Evaluating Climate Variability Impacts on Agricultural Output and Sustainability: A Micro-Level Analysis of Omalur Taluk Salem District, Tamil Nadu

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Abstract*—This study evaluates the impacts of climate variability on agricultural output and sustainability in Salem District, Tamil Nadu, where agriculture remains the primary livelihood source amid intensifying environmental pressures. Employing a micro-level analytical framework, the research examines climate-agriculture dynamics through comprehensive data spanning 2011-2021, integrating both primary survey data from farmers and secondary meteorological records. Statistical analysis using unit root tests and time-series models assesses relationships between climatic variables (temperature, rainfall, humidity) and productivity of major crops, particularly paddy and turmeric. Results reveal that while climate variables demonstrate stationary fluctuations rather than random volatility, their direct influence on production levels remains statistically insignificant during the study period. This suggests that non-climatic factors—including soil fertility, irrigation infrastructure, and agronomic practices—exert more substantial effects on agricultural sustainability. However, observed production variability indicates emerging vulnerabilities requiring proactive adaptation measures. The study recommends expanding temporal scope, incorporating additional crop varieties, and examining farmer adaptation strategies to comprehensively understand climate-agriculture linkages. These insights are crucial for formulating evidence-based agricultural policies and climate-resilient farming interventions to ensure long-term food security and sustainable livelihoods in Salem District.

***Index Terms*—Agricultural Production, Climate Change, Farm techniques, unit root test, food security and sustainability**

I. INTRODUCTION

Climate change stands out as the paramount environmental concern, with economic and scientific research endeavors striving to quantify its potential impacts on agricultural society. The present research work has consistently highlighted the significant contribution of human activities, notably production and consumption, to the emission of substantial amounts of carbon dioxide and other greenhouse gases, resulting in elevated surface temperatures. The resultant warming trend fuels a surge in extreme weather phenomena, encompassing droughts, floods, erratic precipitation patterns, sea-level rise, and shifts in ocean currents, collectively posing severe threats to ecosystems and human well-being. Of particular concern is the profound impact of climate change on agriculture, the fundamental activity sustaining human life on Earth. Agricultural productivity, contingent upon cultivated areas and yield per unit, faces substantial risks from shifting temperature and rainfall patterns, potentially jeopardizing global food security.

A wealth of research, including seminal works by the Liverman (1986), and Benhin (2006), as well as studies by Bosello et al. (2005), has sought to predict the ramifications of climate change on agricultural output, with varying projections ranging from improvements in high-latitude regions to reductions in mid-continental agricultural zones. Interdisciplinary efforts have integrated state-of-the-art models from climatology, agronomy, and economics to forecast future impacts, encompassing both direct alterations in crop yields and their global economic repercussions. In the context of India, where agriculture plays a pivotal role in the economy, contributing 18% of GDP in 2013-14 and employing over 60% of the workforce, the stakes are particularly high. Agricultural activities underpin several key industries, including textiles,

jute, and sugar, while a substantial portion of the country's exports comprises agricultural products. Rice, serving as the staple for 65% of India's population, exemplifies the centrality of agriculture to the nation's food security, constituting over half of total food grain and cereal production. However, recent years have witnessed mounting environmental pressures on India's agricultural sector, exacerbated by climate change, burgeoning populations, and emerging industries. The sector's vulnerability is compounded by its reliance on monsoon rains, with rising temperatures intensifying evapotranspiration rates and exacerbating crop stress, particularly in regions lacking irrigation infrastructure. The Indian Meteorological Department's classification of monsoon seasons underscores the significance of rainfall patterns, with deviations impacting crop yields, as evidenced by the prevalence of heat stress and drought-induced production declines in major crops like rice, turmeric, cotton, vegetables, fruits and millets across the country over the past decades in India. Thus, the present study has focused to analyse the impact of climate change on agricultural production in Salem district of Tamil Nadu, India.

II. RESEARCH PROBLEM

Jesper et al. (2005) highlight the critical importance of stochastic external factors, such as weather conditions, in agricultural production, as local temperature, moisture levels, and wind speed significantly impact all stages of production beyond the compensatory capacity of technological interventions. Despite this, the repercussions of climate change on crops cultivated in Salem, encompassing both food and cash crops, remain largely unexplored within the context of shifting climatic conditions, with scant research quantifying these impacts and overlooking the pivotal role of adaptation strategies. Philander (2008) underscores the diverse and region-specific manifestations of climatic variability, which affect different areas differently at local, regional, and global scales, with variations depending on the agricultural products under consideration. Salem divergent geo-climatic features, characterized by heavy monsoon rainfall averaging 3107mm annually, with the majority (68%) occurring during the southwest monsoon, further underscore the intricacies of climatic uncertainties. Rao et al. (2009) notes cyclic trends in annual rainfall in Salem over the past half-century, with declining trends in annual and southwest monsoon rainfall and an increasing trend in post-monsoon precipitation, potentially leading to a shift from wetter to drier zones within the state's humid climate, significantly impacting agriculture. The economic implications of climate change span a spectrum of outcomes, with potential positive effects, such as increased agricultural productivity or boosted tourism in response to temperature shifts, overshadowed on a global scale by predominantly negative impacts, as highlighted by the Ministry of Statistics and Programme Implementation (2013), which notes the gradual effects on economic processes, like increasing energy demand due to rising temperatures, alongside sudden economic shocks triggered by extreme events like floods or forest fires. However, assessing the precise impact of climate change on agriculture faces inherent complexity, as it operates within a multifaceted framework where climate is just one among many determinants of agricultural output, with technological advancements, socio-economic factors, and broader environmental issues also exerting significant influence. To comprehensively gauge the implications of climate change on agriculture, large-scale studies are imperative, encompassing the broader trends in climate change, such as mean annual temperature and precipitation variations, and their specific impacts on different crops at various stages of growth and propagation.

Research Objectives

1. To assess the impact of climate change on agricultural production in the mentioned study district of Tamil Nadu.

Research Hypothesis

1. The selected climatic variables do not significantly affect the agricultural production in Salem district.

III. METHODOLOGY AND RESEARCH DESIGN

The study employed both primary and secondary data collection methods. Primary data was gathered through structured schedules and questionnaires tailored to the study's objectives. Secondary data was sourced from published records of various government agencies, including the State Planning Board,

Department of Agriculture, Department of Economics and Statistics, and the Indian Meteorological Department (IMD). Following the World Meteorological Department's guidelines, a 30-year meteorological dataset served as the baseline for analyzing climate change trends in the selected district of Tamil Nadu. Rainfall and temperature trends were analyzed as time series data, categorized by month over the 30-year period. For each district, meteorological data were classified into various parameters such as annual mean rainfall, annual mean temperature, annual mean maximum temperature, and annual mean temperature range. Seasonal data included monsoon, post-monsoon, winter, and summer mean rainfall and temperature. Further classifications were made for mean maximum and mean minimum temperatures, as well as temperature ranges across different seasons. Additionally, the study incorporated time series data on the area and production of selected crops, such as paddy and turmeric from 2003 to 2023. Field surveys provided insights into farmers' experiences and agricultural practices, focusing on panel data encompassing annual crop production from 2013 to 2023. Information on agricultural land area, crop allocation, and cultivation costs, including labor, seeds, irrigation, fertilizers, pesticides, machinery, and soil conservation expenses, was also recorded. With regard to data analysis, unit root test has employed.

IV. RESULTS AND DISCUSSIONS

Table 1 Discussion on Impact of Climate Change and Paddy Production from 2011 - 2021

SI. No	Variables	r value	p value	Decision
1	Production	-3.45	.024	Stationary
2	Annual mean rainfall	-2.91	.019	Stationary
3	Monsoon Rainfall	-1.05	.020	Stationary
4	Post monsoon rainfall	-2.37	.038	Stationary
5	Winter rainfall	-4.10	.000	Stationary
6	Summer rainfall	-2.92	.008	Stationary
7	Annual mean maximum temperature	-1.87	.007	Stationary
8	Annual mean minimum temperature	-1.92	.005	Stationary
9	Annual mean temperature	-0.95	.043	Stationary
10	Annual mean temperature range	-1.03	.099	Stationary

Source: Computed (Statistical Hand book, Salem district)

Table 1 portraits the results of a unit root test model for cointegration analysis, examining the impact of climate change variables on paddy production from 2011 to 2021. The variables assessed include production, annual mean rainfall, monsoon rainfall, post-monsoon rainfall, winter rainfall, summer rainfall, annual mean maximum temperature, annual mean minimum temperature, annual mean temperature, and annual mean temperature range. Statistical analysis reveals that all variables exhibit stationary behavior, as evidenced by their respective r values and p values. Notably, production and all climate variables display negative r values ranging from -0.95 to -4.10, indicating a lack of correlation between the variables. However, the p values for all variables are below the conventional significance level of 0.05, indicating that the variables are stationary. This suggests that the fluctuations observed in paddy production and climate variables over the specified time period are not due to random chance but rather reflect underlying trends or patterns. The diagram illustrates the stationary behavior of the variables, with production and climate variables showing consistent patterns over time without significant deviations. These findings suggest that while climate change variables may influence paddy production, the relationship is not statistically significant within the context of the study period.

Other factors beyond climate, such as agricultural practices, soil quality, and pest management, may play a more substantial role in determining paddy production levels in this region. Therefore, based on the stationary behavior of the variables observed in the unit root test model, it can be interpreted that the impact of climate change on paddy production in the study area is not statistically significant. Further

research incorporating additional variables and a longer time frame may provide deeper insights into the complex dynamics between climate change and agricultural production, enabling more robust policy interventions and adaptation strategies to mitigate the effects of climate change on agriculture.

Table 2 Discussion on Impact of Climate Change and Turmeric Production from 2011 - 2021

SI. No	Variables	r value	p value	Decision
1	Production	-2.54	.046	Stationary
2	Annual mean rainfall	-1.18	.037	Stationary
3	Monsoon Rainfall	-3.48	.015	Stationary
4	Post monsoon rainfall	-5.77	.042	Stationary
5	Winter rainfall	-5.13	.009	Stationary
6	Summer rainfall	-3.02	.003	Stationary
7	Annual mean maximum temperature	-2.76	.010	Stationary
8	Annual mean minimum temperature	-5.65	.008	Stationary
9	Annual mean temperature	-3.57	.000	Stationary
10	Annual mean temperature range	-2.35	.001	Stationary

Source: Computed (Statistical Hand book, Salem district)

Table 2 analyse the outcomes of a unit root test model for cointegration analysis, elucidating the relationship between climate change variables and turmeric production from 2011 to 2021. Ten variables were examined, including turmeric production, annual mean rainfall, monsoon rainfall, post-monsoon rainfall, winter rainfall, summer rainfall, annual mean maximum temperature, annual mean minimum temperature, annual mean temperature, and annual mean temperature range. Statistical analysis indicates that all variables exhibit stationary behavior, as indicated by their respective r values and p values. Notably, turmeric production and all climate variables display negative r values ranging from -1.18 to -5.77, indicating a lack of correlation between the variables. However, the p values for all variables are below the conventional significance level of 0.05, signifying that the variables are stationary. This suggests that the fluctuations observed in turmeric production and climate variables over the specified time period are not random but rather reflect underlying trends or patterns. The diagram illustrates the stationary behavior of the variables, depicting consistent patterns over time without significant deviations. These findings imply that while climate change variables may impact turmeric production, the relationship is not statistically significant within the study period. Other factors such as soil quality, pest management, and farming techniques may exert a more substantial influence on turmeric production in this region. Thus, based on the stationary behavior observed in the unit root test model, it can be interpreted that the impact of climate change on turmeric production in the study area is not statistically significant. Further research incorporating additional variables and a longer time frame could provide deeper insights into the intricate dynamics between climate change and agricultural production, facilitating the development of more effective adaptation strategies and policy interventions to mitigate the effects of climate change on turmeric cultivation.

V. JUSTIFICATION OF RESEARCH HYPOTHESIS

The research hypothesis posits that selected climatic variables do not significantly affect agricultural production in Salem district. This hypothesis is supported by the findings from the unit root test models presented in Tables 1 and 2, which examined the relationship between climate change variables and production of two key crops, paddy and turmeric, over a span of a decade. The stationary behavior observed in all variables, including production, annual mean rainfall, and temperature indicators, suggests that fluctuations in agricultural production and climate variables are not random but rather reflect underlying trends or patterns. These findings align with previous literature that highlights the complex dynamics between climate change and agricultural outcomes. For instance, studies such as Gupta et al. (2018) and Kumar et al. (2020) emphasize the multifaceted nature

of agricultural production, indicating that factors beyond climate, such as soil quality, irrigation practices, and pest management, significantly influence crop yields. Furthermore, research by Reddy et al. (2019) underscores the importance of considering regional variations and local agricultural practices when assessing the impact of climate change on crop production. In the context of Salem district, where diverse agricultural practices and soil types prevail, the influence of climatic variables on agricultural production may be attenuated by these local factors. Moreover, the stationary behavior observed in both paddy and turmeric production suggests that the impact of climate change on these crops may not be statistically significant within the study period. However, it is essential to acknowledge the limitations of the study, including the relatively short timeframe and the focus on specific crops, which may not capture the full extent of climate variability and its effects on agriculture. Thus, while the research hypothesis is supported by the findings from the unit root test models and existing literature, further research incorporating additional variables and a longer timeframe is warranted to provide a comprehensive understanding of the complex relationship between climate change and agricultural production in Salem district.

VI. CONCLUSION

In conclusion, this study has shed light on the intricate dynamics between climate change and agricultural production in Salem district, Tamil Nadu, India. Through the analysis of climate variables and crop production data from 2011 to 2021, it was found that while fluctuations in production and climatic indicators were observed, they exhibited stationary behavior, indicating underlying trends rather than random variability. These findings provide support for the research hypothesis, which posited that selected climatic variables significantly affect agricultural production in the study area. However, it is crucial to acknowledge the complexity of the relationship between climate change and agriculture, as highlighted by previous literature and the limitations of this study. Factors beyond climate, such as soil quality, irrigation practices, and pest management, may play a substantial role in determining crop yields. Moreover, the relatively short timeframe and focus on specific crops may limit the generalizability of the findings. Therefore, further research incorporating additional variables and a longer timeframe is recommended to gain a more comprehensive understanding of the impact of climate change on agricultural production in Salem district. This deeper understanding will be instrumental in informing policy interventions and adaptation strategies to mitigate the effects of climate change on agriculture and ensure food security in the region.

VII. POLICY SUGGESTIONS

- Encourage the adoption of climate-smart agricultural practices tailored to the specific needs and conditions of farmers in Salem district.
- Invest in improving irrigation infrastructure and water management techniques to mitigate the impact of rising temperatures and erratic precipitation patterns.
- Provide financial incentives and support for the implementation of sustainable farming practices, such as organic farming and agroforestry, to enhance resilience to climate change.
- Foster knowledge sharing and collaboration between government agencies, research institutions, and local farmers to facilitate the dissemination of best practices and technologies for climate adaptation in agriculture.
- Integrate climate change considerations into agricultural policies and planning processes at the local and regional levels to ensure long-term sustainability and resilience of the agricultural sector.

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