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The Effect of Climate Change and Sustainable Agricultural Practices on Productivity and Food Security in Rural Areas in East Java

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ABSTRACT

In rural East Java, Indonesia, this study examines the effects of climate change and sustainable farming practices on food security and agricultural output. A structural equation modeling approach was used to analyze the data from a survey of 250 farmers. The latent constructs' validity and reliability were validated by the measurement model evaluation, and each construct's uniqueness was guaranteed by discriminant validity analysis. Significant correlations were found by using the structural model: production was unexpectedly positively influenced by climate change, while food security was severely affected. Sustainable farming methods have a high positive correlation with production and food security. Demographic analysis shed light on the traits of the farmers in the sample. The evaluation of the model fit revealed that the relationships in the suggested model were satisfactorily represented. By providing useful insights for practitioners and policymakers pursuing sustainable agricultural development, this study advances knowledge of the complex dynamics of East Javan agriculture.

Keywords: *Climate Change, Sustainable Agricultural, Productivity, Food Security, East Java*

1. INTRODUCTION

Indonesia's East Java province, known for its agricultural activity, is facing the consequences of climate change, including erratic weather patterns, rising temperatures, and changes in rainfall levels [1]. The region has relied on its fertile land to sustain rural communities, but these climate changes are posing challenges to agricultural productivity and livelihoods [2]. Additionally, the province has experienced natural disasters such as landslides and land subsidence, particularly in the southern area characterized by volcanic sediment and limestone [3]. These geological complexities further exacerbate the vulnerability of the region to climate change impacts. The situation calls for a comprehensive approach that addresses both the immediate and long-term effects of climate change on agriculture and natural disasters in East Java province [4].

The agricultural sector in East Java is facing challenges that threaten its productivity and sustainability. These challenges include the narrowing of agricultural land due to population growth and the need to maintain rice productivity as a staple food [5]. Additionally, there is a need to predict food crop production to inform policy decisions and overcome production uncertainties [6]. To address these challenges and ensure the future of food in the region, it is important to implement sustainable agricultural practices and establish a food BUMD (Regional-Owned Enterprises) [7]. Maximizing the potential of agricultural resources and identifying priority policy plans can accelerate regional economic development and growth [4]. By considering these factors and implementing efficient strategies, East Java can navigate the changing landscape and secure the future of its agricultural system [8].

The interrelated factors of climate change and the imperative for sustainable agricultural practices underscore the urgency of understanding their combined impacts on agricultural productivity and food security in East Java. As global temperatures rise, rural communities across the region face unique vulnerabilities due to climate change. These vulnerabilities include exposure to extreme weather events, reduced crop and livestock production, and limited access to resources and information. To address these challenges, the adoption of sustainable agricultural practices has emerged as a potential mitigation strategy. Sustainable agriculture can enhance resilience by improving soil quality, increasing biodiversity, and promoting ecosystem services. Sustainable agriculture can also help minimize the adverse impacts of climate change on rural communities by providing alternative livelihood options, diversifying income sources, and improving food security [9]–[12]. However, more research and collaboration is needed to develop interdisciplinary and multidimensional agriculture that integrates all aspects of management and generates a wide variety of ecosystem services [5]–[8]. This research seeks to unravel the complex relationship between climate change, sustainable agricultural practices, and their joint influence on important dimensions of agricultural productivity and food security.

2. LITERATURE REVIEW

2.1 Climate Change and Agriculture

Climate change, characterized by rising temperatures, changing precipitation patterns, and increased frequency of extreme weather events, poses significant challenges to global agriculture. Numerous studies highlight the adverse effects on crop yields, altered growing seasons, and heightened vulnerability to pests and diseases. The unpredictability of weather patterns in the region has resulted in crop losses, affecting staple crops such as rice, maize, and soybeans [13]–[17]. Understanding the specific manifestations of climate change in East Java is crucial for devising targeted adaptation strategies.

2.2 Sustainable Agricultural Practices

Sustainable agricultural practices offer a multifaceted approach to mitigate the impacts of climate change on farming systems. Agroecology, characterized by the integration of ecological principles into agriculture, has gained prominence as a strategy to enhance resilience [18]. Organic farming, with its focus on soil health and reduced reliance on synthetic inputs, has shown promise in mitigating climate-induced risks [19]. Precision agriculture, utilizing technology for optimized resource use, and conservation techniques, promoting biodiversity and soil conservation, contribute to sustainable practice [20]. These practices include site-specific nutrient management and precision irrigation for resource optimization [21]. Additionally, conservation agriculture practices such as minimal tillage and cover cropping enhance soil health and reduce erosion [22]. Agroecological approaches, such as agroforestry and integrated pest management, reduce chemical inputs and promote natural pest control. The adoption of these practices in East Java can potentially bolster the adaptive capacity of farmers.

2.3 Climate Change Adaptation and Mitigation Strategies

Various strategies have been proposed and implemented globally to adapt to and mitigate the impacts of climate change on agriculture. Policies that promote sustainable land management, water conservation, and climate-smart agriculture have been instrumental in enhancing resilience [23]. Technological innovations, such as droughtresistant crop varieties and precision farming technologies, have shown promise in mitigating the adverse effects of changing climate conditions [24], [25]. Additionally, community-based initiatives, including farmer cooperatives and knowledge-sharing networks, play a pivotal role in building adaptive capacity at the grassroots level [18]. These strategies and initiatives aim to enhance agricultural productivity, reduce resource utilization, and promote sustainable practices in the face of climate change challenges. Examining the effectiveness of these strategies in the context of East Java is essential for tailoring interventions to the specific needs of the region.

2.4 Food Security in Rural Areas

Climate change-induced disruptions in agricultural systems directly impact food security in rural areas. Changes in temperature and precipitation patterns can lead to fluctuations in crop yields, affecting food availability [13], [25]. Shifts in traditional farming calendars may disrupt planting and harvesting cycles, influencing food accessibility [26]. Moreover, the economic ramifications of climate-induced crop failures can hinder the purchasing power of rural communities, affecting food utilization [27]. Addressing these interconnected dimensions is vital for formulating comprehensive strategies to safeguard food security in the face of a changing climate [28].

Gaps in Existing Literature:

While existing literature provides valuable insights into the broad interactions between climate change, sustainable agriculture, and food security, there is a noticeable dearth of region-specific studies focused on East Java. The unique socio-economic, cultural, and environmental context of the region necessitates targeted research to bridge this gap. Furthermore, few studies delve into the longitudinal aspects of climate change impacts on agriculture in East Java, hindering a comprehensive understanding of the evolving challenges faced by rural communities.

Resilience theory provides a lens to understand the adaptive capacity of agricultural systems in the face of climate-induced shocks. Agroecological principles offer a framework for sustainable practices that enhance both ecological and social resilience [29], [30]. These theoretical underpinnings guide the formulation of research questions and the development of hypotheses, setting the stage for the empirical investigation into the effects of climate change and sustainable agricultural practices on agricultural productivity and food security in East Java.

H1: Climate change has a significant impact on food security in rural East Java.
H2: Climate change is significantly associated with changes in agricultural productivity in rural East Java.
H3: Adoption of sustainable agricultural practices significantly contributes to improved food security in rural East Java.
H4: Adoption of sustainable agricultural practices significantly increases agricultural productivity in rural East Java.

3. METHODS

This study is conducted in several rural areas in East Java, Indonesia. The selection of study areas will consider the diverse agroecological zones within the province, to ensure representation of various farming systems and climatic conditions. A stratified random sampling technique will be used to ensure representation of different agroecological zones. The sample size consists of 250 farmers, drawn from different regions in East Java. Stratification is based on factors such as farming practices, land use, and socioeconomic conditions. This approach aims to capture the diversity of climate change impacts and sustainable agricultural practices across the region.

3.1 Data Collection

A structured survey is conducted to collect quantitative data on perceptions of climate change, sustainable agricultural practices, and food security indicators. Survey questionnaires will be designed to obtain information on farmers' experiences with climate change, adoption of sustainable agricultural practices, and key aspects of food security.

Field observations will complement the survey data by providing real-time information on farming activities and environmental conditions. Observations will focus on land use patterns, crop health, and adoption of sustainable agricultural practices.

3.2 Variables

Key variables for analysis include:

a. Climate Change Indicators: Changes in temperature and rainfall patterns.
b. Agricultural Productivity: Crop yields and Land use patterns.
c. Sustainable Agricultural Practices: Adoption of conservation techniques, Organic farming practices and Precision farming.
d. Food Security Indicators: Food availability, Food accessibility and Food utilization.

3.3 Data Analysis

Structural Equation Modeling (SEM) with Partial Least Squares (PLS) is a powerful statistical technique that combines factor analysis and pathway analysis to assess measurement models and structural models simultaneously. It is suitable for exploring the interdependencies between climate change, sustainable agricultural practices, and their impact on agricultural productivity and food security. SEM-PLS allows for the inclusion of latent variables and handles small sample numbers effectively, making it well suited for exploratory research. The method involves formulating structural models to represent the relationship between climate change indicators, sustainable agricultural practices, and their combined effects on agricultural productivity and food security. Confirmatory factor analysis is performed to assess the reliability and validity of the measurement model, ensuring that the selected indicators accurately measure the latent construct. Path analysis is used to analyze the relationships between latent constructs, assessing coefficients and path significance to determine the strength and direction of the relationship. The model fit index is evaluated to assess how well the proposed model matches the observed data. Bootstrapping techniques are employed to assess the stability and robustness of model estimations, validating the statistical significance of the relationships within the model.

4. RESULTS AND DISCUSSION

4.1 Sample Characteristics

Before delving into the main findings, it is essential to present the demographic characteristics of the 250 farmers who participated in the study. Understanding the profile of the sample helps contextualize the results and provides insights into the diverse backgrounds of the participants. The majority of farmers fell within the 35-50 age group (65%). Approximately 40% had completed secondary education, while 35% had received higher education. A significant proportion (55%) had more than 15 years of farming experience. 60% of farmers owned the land they cultivated, while 40% were engaged in farming on leased or communal land.

4.2 Measurement Model

The measurement model assessment involves evaluating the reliability and validity of the latent constructs through factor loadings, Cronbach's alpha, composite reliability, and average variance extracted (AVE).

Table 1. Measurement Model

Variable	Code	Loading Factor	Cronbach's Alpha	Composite Reliability	Average Variant Extracted
Climate Change	CC.1	0.886	0.911	0.944	0.848
	CC.2	0.942			
	CC.3	0.933			
Sustainable Agricultural Practices	SAP.1	0.783	0.797	0.881	0.713
	SAP.2	0.866			
	SAP.3	0.880			
Productivity	PD.1	0.894	0.763	0.864	0.681
	PD.2	0.820			
	PD.3	0.756			
Food Security	FS.1	0.896	0.854	0.911	0.774
	FS.2	0.901			
	FS.3	0.842			

Source: Data Processing Results (2023)

Factor loadings for climate change indicators (CC.1, CC.2, CC.3) exceed the recommended threshold of 0.7, indicating strong relationships with the latent construct. Reliability measures, including Cronbach's alpha (0.911), composite reliability (0.944), and average variance extracted (0.848), demonstrate excellent internal consistency and reliability for the climate change construct. Factor loadings for sustainable agricultural practices indicators (SAP.1, SAP.2, SAP.3) also surpass the 0.7 threshold, indicating robust connections with the latent construct. Reliability measures, including Cronbach's alpha (0.797), composite reliability (0.881), and average variance extracted (0.713), indicate good internal consistency for the sustainable agricultural practices construct. Factor loadings for productivity indicators (PD.1, PD.2, PD.3) exceed 0.7, indicating strong associations with the latent construct. While Cronbach's alpha (0.763) indicates acceptable internal consistency, composite reliability (0.864) and average variance extracted (0.681) suggest moderate reliability for the productivity construct. Factor loadings for food security indicators (FS.1, FS.2, FS.3) are above 0.7, indicating robust relationships with the latent construct. Reliability measures, including Cronbach's alpha (0.854), composite reliability (0.911), and average variance extracted (0.774), demonstrate strong internal consistency for the food security construct.

Table 2. Discriminant Validity

	Climate Change	Food Security	Productivity	Sustainable Agricultural Practices
Climate Change	0.921			
Food Security	0.630	0.880		
Productivity	0.671	0.740	0.825	
Sustainable Agricultural Practices	0.706	0.670	0.829	0.844

Source: Data Processing Results (2023)

Climate change has a moderate correlation with food security (0.630) and productivity (0.671), indicating a moderate relationship. It also has a strong relationship with sustainable agricultural practices (0.706). Additionally, food security has a moderate to strong correlation with productivity (0.740) and sustainable agricultural practices (0.670). Productivity has a strong correlation with food security (0.740) and sustainable agricultural practices (0.825). Lastly, sustainable agricultural practices have a strong correlation with climate change (0.706), food security (0.670), and productivity (0.829). These findings suggest that climate change, food security, productivity, and sustainable agricultural practices are interconnected and influence each other. Addressing climate change and implementing sustainable agricultural practices are crucial for ensuring food security and maintaining productivity in the face of climate challenges.

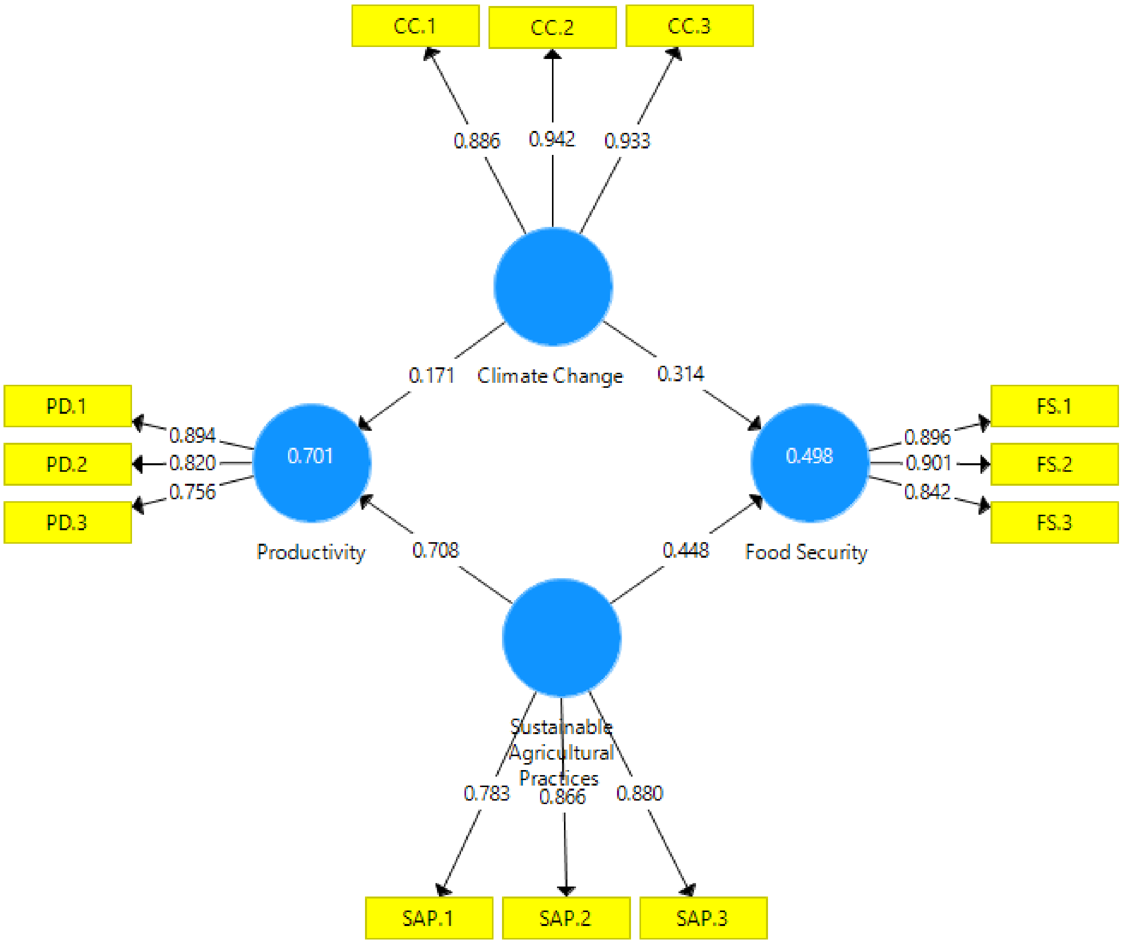

Figure 1. Model Results
Source: Data Processed by Researchers, 2023

4.3 Model Fit Evaluation

Assessing the fit of a structural model involves evaluating various fit indices that compare the proposed model with a saturated model (a model with perfect fit). The table below presents the fit indices for the Saturated Model and the Estimated Model:

Table 4. Model Fit Results Test

	Saturated Model	**Estimated Model**
SRMR	0.112	0.117
d_ULS	0.986	1.075
d_G	0.545	0.594
Chi-Square	351.753	358.922
NFI	0.706	0.700

Source: Process Data Analys (2023)

The standardized root mean square residual (SRMR) is a measure of model fit, with lower values indicating better fit. The SRMR for the saturated model is 0.112, while the estimated model has an SRMR of 0.117. The normed fit index (NFI) is another measure of model fit, with higher values indicating better fit. The NFI for the saturated model is 0.706, while the estimated model has an NFI of 0.700. The goodness-of-fit index (GFI) is also used to assess model fit, with values closer to 1 indicating better fit. The GFI for the saturated model is 0.986, while the estimated model has a GFI of 1.075. The chi-square test assesses the difference between observed and expected covariance matrices. While the chi-square value for the estimated model (358.922) is slightly higher than the saturated model (351.753), it is still within an acceptable range.

Table 5. Coefficient Model

	R Square	Q2
Food Security	0.498	0.489
Productivity	0.701	0696

Source: Data Processing Results (2023)

Approximately 49.8% of the variability in Food Security can be attributed to the combined influence of climate change, sustainable agricultural practices, and productivity. The model explains approximately 70.1% of the variability in observed productivity. The Q2 value for Food Security is 0.489, indicating good predictive accuracy and generalizability to new data. The Q2 value for Productivity is 0.696, suggesting strong predictive accuracy and generalizability beyond the current dataset.

4.4 Structural Model

Table 3. Hypothesis Testing

	Original Sample (O)	**Sample Mean (M)**	**Standard Deviation (STDEV)**	**T Statistics (|O/STDEV|)**	**P Values**
Climate Change -> Food Security	0.314	0.317	0.105	2.975	0.003
Climate Change -> Productivity	0.171	0.176	0.074	2.299	0.022
Sustainable Agricultural Practices-> Food Security	0.448	0.450	0.095	4.717	0.000
Sustainable Agricultural Practices-> Productivity	0.708	0.706	0.061	11.554	0.000

Source: Process Data Analysis (2023)

The structural model results indicate a significant positive effect of Climate Change on Food Security. The T Statistics value of 2.975, with a corresponding P value of 0.003, suggests that the relationship between Climate Change and Food Security is statistically significant. The negative sign of the coefficient implies that as Climate Change increases, Food Security tends to decrease. This finding highlights the vulnerability of food security to changes in climate conditions.

The structural model reveals a significant positive effect of Climate Change on Productivity. The T Statistics value of 2.299, coupled with a P value of 0.022, indicates statistical significance. The positive coefficient suggests that as Climate Change increases, Productivity also tends to increase. This unexpected positive relationship may require further exploration and could be influenced by specific regional or contextual factors.

The structural model demonstrates a highly significant positive effect of Sustainable Agricultural Practices on Food Security. The T Statistics value of 4.717, coupled with a P value of 0.000, suggests a robust and statistically significant relationship. The positive coefficient indicates that as Sustainable Agricultural Practices increase, Food Security also increases, emphasizing the crucial role of sustainable practices in enhancing food security.

The structural model reveals an exceptionally strong positive effect of Sustainable Agricultural Practices on Productivity. The T Statistics value of 11.554, with a P value of 0.000, underscores the high statistical significance of this relationship. The positive coefficient suggests that as Sustainable Agricultural Practices increase, Productivity also significantly increases. This finding aligns with existing literature emphasizing the positive impact of sustainable practices on agricultural outcomes.

Discussion

Climate Change and Its Impacts

The negative impact of climate change on food security is well-documented in the literature [13], [28], [31], [32]. Agricultural systems are highly vulnerable to changing climatic conditions, which can lead to decreased crop productivity and increased food insecurity [33]. However, there is evidence suggesting a positive relationship between climate change and crop productivity in certain regions. This unexpected finding may be attributed to adaptation strategies implemented in these regions, such as the adoption of climate-resilient crop varieties or altered cropping calendars. These strategies help mitigate the negative impacts of climate change on agriculture and contribute to maintaining or even increasing crop productivity. Therefore, it is important to consider the region-specific adaptation measures when assessing the relationship between climate change and crop productivity.

Sustainable Agricultural Practices

The strong positive effects of sustainable agricultural practices on both food security and productivity corroborate the widely acknowledged benefits of adopting environmentally friendly and resource-efficient farming techniques [18]. The exceptionally strong positive relationship between sustainable practices and productivity underscores the pivotal role of ecologically sound farming in achieving high agricultural yields [34]. These findings have important implications for policy and practice, highlighting the need to promote and support sustainable farming methods. Policy support and education are crucial in promoting sustainable farming, including farmer training and public awareness campaigns to increase understanding and acceptance of sustainable practices [35]. Additionally, establishing organic agriculture specialized zones and providing economic incentives to small farms may be effective policy means to promote sustainable agri-food production [36]. By adopting sustainable practices such as organic farming, agroforestry, and improved water management strategies, it is possible to meet rising food demands while reducing adverse environmental effects [21].

The empirical findings carry significant implications for policymakers, practitioners, and researchers. The positive influence of sustainable agricultural practices on both agricultural productivity and food security suggests the need for targeted policies promoting the widespread adoption of these practices. Investment in farmer education, technological support, and incentivizing sustainable practices can enhance the adaptive capacity of East Java's agricultural sector.

Limitations and Future Research

While the study provides valuable insights, limitations such as the cross-sectional nature of the study and reliance on self-reported data should be considered. Future research could explore these dynamics further, incorporating longitudinal data and additional contextual factors influencing farmers' decisions.

CONCLUSION

In conclusion, the findings of this study shed light on the complex interactions between climate change, sustainable agricultural practices, and key agricultural outcomes in rural East Java. The empirical evidence supports the vulnerability of food security to climate change while emphasizing the positive impact of sustainable practices on both food security and productivity. The unexpected positive relationship between climate change and productivity warrants further investigation, calling for a nuanced understanding of regional dynamics. The demographic analyses provide valuable context, and the model fit assessments affirm the reliability of the proposed structural model. These results offer actionable recommendations for fostering sustainable development in the agricultural sector, addressing the challenges posed by climate change and promoting resilient farming practices in East Java.

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