I. INTRODUCTION

1.1. Background

The agricultural sector has a strategic role in meeting national food needs, where rice is the main commodity that supports food security in Indonesia. Most Indonesian farmers rely on rice crops as the main source of income for farmers (Wahyuni et al., 2024). Along with population growth and increasing per capita rice consumption, the demand for rice will continue to increase every year. Increasing the productivity of rice farming is an important factor in maintaining food availability while improving the welfare of farmers. Not only does it have implications for the stability of national food security, but it also contributes to rural economic growth through increasing income, job creation, and strengthening the agribusiness system. If rice production is insufficient, it can have an impact on various aspects of people's lives, both in terms of economy, environment, and social.

Challenges in increasing farming productivity do not only come from factors that can be controlled by farmers, but can also come from factors beyond the control of farmers, one of which is the occurrence of climate change. Climate change is a big challenge for the agricultural sector because it has a direct impact on planting patterns, productivity, and the quality of production products. Climate change has a direct impact on the production of food crops, especially rice (Zaini and Saitama, 2023). Increased air temperatures, changes in rainfall patterns, prolonged drought, and increased attacks of plant-pesting organisms are the main obstacles for farmers in carrying out farming optimally. The agricultural sector is particularly sensitive to the impacts of climate change because it relies on the water and weather cycles

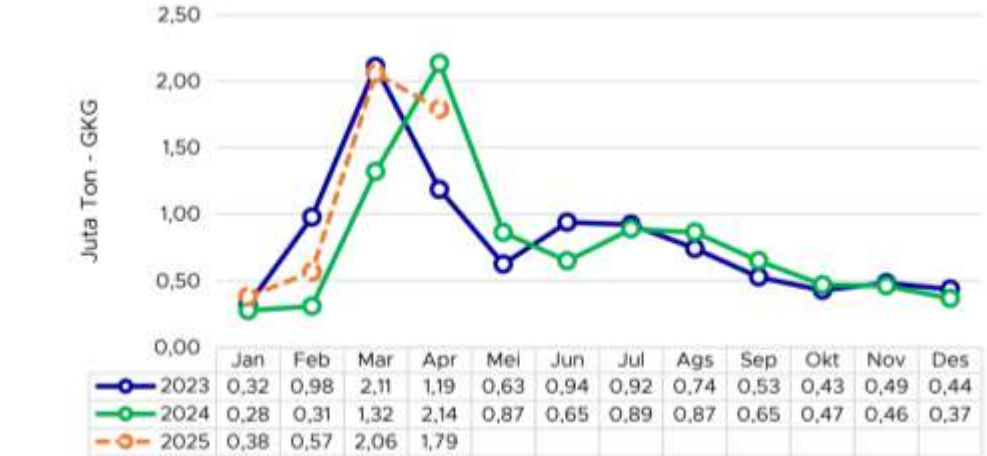
to maintain its productivity (Arham and Adiwibowo, 2022). In addition, the impact of climate change on the agricultural sector is very diverse, including aspects of resources, agricultural infrastructure, production systems, food security, farmers' welfare, and society as a whole (Raihannur and Nadhira, 2025). Climate change is predicted to have a negative impact on various aspects of life and the development sector, especially in the agricultural sector, and has the potential to pose new challenges for the sustainability of agricultural product production, especially food (Asir et al., 2022).

International Panel for Climate Change (IPCC) (2023), explaining that climate change manifests itself in various forms, such as rising global average temperatures, changes in rainfall patterns, increasing the frequency and intensity of extreme weather events (e.g. floods, droughts, and heat waves), and rising sea levels (Raihannur and Nadhira, 2025). Rainfall is one of the main factors that determine the high and low productivity of rice. Excessive rainfall intensity can reduce production yields, as these conditions make plants more susceptible to pest and disease attacks thereby reducing the quantity of harvest (Widiarta, 2016). In addition, excess water in the land also has the potential to trigger the process of nutrient leaching, erosion, floods, and landslides. The prolonged dry season also has a negative effect on rice productivity. Drought that occurs due to the lack of water availability in the land can cause rice plants to dry out, wither, and potentially fail to harvest (Dewanti et al., 2024).

Based on data from the Central Statistics Agency (BPS), East Java Province has consistently become the province with the highest rice production in Indonesia. This can be seen from its production achievement which is in the range of 9.5 to 10 million tons of Milled Dry Rice (GKG) every year. In 2021, East Java's rice

production reached around 9.79 million tons of GKG, then in 2022 it was recorded at 9.52 million tons of GKG, and in 2023 it increased again to around 9.72 million tons of GKG. This achievement places East Java as the largest contributor to national rice production with a contribution of around 17-18% every year, thus strengthening its role as one of the main rice barns in Indonesia.

East Java Province will experience a significant decline in rice production in 2024. The development of rice production in East Java Province in the last three years shows that there are quite real fluctuations. In 2023, rice production is still relatively stable, but in 2024 it will decline before returning to the projected increase in 2025. This dynamic reflects the influence of climate factors, land availability, and the effectiveness of the application of agricultural technology on the rice production system. East Java Province rice production data for 2023 – 2025 is presented in figure 1.1.



	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Ags	Sep	Okt	Nov	Des
2023	0,32	0,98	2,11	1,19	0,63	0,94	0,92	0,74	0,53	0,43	0,49	0,44
2024	0,28	0,31	1,32	2,14	0,87	0,65	0,89	0,87	0,65	0,47	0,46	0,37
2025	0,38	0,57	2,06	1,79								

Keterangan: [1] Produksi padi Januari–April 2025 adalah angka sementara
Perbedaan angka di belakang koma disebabkan oleh pembulatan angka

Figure 1.1 Development of Rice Production in East Java Province (million tons-GKG) in 2023-2025
Source: Central Statistics Agency of East Java Province, 2024

Figure 1.1 shows that throughout 2024, rice production in East Java Province will reach around 9.28 million tons of dry milled grain (GKG), a decrease of 0.44

million tons of GKG (4.53%) compared to 2023 which reached 9.72 million tons of GKG. The lowest production was recorded in January at 0.28 million tonnes of GKG, then increased to peak in April at 2.14 million tonnes of GKG, before declining and stabilising in the range of 0.65 – 0.89 million tonnes of GKG from May to August. The downward trend continued until the end of the year, with production in December amounting to 0.37 million tons of GKG. This pattern shows seasonal fluctuations influenced by rainfall factors, land readiness, and availability of production inputs, while provisional data from January to April 2025 show a higher production trend compared to the same period in 2024.

In general, East Java Province will experience a decline in rice production in 2024, but different conditions occur in Sidoarjo Regency. According to data from the Central Statistics Agency of East Java Province in 2024, Sidoarjo Regency is one of the districts in East Java that has experienced an increase in rice production. Rice production in Sidoarjo Regency will increase from 195.8 thousand tons of GKG in 2023 to 197.8 thousand tons of GKG in 2024. The selection of Sidoarjo Regency as the focus of discussion is based on its strategic position as one of the main buffer areas for food needs in the Gerbangkertosusila area (Gresik, Bangkalan, Mojokerto, Surabaya, Sidoarjo, and Lamongan), as well as its unique characteristics as a productive agricultural area in the midst of the rapid development of industrial areas and urbanization. Sidoarjo Regency also has a large area of technically irrigated rice fields with high planting intensity, so that it is able to maintain a significant contribution to regional rice production (Rustianingsih, 2024).

The increase in rice production did not occur evenly throughout the Sidoarjo Regency area, different conditions occurred in Buduran District which actually experienced a decrease in rice production in the same year. Buduran District is one

of the areas that contributes to rice production in Sidoarjo Regency. Based on data from BPS Sidoarjo Regency (2024), the area of rice fields in Buduran District reaches around 487 hectares with the number of rice farmers of more than 600 people who are members of several farmer groups. The decline in agricultural production and the decrease in agricultural land area in Buduran District can be seen in table 1.1.

Table 1.1 Changes in Land Area and Rice Production in Five Districts in Sidoarjo Regency in 2023 and 2024

Districts	Land Area (Ha)		Wide Change	Rice Production (Tons)		Production Change
	2023	2024	(%)	2023	2024	(%)
Buduran	505	487	-3,56	6,612	6,437	-2,65
Sidoarjo	552	539	-2,36	3,955	3,913	-1,06
Waru	276	269	-2,54	1,977	1,938	-1,97
Taman	260	255	-1,92	1,876	1,841	-1,87
Jabon	828	809	-2,29	5,937	5,907	-0,51

Source: BPS Sidoarjo Regency, 2023 and BPS Sidoarjo Regency, 2024

Table 1.1 shows changes in land area and rice production in five sub-districts in Sidoarjo Regency in 2023 and 2024. In general, 5 sub-districts experienced a decrease in land area and rice production, although with varying levels of decline. The most significant decline occurred in Buduran District, both on land and production, indicating that there is heavier pressure than other areas. Buduran District experienced the largest decline, namely the land area decreased by 3.56% and rice production decreased by around 2.65%. The vulnerability of Buduran District to climate change is not only reflected in the decrease in land area and rice production, but also from the increasing frequency of natural disaster events presented in Table 1.2.

Table 1.2 Number of Natural Disaster Incidents in Five Districts in Sidoarjo Regency in 2023 and 2024

Districts	Natural Disaster Events	
	2023	2024
Buduran	5	9
Tulangan	4	4
Prambon	3	5
Gedangan	5	6
Garden	3	3

Source: National Disaster Management Agency, 2025

Table 1.2 shows the number of natural disaster events in five sub-districts in Sidoarjo Regency in 2023 and 2024. Based on data, Buduran District again occupies the most vulnerable position, as shown by an increase in the number of disaster events from 5 incidents in 2023 to 9 incidents in 2024. Based on data from the Regional Disaster Management Agency (BPBD) of Sidoarjo Regency, natural disasters that occurred in Buduran District in 2023 and 2024 were dominated by flash floods, droughts, and tornadoes. This surge in incidents shows an increase in environmental vulnerability that is not in line with the stability of agricultural production. The increase in the frequency of disasters greater than other sub-districts can be caused by geographical factors in Buduran District which is prone to flash floods, waterlogging, or extreme climatic phenomena such as erratic rainfall. This condition further exacerbates the pressure on the agricultural sector, especially rice, because disasters have a direct impact on reduced planting area, decreased productivity, and increased risk of crop failure. Based on these conditions, Buduran District is a clear example of an area that faces the dual challenge of declining agricultural productivity as well as increasing the threat of climate disasters.

The relationship between the decrease in production and the increase in the frequency of disasters that occur in Buduran District is even stronger when

associated with the results of the study Aditya et al., (2021), explaining that the uncertainty of rainfall and high climate variability can affect rice productivity. Aditya et al., (2021) revealed that rainfall variability and high climate variability, especially in the critical months of the growing season, can disrupt the growth process of rice crops, reduce water availability, and increase the risk of crop failure. The study confirms that rainfall instability as well as climatic anomalies such as El Nino, La Nina, and Dipole Mode can reduce rice productivity through disturbances in the vegetative and generative phases of plants. This finding provides a scientific basis that climate change events, one of which is changes in rainfall patterns, are crucial factors that contribute to fluctuations in rice production.

The decrease in production in Buduran District is a shift in rainfall patterns and drought prone which increases the risk of crop failure (Dewanti et al., 2024). Data from the Meteorology, Climatology, and Geophysics Agency (BMKG) in the Buduran District area shows that there is a negative rainfall anomaly in the main planting season, which has an impact on planting delays and a decrease in harvest intensity. The uncertainty of rainfall in Buduran District causes farmers to have difficulty in determining the right time to start the planting season, as well as increasing the possibility of crop failure due to erratic rains that last for a long time (Dewanti et al., 2024).

Rainfall is one of the main factors that determine the high and low productivity of rice. Excessive rainfall intensity can reduce production yields, as these conditions make plants more susceptible to pest and disease attacks thereby reducing the quantity of harvest (Widiarta, 2016). In addition, excess water in the land also has the potential to trigger the process of nutrient leaching, erosion, floods, and landslides. The prolonged dry season also has a negative effect on rice productivity.

Drought that occurs due to the lack of water availability in the land can cause rice plants to dry out, wither, and potentially cause crop failure (Dewanti et al., 2024).

According to the BMKG report in 2024, the average temperature will increase by around 0.2°C to 0.3°C every decade, with predictions of temperature rise that will continue in the future. The increase in temperature in Buduran District in 2024 is caused by a combination of global warming due to greenhouse gas emissions and regional climate anomalies El Nino and La Nina (Aditya et al., 2021). This increase in temperature has the potential to reduce agricultural production, especially food crops such as rice which are very sensitive to temperature changes. IPCC (2021) also states that an increase in temperature of more than 1°C can potentially reduce rice production in Indonesia by up to 4–6% per hectare. The impact of increased air temperature on the growth and yield of rice crops is not only felt at the individual plant level, but can also affect productivity and overall harvest quality (Nurhidayat et al., 2024).

Higher climate variability also increases production risks. Rahman et al., (2017) reveals that temperature and precipitation variability explain up to 41–49% of rice yield variability, with a tendency to increase minimum temperature and decrease Diurnal Temperature Range (DTR) which has a negative impact on productivity. Arya et al., (2020) also states that in the South Asian region, especially in India, Nepal, and Pakistan, a temperature increase of 1.5–2°C accompanied by changes in rainfall patterns can reduce rice yields by 6–8% and increase the frequency of extreme climatic events, such as droughts and floods, leading to degradation of rice fields and shortening of the planting season. The geographical location of Buduran District, which is located in a lowland area with relatively high tropical rainfall, causes the water distribution system on agricultural land to be

greatly influenced by the dynamics of rainfall and surface flow, so that increased climate variability has the potential to directly disrupt the stability of rice production in Buduran District.

The impact of climate change not only impacts farming activities, but also threatens the sustainability of the agricultural sector as a whole by affecting economic, social, and environmental aspects. Climate change has a real impact on the economic aspects of rice farming in Buduran District, especially through a decrease in farmers' income due to crop failure and increased production costs due to climate change. This condition is increasingly felt when the phenomenon of wet drought occurs in Buduran District, which causes rainfall to remain high in the dry season so that agricultural land is flooded and disrupts the rice cultivation process. The statement of Bayu Dwi, an agrometeorologist quoted from Kompas.com, corroborated that the phenomenon of wet drought can have an impact on crop failure, because high rainfall in the dry season causes agricultural land to be flooded and disrupts the food production process. This condition encourages an increase in the risk of planting failure and uncertainty of production results, which ultimately puts great pressure on the economic aspects of farmers and poses serious challenges to the sustainability of rice farming in the Buduran District area.

Climate change has a significant impact on the social aspects of rice farmers in Buduran District, Sidoarjo Regency, especially at the individual and household levels of farmers. Uncertainty in the planting season, shifts in rainfall patterns, and increasing frequency of disasters such as floods and droughts cause farmers to make various forms of adaptation, both socially and behaviorally. This condition gives rise to psychological pressure in the form of anxiety about crop success and income uncertainty, which indirectly affects social stability and decision-making in farmer

families. Sheikh et al., (2024) states that the perception of climate risk drives farmers to adapt, but access to knowledge and social support greatly influences the success of such adaptation. This condition is reflected in rice farmers in Buduran District, farmers who have good knowledge and social networks tend to be more responsive in anticipating risks, while farmers with limited resources are the most vulnerable group to the impact of climate change. Therefore, the social dimension in the context of climate change in Buduran District is not only related to interaction between farmers, but also reflects the capacity of individuals and communities in responding to increasing environmental pressures.

The environmental aspect is also experiencing significant pressure due to climate change, especially in the rice farming area in Buduran District, Sidoarjo Regency. Climate change accelerates the destruction of soil structures, decreases the content of organic matter, reduces water availability, and disrupts the balance of agricultural ecosystems (Suhaini et al., 2025). The environmental pressure is increasingly evident in Buduran District, as conveyed by the Head of the Sidoarjo Regency DKPP, Dr. Eni Rustianingsih who was quoted from the Republic of East Java, around 1.000 hectares of rice land are experiencing drought to cracks that have the potential to cause crop failure. Meanwhile, some agricultural areas in Buduran District also experienced flooding due to high rainfall. The phenomenon between drought and flooding in one region shows the high vulnerability of the agricultural environment to climate change. This condition confirms that climate change not only threatens the productivity of rice fields in Buduran District, but also disrupts the sustainability of the agricultural ecosystem as a whole. These environmental pressures pose a major challenge to the future of the agricultural

sector, where food security and farmers' well-being are increasingly vulnerable to extreme climate fluctuations (Ikhwali et al., 2022).

Understanding and implementing rice cultivation practices that are adaptive to the dynamics of climate change is an important component in maintaining the sustainability of farming. Research in Vietnam shows that increasing farmers' awareness of climate change risks plays an important role in driving the adoption of various adaptation strategies, such as the selection of tolerant varieties, adjustment of planting patterns, and more efficient water management (Hue et al., 2024). These findings confirm that the higher the climate literacy farmers have, the greater their ability to make appropriate cultivation decisions and be responsive to changing climate conditions. Therefore, strengthening climate literacy for rice farmers in Buduran District is a very important aspect to increase the resilience of farming to increasingly uncertain climate risks.

Conversely, low levels of farmers' awareness can lead to delays in responding to changes in extreme weather patterns, which ultimately increases the risk of crop failure and lowers productivity. Therefore, increasing climate literacy and adaptive agricultural extension are key in strengthening farmers' ability to face increasingly uncertain climate dynamics. Understanding the impact of climate change on the agricultural sector is an important basis for formulating appropriate mitigation strategies to ensure the sustainability of national food systems amid global uncertainty.

Mitigation is a strategic effort to prevent various risks that can potentially suffer losses (Arsyadona et al., 2025). Mitigation also includes efforts to reduce greenhouse gas emissions so that they can reduce the negative impact of climate change that occurs in Buduran District. The importance of mitigation strategies is

increasingly evident because climate change has posed a major threat to the sustainability of agriculture, especially key food commodities such as rice. Emeliani et al., (2025) emphasizing that farmers' level of knowledge and awareness of climate change risks plays an important role in improving their ability to adapt, so that farming becomes more resilient to various climate pressures. Without a mitigation strategy, farmers will be more vulnerable to the risk of crop failure, decreased productivity, increased production costs, and decreased crop quality due to climate change, plant pest organism (OPT) attacks. The instability of rice production will potentially threaten national food security, considering that rice is the main source of food for the Indonesian people. Therefore, the implementation of effective mitigation strategies is indispensable to face the challenges of climate change.

The sustainability of rice farming is a very important issue to pay attention to, especially in areas with high levels of vulnerability to climate change such as Buduran District. Sustainability is not only measured by the ability of farmers to maintain productivity, but also by how the farming system is able to run consistently in the long term while maintaining economic, social, and environmental balance. Economic sustainability is reflected in the ability of farmers to obtain a stable income even though productivity is affected by climatic conditions. Social sustainability can be seen from the ability of farmers to maintain the sustainability of knowledge, farmer group networks, and the quality of farmer household life. Meanwhile, environmental sustainability emphasizes the importance of maintaining soil quality, water availability, and the use of environmentally friendly agricultural inputs. If these three dimensions are not maintained, the sustainability of rice farming has the potential to weaken, which

can ultimately threaten local food security and farmers' welfare. Therefore, the study of the level of sustainability of rice farming in Buduran District is very relevant as a basis for strategic decision-making in facing the challenges of climate change.

This research needs to be carried out because rice farming has a vital role in maintaining local food security and as the main source of income for farmers in Buduran District. The condition of declining rice production that occurred in Buduran District, Sidoarjo Regency, shows that there is a real vulnerability to the impacts of climate change, such as flash floods, rainfall anomalies, and droughts that are increasingly frequent. In line with these conditions, measuring the level of sustainability of farming based on economic, social, and environmental dimensions is important to know the extent to which rice farming activities can continue to run sustainably. Not only that, the identification of mitigation strategies implemented by farmers is also important to understand the mitigation efforts that have been carried out and those that still need to be strengthened. The results of this study are expected to provide a comprehensive understanding of the actual conditions of rice farming in Buduran District, as well as the basis for the formulation of more appropriate mitigation strategies to support sustainable agriculture, maintain food security, and improve the welfare of farmers in the midst of climate change challenges.

1.2. Problem Formulation

The main problem faced by rice farmers in Buduran District, Sidoarjo Regency, is the pressure due to climate change which is characterized by uncertainty of rainfall, prolonged dry season, and increasing intensity of extreme weather. This condition poses a risk of decreased productivity, changes in planting patterns, and

disruption of the quality of rice production. If not anticipated, this can threaten the sustainability of farming, both from an economic, social, and environmental perspective. In addition, the limited knowledge and resources of farmers in dealing with climate change are also an obstacle in itself. Therefore, it is necessary to conduct a study on how the sustainability of farming is reviewed from the economic, social, and environmental dimensions as well as mitigation strategies implemented by farmers in facing climate challenges. Based on these problems, the formulation of the problem in this study is as follows:

1. How does climate change affect rice production in Buduran District, Sidoarjo Regency?
2. How is the level of sustainability of rice farming in facing the challenges of climate change viewed from the economic, social, and environmental dimensions?
3. What are the mitigation strategies that farmers are carrying out in dealing with the impact of climate change on rice farming activities?

1.3. Research Purpose

Based on the formulation of the problem above, the objectives of this study are as follows:

1. Analyzing the influence of climate change events on rice production in Buduran District, Sidoarjo Regency.
2. Measuring the level of sustainability of rice farming in facing climate change challenges from economic, social, and environmental dimensions.
3. Formulate mitigation strategies carried out by farmers in dealing with the impact of climate change on rice farming activities.

1.4. Significance

1. For Students

   This research is a means to increase insight and understanding of the sustainability of rice farming in the face of climate change, as well as to train skills in applying theories, analysis methods, and academic concepts to field research practices

2. For Colleges

   This research contributes to enriching the academic literature in the field of agribusiness and agricultural sustainability issues, and can be a reference for students, lecturers, and other researchers interested in similar studies.

3. For Farmers

   This study provides useful information on the impact of climate change on the productivity and sustainability of rice farming, as well as provides insight into mitigation strategies that can be applied to increase the resilience of farming businesses.

4. For Local Governments

   The results of this research can be used as a consideration in formulating agricultural development policies, especially in facing the challenges of climate change. In addition, this research can also be an input in the planning of food security programs and mitigation strategies based on field data, thereby supporting more sustainable agricultural development.