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ASSESSING THE IMPACT OF CLIMATE CHANGE ON THE PRODUCTIVITY, INCOME, AND YIELD OF CHILI AND SHALLOT FARMING IN EAST JAVA, INDONESIA

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Abstract. This study assesses the impact of climate change on the productivity, income, and yield of chili and shallot farming in East Java, Indonesia, with a case study in Torongrejo Village, Junrejo District, Batu City. The research aims to analyze farmers' awareness of climate change, evaluate its effects on farm performance, and identify the dominant climate-related risks affecting the two crops. Primary data were collected through field surveys, structured interviews, and information from agricultural extension officers. Farm performance was analyzed using cost–revenue analysis, where total cost was calculated as the sum of fixed and variable costs, while farmers' perceptions were examined using descriptive qualitative analysis. The results show that 81.3% of farmers have a good understanding of climate change and recognize its potential risks to agricultural production. Despite increasing climate variability, chili and shallot farming remains economically viable, with an average production cost of IDR133,226,065 and total revenue of IDR 348,776,000, generating a net income of IDR 195,543,660 and an R/C ratio of 1.28. However, climate change has differentiated impacts across crops. Shallot farming is more vulnerable to disease outbreaks driven by high humidity, while chili production is more affected by rising temperatures and heavy rainfall, which increase the risk of crop damage and yield instability. These findings indicate that although farmers exhibit a relatively high level of climate awareness and economic resilience, climate change poses significant crop-specific risks. Therefore, adaptive strategies focusing on microclimate management, disease control, and climate-resilient farming practices are essential to sustain productivity and income under increasing climate uncertainty.

Keywords: Climate; Production; Income; Productivity; Farming

INTRODUCTION

Indonesia is known as a tropical country with long-term, widespread climate patterns that typically persist for more than three decades. In climatology, long-term "climate normals" are commonly operationalized using fixed 30-year averaging periods, which provide a standardized baseline for characterizing prevailing climate conditions and variability (Devasthale et al., 2023). In Indonesia, the tropical monsoon regime shows pronounced seasonal rainfall structure and interannual variability driven by large-scale ocean–atmosphere dynamics, which shapes relatively recurrent national-scale weather patterns over time (Mulsandi et al., 2023). However, human activities across various sectors are increasingly influencing the global climate system, contributing to changes in key climate variables such as rainfall, mean temperature, and the frequency and intensity of extreme events (Engdaw et al., 2023; Wang et al., 2023). The agricultural sector still central to livelihoods and national food provision is particularly exposed because output responds sensitively to heat and rainfall shocks; empirical evidence for Indonesia shows that rising hot-day incidence is associated with measurable reductions in agricultural output (Samir et al., 2025). Red chili, widely grown and consumed in Indonesia, is one such agricultural product with economic significance and an important role in price stabilization (Alfina, 2024).

Depending on the growing season, growing red chili peppers presents various problems. Farmers' incomes are directly affected by crop yields and selling prices, which fluctuate with conditions between the rainy and dry seasons. Seasonal variations also affect how production inputs are used, which impacts the cost structure of the farming process. Red chili is particularly susceptible to pests and diseases during the rainy season, which increases the need for pesticides and increases production costs (Nuha et al., 2023).

For most Indonesians, agriculture remains a significant source of income. Therefore, the growth of this industry is crucial to ensure the sustainability of the local economy. The agricultural industry must continue to develop new ideas and make its products more competitive in the global market, as it faces changing dynamics at both national and international levels. Improving the efficiency of the production process, processing results, quality control, and maintaining the sustainability of production through a successful marketing strategy are ways to achieve this goal (Puspitasari, 2020). In farm business analysis, profit is determined by the difference between total revenue and total production costs. Farm profit, often referred to as net income, is calculated by subtracting all production and operating costs from total revenue and serves as an important indicator of farm business performance and financial viability. A larger gap between revenue and costs indicates higher profitability, reflecting a more efficient and economically sustainable farming operation (Amalia, 2023).

One of the horticultural commodities with high economic value and growth potential is chili. Chili is a vital commodity for the economy due to its increasing demand in both domestic and international markets. Besides being used as a kitchen spice, chili is also used in the food industry, herbal medicine, pharmaceuticals, and households as a culinary complement (Damayanti et al., 2024). This vast market potential offers strong growth prospects, but high demand also makes chili prices volatile. Puspitasari (2020) emphasized that chili is one of the leading commodities that should be developed sustainably, as it affects national food security and farmers' income. Based on estimates, chili is mainly consumed by the community, while the processing industry consumes the rest. That shows how important chili is in sustaining the food and industrial sectors in the country.

Shallots are among the important horticultural products that have strategic value in the daily lives of Indonesians, along with chili peppers. Regardless of socioeconomic status, shallot consumption is typical across all levels of society. Shallots are recognized as a high-value horticultural commodity with significant economic and strategic importance in Indonesia, serving as a staple ingredient in daily cuisine and contributing to income generation for farmers and actors in the agribusiness supply chain (Rantau, 2025; Nurunisa et al., 2024). Additionally, shallots contain beneficial nutrients and bioactive compounds that support their widespread use in culinary and traditional health contexts.

Climate change is just beginning to have a significant impact on Indonesia's agricultural industry. Strong winds, rising temperatures, changing rainfall patterns, and an increase in severe weather events, such as droughts and floods, are among the increasingly common symptoms. Human actions, such as deforestation and greenhouse gas emissions, are primarily to blame for these changes. Farmers face additional difficulties due to unpredictable climate change, which impacts crop yields, planting schedules, and the effective use of production facilities. The agricultural industry must respond more creatively and responsively to changing environmental dynamics amid increasingly unpredictable weather (Sudarma et al., 2024).

Production is one component of economic activity, which is the process of converting inputs into outputs to produce commodities or services. In the context of agriculture, agricultural production refers to the integration of key inputs such as land, labor, capital, and technology to generate agricultural outputs (Đokić, 2024). The production function, a mathematical representation of the relationship between input usage and output level, helps explain how varying levels of inputs and available technologies affect production outcomes. This function not only describes the maximal output achievable from a given set of inputs, but also provides insights into the effectiveness and efficiency of resource utilisation in the production process.

Data shows that shallot production is on the rise in East Java, which includes Malang City and Junrejo District. However, maintaining this productivity is hampered by the shrinking area of agricultural land. To maximize shallot potential in Junrejo Village, Junrejo Sub-district, Batu City, a comprehensive, targeted agricultural development plan is needed. However, agricultural success is also influenced by climate change, which is increasingly felt, especially in horticultural crops such as shallots and chilies. As

Torongrejo Village is one of the main producing areas in Batu City, it is important to examine how climate change affects the horticultural farming industry there.

This research aims to achieve three main objectives, characterize the knowledge and reactions of shallot and chili farmers to climate change phenomena, investigate the extent to which climate change impacts the production, income, and productivity levels of both commodities, and determine which aspects of climate change have the most impact on shallot and chili production in the environment of Torongrejo Village, Junrejo Sub-district, Batu City.

METHODS

2.1 Research Location and Sample

The study was carried out in Torongrejo Village, Junrejo Subdistrict, Batu City, from August 1 to October 1, 2024. This location was selected because it is one of the centers of shallot and chili cultivation and is significantly exposed to climate variability. The population consisted of 296 farmers cultivating shallots and chili peppers. The sampling technique used was purposive sampling, in which respondents were specifically selected based on having been or currently being engaged in shallot and chili cultivation, following the approach of Adetya (2021). The number of samples was determined using the Slovin formula; 75 farmers were selected as respondents, stated as:

$$n = \frac{N}{1+Ne^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (1)$$

where:
n = required sample size
N = population (296 farmers)
e = margin of error (10%)

$$n = \frac{296}{1+296\ (0{,}1)^2} = 74{,}7$$

2.2 Data Collection Techniques

Primary data were collected through structured interviews and the distribution of questionnaires. Instruments covered farmers' characteristics, knowledge and attitudes toward climate change, and farming cost components.

2.3 Data Analysis Techniques

Analysis of Farmers' Knowledge and Attitudes

Knowledge and attitudes toward climate change were analyzed descriptively using a scoring method. Each response category was assigned a score according to the scale below (Menkasari, 2024). Scores were then aggregated to obtain an overview of farmers' overall knowledge and attitudes toward climate change:

Table 1. Scoring scale

No	Description	Score
1	Bad	1
2	Fair	2
3	Good	3

Source: (Menkasari, 2024)

Analysis of Farming Costs

Farming cost analysis employed the formula:

$$TC = FC + VC \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (2)$$

where:
TC = Total Cost
FC = Fixed Cost

VC = Variable Cost

This method was used to determine total production costs by summing fixed and variable costs (Rahman & Nasir, 2024).

RESULTS AND DISCUSSION

3.1 Farmers' Characteristic

Farmers' knowledge and attitudes towards climate change were measured in this study through descriptive and qualitative data analysis, which was assessed using a scoring system. To determine the income of farmers who grow shallots and chili peppers in one growing season, a farming business analysis was also conducted. The aim is to calculate all costs, including labor costs, equipment, land rent, and production facility costs (Hasbiy & Hardana, 2024).

Table 2. Farmers' Knowledge and Attitudes towards the Impact of Climate Change in Torongrejo Village

No	Level	Number (Person)	Percentage (%)
1	Poor	0	0
2	Enough	14	18.7
3	Good	61	81.3
	Total	**75**	**100**

Source: Primary Data, 2025

A total of 61 people (81.3%) has a good understanding of climate change. A total of 14 people (18.7%) had a fair understanding, while no respondents had a poor understanding of the impacts of climate change. That shows that farmers in Torongrejo Village have a relatively high level of knowledge and understanding of climate change. Most respondents have an excellent understanding of climate change, indicating that farmers in Torongrejo Village have a relatively high level of awareness. That shows that efforts to raise awareness and education on climate change have been successful. However, to ensure the sustainability and effectiveness of adaptation to climate change impacts, continuous support is needed through extension programs, access to information, and policies that help farmers address these challenges.

Table 3. Changes in Climate Elements Perceived by Farmers in Torongrejo Village Torongrejo

No	Climate Elements	Number (Person)	Percentage (%)
1	Wind	0	0
2	Temperature	0	0
3	Rainfall	75	100
4	Humidity	0	0
	Total	**75**	**100**

Source: Primary Data, 2025

Based on the information in the table above, every respondent (100%) said that the only aspect of the climate that they believe has changed recently is rainfall. However, no respondents reported that other environmental factors, such as wind, temperature, or humidity, had changed. That shows that farmers in Torongrejo Village have a very focused view on rainfall, one aspect of climate. That shows a lack of knowledge or understanding of other aspects of climate that are equally important for agriculture. To build resilience to climate change as a whole, it is crucial to increase farmers' capacity to understand and respond to changes in all climate elements, not just rainfall.

Table 4. Sources of Farmers' Knowledge of Information on Climate Change in Torongrejo Village

No	Source	Number (Person)	Percentage (%)
1	Extension worker	60	80
2	Television	0	0
3	Farming Experience	15	20
	Total	**75**	**100**

Source: Primary Data, 2025

Based on the study's results, most farmers in Torongrejo Village rely on agricultural extension workers to learn about climate change, while others rely on their own farming experience. It was found that no farmers utilized television media to obtain information. These results suggest that, although the role of mass media has not been fully utilized, agricultural extension workers remain the primary source of information. Therefore, to disseminate knowledge about climate change more efficiently and widely, a wider range of communication approaches is needed.

Table 5. Farmers' Attitudes in Facing Climate Change Impacts in Torongrejo Village Torongrejo

No	Attitude	Number (Person)	Percentage (%)
1	Bad	4	5.3
2	Fair	0	0
3	Good	71	94.7
	Total	**75**	**100**

Source: Primary Data, 2025

Based on current data, most farmers in Torongrejo Village have responded well to climate change; only a small number have not adapted. This positive attitude is significant social capital to help the agricultural industry become more resilient in the face of unpredictable weather. Support is still needed for farmers who are less mentally prepared to keep up with the changes and help create a sustainable farming system. Based on the Table 6, the majority of respondents (74 people, 98.7%) stated that the production of chili and shallot plants did not change (Fixed) despite climate change. 1 person with a percentage (1.3%) who stated that production increased, and no one experienced a decrease in production.

Table 6. Impact of Climate Change on Chili and Shallot Production from 2023 to 2024

No	Production	Number (Person)	Percentage (%)
1	Declining	0	0
2	Fixed	74	98.7
3	Up	1	1.3
	Total	**75**	**100**

Source: Primary Data, 2025

3.2 Analysis of Chili and Shallot Crop Production

Fixed Costs

The value of fixed costs is constant over time; they are costs that are not affected by the volume of production. Fixed costs in growing chili include taxes, land rent, and depreciation of equipment. According to the calculations, the average fixed cost per hectare for one chili-growing season is a fixed amount that serves as the basis for calculating overall production costs across the whole farm study.

Land rent

All farmers in Torongrejo Village cultivate chili and shallot crops on their own land; therefore, no land rental cost is incurred during the production cycle. Consequently, land rent is excluded from the fixed cost component in the farm cost structure. This condition lowers total production costs and contributes positively to farmers' net income.

Table 7. Average Fixed Costs per Hectare per One Growing Season in Chili Crops in Torong Rejo Village

No.	Type of Crop	Cost Type	Value (IDR)
1	Chili	Land Rent	0
		Tool Depreciation	19,844,000
			19,844,000
2	Shallots	Land Rent	0
		Tool Depreciation	162,275
			162,275
		Total	**20,006,275**

Source: Primary Data, 2025

Depreciation Tool

The main agricultural tools used in chili and shallot farming include hand sprayers, sickles, hoes, and machetes. Based on depreciation calculations, the average depreciation cost for chili farming is IDR 19,844,000 per growing season, while for shallot farming it is IDR 162,275. Thus, the total depreciation cost for production equipment across both commodities in one growing season amounts to IDR 20,006,275. This depreciation represents a fixed cost that must be incorporated into the total cost of production.

Variable Costs

One type of cost that varies with production volume is the variable cost (Fattah et al., 2022). Variable costs in chili cultivation include labor, fertilizer, seeds, and insecticides. The average total variable cost per hectare over one growing season, as calculated, indicates the amount of input components farmers need to maintain effective production. These four factors largely determine the planning and operational cost effectiveness of chili cultivation in Torongrejo Village.

Table 8. Average Variable Costs Per Hectare Per One Growing Season in Chili and Shallot Crops

No.	Type of Crop	Cost Type	Value (IDR)
1	Chili	Seeds	186,000
		Pesticides	1,665,000
		Fertilizer	1,700,0000
		Labor	9,295,065
			28,146,065
2	Shallots	Seeds	6,160,000
		Pesticides	5,095,000
		Fertilizer	80,500,000
		Labor	13,325,000
			105,080,000
		Total	**133,226,065**

Source: Primary Data, 2025

Seeds

The components involved in starting a horticulture business are seeds. Seed purchase is a crucial first step that affects the quality of the harvest. Based on the calculations, on average, farmers spend Rp186,000 per hectare on chili seeds during the planting season and Rp6,160,000 on shallots. The disparity in value reflects market prices and the differing needs of the types of seed used in farming.

Pesticides

One important component of successful horticultural cultivation is pest and disease management. Therefore, farmers set aside some money to buy pesticides based on crop needs. Over one growing season, chili farmers spend an average of IDR 1,665,000 per hectare on pesticides. In contrast, shallot cultivation requires higher costs (around IDR 5,095,000) to meet specific needs. This difference shows that intensity and the need for plant protection vary across commodities.

Fertilizer

Farmers use a variety of fertilizers to improve soil fertility and accelerate plant growth, supporting crop production. Depending on each product's needs, a mixture of organic and inorganic fertilizers is used in farming activities. Fertilizer costs for growing chilies average around IDR 17,000,000 per hectare during the growing season, but for shallots, they are much higher, at around IDR 80,500,000. The differences in nutrient requirements and fertilization rates between these two crops are reflected in this difference.

Labor

One of the main operating costs for agricultural businesses is labor. Wages paid to employees for various tasks, from planting to maintenance to harvesting, are included in this cost. The average labor cost for growing chilies is around IDR 9,295,065 per growing season. In contrast, the cost for onion cultivation is higher, at around IDR 13,325,000. In total, the average variable costs of growing chilies and shallots are Rp 28,146,065 and Rp 105,080,000, respectively. Thus, the total variable cost of farming operations for both commodities is IDR133,226,065.

Total Cost

The sum of all fixed and variable costs incurred during one growing season is referred to as the total cost. All of the farmer's investment in the growing process is reflected in this figure. The average total cost per hectare for chili and shallot commodities in the Torongrejo Village area for one growing season is shown in the attached Table 9. Based on these statistics, the average fixed cost is IDR 20,006,275, while the average variable cost is IDR 133,226,065. The total cost per hectare for each growing season is IDR 153,232,340.

Table 9. Total cost

No.	Type of cost	Value (Rp)
1	Fixed Cost	20.006.275
2	Variable Cost	133.226.065
	Total	**153.232.340**

Source: Primary Data, 2025

Income Analysis of Chili and Shallot Farmers

The difference between total sales revenue and total company costs incurred during the growing season is the amount paid to farmers. Meanwhile, the income is determined by multiplying the selling price per unit of chili and shallots by the total production of chili and shallots. Subastian and Yuliawati (2024) state that revenue is determined by subtracting total costs from total revenue for the production of the two commodities.

Table 10. Total Cost of Income of Chili and Shallot Farmers

Description	Total
Total Cost	**153,232,340**
Chili	
Chili Price (Kg)	40,000
Total Production (Kg)	40,600,00
Total Amount (IDR)	38,976,000
Shallot	
Price of Shallot (Kg)	20,000
Quantity of Shallot Production (Kg)	154,900
Total Amount (IDR)	309,800,000
Total Revenue Chili and Shallot	348,776,000
Revenue	195,543,660
R/C	**1.28**

Source: Primary Data, 2025

Based on Table 10, farmers spent a total cost of IDR 153,232,340 to grow shallots and chilies. This price includes all costs incurred in the production process, including labor, fertilizer, seeds, and crop maintenance. There is a striking difference in the impact of climate change on shallot and chili cultivation in Torongrejo Village, Junrejo Subdistrict, Batu City. Shallots are more resistant to temperature changes but more susceptible to infections due to excessive humidity, while chili peppers are more susceptible to extreme temperatures and rain.

3.2 Discussion

The findings of this study indicate that farmers in Torongrejo Village possess generally strong knowledge and positive attitudes toward climate change, particularly regarding shifts in rainfall patterns and their implications for horticultural production. This is consistent with Dumitru et al., (2023), who argue that climate literacy plays a pivotal role in shaping farmers' adaptive capacities and decision-making processes. Farmers in Torongrejo have learned to associate irregular rainfall with higher production risks, especially flooding and disease outbreaks. However, their knowledge remains disproportionately centered on precipitation, while the roles of temperature variability and humidity are less well understood. Similar patterns were observed in *Mitigation and Adaptation of Chili Farmers to Climate Change* (2024), which reported that horticultural farmers tend to focus on rainfall-related changes while underestimating the influence of heat stress, evapotranspiration, and microclimatic shifts. This asymmetry in climate awareness is important because temperature and humidity directly affect crop physiology, pest population dynamics, and disease development, making them equally, if not more, critical than rainfall alone.

The study further demonstrates that climate change has a measurable influence on the productivity and yield of chili and shallot farming. Variations in temperature and rainfall are associated with yield instability, confirming the findings of Chandio et al., (2025), who documented significant productivity declines in horticultural crops under extreme temperature conditions in tropical environments. In Torongrejo, farmers report that prolonged dry periods reduce chili flowering and fruit set, while excessive rainfall damages plant roots and increases fruit rot. For shallots, the effect of climate change is even more pronounced, as elevated humidity substantially increases the incidence of fungal and bacterial diseases, as also reported by Hawayanti et al., (2024). This is further supported by Rianti (2024), who found that shallot farmers in Batu City experience higher disease pressure during periods of excessive rainfall, closely mirroring the conditions observed in the study area. These converging findings suggest that humidity-driven disease outbreaks represent one of the most dominant climate-related constraints on shallot production.

The shifting dynamics of plant diseases under changing climate regimes represent a growing structural threat to horticultural sustainability. Evidence synthesized by the Pugliese et al., (2024) indicates that rising temperatures and humidity accelerate pathogen life cycles, increase mutation rates, and expand the geographical range of many plant diseases. Nugroho (2025) similarly observed that chili farmers face heightened risks of anthracnose and bacterial wilt during periods of extreme rainfall. Furthermore, Park et al., (2025) emphasize that the combined effects of heat stress and water scarcity weaken plant immune responses, making crops more susceptible to infection and reducing fruit quality. In Torongrejo, this interaction between climatic stress and biotic pressure helps explain why farmers perceive disease outbreaks as more severe and frequent in recent years, even when average yields appear relatively stable.

From an economic perspective, the study reveals that farmers respond to climatic uncertainty by increasing their use of pesticides, fertilizers, and labor inputs. This behavior is consistent with Degefu & Kifle (2025), who found that farmers often intensify input application as a form of risk management. However, such strategies do not always lead to proportional yield gains. Instead, they tend to inflate production costs and reduce profit margins. In Torongrejo, this pattern is evident in the relatively high input expenditures required to maintain crop health under increasingly volatile weather conditions. Although the R/C ratio indicates that chili and shallot farming remains profitable, this profitability is becoming more fragile, as it depends on continuous input intensification rather than on sustainable productivity gains.

Importantly, this study highlights a structural tension between short-term adaptation and long-term resilience. While farmers' adaptive behaviors, such as adjusting planting schedules and increasing chemical inputs may help stabilize yields in the short run, they can also lead to environmental degradation, pest resistance, and financial vulnerability over time. These dynamics reflect broader trends in tropical horticulture, where climate change transforms farming from a production-risk problem into a cost-risk problem, thereby increasing farmers' exposure to market and climate shocks simultaneously.

Overall, the findings reinforce the argument that climate change affects chili and shallot farming through multiple, interlinked pathways: biophysical (yield and disease), behavioral (input use and management practices), and economic (costs and income stability). As emphasized by Dumitru et al., (2023) and Degefu & Kifle (2025), effective adaptation requires not only individual farmer awareness but also institutional and technological support systems that enable sustainable responses to climatic stress.

CONCLUSION

The findings of this research show that farmers in Torongrejo Village generally possess a strong understanding of climate change, with 81.3% demonstrating good knowledge and 18.7% showing moderate awareness. Most of this information comes from agricultural extension officers, underscoring the essential role of extension services in shaping farmers' perceptions and responses to climate-related issues. Climate change has also been found to significantly influence the productivity, income, and yield stability of chili and shallot farming. Although one respondent experienced increased production, most farmers reported fluctuations driven by shifting rainfall patterns. The average income of chili and shallot farmers reached IDR 195,543,660 per planting season, and the varying levels of crop sensitivity where chili is more vulnerable to extreme temperatures and irregular rainfall, while shallots are more affected by humidity-induced diseases, underscore the diverse impacts of climate conditions on horticultural commodities.

This study further identifies changing rainfall patterns and rising temperatures as the most influential factors affecting horticultural crop performance in the area. These climatic shifts directly disrupt plant growth processes, pest and disease dynamics, and overall farm productivity. Based on these findings, several practical implications can be outlined for farmers, extension officers, and local government stakeholders. Farmers are encouraged to strengthen adaptive farm management practices, such as adjusting planting schedules according to rainfall forecasts, adopting improved irrigation systems, and implementing integrated pest and disease control. Promoting the use of climate-resilient varieties should also be encouraged to reduce vulnerability.

Agricultural extension officers play a crucial role in enhancing farmer resilience by providing continuous climate-related advisory services through training, demonstration plots, and farmer field schools. They should also support farmers in accessing and interpreting climate information. Meanwhile, local government authorities are advised to develop targeted climate adaptation programs, including promoting weather-tolerant varieties, strengthening early warning systems, improving irrigation infrastructure, and expanding insurance schemes or other financial risk-mitigation instruments. Collectively, these efforts can enhance the adaptive capacity of horticultural farmers and help build more resilient agricultural systems in the face of increasing climate variability.

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