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Economic impact of climate change on farmers' income in Ramanathapuram district: A ricardian analysis

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ABSTRACT

Climate change presents a growing challenge to agriculture, particularly in drought-prone regions like Ramanathapuram district, Tamil Nadu, where farming remains a primary livelihood. The present study was carried out from January to June 2024 in Ramanathapuram district, Tamil Nadu, focusing on analyzing the effects of climate change on farmers' livelihoods. This study employs the Ricardian model to assess the long-term impact of climate variability on farm income and employment, utilizing climate data from 1994 to 2023 and survey responses from 120 randomly selected farmers. Findings indicate a 1.3°C rise in maximum temperature and a 22% decline in rainfall over the study period, contributing to a 38% reduction in crop yields, with paddy, pulses, and millet being the most affected. The Ricardian analysis revealed that a 1% increase in maximum temperature during the rainy (*kharif*) season reduces net farm income by 0.45%, while a 1% rise in rainfall enhances income by 0.23%. Farmers identified drought (91.7%), groundwater depletion (82%), and soil degradation (65%) as major climate-induced challenges. Additionally, agricultural labour demand declined by 25%, prompting many farmers to shift to non-agricultural employment. Despite the critical role of agriculture in rural livelihoods, limited research has focused on quantifying the economic implications of climate change in Tamil Nadu's coastal districts. This study bridges this gap by providing empirical evidence on climate-induced income and employment shifts, emphasizing the need for climate-resilient policies and sustainable agricultural strategies to ensure long-term economic stability.

Keywords: Climate change, Climate trend, Employment, Ricardian analysis

Climate change, defined by the Intergovernmental Panel on Climate Change (Ahmad *et al.* 2011) as long-term alterations in climate properties, has led to significant impacts globally. Between 1970 and 2021, India experienced 573 extreme weather events, resulting in 138,377 fatalities (IMD Annual Report 2021). Recent years have seen unprecedented high temperature and prolonged dry spell (Panda *et al.* 2017). Projections from the Coupled Model Intercomparison Project Phase 5 (CMIP5) suggests India will experience a temperature increase of upto 2°C by 2030 and 4.8°C by 2080, alongside a rise in precipitation (Chaturvedi *et al.* 2012, Panda *et al.* 2017). Agriculture, which contributes about 16% to India's GDP and employs over half of its population, is highly vulnerable to climate change. Despite its decreasing GDP share from 54% in 1960–61 to 16% in 2020–21 (Majumder 2021), agriculture remains crucial, employing 42% of the workforce and covering 60% of the land area (Gautam and Dhaka 2022). Climate change is significantly affecting agriculture, with rising maximum temperatures contributing to heat stress and productivity declines (IPCC 2014).

India's extensive 6,100 km coastline supports nearly 250 million people living within 100 km of the shore, largely dependent on agriculture (Sharma *et al.* 2023). Tamil Nadu, with a 1,076 km coastline, is a significant coastal state (Zacharia *et al.* 2016). Coastal communities are increasingly affected by climate events, threatening food security, water availability, infrastructure, and agricultural income (Rahman *et al.* 2023). The economic impacts of climate change are severe, particularly in coastal areas, leading to reduced agricultural yields, fluctuating precipitation patterns, and declining animal production, all contributing to decreased net income for farmers (Wakatsuki *et al.* 2023). Employment in vulnerable sectors like fisheries, tourism, and agriculture faces job losses and economic instability (Ajayi *et al.* 2022, Siskou 2022). Rising sea levels, coastal erosion, and extreme weather events exacerbate these challenges. Addressing the links between climate change, coastal employment, and net income is crucial for sustainable development and the well-being of coastal populations (Mambo 2022).

While numerous studies have examined the broad impacts of climate change on agriculture (Chaturvedi *et al.*

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2012, Panda *et al.* 2017), limited research has specifically assessed its economic implications on farmers' income at the district level, particularly in coastal regions. Existing literature primarily focuses on national and state-level trends, leaving a critical gap in understanding localized vulnerabilities (Rahman *et al.* 2023). Additionally, most studies rely on short-term climate data, whereas long-term assessments are crucial for capturing climate variability and its cumulative effects on rural livelihoods (Mambo 2022). This study aims to bridge these gaps by employing a Ricardian analysis to quantify the economic impact of climate change on farmers' income in Ramanathapuram district, Tamil Nadu. This region, characterized by its extensive coastline and agrarian economy, is particularly susceptible to climate-induced challenges. By incorporating long-term climate data and examining localized economic consequences, this study provides granular insights for policymakers and stakeholders, enabling targeted adaptation strategies to mitigate income losses and enhance agricultural resilience.

MATERIALS AND METHODS

The present study was carried out from January to June 2024 in Ramanathapuram, Tamil Nadu, focusing on analyzing the effects of climate change on farmers' livelihoods. Ramanathapuram district was selected for this study due to its high vulnerability to climate change, characterized by erratic rainfall patterns, rising temperatures, and semi-arid conditions that significantly impact agricultural livelihoods. The district heavily relies on agriculture, making it a critical area to assess the effects of climate variability on farmers' income and employment. Thiruvadanai, Mandapam, Muthukulathur, and Kamuthi blocks were purposively chosen because they represent the diversity of the district's cropping systems, as these are the only blocks cultivating all major crops, including paddy, pulses, and millets. This diversity allowed for a comprehensive analysis of climate change effects across various agricultural ecosystems. The selection of these blocks ensures that the findings reflect the broader agricultural challenges in the region, providing valuable insights into climate adaptation strategies that could be applicable to similar semi-arid areas.

Six villages from each block were selected, and five farmers from each village were randomly chosen, resulting in a sample size of 120 respondents. Primary data was collected through structured interviews focusing on socio-economic factors, farming practices, income, employment, and adaptation strategies. Additionally, climate data from 1994 to 2023, including temperature and rainfall trends, was sourced from the Regional Meteorological Centre in Chennai to assess the long-term impacts of climate variability on farmers' livelihoods. This combination of primary and secondary data provided a holistic view of the climate change effects and farmers' adaptive responses.

Trend analysis was performed using a basic linear regression model, expressed as:

$$Y_t = \beta_0 + \beta_{1t} + \epsilon_t$$

Where Y_t, Climate variable at time t; β_0, Intercept (the value of Y, when t=0); β_1, Slope that indicates the rate of change in the climate variable over time, and ϵt, Error term, capturing the variability not explained by the model.

The Ricardian model was used to assess the economic impact of climate change on cropland value by regressing net income against climatic variables such as temperatures and rainfall during the *kharif* and *rabi* seasons, along with other factors like education, farm experience, family size, and extension contacts (Ali *et al.* 2021). The model equation is given by:

$$V = \beta_0 + \beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5 + \beta_6 + \beta_7 + \beta_8 + \beta_9 + \beta_{10} + \beta_{11} + \beta_{12} + \beta_{13} + \beta_{14} + \beta_{15} + \beta_{16} + \beta_{17} + \beta_{18} + \mu$$

Where β_1, KMAXTEM (*Kharif* season maximum temperature in °C); β_2, KMATEM^2 (Squared *kharif* season maximum temperature in °C); β_3, KMINTEM (*Kharif* season minimum temperature in °C); β_4, KMINTEM^2 (Squared *kharif* season in minimum temperature); β_5, KRAIN (*Kharif* season rainfall in mm); β_6 = KRAIN^2 (Squared *kharif* season rainfall in mm); β_7, KRAINDAY (Total rainy days during the *kharif* season); β_8, RMAXTEM (*Rabi* season maximum temperature in °C); β_9 = RMAXTEM^2 (Squared *rabi* season maximum temperature in °C); β_{10}, RMINTEM (*Rabi* season minimum temperature in °C); β_{11}, RMINTEM^2 (Squared *rabi* season minimum temperature in °C); β_{12}, RRAIN (*Rabi* season rainfall in mm); β_{13}, RRAIN^2 (Squared *rabi* season rainfall in mm); β_{14}, RRAINDAY (Number of rainy days in the *rabi* season); β_{15}, EDU (Education in years); β_{16}, FARMEXP (Farm experience in years); β_{17}, FAMSIZE (Family size in numbers); β_{18}, EXTN (Extension contacts in number of times); β_0, Intercept; μ, Error term.

Garrett's ranking technique was applied to rank farmers' perceptions of climate change factors and strategies, using the formula:

$$\text{Percent position} = 100 \times (R_{ij} - 0.5) / N_j$$

Where R_{ij}, Ranking given to the i^{th} attribute by the j^{th} individual; N_j, Number of attributes ranked by the j^{th} individual.

Percent positions from Garrett's table were converted to scores, summed, and averaged for each factor (Elum *et al.* 2017). The percent positions were converted to scores, summed, and averaged for each factor to determine the most important attributes.

RESULTS AND DISCUSSION

The climate trend in Ramanathapuram district was analysed using 30 years of data (1994–2023) on maximum temperature, minimum temperature, and rainfall (Yihui *et al.* 2023). The analysis highlights significant patterns during this period (Fig. 1), with the maximum temperature showing a clear upward trend, increasing from around 30°C to approximately 38°C, indicating a warming trend that could increase heat stress, affecting human health and agricultural productivity (De Lima *et al.* 2021). Conversely, the minimum temperature exhibits a slight downward trend,

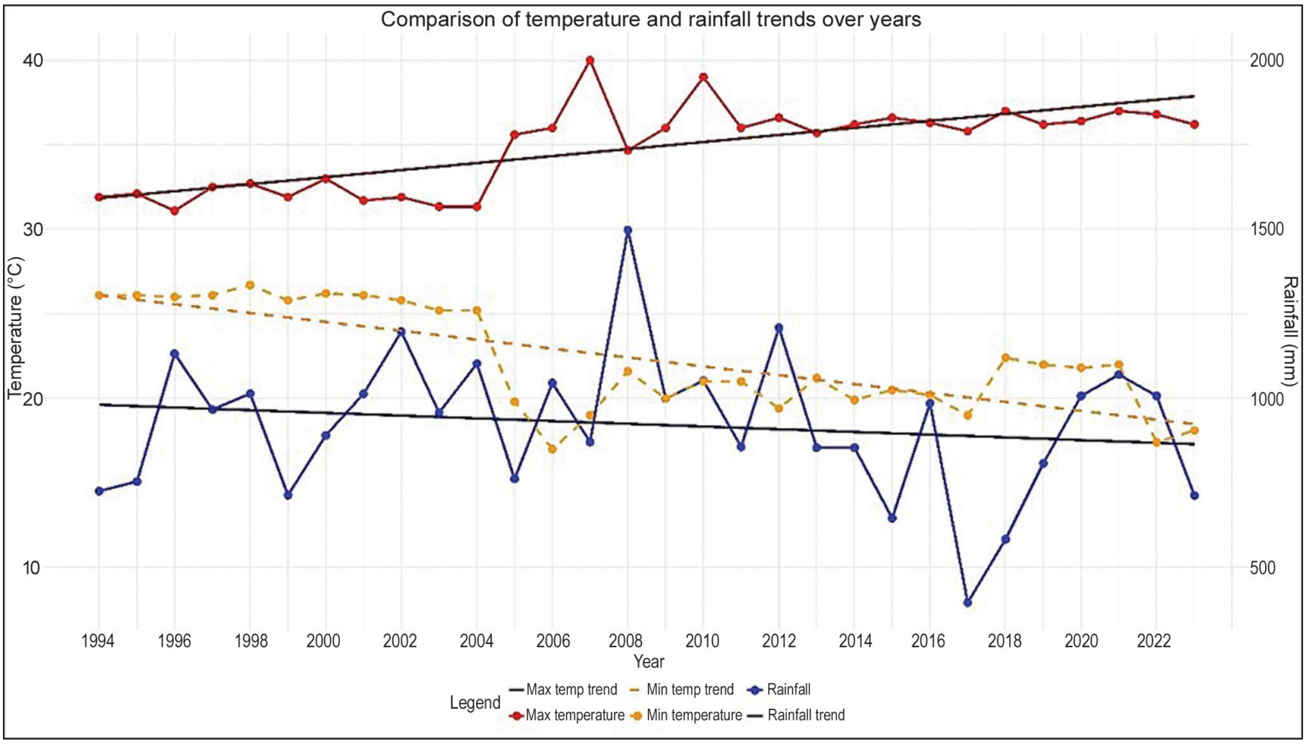

Fig. 1 Trends in temperatures and rainfall.

fluctuating between 18°C and 25°C, which could result in greater day-night temperature variations, potentially impacting crop growth. Rainfall showed a gradual decline, with notable year-to-year variability, decreasing from an initial average of around 1500 mm to below 1000 mm, indicating a growing risk of water scarcity. The mean values indicate that the average maximum temperature is 34.85°C, the minimum temperature is 22.28°C, and rainfall is 885.34 mm. The combined effect of rising temperatures and declining rainfall underscores the need for climate-resilient agricultural practices (Mamun *et al.* 2024) and water management strategies in Ramanathapuram to mitigate the potential adverse impacts on livelihoods and food security.

Farmers' perceptions regarding climate change impacts (Fig. 2) were ranked using the Garrette ranking method (Elum *et al.* 2017), revealing a high level of concern over persistent drought, with 91.66% of farmers identifying it as the most pressing issue. Groundwater depletion (75%) becomes scarcer due to reduced rainfall, farmers are increasingly reliant on groundwater for irrigation. Temperature fluctuations (58.33%) disrupt crop growth, leading to unpredictable yields and increased risks of crop failure, while 41.66% reported pest prevalence, 25% noted soil salinity changes, and 8.33% mentioned irregular rainfall and flooding. Farmers anticipate that climate change will lead to more frequent and severe water shortages, with groundwater depletion and water scarcity being prioritized over other concerns such as temperature fluctuations and pest infestations (Dessai and Sims 2010; Carlton *et al.* 2016). Poor groundwater recharge due to insufficient rainfall and inefficient irrigation infrastructure further exacerbate the problem, leaving farmers with limited options for sustainably managing their crops. Similar findings have been reported by Reddy *et al.* (2022), emphasizing the urgent need for effective water management strategies and climate-resilient agricultural practices to mitigate the impacts of these challenges on the farming community.

The economic performance of farmers was analysed by average annual income, showing that 10.01% of farmers

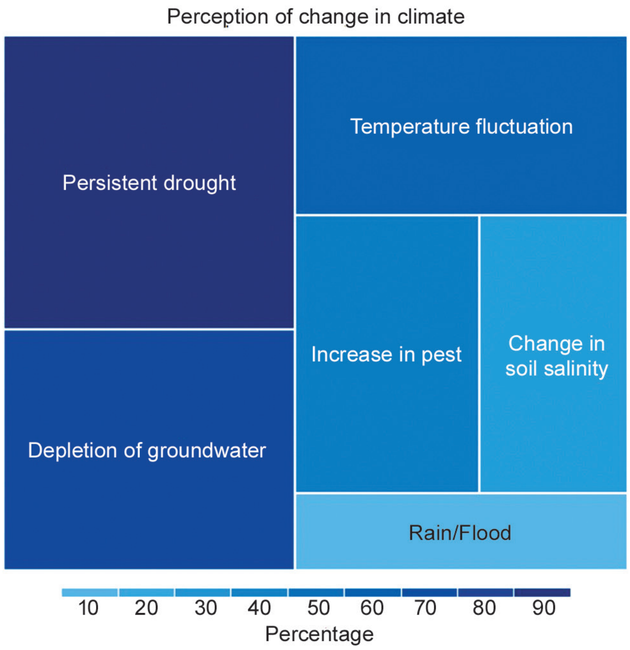

Fig. 2 Perception of climate change.

earn up to ₹75,000 (Fig. 3). These farmers often face considerable financial challenges, largely due to limited landholdings, restricted access to essential agricultural inputs such as high-quality seeds, fertilizers, and irrigation, and overall lower profitability in farming. The majority of farmers, 24.44%, earn more than ₹2 lakhs annually, with 66.66% falling within the ₹75,000 to ₹2 lakh income range. These middle-income farmers, while more financially secure than those in the lower-income group, still face significant challenges in sustaining their livelihoods. According to Pender and Gebremedhin (2008), the majority of farmers fall into the middle-income, facing financial challenges due to limited landholdings, restricted access to agricultural resources, or lower farming profitability. Larger farm sizes correlated with better economic outcomes were consistent with international findings (Kimura and Le Thi 2013). While most farmers report moderate annual incomes, a subset faces financial difficulties (Garzon Delvaux *et al.* 2020), highlighting the need for targeted support to boost economic resilience.

The impact of climate change on farmers' net income was examined using the Ricardian cross-sectional model, revealing significant insights into the influence of both climatic and socio-economic factors on agricultural net income in Ramanathapuram district. With an adjusted R^2 of 0.82, the model indicated that 82% of the variation in farmers' net income can be attributed to these factors, underscoring the substantial role they play in determining economic outcomes for farmers (Table 1). Net income exhibited a strong response to climatic conditions during both the *kharif* and *rabi* seasons. Specifically, a 1% decrease in maximum temperature during the *kharif* season was found to increase the net income of farmers at ₹1079.3 significantly. The coefficient of the minimum temperature was negative and statistically significant at the 1% level, highlighting that lower temperatures during the *kharif* season are beneficial for crop growth and yield as well as increase the net income of the farmers by ₹24.87. However,

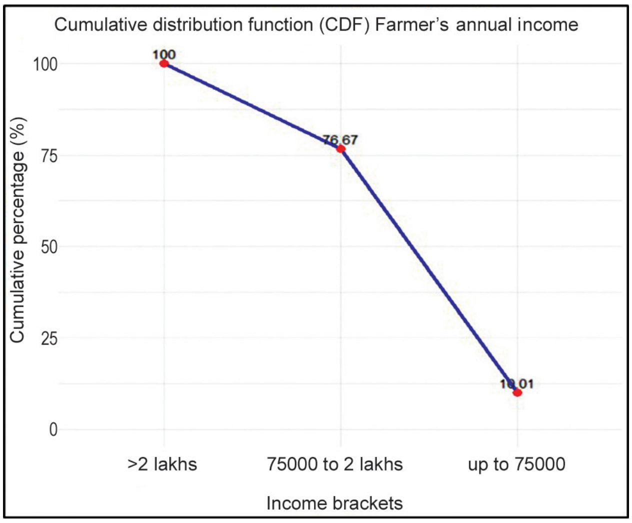

Fig. 3 Annual income of farmers.

the quadratic relationship observed for the *kharif* season's maximum temperature, with a positive coefficient, suggested that while moderate reductions in temperature boost net income, extreme temperature increases are detrimental. These findings align with broader research indicating that extreme heat can cause heat stress in crops, reducing agricultural productivity (Kalli and Jena 2022). Rainfall during the *rabi* season had a positive impact on net income, with a coefficient that was statistically significant at the 5% level. A 1% increase in rainfall during this period led to a corresponding rise in net income by ₹4,601.954. However, the quadratic term for rainfall was negative and significant at the 5% level, suggesting that while moderate rainfall is beneficial, excessive rainfall can lead to waterlogging, which diminishes crop yields and net income. This highlights the delicate balance needed for optimal rainfall, as both insufficient and excessive precipitation can harm agricultural productivity. Socio-economic factors, including education and farm experience, also played crucial a role in determining farmers' net income. A 1% increase in education from the mean resulted in a net income rise of ₹405.41, indicating that more educated farmers are better equipped to adopt improved farming practices, enhance productivity, and make informed decisions. Similarly, farm experience positively impacted net income, with a 1% increase contributing to an additional ₹374.57 in earnings. This suggested that experienced farmers have accumulated knowledge and skills that enable them to better cope with climate variability and optimize their farm operations. Conversely, family size had a negative effect on net income. A 1% increase in family size was associated with a ₹153.26 decrease in net income, indicating that larger families may strain household resources and reduce per capita earnings. This finding underscores the economic pressures faced by households with more dependents, where limited resources must be distributed among a greater number of individuals. These results highlight the critical influence of both climatic and socio-economic factors on farmers' net income. While education and farm experience enhance resilience and productivity, family size can impose economic burdens, particularly in the context of climate change. The findings suggested the need for targeted interventions to improve access to education and farming resources, as well as better resource allocation in larger households, to ensure sustainable economic stability in the face of ongoing climate challenges (Huong *et al.* 2019, Hanif *et al.* 2010, Ali *et al.* 2021).

Perceptions of climate change impacts on income and employment showed that 65.62% of respondents believe low-income individuals are most vulnerable to climate change, highlighting concerns about economic inequality. Increased working hours due to climate change were reported by 64.66%, meaning farmers are spending more time in their fields to make up for losses and to ensure that they can meet their basic needs. While 53.75% expressed fears of job loss. Some respondents (37.06%) anticipated reduced work hours due to shifting seasonal patterns, while only 26.93% of respondents believed that

Table 1 Effect of climate change on net income

Particulars	Coefficients	*P* value
Intercept	89762.439	0.074
Kharif season maximum temperature	-1079.300**	0.038
Kharif season minimum temperature	24.870**	0.048
Kharif season rainfall	-1994.949	0.958
Total rainy days in the *kharif* season	220.661	0.732
Squared *kharif* season maximum temperature	4132.051	0.571
Squared *kharif* season minimum temperature	-115.111	0.085
Squared *kharif* season rainfall	1464.991	0.178
Rabi season maximum temperature	-1232.811	0.926
Rabi season minimum temperature	-6.221	0.094
Rabi season rainfall	4601.954*	0.010
Total rainy days in the *rabi* season	90.500	0.073
Squared *rabi* season maximum temperature	159.518	0.061
Squared *rabi* season minimum temperature	-69.289	0.092
Squared *rabi* season rainfall	-103.786*	0.011
Education	405.419*	0.010
Farm experience	374.574*	0.011
Family size	-153.266**	0.042
Extension contacts	887.111	0.704

R^2 = 0.76 Adj R^2 = 0.82 n = 120; **Significant at 1% level; *Significant at 5% level.

Table 2 Climate change mitigation measures in the Ramanathapuram district

Climate-smart technologies	Percentage (%)
Soil Test	57.50
Drought tolerant crops	23.33
Increased FYM	69.16
Early planting	52.50
Water management	51.66
Rainwater harvesting	46.66
Improved insurance	3.33
Seed treatment	65.83
Mixed farming	71.66
Mulching	20.00
Variety selection	7.50
Adjusting dates	48.33
Changing cropping pattern	80.00

high-income individuals would be significantly affected by climate change. This perception reflects the reality that wealthier groups have more resources at their disposal to adapt to the impacts of climate change, such as investing in climate-resilient infrastructure, advanced technologies, and crop insurance. This highlights the growing economic vulnerabilities of low-income groups and underscores the importance of targeted interventions to reduce inequality and support the resilience of the most affected populations (Rao 2014, Eriksen *et al.* 2020).

The climate change mitigation measures in Ramanathapuram district revealed significant differences in farmers' abilities to adapt to climate change (Table 2). While changing cropping patterns (80%), and mixed farming (71.66%), are widely adopted (Sati 2024), According to Paroda (2018) farmers struggle to implement resource-intensive practices like high FYM application and advanced water management due to limited land, finances, and resources. Soil tested was also practiced by a significant portion of farmers (57.50%), while more than half adopted early planting (52.50%) and water management techniques (51.66%) to adapt to changing weather patterns. Rainwater harvesting (46.66%) and adjusting planting dates (48.33%) were moderately practiced to conserve water and optimize crop growth periods. Some technologies have seen lower adoption rates. For instance, only 23.33% of farmers grew drought-tolerant crops, and only 20% used mulching to conserve soil moisture. According to Guo *et al.* (2022), lower adoption rates of seed treatment and varietal selection among farmers further reflect economic and informational barriers. These disparities point to the need for targeted support to help farmers for adopting effective climate change mitigation measures and improve their resilience to climate change.

In response to the increasing challenges posed by climate change, farmers in Ramanathapuram district have adopted various strategies to mitigate its adverse effects on their livelihoods and agricultural practices. One of the most prominent strategies has been the adoption of low-premium crop insurance, with 70.12% of farmers opting for this as their primary form of risk management. Crop insurance serves as a safety net, protecting farmers from financial losses caused by unpredictable weather patterns, such as drought or flood, which are becoming more frequent due to climate change. Loan waivers were the second most adopted strategy, with 58.20% of farmers relying on this approach. Loan waivers, typically implemented by governments, provide financial relief to indebted farmers who are unable to repay loans due to crop failures or reduced yields caused by erratic weather. New crop varieties were used by 32.50%, and are often more resistant to drought, pests, and diseases, making them crucial in adapting to the changing climate. While technology adoption remained low at 32.00% (Table 3), highlighting the need to improve access to climate-smart technologies for better resilience (Semeraro *et al.* 2023).

In conclusion, this study highlights the significant impact of climate change on farmers in Ramanathapuram, where drought, groundwater depletion, and temperature fluctuations have led to declining agricultural productivity and income instability. The Ricardian model explained 82% of income variations, showing that education and

Table 3 Strategies adopted by farmers in Ramanathapuram district

Particulars	Mean score	Percentage (%)	Rank
Crop insurance	75	70.12	1
Loan waiver	60	58.20	2
Livestock loans	50	56.66	3
New variety	40	32.50	4
Technology information	24	32.00	5

farm experience enhance income while larger family sizes contribute to financial strain. Employment instability, particularly among low-income households, further exacerbates vulnerability, forcing many farmers toward non-agricultural livelihoods. These findings align with previous studies indicating that climate variability disproportionately affects marginal farmers in drought-prone regions (IPCC 2014, Rahman *et al.* 2023), while research on climate-resilient systems suggested that adaptive strategies like precision farming and agroforestry can mitigate these effects (Ajayi *et al.* 2022). However, despite the availability of coping mechanisms such as crop insurance and loan waivers, a critical gap remains in adopting climate-smart technologies. To address these challenges, policymakers should prioritize expanding access to climate-resilient agricultural technologies, strengthening farmer education, and implementing targeted interventions such as water conservation initiatives and diversified cropping systems. By integrating these measures into agricultural policies, stakeholders can enhance farmers' adaptive capacity, improve economic stability, and ensure food security in the face of ongoing climate change.

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