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Documentation of climate smart agriculture technologies in the agro-climatic zones of Tamil Nadu

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Abstract
Climate change continues to pose serious threats to agricultural productivity and rural livelihoods, particularly in climate-vulnerable regions like Tamil Nadu. In response, Climate-Smart Agriculture (CSA) has emerged as a holistic approach aimed at enhancing productivity, strengthening climate resilience, and reducing greenhouse gas emissions. This study was conducted during 2022-2023 with the objective of documenting CSA technologies practiced across the seven agro-climatic zones of Tamil Nadu. An ex-post facto research design was adopted, covering one representative district from each zone: Villupuram, Namakkal, Coimbatore, Tiruvarur, Ramanathapuram, Kanyakumari, and The Nilgiris. A multi-stage stratified sampling method was employed to select 210 progressive farmers (30 per district) who were either adopters of CSA technologies or participants in the NICRA program. Primary data were collected through structured interviews and focus group discussions. The study revealed a diverse array of CSA practices adapted to local climatic conditions, including improved seed varieties, micro-irrigation systems, moisture conservation techniques, precision-based nutrient management, crop diversification, and the use of agro-advisory services. Notable interventions included rain hose irrigation in drought-prone zones, integrated fish farming in flood-prone areas, and frost-resistant crop varieties in hilly regions. Additionally, livestock management strategies such as smart shelters and feed supplementation were observed as critical adaptations in several zones. The findings highlight the region-specific nature of CSA adoption and underscore the need for targeted policy and extension support to upscale proven technologies. The documented practices serve as a valuable knowledge base for climate-resilient agricultural planning in Tamil Nadu.

Keywords: Climate-smart agriculture, agro-climatic zones, Tamil Nadu and NICRA

Introduction

Climate change has emerged as one of the most pressing global challenges, significantly impacting agriculture, ecosystems, and livelihoods, especially in developing countries like India. According to the Intergovernmental Panel on Climate Change (IPCC, 2021) [4], global surface temperatures have risen by approximately 1.1 °C above pre-industrial levels, with projections indicating a rise of 1.5 °C to 2 °C by the mid-21st century. India, being a climate-vulnerable nation, is already experiencing increased frequency and intensity of extreme weather events, erratic monsoons, droughts, and floods, all of which adversely affect agricultural productivity and food security. In this context, Climate-Smart Agriculture (CSA) has gained prominence as a strategic approach to transform and reorient agricultural systems under the new realities of climate change. CSA aims to achieve three core objectives: (i) sustainably increase agricultural productivity and incomes, (ii) build resilience and adaptation to climate change, and (iii) reduce or remove greenhouse gas emissions, where possible. Technologies such as drought-resistant crop varieties, precision farming, water-saving irrigation techniques (e.g., drip and sprinkler systems), integrated nutrient and pest management, conservation agriculture, and agroforestry are some of the key components of CSA.

Tamil Nadu, situated in the southeastern part of India, is highly vulnerable to climate change due to its diverse topography and dependence on monsoon rainfall. The state is divided into seven agro-climatic zones, namely North Eastern Zone, North Western Zone, Western Zone, Cauvery Delta Zone, Southern Zone, High Rainfall Zone and Hilly Zone.

Each zone varies significantly in rainfall patterns, soil types, cropping systems, and exposure to climate risks. For instance, the Cauvery Delta Zone, known as the rice bowl of Tamil Nadu, has been facing frequent water scarcity and salinity intrusion, while the Western Zone is increasingly affected by prolonged dry spells. According to the Tamil Nadu State Action Plan on Climate Change (TNSAPCC, 2021) [11], agricultural output in the state could decline by 10%-15% over the next two decades if no adaptation measures are adopted. To address these risks, the Government of Tamil Nadu has been actively promoting CSA technologies under schemes such as the Tamil Nadu Climate Change Mission, National Mission on Sustainable Agriculture (NMSA), and State Agriculture Extension Programs. Efforts include promotion of micro-irrigation (adopted in over 5.3 lakh hectares as of 2023), System of Rice Intensification (SRI) in paddy cultivation, and introduction of climate-resilient crop varieties in drought-prone areas.

This study aims to document and assess the Climate-Smart Agriculture technologies adopted across different agro-climatic zones of Tamil Nadu and analyze zone-specific practices.

Methodology

To evaluate the constraints faced by farmers in the adoption of Climate-Smart Agriculture (CSA) technologies, an ex-post facto research design was adopted. This design was considered suitable as the variables under investigation had already occurred and were beyond the control or manipulation of the researcher.

The study was carried out during the agricultural year 2022-2023, covering all seven agro-climatic zones of Tamil Nadu. From the North Eastern Zone, Villupuram district was selected, while Namakkal district represented the North Western Zone. Coimbatore district was chosen from the Western Zone, and Tiruvarur district was identified as the representative for the Cauvery Delta Zone. For the Southern Zone, Ramanathapuram district was selected, whereas Kanyakumari district was chosen to represent the High Rainfall Zone. Lastly, the Hilly Zone was represented by The Nilgiris district. This selection ensured that each agro-climatic region's unique characteristics and challenges in adopting Climate-Smart Agriculture (CSA) technologies were adequately captured.

A multi-stage stratified sampling technique was employed to select respondents. In the first stage, one district was selected from each agro-climatic zone. In the second stage, relevant villages within these districts were identified based on the prevalence of CSA practices. In the final stage, 30 progressive farmers were selected from each district, based on their active engagement in CSA practices and/or participation in the National Innovations on Climate Resilient Agriculture (NICRA) initiative. These farmers were considered key informants due to their practical knowledge and hands-on experience with CSA technologies. Altogether, a total of 210 farmers (30 from each of the 7 districts) constituted the sample size for the study. Data were collected through personal interviews using a structured and pre-tested interview schedule, designed to ensure clarity, relevance and reliability of the information obtained.

Results and Discussion

The Climate Smart Agricultural technologies which increase productivity, improve resilience by reducing greenhouse gas emission and mitigate the consequences of climate change were documented through Climate Smart Rural Appraisal technique and Focus Group Discussion. Based on the perceived climate change consequences, the farmers of each agro-climatic zone adopted different climate smart agricultural practices. The documented Climate Smart Agricultural practices are described in the subsequent sections.

CSA technologies in North Eastern Zone (Villupuram) of Tamil Nadu

Villupuram district of North Eastern Agro-Climatic Zone suffers from prolonged drought due to water scarcity, change in intensity of rainfall and rainy days. To mitigate this consequences, State Department of Agriculture promotes several adaptation strategies through KVKs. The Climate Smart Agricultural technologies adopted by the farmers are;

- Adoption of efficient irrigation methods such as rain hose irrigation, drip and sprinkler irrigation
- Construction of fish pond to conserve water
- Utilization of crop insurance
- Cultivation of crops based on weather based agro-advisory services
- Adoption of drought resistant, pest and disease resistant varieties
- Use of improved agricultural implements
- Use of soil health for precision based nutrient management

CSA technologies in North Western Zone (Namakkal) of Tamil Nadu

Namakkal district of North Western Agro-Climatic Zone experiences severe drought and less number of rainy days. To mitigate the consequences of climate change, the KVK under TANUVAS in this region, promotes strategies through NICRA (National Innovations on Climate Resilient Agriculture). The Climate Smart Agricultural technologies adopted by the farmers of Namakkal region are enlisted as follows

- Adoption of improved seed varieties like drought resistant, pest and disease varieties with increased yield.
- Construction of ponds.
- Contingent crop planning measures like change in sowing and harvesting date.
- Adoption of efficient water use measures like drip and sprinkler irrigation.
- Farm diversification through jasmine cultivation and livestock management.
- Adoption of improved livestock and use of smart house for livestock's.
- Use of improved agricultural implements.
- Diversified crop cultivation by allocating agricultural land and changing the cropping pattern.

CSA technologies in Western Zone (Coimbatore) of Tamil Nadu

Though Coimbatore district has favorable climatic conditions of crop growth, the critical stages of crop growth is greatly affected by change in intensity of rainfall and unpredicted rainfall which results in reduced yield and productivity. In order to overcome the effects of climate change, the CSA technologies adopted by the farmers are

- Contingent crop planning measures like change in sowing and harvesting date.
- Use of improved agricultural implements.
- Use of efficient irrigation measures such as drip and sprinkler irrigation; intermittent irrigation and residue mulching.
- Adoption of crop intensification and diversification practices through intercropping with legumes.
- Utilization of crop insurance.

- Cultivation of crops based on weather based agro-advisory services.

CSA technologies in Cauvery Delta Zone (Tiruvarur) of Tamil Nadu

In Tiruvarur district, the farmers experience climatic change consequences such as increased intensity of rainfall, unpredictable rainfall during the critical stages of crop growth and increased flooding reduces the crop yield and productivity. To adapt the climatic change consequences, the farmers of Tiruvarur district adopt strategies such as

- Contingent crop planning measures like change in sowing and harvesting date.
- Use of improved seed varieties such as seed varieties that are resistant to water logging and frequent pest and disease attack.
- Construction of fish pond and adoption of fish farming.
- Use of improved agricultural implements.
- Utilization of crop insurance.
- Cultivation of crops based on weather based agro-advisory services.

CSA technologies in Southern Zone (Ramanathapuram) of Tamil Nadu

Ramanathapuram district of Southern Agro-Climatic Zone experiences severe drought due to increase in temperature, delayed onset of monsoon and lack of water conservation measures. Further, delayed rainfall at the critical stages of crop growth reduces crop yield. Hence, the farmers of Ramanathapuram district adapt to climatic change consequences by.

- Adoption of efficient irrigation measures such as drip and sprinkler irrigation.
- Use of improved agricultural implements.
- Adoption of crop intensification and diversification measures such as intercropping with legumes.
- Utilization of crop insurance
- Cultivation of crops based on weather based agro-advisory services.

CSA technologies in High Rainfall Zone (Kanyakumari) of Tamil Nadu

Even in high rainfall zone, the farmers experience climatic change consequences such as increased intensity of rainfall, increased flood, change in number of rainy days, frequent pest and disease outbreaks. The CSA practices adopted by Kanyakumari farmers are;

- Adoption of water conservation measures such as residue mulching, construction of ponds and check dam to conserve water.
- Adoption of efficient irrigation measures such as drip for coconut farm.
- Diversification of farm by cultivating coconut and cashew.
- Adoption of improved seed varieties such as drought resistant and varieties resistant to water logging.

CSA technologies in Hilly Zone (The Nilgiris) of Tamil Nadu

The Nilgiris district of Tamil Nadu encounters climatic change consequences such as increased pest and disease outbreak, severe frost damage, delayed onset of monsoon, increased intensity of rainfall, water logging and change in number of rainy days. Hence, the farmers adapt CSA practices such as;

- Adoption of improved seed varieties with pest resistant and disease resistant varieties, varieties resistant to frost damage and water logging.
- Utilization of crop insurance.
- Cultivation of crops based on weather based agro-advisory services.
- Diversification of crop by allocating land under different crops such as carrot, beetroot, radish in small land holdings
- Adoption of crop intensification by changing the cropping pattern.

Table 1: Documented CSA technologies in Agro-Climatic Zones of Tamil Nadu

S. No.	Documented CSA technologies in Agro-Climatic Zones of Tamil Nadu
1	Adoption of improved seed varieties
2	Adoption of moisture conservation practices
3	Adoption of micro-irrigation measures
4	Use of improved agricultural implements
5	Improved livestock and smart house for livestock
6	Adoption of additives and supplements in livestock feed
7	Crop intensification
8	Crop diversification
9	Precision based nutrient management
10	Crop insurance
11	Weather based agro-advisory services
12	Use of organic manures, fertilizers, green manures, and green leaf manures
13	Use of biofertilizers and slow releasing nitrogenous fertilizers
14	Fodder management
15	Farm diversification

From the Table 1. The documented CSA interventions in Agro-Climatic Zones of Tamil Nadu are adoption of improved seed are adoption of improved seed varieties that are resistant to drought, salinity, water logging and high yielding varieties; adoption of moisture conservation practices like construction of farm pond, mulching, rainwater harvesting practices; adoption of micro-irrigation measures such as rain hose irrigation, drip irrigation, sprinkler irrigation; use of improved agricultural implements such as combined harvester, drum seeder, rotavator, groundnut harvester. Meanwhile, as rearing of livestock is an indispensable part of farmer's life, they use improved livestock and smart house for livestock to prevent it from snakebites and increase their yield by providing a favorable climate. Further, use of livestock additives and supplements in its feed to provide nutrition to combat climate change consequences like increased heat decreases the ability in digestion, lack of high nutritious fodder.

Adoption of crop intensification practices like intercropping with legumes, multi-tier cropping and crop diversification practices like cultivation of horticultural crops and ornamental crops to ensure assured income in case of crop failure. Adoption of precision based nutrient management practices by analyzing soil health status to improve resilience, utilization of crop insurance to recover insurance for crop loss, adoption of weather based agro-advisories to plan agricultural activities in prior, use of organic manures, fertilizers, green manures and green leaf manures to improve resilience and restore the nutrients of soil, use of biofertilizers and slow releasing nitrogenous fertilizers to improve productivity of the crops. Fodder management and farm diversification practices were adopted by the farmers to improve the farm productivity and ensure assured irrigation. The findings are in line with the studies of Udmale *et al*., (2014) [12], Varadan and Kumar (2014) [13], Jasna (2015) [6], Prabhavati (2016) [10], Gopal (2017) [3] and Murthy (2019) [8].

Conclusion

The present study systematically documented the Climate-Smart Agriculture (CSA) technologies adopted across the diverse agro-climatic zones of Tamil Nadu, providing a comprehensive understanding of region-specific responses to climate change. The findings highlight that farmers, despite facing distinct climatic challenges such as drought, water scarcity, flooding, and unpredictable rainfall, have adopted a variety of CSA practices tailored to their local agro-ecological conditions. Key interventions included the adoption of improved seed varieties resistant to drought, pests, diseases, and waterlogging; efficient irrigation systems like drip and sprinkler irrigation; and water conservation structures such as farm ponds and check dams. Farmers have also embraced contingency crop planning, crop diversification and intensification, use of organic and bio-fertilizers, and precision nutrient management practices. Additionally, livestock-based climate adaptation strategies-such as smart livestock housing and feed supplementation-were found to be crucial in some zones.

The study reveals that the adoption of CSA technologies was significantly influenced by access to extension services, participation in programs like NICRA, and localized agro-advisories. Despite the promising practices observed, challenges remain in terms of widespread adoption, awareness dissemination, and infrastructural support. Overall, the documentation underscores the importance of promoting context-specific CSA interventions, strengthening institutional support, and enhancing farmer training and awareness to build resilient and sustainable agricultural systems in the face of climate variability. These insights are expected to aid policymakers, researchers, and extension agencies in scaling up climate-resilient agricultural practices across Tamil Nadu and similar agro-climatic settings.

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