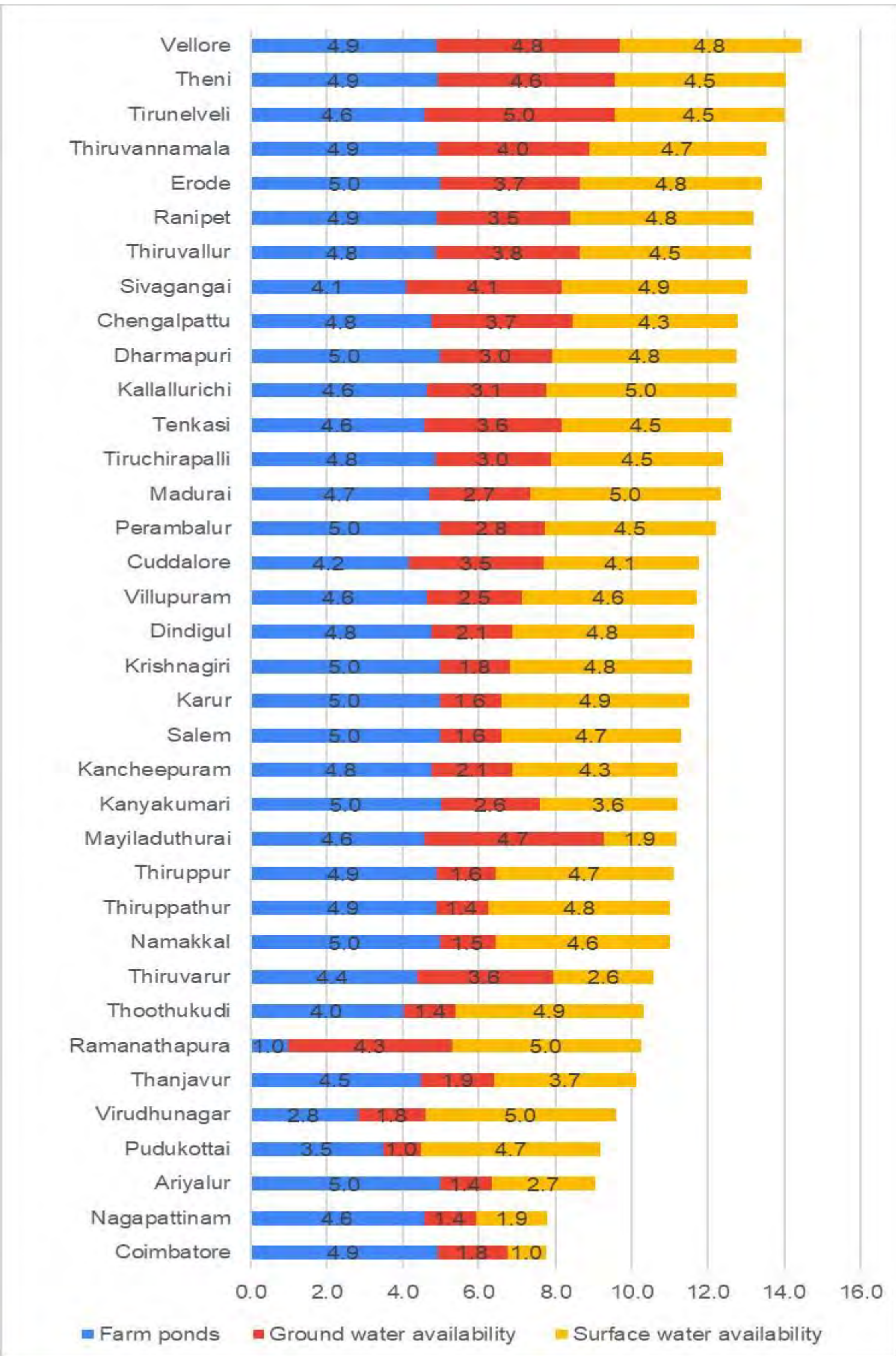


Figure 37 Districts level drivers influence the water vulnerability

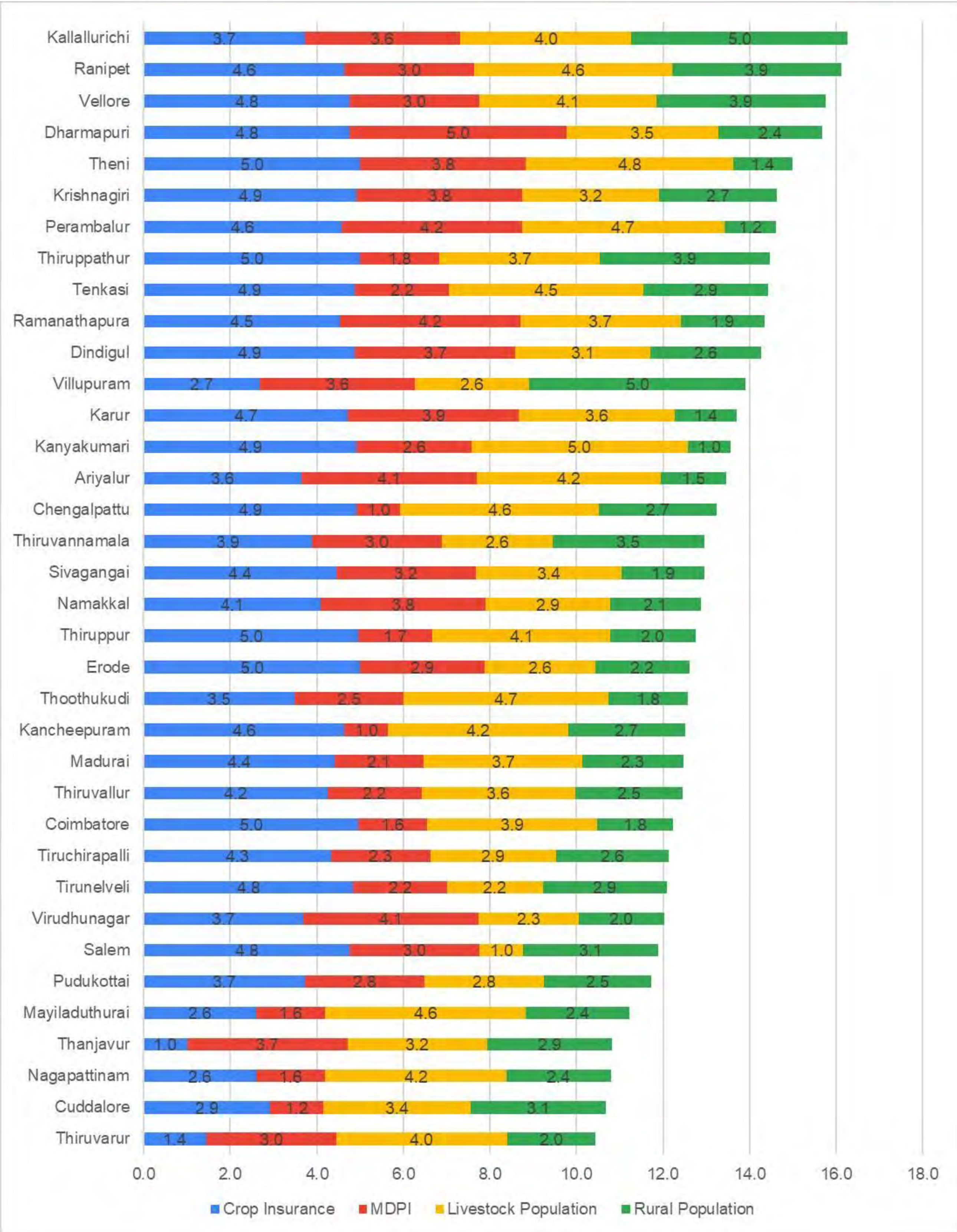


Figure 38 Districts level drivers influence the Socio-economicvulnerability

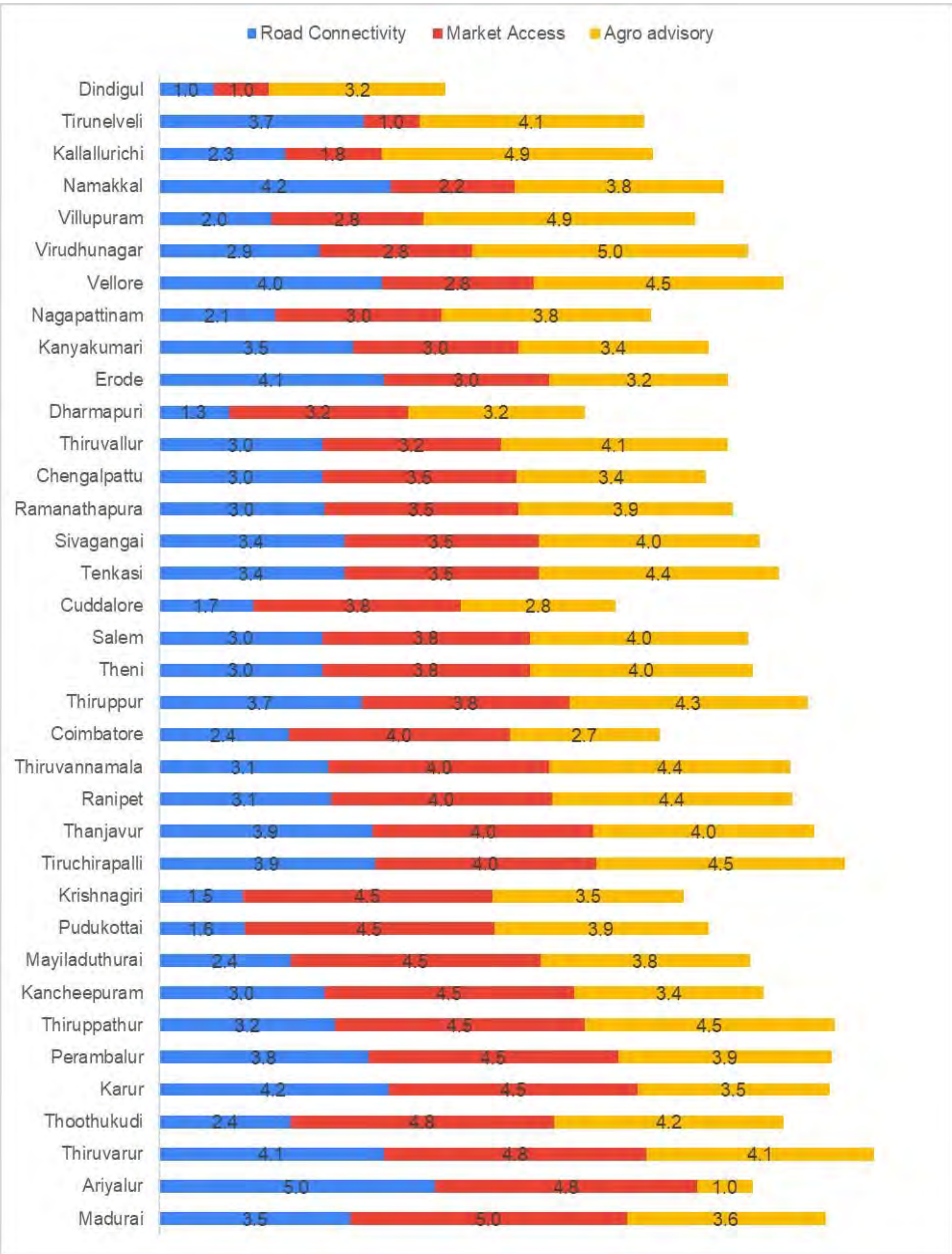


Figure 39 Districts level drivers influence the institutional and Infrastructure vulnerability

Additionally, the provision of agro-advisory services plays a vital role in determining a district's agricultural resilience. These services provide farmers with timely information on best practices, weather forecasts, and strategies for managing resources more effectively. A lack of access to such services increases the vulnerability of farmers, as they may not have the information needed to adapt to changing conditions.

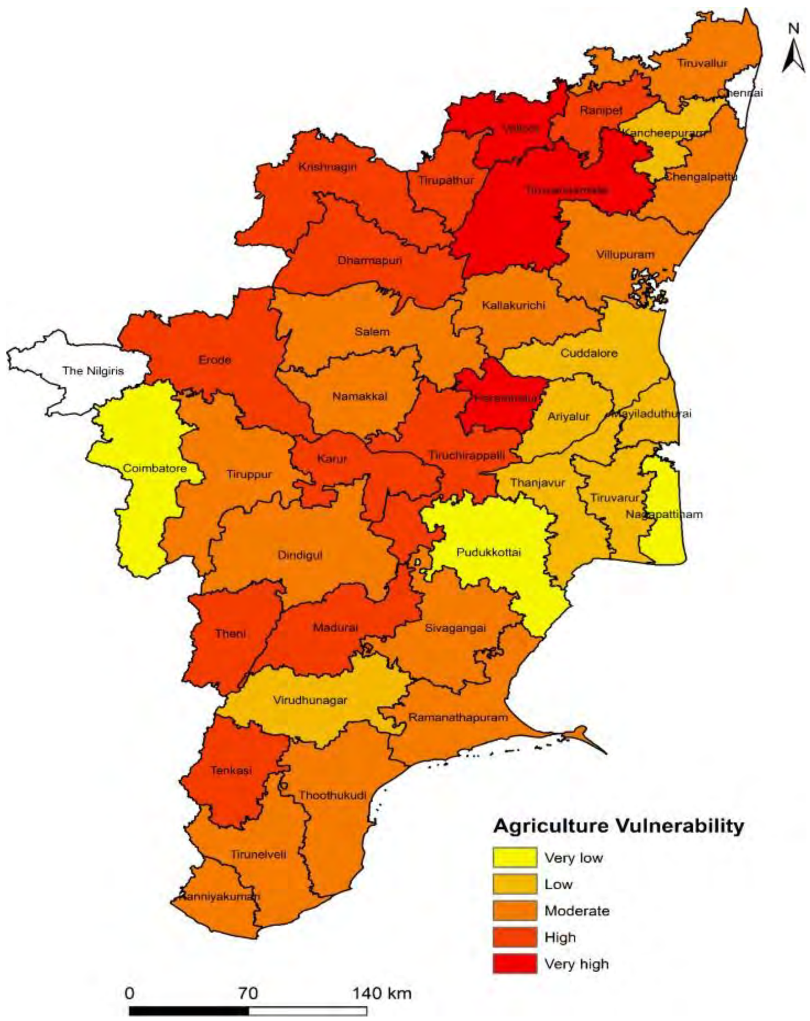


Figure 40 District level composite vulnerability of Tamilnadu

In these districts, while conditions may not be as severe as in Thiruvannamalai, Vellore, or Perambalur, there remains a heightened risk to agricultural sustainability, necessitating focused interventions to mitigate vulnerability. In contrast, districts such as Thanjavur, Virudhunagar, Thiruvarur, Mayiladuthurai, Cuddalore, Pudukottai, and Coimbatore exhibit relatively low levels of agricultural vulnerability. These regions benefit from more favorable conditions, such as better surface water availability, greater access to irrigation, and possibly lower reliance on rainfed farming. This enables farmers in these districts to be more resilient to climatic variability

Several other districts, including Theni, Tenkasi, Karur, Thiruppathur, Ranipet, Madurai, Krishnagiri, Dharmapuri, Tiruchirappalli, and Erode, are categorized as having high agricultural vulnerability. These areas face similar challenges, such as limited water resources, a significant proportion of rainfed agriculture, and constraints related to cropping intensity. and water scarcity, reducing their overall vulnerability.

In contrast, districts such as Thanjavur, Virudhunagar, Thiruvarur, Mayiladuthurai, Cuddalore, Pudukottai, and Coimbatore exhibit relatively very low levels of agricultural vulnerability. These regions benefit from more favorable conditions, such as better surface water availability, greater access to irrigation, and possibly lower reliance on rainfed farming. This enables farmers in these districts to be more resilient to climatic variability and water scarcity, reducing their overall vulnerability.

Nagapattinam stands out for displaying very low agricultural vulnerability. This could be attributed to strong water resource management systems, effective agro-advisory services, and an agricultural infrastructure that supports sustainable farming practices. The presence of irrigation networks, coupled with lower dependency on rainfed agriculture, contributes to Nagapattinam's agricultural resilience.

These regional differences in agricultural vulnerability underscore the importance of localized strategies for improving agricultural sustainability. Districts facing higher vulnerability require tailored interventions, such as enhanced water conservation practices, increased access to irrigation, and strengthened agro-advisory services, to help farmers cope with the challenges posed by fluctuating water availability and climatic variability. Conversely, maintaining and further enhancing agricultural resilience in districts with lower vulnerability should focus on sustaining current practices and preventing emerging risks.

### 3.3.3 Agriculture Risk

According to the IPCC Assessment Report, AR6, Agriculture risk has been calculated based on hazard, exposure, and Vulnerability. Flood and drought as hazard, Rural Population, rainfed agriculture and net sown area as exposure, small & marginal farmer and Groundwater Exploitation as vulnerability (sensitivity), cropping intensity, surface water availability, Number of farm ponds, Agro advisory, Market access, Road Connectivity, Livestock population, Crop insurance and Multi-Dimensional Poverty Index (MDPI) as Adaptive capacity of Vulnerability

Agriculture risk refers to the chance of adverse outcomes or the possibility of damages arising from several factors. These factors include the potential occurrence of events (hazard), the people, their livelihoods, and assets in regions where droughts might occur (exposure), and the vulnerability of the exposed entities hit by a drought event (vulnerability) Cardona et al. (2012).

The hazard, exposure, and vulnerability information computed in the form of Hazard, Exposure, Vulnerability, and composite crop risk, respectively, is combined to evaluate the Agriculture Risk Index (ARI). Agriculture risk refers to the chance of adverse outcomes or the possibility of damages arising from several factors. These factors include the potential occurrence of events (hazard), the people, their livelihoods, and assets in regions where droughts might occur (exposure), and the vulnerability of the exposed entities hit by a drought event (vulnerability) Cardona et al. (2012). The hazard, exposure, and vulnerability information computed in the form of hazard, exposure, vulnerability, and composite crop risk, respectively, are combined to evaluate the Agriculture Risk Index (ARI).

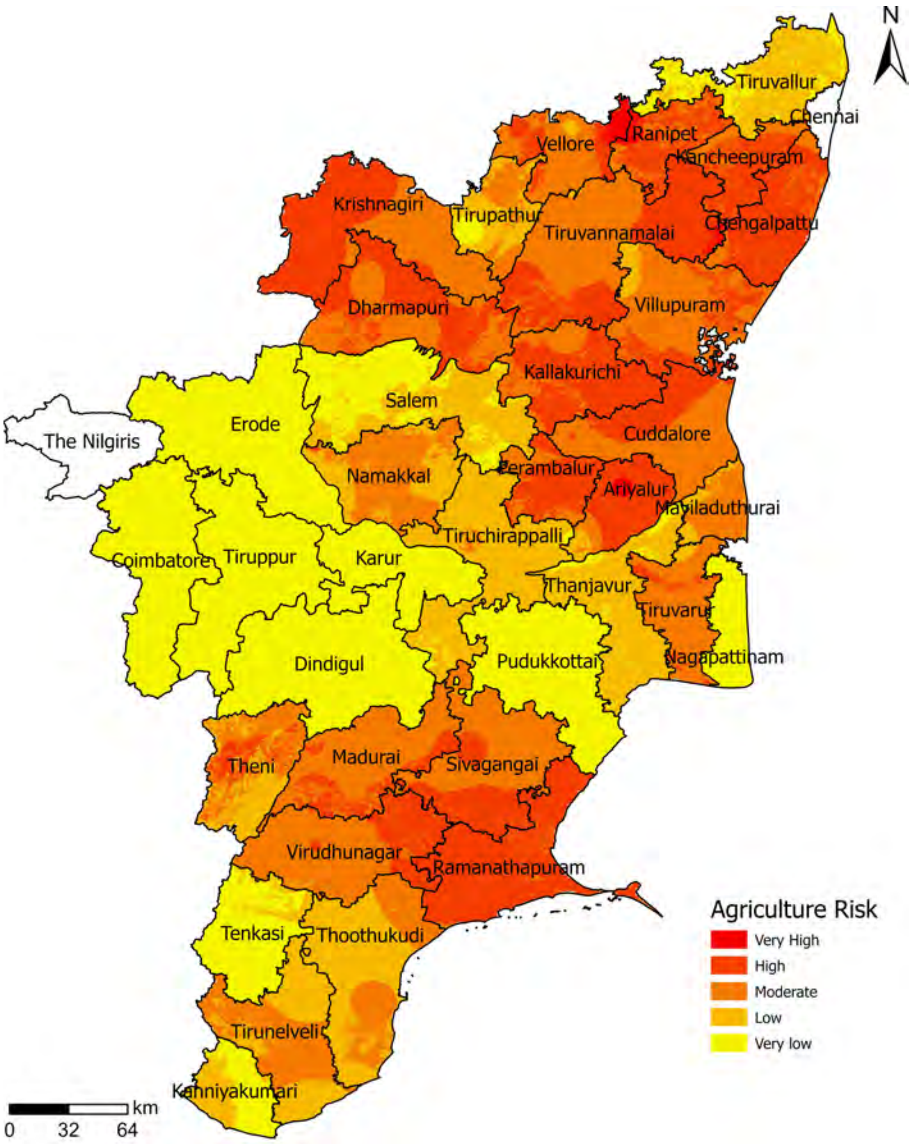


Figure 41 Agriculture Risk of Tamil Nadu for a Future Period (2021–2050)

The agriculture risk spatial distribution of Tamil Nadu under the SSP2-4.5 scenario for the near century period is shown in Fig. 41. Districts such as Ranipet, Ariyalur, Perambalur, Ramanathapuram, Kallakurichi, Chengalpattu, Dharmapuri, Kancheepuram, Cuddalore, Krishnagiri, Vellore, Thiruvannamalai, and Sivagangai, shows a very high agriculture risks in the near century period. Due to climate change, Mayiladuthurai, Villupuram, Thiruvarur, Nagappattinam, Madurai ,Thirunelveli, Virudhunagar and Theni would be at high risk in agriculture. Erode, Thiruppur and Coimbatore indicate a very low agriculture risk in Tamil Nadu.

## 4. Agriculture Risk Assessment of Agro Climatic Zone of Tamil Nadu

Climate change impacts five major crops (Rice, Maize, Sorghum, Black gram, and Groundnut) in Six agro-climatic Zones of Tamil Nadu. The high-altitude Zones are negligible due to the minimal cultivation of field crops in hilly areas. Agriculture risk has been assessed based on IPCC Assessment Report AR6 framework. Risk has been calculated based on the simulation of the primary crop yield of Tamil Nadu by using the DSSAT crop simulation model for the baseline (1985-2014) and Near Century (2021-2050).

### 4.1. Agriculture Risk assessment of NEZ

#### 4.1.1 Climate Change Impact on Major Crops of NEZ

The spatial impact of climate change on major crops in the NEZ of Tamil Nadu from 2021 to 2050 is depicted in Figure. 42. In this zone, rice yields are projected to decrease by approximately 2.2% to 13.7%. Particularly in the coastal regions of the NEZ, rice yields could decline by up to 13.7%. The high intensity of rainfall during the northeast monsoon significantly affects standing crops. Maize yields in this zone are expected to decrease by about 2.7% to 23.4% during the same period (Table.13). Maize is susceptible to both high temperatures and rainfall. Notably, maize yields show a significant decline in the NC region compared to other crops.

Table 13 Projected Crop Yield Change of NEZ during Near Century (2021-2050)

| Crop | Yield Change (%) | Very high-impact districts |
|---|---|---|
| Rice | -13.7 to -2.2 | Chengalpattu, Kancheepuram, Ranipet and Kallakuruchi |
| Maize | -23.4 to -2.7 | Chengalpattu, Kancheepuram, Villupuram, Kallakurichi, Tiruvallur, Ranipet, Tiruvannamalai and Cuddalore |
| Sorghum | -14.1 to -6.9 | Vellore, Cuddalore, Kallakurichi, Tiruvannamalai, Ranipet, Villupuram |
| Black gram | -7.1 to 14.4 | Chengalpattu and Kancheepuram |
| Groundnut | -13.7 to 12.4 | Cuddalore, Ranipet, Villupuram, Kallakurichi andTiruvannamalai |

Black gram yields exhibit considerable variation in this zone, ranging from an increase of 14.4% in the western, northern, interior, and some southern regions to a decrease of 7.1% in the eastern parts. Groundnut yields also vary widely across the zone, ranging from an increase of 12.4% to a decline of 13.7%.

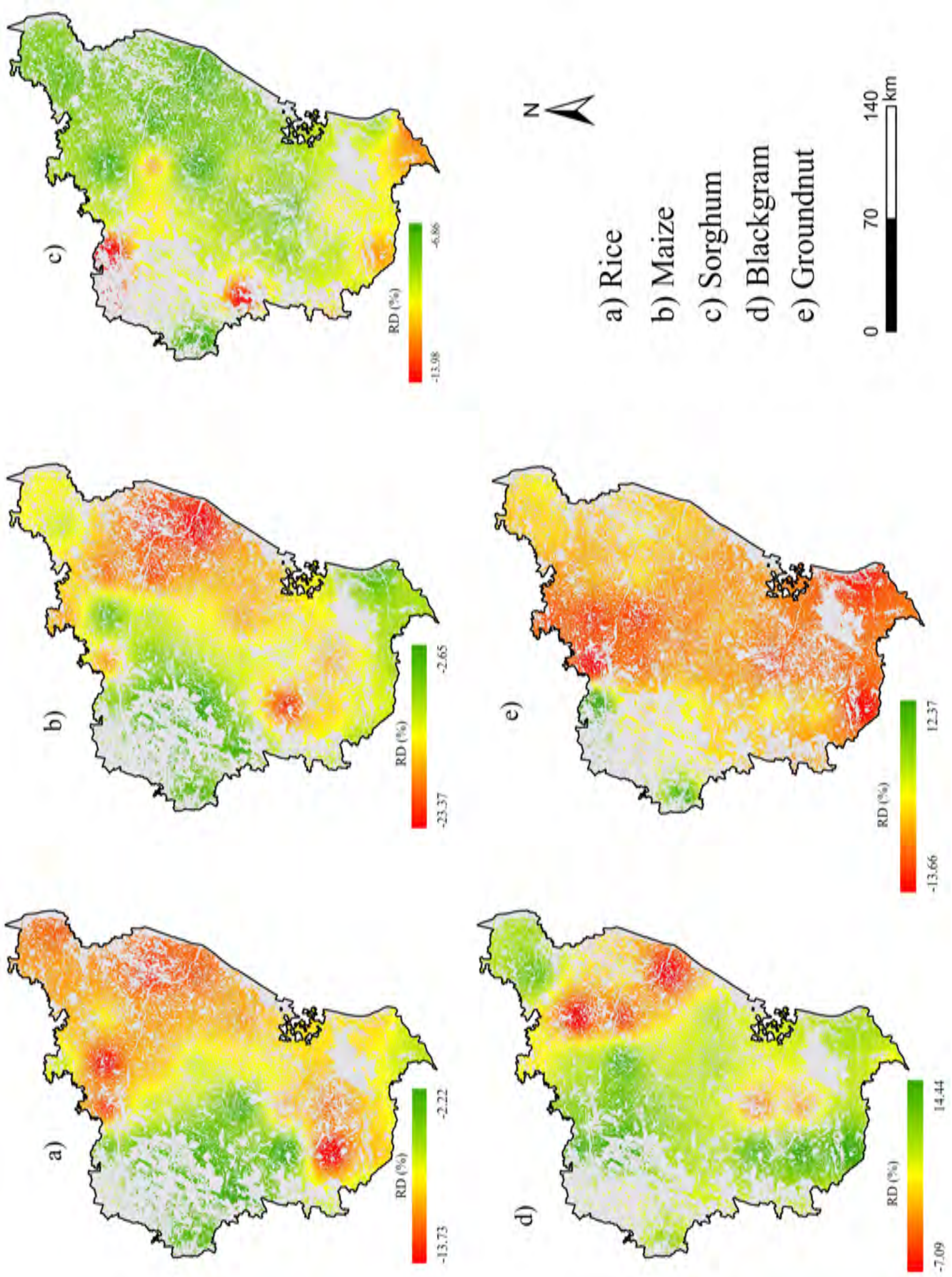


Figure 42 Climate Change impact on major crop yield in NEZ for the period of 2021-2050

### 4.1.2 Agriculture Risk of NEZ

The agriculture risk in the NEZ of Tamil Nadu, which includes Chengalpattu, Ranipet, Kancheepuram, Thiruvannamalai, and Kallakurichi district, is very high (Fig.43). The risk in this Zone is highly influenced by the climate impact on crop yield due to the intensity of the monsoon during the Northeast monsoon period.

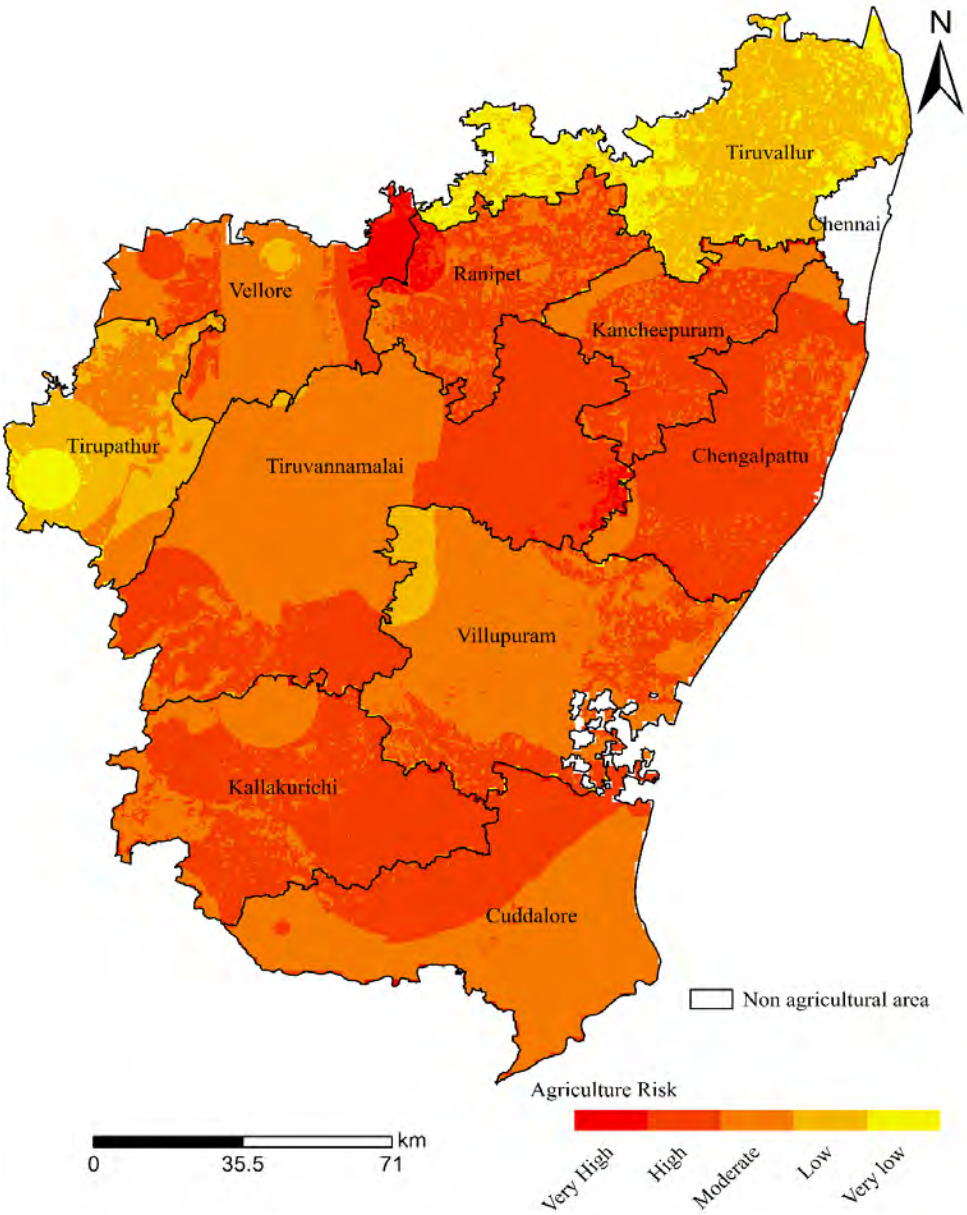


Figure 43 Agriculture Risk Assessment of NEZ

## 4.2 Agriculture Risk assessment of NWZ

### 4.2.1 Climate Change Impact on Major Crops of NWZ

The spatial distribution of climate change impacts on major crops in the NWZ of Tamil Nadu for the period 2021-2050 is comprehensively illustrated in Figure. 44, revealing significant variations across different crops and geographical areas. Rice, a staple crop in the region, is projected to experience yield declines ranging from 3.2% to 10.2%, with some areas potentially facing reductions of up to 13.7%. Maize, highly susceptible to fluctuations in temperature and rainfall, is expected to see yield reductions between 2.2% and 15.8% during the same period. Sorghum appears to be the most severely affected crop, with projected yield decreases of 4.7% to 16% (Table.14). Black gram yields show considerable spatial variability across the North WZ, with notable declines, particularly in the southern and northwestern parts.

Groundnut yields also exhibit substantial variation, ranging from a potential increase of 2.4% in the eastern parts of the zone to decreases of up to 11.1% in other areas. This diverse impact on groundnut is unique, as it's the only crop showing potential yield increases in certain areas amidst an overall trend of decline. The eastern sections of the zone stand out with their projected slight increase in groundnut yields, contrasting sharply with the substantial declines expected in the remaining parts of the NWZ. These projections underscore the complex and varied effects of climate change on agricultural productivity in the region, highlighting the need for crop-specific and location-specific adaptation strategies to mitigate potential food security risks.

Table 14 Projected Crop Yield Change of NWZ during Near Century (2021-2050)

| Crop | Yield Change (%) | Very high-impact districts |
|---|---|---|
| Rice | -10.2 to -3.2 | Dharmapuri, Krishanagiri, Salem and Namakkal |
| Maize | -15.8 to -2.2 | Dharmapuri, Krishanagiri, Salem and Namakkal |
| Sorghum | -16.1 to -4.7 | Salem and Namakkal |
| Black gram | -3.2 to 6.3 | Namakkal |
| Groundnut | -11.1 to 2.4 | Dharmapuri, Krishanagiri, Salem and Namakkal |

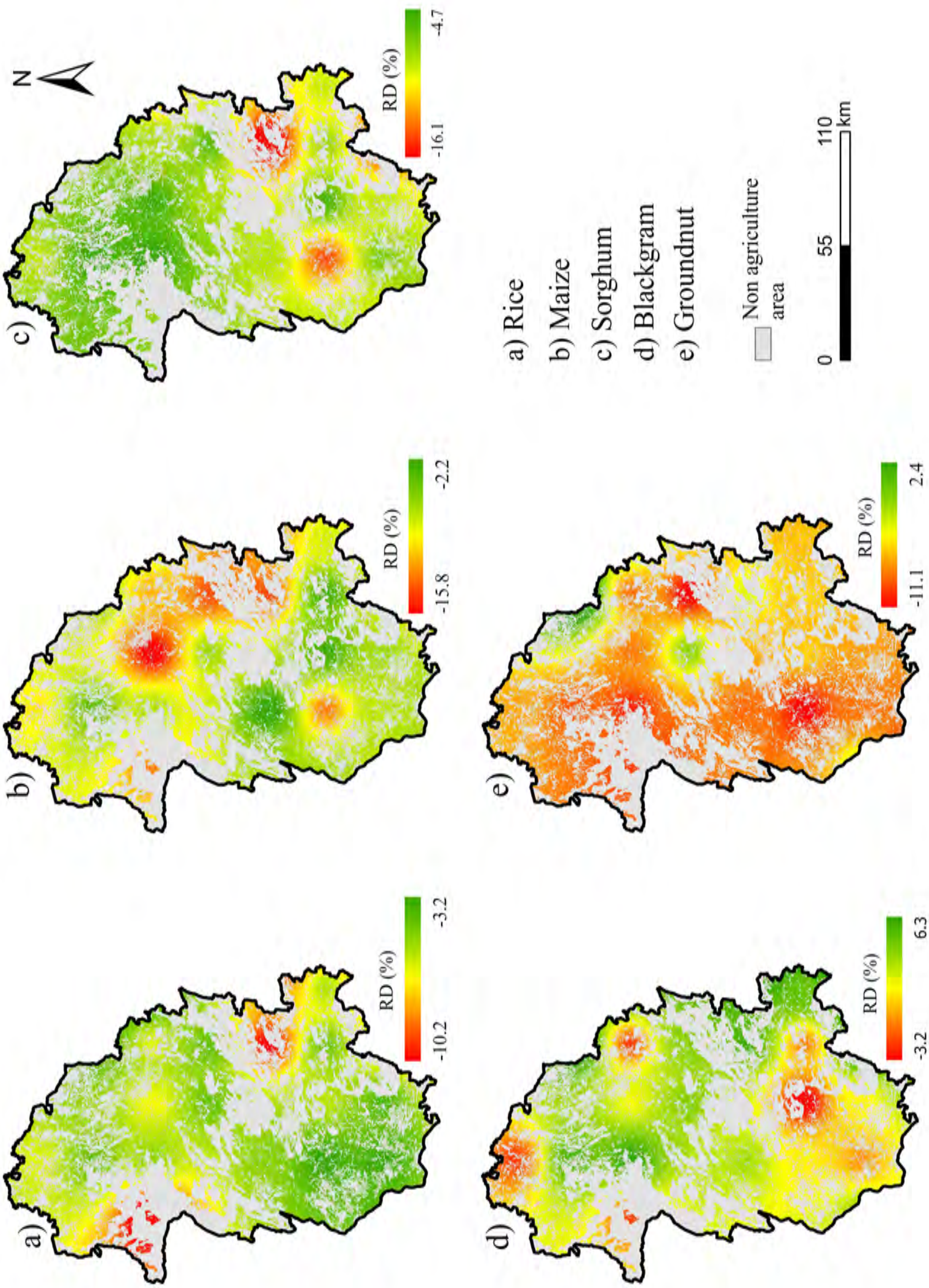


Figure 44 Climate Change impact on major crop yield in NWZ for the period of near Century

Krishnagiri district is projected to witness declines in crop yields: groundnut by 8.64%, maize by 11.58%, rice by 7.39%, and sorghum by 9.14%. Similarly, in Salem district, the yields of sorghum, maize, groundnut, and rice would be reduced by 11.41%,10.07%, 9.21%, and 7.05%, respectively.

### 4.2.2 Agriculture Risk of NWZ

The NWZ shows significant variation in agricultural risk across different districts. This means that some areas are more vulnerable to agrarian challenges than others. Krishnagiri and Dharamapuri would be high risk due to climate change (Figure.45). Kishnagiri and Dharmapuri indicate a very higher risk than Salem.

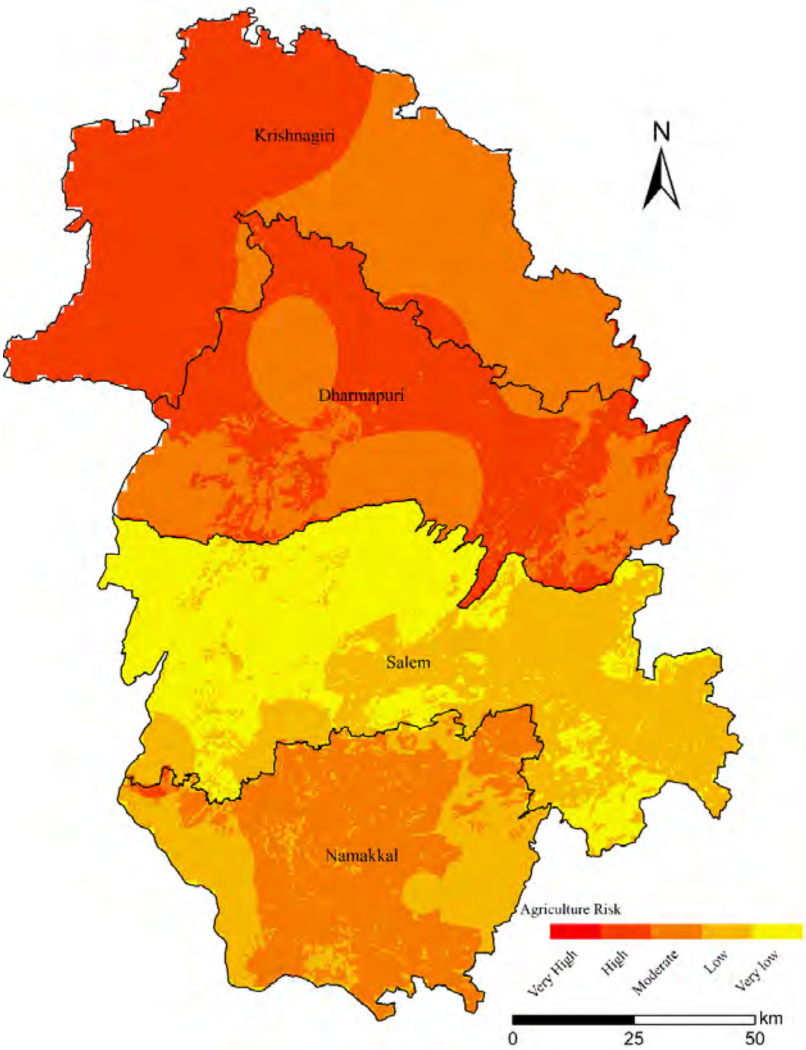


Figure 45 Agriculture Risk Assessment of NWZ

## 4.3 Agriculture Risk Assessment of CDZ

### 4.3.1 Climate Change Impacts on Major Crops in CDZ

The CDZ is projected to experience substantial difficulties in crop production, even with increased rainfall and maximum temperature. Rice yields are expected to decrease between 4.1% and 9.8%, with some areas potentially seeing reductions of up to 13.7%. Among the crops affected, sorghum is anticipated to face the most severe decline, ranging from 17.3% to 4.3%. Maize yields are projected to fall between 14.7% and 0.3%, while groundnut production may decrease by 14.1% to 3.3%. In contrast, black gram stands out as the sole crop showing potential growth, possibly increasing yields from 0.7% to 14.7% (Table.15). The CDZ is expected to face significant challenges in the future despite increases in rainfall and maximum temperature. Crop yield projections show substantial declines for sorghum, maize, groundnut, and rice, while black gram may see a slight increase. Although a 31% rise in rainfall could be beneficial, proper water management will be crucial to maximize its potential. The slight increase in maximum temperature could worsen heat stress for crops, while higher minimum temperatures may increase vulnerability to pests and diseases. Specific districts are projected to experience notable yield reductions for different crops. Additionally, climate change-induced sea level rise threatens coastal areas, potentially causing saltwater intrusion and negatively impacting rice production in these regions.

*Table 15 Projected Crop Yield Change of CDZ during Near Century (2021-2050)*

| Crop | Yield Change (%) | Very high-impact districts |
|---|---|---|
| Rice | -4.1 to 9.7 | Nagappattinam, Thanjavur and Thiruchirappalli |
| Maize | -4.7 to 0.34 | Mayiladuthurai, Perambalur, Thanjavur, Ariyalur, Tiruvarur, Nagapattinam and Karur |
| Sorghum | -17.3 to -4.34 | Nagapattinam, Mayiladuthurai, Tiruchirappalli, Tiruvarur , Thanjavur, Perambalur and Ariyalur |
| Black gram | 0.7 to 14.7 | Karur |
| Groundnut | -14.1 to -3.3 | Tiruvarur, Mayiladuthurai, Nagapattinam, Thanjavur, Karur, Perambalur, Ariyalur and Tiruchirappalli |

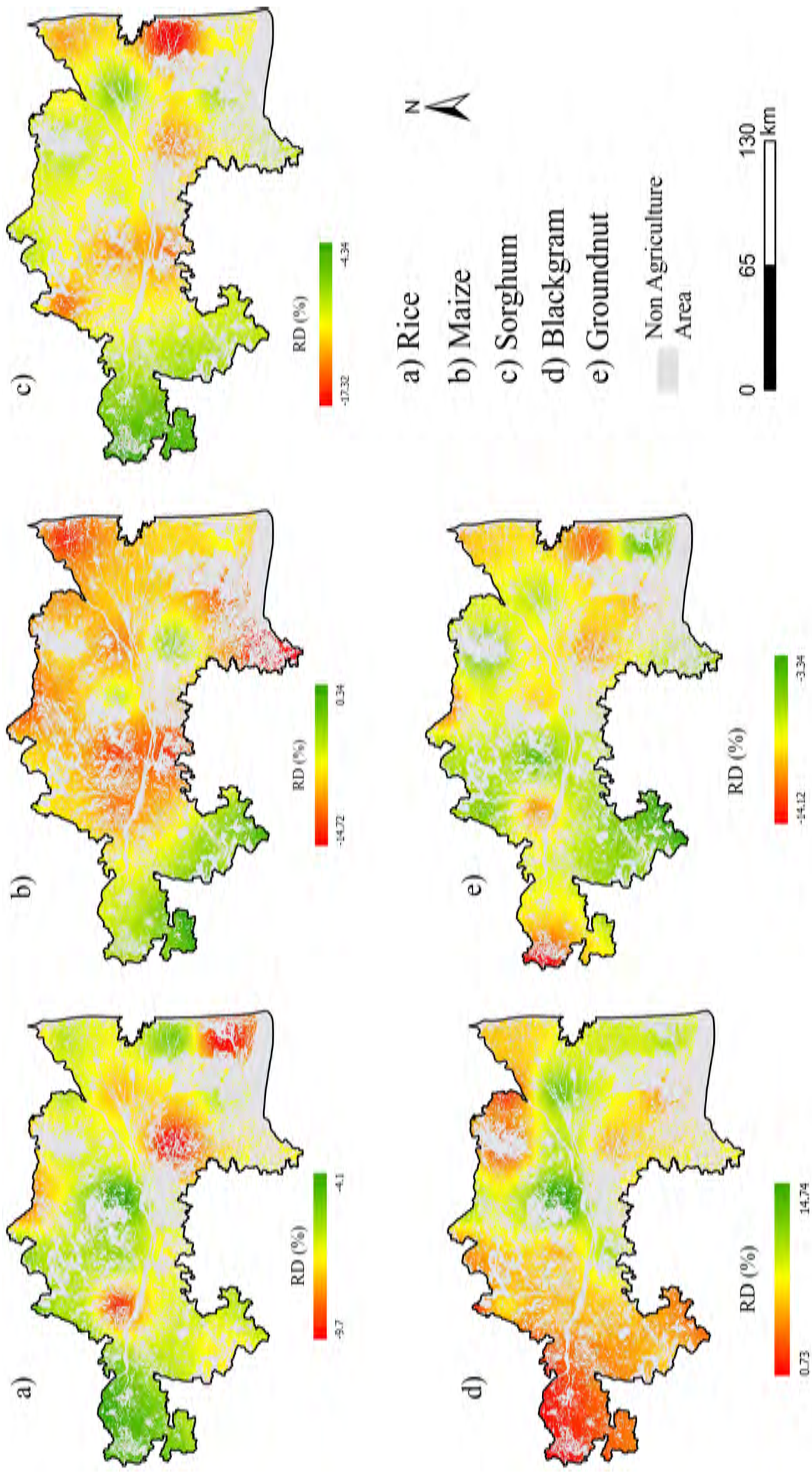


**Figure 46 Climate Change impact on crop yield in CDZ for Near Century**

### 4.3.2 Agriculture Risk of CDZ

The CDZ shows significant variation in agricultural risk across different districts. This means that some areas are more vulnerable to agrarian challenges than others.

High-risk districts: Ariyalur and Perambalur districts stand out as having very high agricultural risk compared to other districts in the CDZ. This high risk is attributed to two main factors: a) Rainfed agriculture: These districts likely rely heavily on rainfall for their crops, making them more susceptible to drought and irregular precipitation patterns. b) Cropping intensity: The high cropping intensity in these districts may indicate that farmers are cultivating crops more frequently or densely, which can put additional stress on the land and increase vulnerability to environmental changes.

Moderate-risk districts: Nagapattinam, Thiruvarur, and Mayiladuthurai are classified as having moderate agricultural risk. This suggests that while they face some challenges, they are not as vulnerable as Ariyalur and Perambalur.

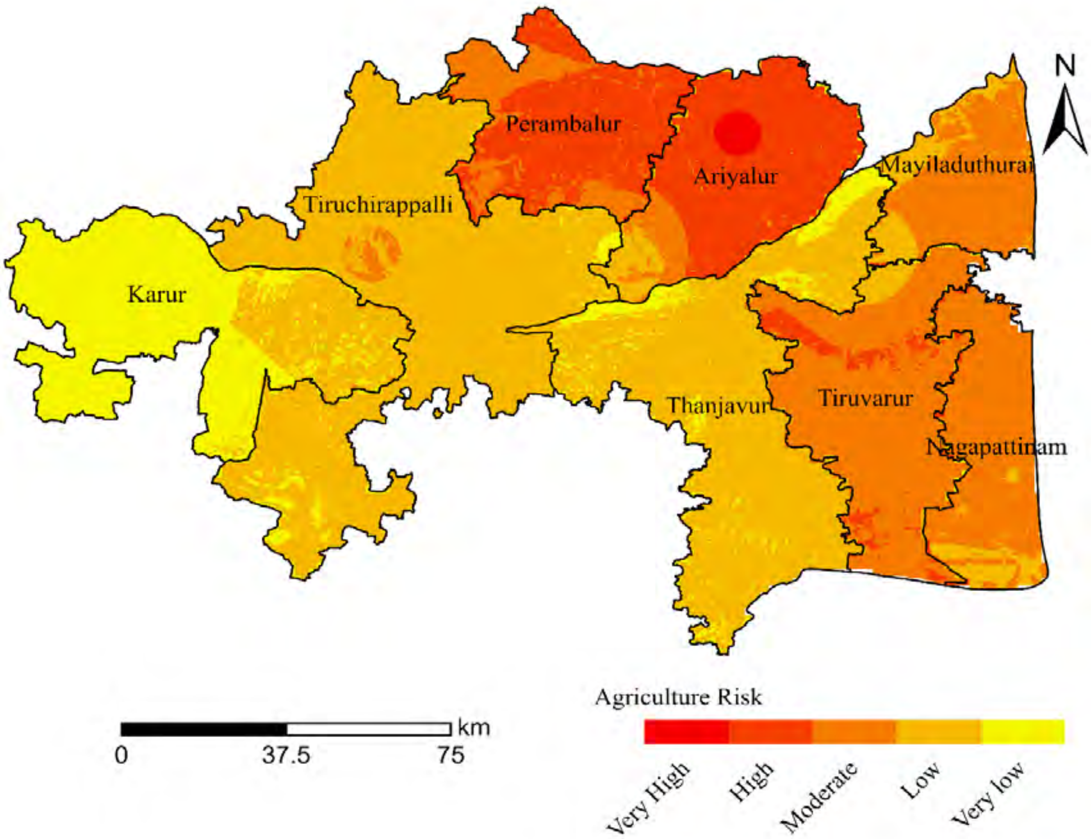


Figure 47 Agriculture Risk Assessment of CDZ

Despite the expected impacts of climate change on crop yields in the region, the overall agricultural vulnerability of the CDZ is assessed as low. This might seem counterintuitive, given the high-risk areas mentioned earlier. This could indicate that: a) Most of the CDZ have relatively resilient agricultural practices. b) There may be mitigating factors or adaptation strategies in much of the zone. c) The high-risk areas (Ariyalur and Perambalur) might represent a smaller portion of the total agricultural output of the CDZ.

The high risk in the Ariyalur and Perambalur districts "highly influences drought." These districts are particularly prone to drought conditions, likely due to their geographical and climatic characteristics. The agricultural sector in Ariyalur and Perambalur is especially sensitive to drought events, which can potentially severely impact crop yields and farm livelihoods. Local agrarian practices, water management strategies, and land use patterns in these districts may inadvertently contribute to increased drought risk, creating a feedback loop that exacerbates the situation.

This multi-faceted drought risk in Ariyalur and Perambalur underscores the need for targeted drought mitigation strategies, improved water resource management, and climate-resilient agricultural practices tailored to these districts' specific conditions.

## 4.4. Agriculture Risk assessment of WZ

### 4.4.1 Climate Change Impact on Major Crops of WZ

Figure 48 depicts the impact of climate change on the major crops of WZ (Coimbatore, Erode, and Tiruppur) from 2021 to 2050. The map clearly shows considerable variation in all crops in the zone. Among the five crops, groundnut would decline largely, followed by sorghum, maize, rice, and black gram (Figure 48). Coimbatore district in WZ showed a crop yield would be highly impacted due to climate change (Table.16)

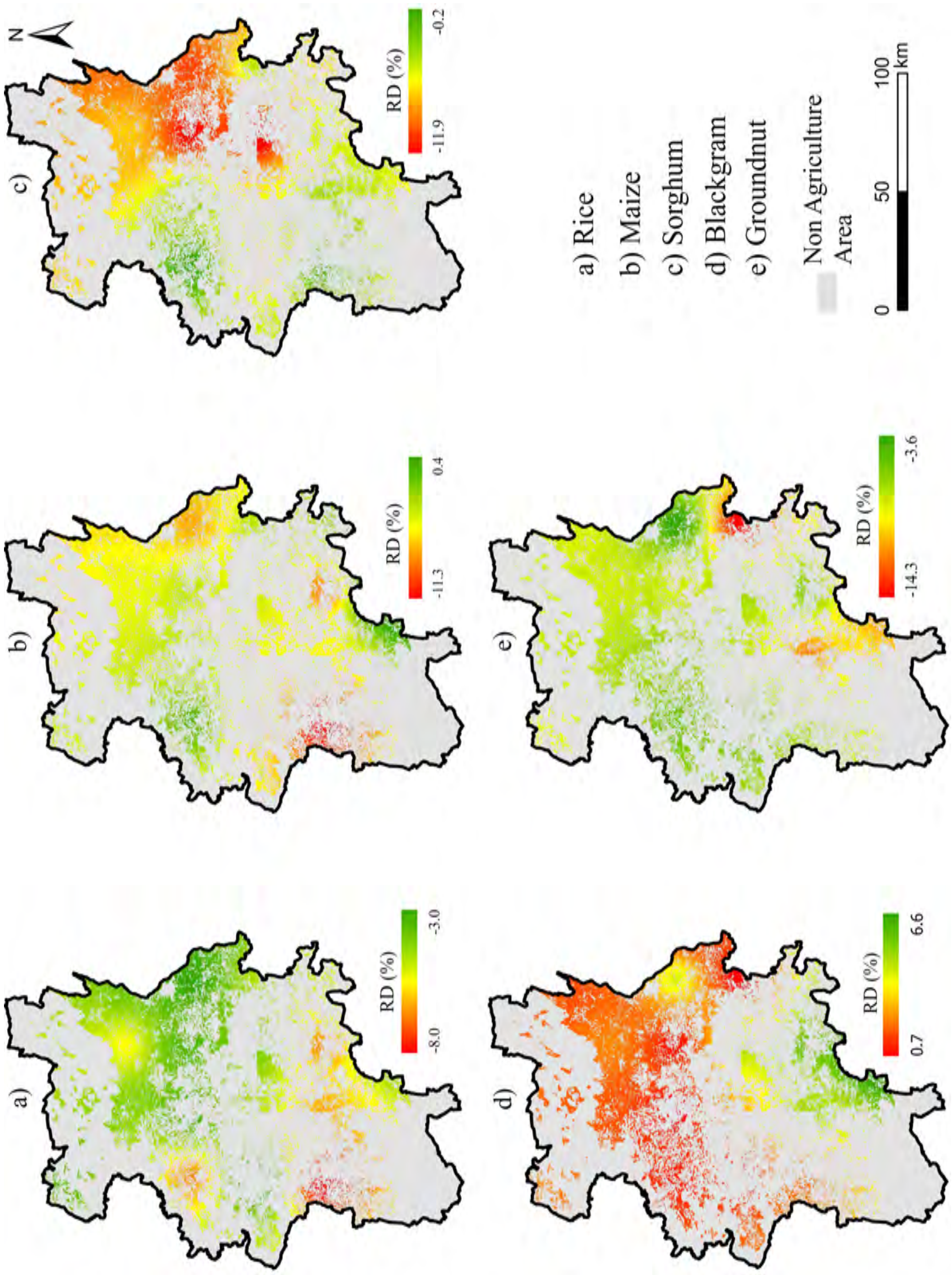


Figure 48 Climate Change impact of crop yield in WZ for 2021-2050

Table 16 Projected Crop Yield Change of WZ during Near Century (2021-2050)

| | Yield Change (%) | Very high-impact districts |
|---|---|---|
| Rice | -13.1 to -8.0 | Coimbatore |
| Maize | -11.3 to 0.4 | Coimbatore |
| Sorghum | -0.2 to 11.9 | Erode and Tiruppur |
| Black gram | 0.7 to 6.6 | Erode and Coimbatore |
| Groundnut | -14.3 to -3.6 | Coimbatore, Tiruppur and Erode |

### 4.4.2 Agriculture Risk of WZ

The Western Zone (WZ) of Tamil Nadu, encompassing districts like Coimbatore, Tiruppur, Erode, and Salem, shows a comparatively lower agricultural risk than other agroclimatic zones in the state, despite the anticipated decline in crop yields due to climate change (Figure.49). Several key factors contribute to the zone's higher adaptive capacity and resilience. First, the region benefits from well-developed road connectivity, which facilitates efficient access to markets, agricultural services, and inputs, while also ensuring timely distribution of produce during adverse weather conditions. Additionally, surface water availability, supported by reservoirs, tanks, and canals, provides a reliable water supply for irrigation, helping to buffer the impact of erratic rainfall. The presence of crop insurance programs also plays a vital role in safeguarding farmers against climate-induced losses, providing financial security during periods of crop failure. Furthermore, agro-advisory services in the Western Zone deliver crucial weather forecasts, pest management strategies, and crop health information, enabling farmers to make informed decisions and better adapt to changing climatic conditions. Farm ponds, which are increasingly being adopted by farmers, serve as water storage facilities that enhance irrigation efficiency and ensure water availability during dry spells. Collectively, these factors contribute to the Western Zone’s enhanced resilience and capacity to adapt to climate-related challenges, reducing overall agricultural risk despite the projected decline in yields. This highlights the importance of integrated risk management strategies in fostering long-term agricultural resilience in the region.

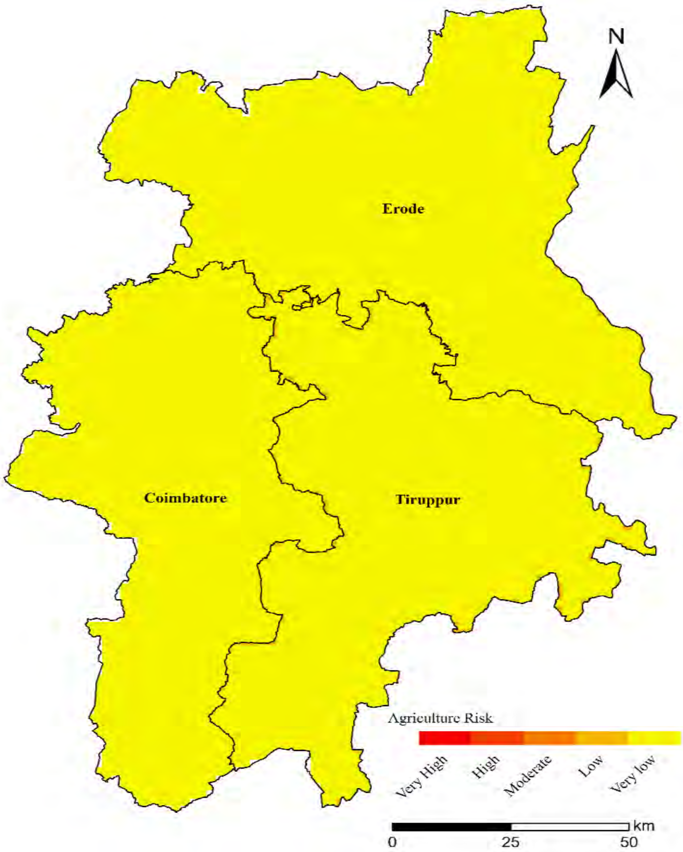


Figure 49 Agriculture Risk of WZ

## 4.5 Agriculture Risk Assessment of SZ

### 4.5.1 Climate Change Impact on Major Crops of SZ

A widespread decrease in rice yields is anticipated across all districts. The severity of the decline ranges from a minimal 0.4 % to a substantial 13.8 % (Figure 50). This variation suggests that some areas will be more resilient to climate change while others may face more severe challenges in rice cultivation. Maize production is expected to experience significant reductions in several districts. Pudukkottai is projected to be the most severely affected, with an estimated 13.70% decline in maize yields. Following closely behind are Tirunelveli, Tuticorin, and Tenkasi, which are also expected to see considerable drops in maize output, though specific percentages for these districts are not provided. Sorghum yields in this

Theni district of the Southern Agro Climatic Zone might fall by 15.52%, marking the most drastic projected fall for this crop. Other districts like Madurai, Sivagangai, and Pudukkottai are also expected to see hefty drops in sorghum production (Table.17). The situation looks quite challenging for sorghum farmers in these parts, and they may need to prepare for tough times ahead. The cultivation of groundnuts is projected to face steep declines in several districts. The most affected areas for groundnut production are expected to be Theni, Thoothukudi, Ramanathapuram, Dindigul, and Madurai. While the exact percentages of decline are not provided for each of these districts, the term "steepest declines" suggests that these reductions are likely to be significant.

Table 17 Projected Crop Yield Change of SZ during Near Century (2021-2050)

| Crop | Yield Change (%) | Very high-impact districts |
|---|---|---|
| Rice | -13.8 to -0.4 | Virudhunagar, Tirunelveli, Theni, Thoothukudi, Tenkasi, Sivagangai, Ramanathapuram, Pudukkottai, Madurai and Dindigul |
| Maize | -13.7 to 14.5 | Pudukkottai, Tirunelveli, Virudhunagar, Thoothukudi, Tenkasi, Sivagangai and Ramanathapuram |
| Sorghum | -19 to -0.3 | Theni, Sivagangai, Madurai and Pudukkottai |
| Black gram | 0.7 to 9.4 | Ramanathapuram |
| Groundnut | -16.5 to -0.8 | Theni, Thoothukudi, Virudhunagar, Ramanathapuram, Madurai and Dindigul |

The primary factor contributing to these projected yield reductions is the anticipated increase in temperatures, particularly during critical growth stages of the crops. Elevated temperatures can be especially detrimental to crops such as rice and maize, interfering with their normal development processes and ultimately resulting in lower yields. This temperature sensitivity highlights the vulnerability of these staple crops to climate change and underscores the potential challenges facing agriculture in the region

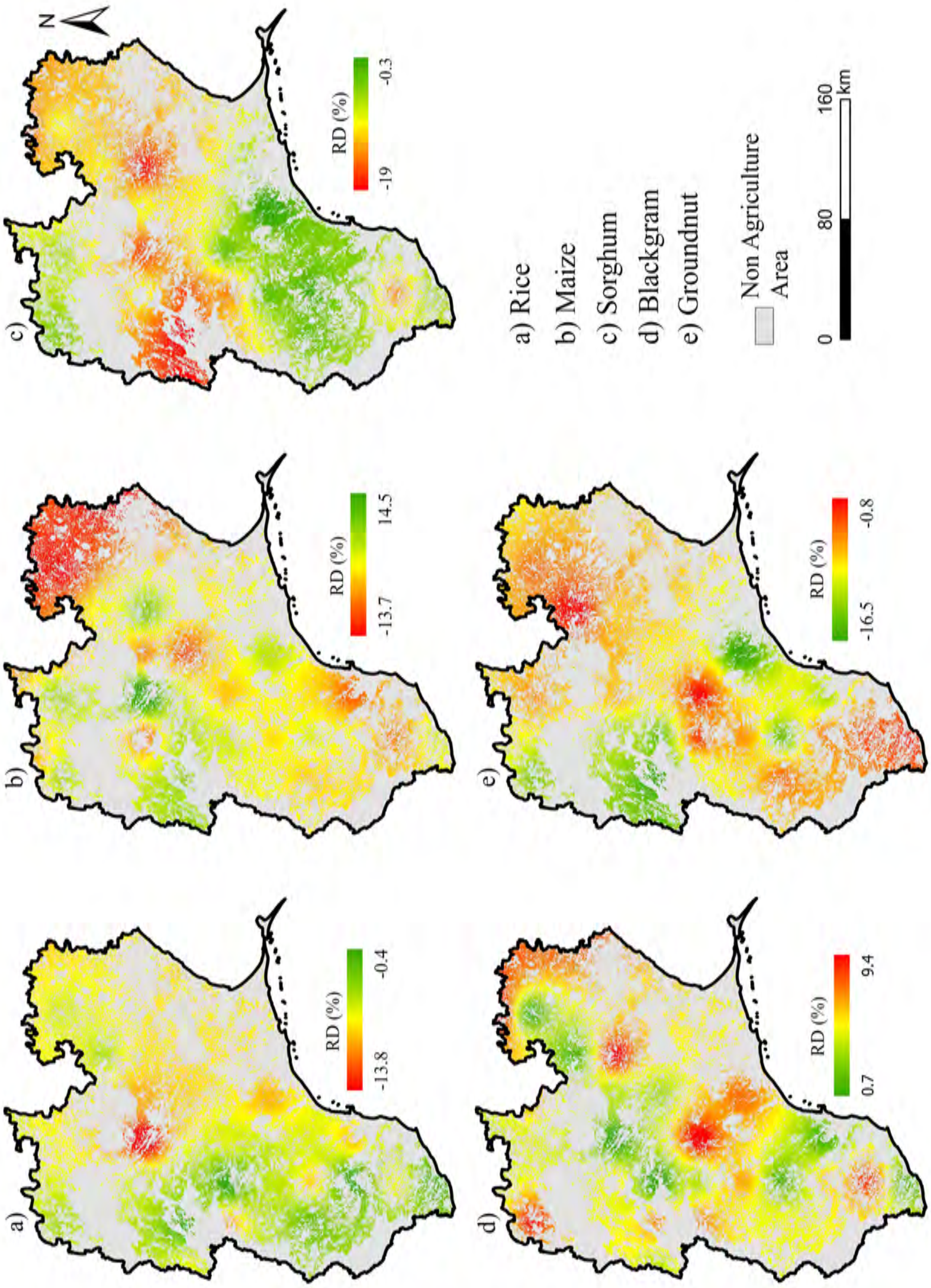


Figure 50 Climate Change impact on crop yield in SZ for 2021-2050

### 4.5.2 Agriculture Risk of SZ

The Southern Zone of Tamil Nadu exhibits varying levels of agricultural risk across its districts, as illustrated in Figure 51. Ramanathapuram stands out as a particularly vulnerable area, facing very high risk due to a combination of socio-economic challenges, institutional deficiencies, water scarcity, and heavy reliance on rain-fed agriculture. Madurai, Sivagangai, and Virudhunagar are classified as high-risk areas, while Pudukkottai, Dindigul, and Tenkasi show deficient risk levels.

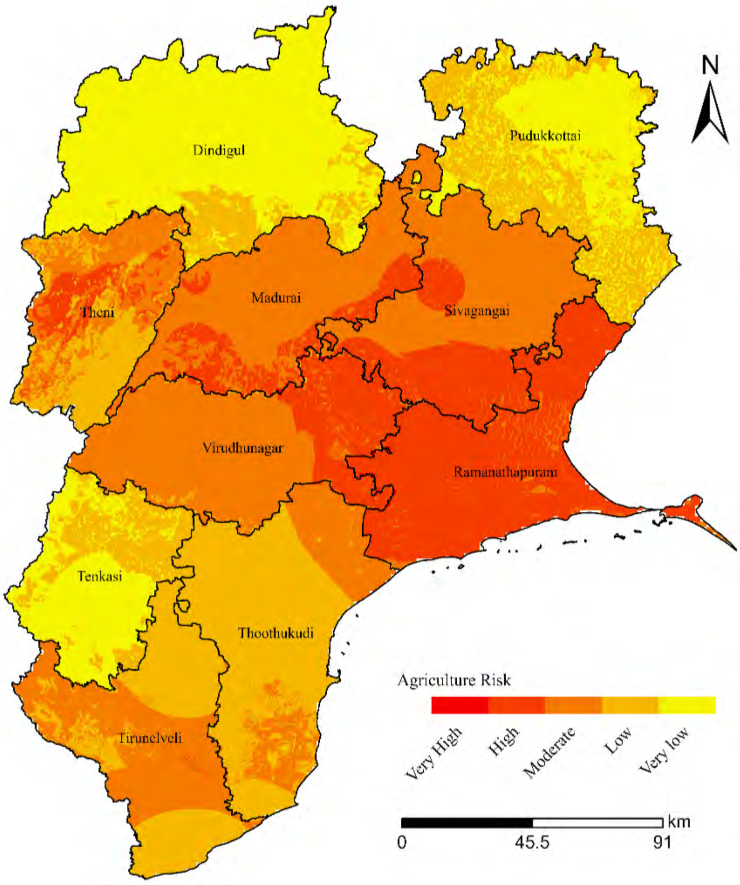


Figure 51 Agriculture Risk of SZ

Although Mayiladuthurai is not specifically mentioned in this analysis, its location in the Cauvery Delta region suggests it may face a different set of challenges. While potentially benefiting from better water resources due to the Cauvery River system, Mayiladuthurai's coastal position makes it vulnerable to sea-level rise and saltwater intrusion. The district may also contend with flood risks and the broader impacts of climate change on agriculture. A comprehensive assessment of Mayiladuthurai's specific socio-economic indicators, agricultural infrastructure, water resource management, and crop diversity would be necessary to accurately determine its agricultural risk profile within the context of the Southern Zone.

## 4.6 Agriculture Risk assessment of HRZ

### 4.6.1 Climate Change impact on major crops of HRZ

The HRZ is witnessing a stark contrast in crop performance. While rice yields gradually decline between 2.8% and 4.3%, black gram production is experiencing a steady increase of 3.5% to 4.9% (Figure.52). This trend divergence is likely attributed to factors such as climate change, soil conditions, and agricultural practices specific to each crop. Understanding these underlying causes is crucial for developing effective strategies to sustain regional agricultural productivity.

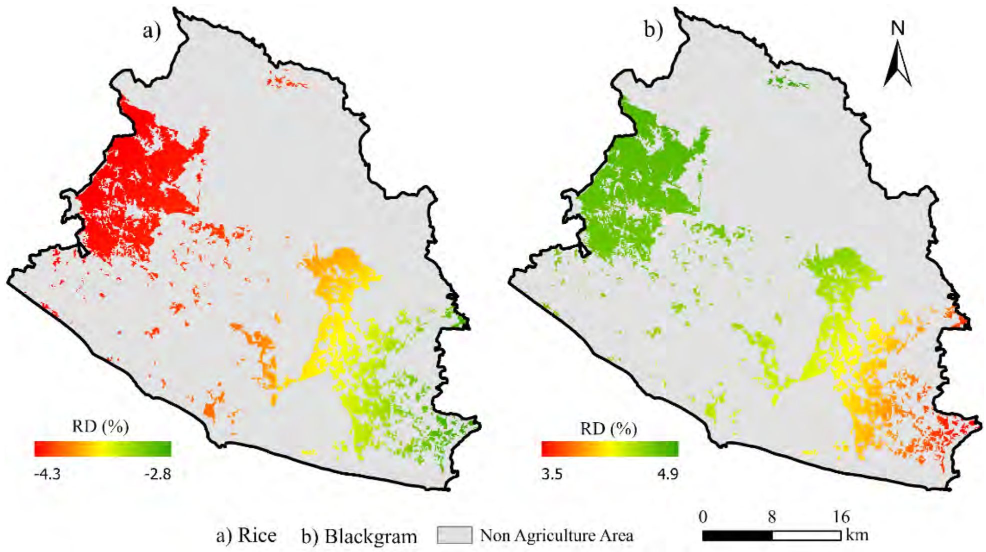


Figure 52 Climate Change Impact on Major crops of HRZ for 2021-2050

In regions where rice dominates agricultural production, incorporating black gram into crop rotation systems offers numerous advantages for farmers. As a leguminous crop, black gram enhances soil fertility through nitrogen fixation, potentially reducing the need for synthetic fertilizers in subsequent rice plantings. This integration can break pest and disease cycles, improving overall crop health and potentially decreasing reliance on pesticides. Black gram's shorter growing season provides flexibility in planting schedules, allowing farmers to maximize land use efficiency. Additionally, it serves as a valuable protein source, contributing to local food security and nutrition. From an economic standpoint, diversifying with black gram can provide an additional income stream, mitigating risks associated with mono-cropping. However, successful implementation requires careful consideration of local market demand, availability of resources such as seeds and knowledge, and potential adjustments to farming practices. By thoughtfully integrating black gram, rice farmers can work towards a more sustainable, resilient, and profitable agricultural system that benefits both their livelihoods and the environment.

### 4.6.2 Agriculture Risk of HRZ

The High Rainfall Zone (HRZ) stands out as a region of relatively low agricultural risk compared to other agricultural zones, as illustrated in Figure 53. This favorable risk profile stems from the HRZ's defining characteristic: abundant and reliable precipitation throughout the growing season. Such consistent rainfall patterns significantly reduce the threat of drought-induced crop failures, a major concern in many other agricultural areas. The ample water supply often eliminates or minimizes the need for irrigation, lowering costs and resource management challenges associated with water infrastructure. Furthermore, the favorable moisture conditions in HRZs support a diverse range of crops, including water-intensive varieties, allowing farmers to spread risk across different agricultural products. The consistent soil moisture levels maintained by regular rainfall reduce plant stress, contributing to more stable and predictable yields. These factors collectively contribute to the HRZ's classification as a low to very low risk agricultural environment, offering farmers in these regions a more secure and potentially profitable farming landscape compared to their counterparts in other, more volatile agricultural zones.

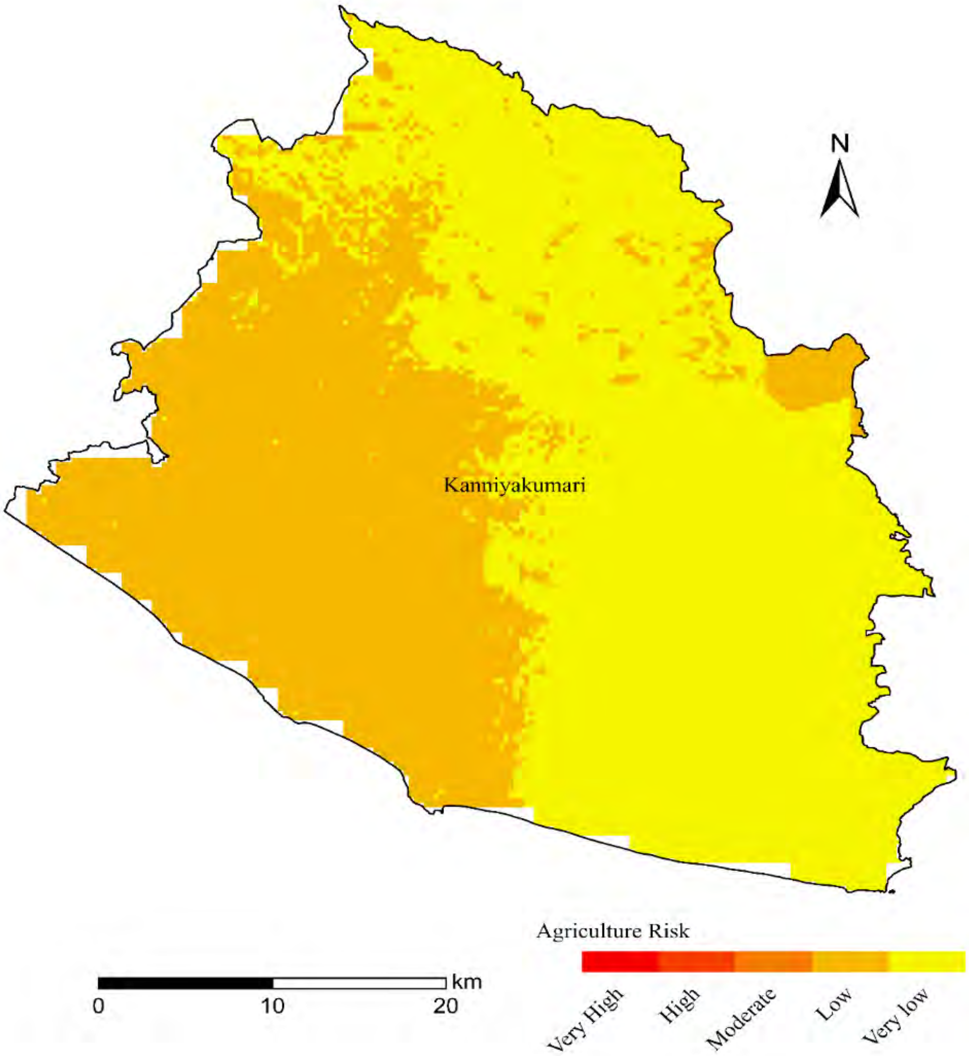


Figure 53 Agriculture Risk of HRZ

## 5. Adaptation strategies

Agricultural adaptation strategies in Tamil Nadu are crucial given the state's agrarian economy and the increasing challenges posed by climate change. Farmers in this southern Indian state have been implementing a variety of measures to mitigate the impacts of erratic weather patterns, water scarcity, soil degradation, and changing rainfall. These strategies aim to enhance the resilience of agricultural systems, reduce vulnerabilities, and improve the livelihoods of rural communities.

The Tamil Nadu State Government outlines specific recommendations for agricultural adaptation. These strategies, outlined in Table 18, focus on enhancing the farming community's resilience and sustainability. By implementing these measures, Tamil Nadu can better cope with the challenges of climate change and ensure food security for its population.

The alluvial plot illustrates the distribution of 39 adaptation strategies across four broad actions aimed at reducing agricultural risk in six agro-climatic zones, as depicted in Figure.54 The grouping of these strategies into four actions highlights the prioritization of measures to adapt the risks faced by the agricultural sector (Table 19). Shifting the sowing window is one of the strategies to minimize the yield loss. monsoon intensity of rainfall is high. The water harvesting structure, such as the construction of checks dam/farm ponds. The government provides a subsidy for the construction of farm ponds. During monsoon failure time or drought, the farmers is irrigating the field with the help of farm ponds. NEZ farmers is construct a large number of check dams. The government of Tamil Nadu has a plan to improve crop productivity through flood and drought-resistant varieties in all the agro climatic zones.

*Table 18 Strategies proposed by the Tamil Nadu State Government*

| Strategy | Status of Actions |
|---|---|
| To enhance the productivity and climate resilience of irrigated agriculture, to avoid mono-cropping, to improve water management, and to increase market opportunities for farmers and agro- agro-entrepreneurs | Tamil Nadu Irrigated Agriculture Modernization Project (TNIAMP):<br>Enhance productivity and water use efficiency in irrigated agriculture focuses on improving irrigation systems and promoting climate-resilient practices<br>National Agriculture Development Programme (NADP):<br>Provides support for various agricultural activities including crop diversification and water management<br>Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)<br>Focuses on improving water use efficiency through precision irrigation and other water-saving technologies<br>National Food Security Mission (NFSM):<br>To increase production of rice, pulses, and coarse cereals through area expansion and productivity enhancement<br>Tamil Nadu State Rural Livelihood Mission (TNSRLM)<br>Supports the formation and strengthening of Farmer Producer Organizations (FPOs)<br>Uzhavan App:<br>A mobile application providing farmers with information on government schemes, market prices, and agricultural advisories |
| To promote Integrated Farming Systems, to protect from crop losses due to climate changes, to make farming more productive, and to generate sustainable and remunerative income by integrating horticulture-based farming with livestock, fishery, agroforestry, and value addition. | Rainfed Area Development (RAD)<br>The Tamil Nadu Irrigated Agriculture Modernization Project (TNIAMP) has components that support IFS.<br>The National Mission for Sustainable Agriculture (NMSA) has been implemented in the state, which includes promotion of IFS |
| Construction of farm ponds. Strengthening existing water harvesting structures and repairing and replacing the shutters in the irrigation tanks and drainage channel | Tamil Nadu Irrigated Agriculture Modernization Project (TNIAMP)<br>This World Bank-funded project includes components for rehabilitating and modernizing irrigation systems, including Mission on Sustainable Dry Land Agriculture (MSDA):<br>This state initiative includes the construction of farm ponds as a key component.<br>Pradhan Mantri Krishi Sinchayee Yojana (PMKSY):<br>This central government scheme, implemented in Tamil Nadu, supports the creation of water sources, including farm ponds.<br>MGNREGA (Mahatma Gandhi National Rural Employment Guarantee Act):<br>MGNREGA funds have been used to construct farm ponds and renovate water bodies. |
| Soil conservation strategies | 36 soil testing labs and 16 mobile soil testing labs are functioning for analyzing soil and irrigation water<br>Integrated Watershed Management Programme (IWMP)-The state has been implementing this program to prevent soil erosion, especially in hilly and drought-prone areas |

The Agriculture Department of the Government of Tamil Nadu has proposed developing and promoting flood and drought-resistant crop varieties. This initiative aims to improve crop productivity across all agro-climatic zones in the state. During the Northeast monsoon season, the samba rice cultivation in the coastal regions, including the Northeastern, Cauvery Delta, Southern, and HRZs, faces severe impacts due to extreme rainfall events. To address this challenge, flood-resistant varieties are proposed to withstand waterlogged conditions and excessive rainfall. Simultaneously, drought-resistant varieties are recommended to tolerate dry spells and moisture stress, ensuring better yields in case of deficient rainfall or drought. By introducing these resilient crop varieties, the department seeks to enhance crop yields' overall productivity and stability.

Land management techniques like leveling, mulching, and minimal/zero tillage are recommended as part of good agricultural practices. Mulching is essential across all agro-climatic zones, especially during drought and continuous dry spells. Crop survival and productivity during prolonged dry periods and water scarcity. It creates an insulating layer, preventing rapid evaporation and maintaining moisture content in the soil. This practice enhances water-use efficiency, protects soil from erosion, and regulates temperature. Mulching is indispensable in drought-prone regions, contributing to soil moisture conservation, mitigating the impact of dry spells, and promoting sustainable crop production across all agro-climatic zones.

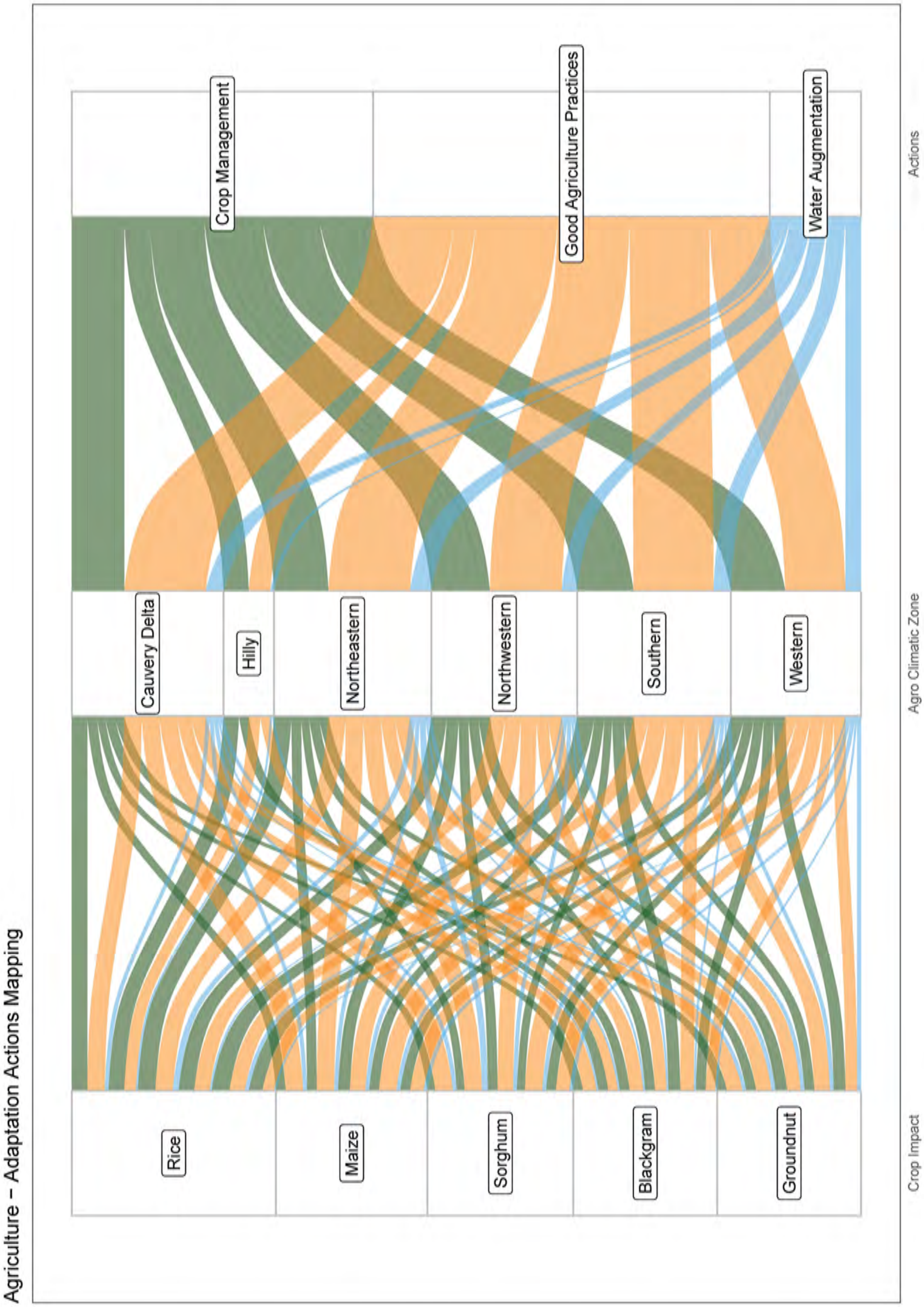


Figure 54 Adaptation mapping with linking of agriculture actions

*Table 19 Actions proposed for sustainable agriculture*

| |
|---|
| CROP MANAGEMENT |
| Modify Sowing/Cropping Patterns |
| Shifting the cropping pattern, Shifting the sowing window |
| Technology intervention |
| Direct seeded rice, Drought/flood tolerant varieties, Traditional varieties, Saline tolerant varieties |
| Agronomic practices |
| Alternate wetting and drying, Crop diversification, Integrated farming system/ weed, pest and nutrient management, Precision farming |
| Community involvement |
| Indigenous technical knowledge, Training and awareness program |
| GOOD AGRICULTURE PRACTICES |
| Land management |
| Deep ploughing to break sub-surface hard pan, Levelling of land, Minimal tillage, Mulching, Restoration of degraded land |
| Soil conservation |
| Contour bunding, Cover cropping, Intercropping, Organic farming, Integrated farming system |
| Soil fertility management |
| Application of Farmyard Manure, Crop rotation, Green and green leaf manures, Management of saline and alkaline soil |
| INSTITUTIONAL AND INFRASTRUCTURE |
| Communication and information infrastructure |
| Agricultural extension services/ agro advisory, Weather forecasting services |
| Crop insurance |
| Crop insurance |
| Market infrastructure |
| Marketing yards, Rural markets (mandis) |
| Storage and handling infrastructure |
| Warehousing |
| Transportation infrastructure |
| Rural roads |
| WATER AUGMENTATION |
| Water conservation |
| Improvise the drainage, Micro irrigation/drip and sprinkler irrigation systems |
| Desiltation/maintenance of water structure |
| Desilting of ooranies, Desilting of Ponds |
| Water harvesting structure |
| Construction of Check dams, Constructions of farm ponds |

### 6. Knowledge dissemination

Climate change poses a significant threat to agricultural productivity and food security. To address this, capacity-building programs are essential for equipping agriculture department staff with the knowledge and skills necessary to assist farmers in adapting to a changing climate. These programs can include training on climate-smart agricultural practices, the use of weather forecasting tools, and techniques for assessing and mitigating climate-related risks. By investing in the professional development of agriculture department staff, governments and organizations can play a crucial role in building resilience within the agricultural sector and ensuring sustainable food production for future generations. This proactive approach will not only benefit farmers and rural communities but also contribute to global efforts to combat climate change.


Figure 55 Release of the Training Manual for Capacity Building Programme

1. These programs can include training on climate risk and vulnerability assessment in the agriculture sector, crop modeling software, and techniques for assessing and adapting climate change risks. By investing in the professional development of agriculture department staff, governments and organizations can play a crucial role in building resilience within the agricultural sector and ensuring sustainable food production for future generations. This proactive approach will benefit farmers and rural communities and contribute to global efforts to combat climate change. As a part of the project on agriculture risk assessment of Tamil Nadu. The Knowledge

dissemination was done through the capacity building programme to create awareness of climate change impacts on agriculture for the policymakers. A four- capacity-building program on "Climate Risk Assessment and Adaptation Plan for Tamil Nadu Agriculture" was held at Climate Studio for Deputy Directors and Agriculture Officers. The program aimed to equip participants with the knowledge and scientific methods to assess climate change risks to agriculture. sixty participants from 36 districts across Tamil Nadu, excluding Chennai and the Nilgiris, attended the program across four sessions: September 21-22, 2023, October 12-13, 2023, November 9-10, 2023, and February 22-23, 2024. The Climate Risk Assessment and Adaptation Plan of Tamil Nadu for Agriculture training manual has been released during the capacity building program (Fig.55).

2. The training programs focus on addressing the impacts of climate change on major crops through adaptation strategies, emphasizing the adoption of good agricultural practices. The primary objective is to equip participants with the knowledge and scientific methods needed to evaluate yield changes of key crops in response to climate risks. Based on current challenges, agricultural department officials have recommended future adaptation actions at the district level through a capacity-building initiative. The proposed adaptation actions suggested by the Agricultural Officers and the Assistant Director of Agriculture are detailed below (Table 20).

Table 20 Adaptation action proposed through knowledge dissemination

| IMPROVE THE PRODUCTIVITY OF CROPS |
| --- |
| Crop management practices, water, soil nutrient management, Fertilizer application dosage and IPM technologies, Intensive cultivation, Micro irrigation, Drought and flood-resistant varieties, Soil fertility improvement, alternate wetting and Drying, Direct seeded rice, Integrated nutrient & pest management & crop change |
| SOIL CONSERVATION STRATEGIES |
| Organic farming, Minimum tillage, Soil cover, mulching, Integrated Farming system, increase soil fertility through green manure crops and green leaf manure crops, Increased use of organic manures like leaf manures, growing high, spread rooted crops like vetiver in bunds to avoid erosion, Crop rotation, Soil amendments addition, optimum use of chemical fertilizers |
| WATER CONSERVATION STRATEGIES |
| Constructing farm ponds and check dams as water management structures, Rainwater harvesting, Mulching and percolation pond for ground water table rises, interlinking of small lakes and rivers, Encouraging the growth of palm trees, Utilizing earthen bunds for water retention and growing water-efficient crops for water conservation. |

Gaps in Policies and Programs Addressing Climate Risks in Agriculture

3. Develop policies and programs that address the specific needs of farmers.
4. Create customized and responsive solutions to farmers' diverse needs.
5. Provide individual field-level insurance to manage risks better.
6. Strengthen agricultural market infrastructure by expanding storage facilities, improving transportation, and enhancing communication systems.
7. Enhance extension services with more comprehensive training, advice, and support for farmers


Figure 56 Glimpses of Capacity building training programme of Agriculture

## Annexure

Figure 57 Field Visit at the Agriculture Research Station in Tamil Nadu

## WAY FORWARD

Climate Change Impact on Agriculture in Tamil Nadu

Investigate and analyze the effects of climate change on agricultural production across vulnerable districts of Tamil Nadu. Implement and evaluate climate-smart and resilient farming techniques tailored to each district's specific environmental conditions and challenges. This approach aims to mitigate the negative impacts of climate change while enhancing crop productivity and farmer livelihoods. Granular Agricultural Risk Assessment

Conduct a comprehensive risk assessment at the block and village levels within Tamil Nadu. Categorize districts based on their vulnerability to climate change impacts, ranging from very high to very low risk. This detailed analysis will help identify localized challenges and opportunities for targeted interventions.

Future Crop Suitability Analysis

Evaluate the suitability of various crops in each district of Tamil Nadu under projected future climate scenarios. This forward-looking assessment will help farmers and policymakers make informed decisions about crop selection and agricultural planning to ensure the region's long-term sustainability and food security.

Climate Change Effects on Horticulture

Examine the specific impacts of climate change on horticultural crops across all districts of Tamil Nadu. Assess how changing climate patterns may affect fruit, vegetable, and ornamental plant production, and identify adaptive strategies to maintain and improve horticultural productivity in the face of environmental challenges.

Block-level Climate Impact Assessment and Adaptation Prioritization

Conduct a detailed analysis of climate change impacts on seasonal and perennial crops (including horticulture and plantation crops) at the block level within each district of Tamil Nadu. Based on this assessment, develop a prioritized list of climate change adaptation actions tailored to the specific needs and vulnerabilities of each area. This approach will ensure that resources and efforts are directed towards the most critical and effective adaptation measures.

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PROGRESS THROUGH KNOWLEDGE

# Centre for Climate Change and Disaster Management
# Department of Civil Engineering, Anna University, Chennai - 600 025

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CCCDM shall contribute to the sustainable development by

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- Disseminating Knowledge of regional climate risks and cadastral level climate resilient actions to cope up with changing climate
- Strengthening the capacity for climate change adaptation, mitigation and disaster risk reduction

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