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MORALITY BEFORE KNOWLEDGE

Climate change adaptation strategies among rice farmers in coastal agro-ecological systems

Eka Tuwu[1,*], Aminuddin Mane Kandari[1], La Ode Muhammad Erif[1], La Gandri[1], Arfiani[1]
[1] *Department of Environmental Sciences, Faculty of Forestry and Environmental Sciences, Halu Oleo University, Kendari, 93231, Indonesia.*
*Correspondence: eka.rahmatiah@gmail.com

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ABSTRACT
Introduction: This study aims to identify the indicators and impacts of climate change experienced by rice farmers in Lawele Village, a coastal area of Buton Island, and to examine the structural and non-structural adaptation strategies they implement. The research also assesses farmers' participation in government-led climate adaptation programs. **Methods**: A descriptive quantitative method was used, involving structured interviews with 30 purposively selected rice farmers. Data were gathered through questionnaires, field observations, and documentation, and analyzed using percentage-based tabulation to describe patterns of climate-related impacts and adaptive responses. **Finding**: All respondents (100%) reported direct impacts of climate change, including pest outbreaks, declining yields, and crop failure, as well as indirect impacts such as increased production costs and reduced income. Structural adaptation measures primarily involved the construction and maintenance of irrigation channels initiated by the government, with farmers contributing to their upkeep. Non-structural adaptations were practiced universally (100%), including fertilizer application and adjustments to cropping patterns to reduce pest pressure and maintain productivity. However, the adoption of pest-resistant improved varieties remained limited, with only 17 farmers (57%) using them, while 13 farmers (43%) had not, largely due to high seed prices, limited technical assistance, and the absence of continuous support programs. Participation in climate adaptation training was also low, with only 15 farmers (50%) having attended government-led extension activities. **Conclusion**: Climate change exerts significant direct and indirect pressures on rice farming in Lawele Village. Although farmers have adopted various adaptation strategies, their implementation is hindered by economic constraints, insufficient technical guidance, and limited engagement in training programs. Strengthening institutional support and providing sustained capacity-building initiatives are essential to enhancing the resilience of rice farming systems in this coastal, climate-vulnerable region. **Novelty/Originality of this article**: This article bridges the experiences of local farmers, adaptation strategies, and institutional participation gaps in the context of coastal rice farming, which has not been widely researched, by providing empirical evidence and insights relevant to policy.

KEYWORDS: adaptation; climate change; impact; lawele village; rice farmers.

1. Introduction

Global warming refers to the long-term increase in the Earth's average surface temperature, primarily driven by the accumulation of greenhouse gases (GHGs) in the atmosphere. These gases—including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)—are largely the result of anthropogenic activities such as the combustion of fossil fuels, land-use changes, industrial processes, and intensified agricultural practices. Their accumulation strengthens the greenhouse effect, trapping additional heat and

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causing a progressive rise in global temperature. The consequences manifest in several environmental disruptions, such as shifting weather patterns, rising sea levels, melting polar ice, altered ocean currents, and increased frequency and intensity of extreme weather events. These environmental transformations have been widely recognized as the primary manifestations of climate change, which continues to be one of the most pressing global challenges of the 21st century (Kandari, 2024a).

Climate change is defined as long-term alterations in temperature, precipitation, wind patterns, and other atmospheric conditions that occur over decades or longer. These changes significantly influence ecological systems, economic activities, and human livelihoods. Among the most critical effects of climate change is drought, which directly impacts the availability of water for agriculture, industry, and domestic needs. Changes in rainfall distribution, increasing temperatures, and prolonged dry seasons disrupt natural water cycles and reduce the reliability of surface and groundwater resources. As Miyan (2014) and Kandari et al. (2024) note, climate-induced droughts are now more frequent, prolonged, and severe across many tropical regions. Overall, approximately 80% of natural disasters worldwide are associated with climate-related phenomena, reflecting the severity of the crisis. In response, Sustainable Development Goal (SDG) 13 emphasizes strengthening resilience to climate-related hazards, mainstreaming climate actions into national planning, and enhancing education and institutional capacity for climate mitigation, adaptation, impact reduction, and early warning systems (Murniningtyas, 2018).

SDG 13 reinforces the need for environmental responsibility and long-term ecological sustainability. It calls for communities to take active roles in conserving natural resources, developing local disaster management strategies, and maintaining ecosystems capable of supporting human life despite increasing environmental pressures. These principles are essential for achieving sustainable development, especially in regions where environmental degradation is closely linked to anthropogenic pressures and inadequate resource management (Idrus & Usi, 2024). Moreover, the SDGs collectively highlight the interconnectedness between climate mitigation and sustainable development pathways. Adaptation strategies, particularly in agriculture, serve as a catalyst for achieving several SDG targets. In relation to Goal 1 (No Poverty), proactive climate adaptation in agriculture helps minimize economic losses among vulnerable farming communities. Similarly, for Goal 2 (Zero Hunger), adaptive agricultural practices sustain productivity and reduce the risk of food shortages. Extension programs and climate training contribute to Goal 4 (Quality Education) by enhancing community knowledge and climate literacy. From a spatial and demographic perspective, strengthened rural resilience supports Goal 11 (Sustainable Cities and Communities) by reducing migration pressures caused by climate stress. Environmentally sustainable farming practices—such as organic farming, crop rotation, and soil conservation—also contribute directly to Goal 15 (Life on Land) by maintaining biodiversity and ecosystem health.

The agricultural sector is among the most climate-sensitive sectors, particularly in tropical countries like Indonesia. Increasing temperatures caused by global warming intensify evapotranspiration rates, accelerating the loss of soil moisture and reducing plant water availability. This condition, combined with unpredictable rainfall patterns and shifting seasons, severely affects plant growth, reproductive cycles, and overall productivity. Rice, one of Indonesia's most important staple commodities, is highly dependent on stable water availability throughout its vegetative and generative stages. Consequently, prolonged droughts, extreme heat, and irregular rainfall significantly disrupt rice cultivation and yield outcomes. Changes in temperature and humidity also influence pest population dynamics, leading to more frequent and severe pest outbreaks that negatively impact crop productivity (Sari et al., 2021).

Rice remains a staple food for most Indonesians and plays a significant role in the national economy. Despite the increasing availability of alternative carbohydrate sources, rice demand continues to grow due to population increases, consumption habits, and cultural preferences. However, rice production is highly sensitive to climatic variability. As

Kandari (2024b) note, rice productivity declines sharply under drought conditions, which inhibit plant growth and reduce yield quality and quantity. In addition, extreme weather events, natural disasters, and pest infestations further exacerbate yield instability, contributing to food price volatility and threatening national food security.

Rice cultivation requires waterlogged soils or submerged fields, which depend on soil texture, structure, and water retention capacity. Fine-textured soils with low porosity are ideal for maintaining flooded conditions essential for rice growth. Soil type influences infiltration rates, water penetration, and soil water-holding capacity, all of which determine the suitability of land for rice farming (Sabudu et al., 2021; Kandari et al., 2024). Soil functions not only as a medium for plant anchorage but also as a reservoir of nutrients and water. Fertile soils—typically 30 cm deep, dark-colored, loosely structured, and containing approximately 25% pore space—are optimal for rice growth (Rozen & Musliar, 2018). Therefore, soil and climatic conditions jointly determine the success of rice cultivation.

National rice production in Indonesia has shown significant fluctuations over the past decade. Between 2013 and 2023, production ranged from approximately 72 million tons to a peak of 82 million tons in 2017 but declined sharply to around 53 million tons in 2023. These fluctuations indicate that domestic rice production struggles to keep pace with rising demand, necessitating rice imports of up to 2.3 million tons in certain years to maintain national food supply stability (Kandari, 2024c). In Southeast Sulawesi, the provincial contribution to rice production reached 478.96 thousand tons in 2022 and 479.41 thousand tons in 2023 (Central Statistics Agency of Southeast Sulawesi, 2023). In Buton Regency, rice production fluctuated from 7,578 tons in 2021, declining to 5,852 tons in 2022, before rising again to 6,430 tons in 2023. These fluctuations were influenced by uneven rainfall distribution, high temperatures, reduced planted areas, pest and disease outbreaks, drought, and flooding, all of which alter farmers' cultivation behaviors (Central Statistics Agency of Buton District, 2024).

Lawele Village, located in Lasalimu District of Buton Regency, covers an area of 56.23 km^2 and possesses approximately 364 hectares of potential rice fields supported by irrigation infrastructure. However, only around 100 hectares are utilized, with 40 hectares realized in Lawele Village (Hafif, 2016). Although the village is endowed with fertile soils and climatic conditions suitable for crop diversification, rice cultivation—farmers continue to face several challenges, such as limited irrigation water, pest attacks, crop diseases, and recurring climate impacts. Limited access to irrigation is particularly critical, as the village depends heavily on rainfall and small surface water resources, making rice fields highly vulnerable to drought periods.

Climate-induced disruptions in rice production are further compounded by socioeconomic constraints that diminish farmers' adaptive capacity. Limited access to climate information, inadequate early warning systems, and insufficient institutional support often impede farmers' ability to anticipate and respond to seasonal anomalies. In rural coastal areas like Lawele, geographic exposure to climate hazards intensifies vulnerability. High agricultural input costs and limited access to improved technologies further restrict farmers' ability to adopt climate-resilient practices, exposing them to heightened production risks and threatening household food security.

Despite the importance of adaptation, empirical studies documenting farmer-level adaptive responses in small coastal villages in Southeast Sulawesi remain scarce. Much of the existing literature focuses on macro-level production trends, climatic anomalies, or regional agricultural development narratives. However, micro-level behavioral responses—such as how farmers perceive climate change, the specific impacts they experience, and the adaptation strategies they employ—are insufficiently explored. Understanding these dynamics is crucial for formulating evidence-based policies that align with local needs and capabilities. Moreover, such insights contribute to strengthening agricultural resilience and accelerating progress toward climate-related SDG targets.

In view of these conditions, conducting research on climate change impacts and adaptation strategies among rice farmers in Lawele Village, Lasalimu District, Buton Regency, is critically important. This study provides much-needed empirical evidence on local climate vulnerabilities, farmer adaptation responses, and the socioeconomic barriers that influence adaptive decisions. The findings are expected to inform policy interventions, support capacity-building initiatives, and enhance the overall resilience of agricultural systems in climate-vulnerable coastal regions.

In addition to environmental and socioeconomic challenges, institutional factors also play a significant role in shaping farmers' adaptive capacity. Effective climate adaptation requires the integration of agricultural extension services, accessible technological innovations, and strong coordination among government agencies, local authorities, and farming communities. However, in many rural regions of Indonesia, including Lawele Village, the coverage of agricultural extension programs is inconsistent and often limited by budget constraints, shortages of trained personnel, and logistical difficulties. As a result, many farmers rely on traditional knowledge or informal community networks when responding to climatic stress, which may not always align with the evolving risks posed by climate change. Strengthening agricultural advisory systems is therefore essential for bridging the knowledge gap and ensuring that farmers have access to scientifically informed strategies for climate resilience.

Moreover, the adaptive responses of farmers are influenced by their perceptions and awareness of climate risks. Studies show that farmers who accurately perceive changing weather patterns and identify climate-related threats are more likely to adopt proactive adaptation measures. Conversely, low awareness or misinterpretation of climate signals often leads to delayed or insufficient adaptation, which increases vulnerability to crop failure. In Lawele Village, the dual challenge of limited climate literacy and insufficient dissemination of climate information further restricts the development of timely adaptation strategies. These limitations are reflected in the low participation rate in training programs, where only half of the surveyed farmers reported receiving any form of climate-related extension service.

Another critical dimension of climate adaptation in agriculture is access to financial resources. Climate-resilient farming practices—including improved irrigation systems, drought-resistant varieties, soil conservation technologies, and integrated pest management—often require upfront investment. However, most smallholder farmers in Lawele Village rely on modest household income and have limited access to credit or agricultural subsidies. High input costs, including fertilizers, seeds, and pesticides, significantly constrain farmers' ability to adopt improved practices. The absence of financial support mechanisms makes it challenging to scale up effective adaptation strategies, particularly among economically vulnerable households.

Furthermore, the spatial characteristics of Lawele Village amplify its exposure to climate risks. As a coastal settlement, the area is influenced by marine climatic conditions, including saltwater intrusion, tidal influences, and coastal storms. These factors may further reduce soil quality and agricultural productivity, especially when combined with prolonged droughts. Coastal agricultural systems are inherently more fragile than inland systems due to their reliance on sensitive hydrological conditions. This unique vulnerability underscores the need for targeted, location-specific adaptation strategies that consider both terrestrial and coastal environmental dynamics.

Given these multifaceted challenges, climate change poses severe threats not only to agricultural productivity but also to long-term food security, household income stability, and community resilience. Addressing these challenges requires a holistic understanding of how climate risks intersect with social, economic, institutional, and ecological dimensions at the local level. Therefore, research focusing on Lawele Village offers valuable insights into the lived experiences of coastal farmers, the effectiveness of current adaptation strategies, and the structural barriers that hinder adaptive capacity. Such research is essential for developing integrated, evidence-based policies that enhance resilience and improve agricultural sustainability in climate-vulnerable regions of Indonesia.

2. Methods

2.1. Study area

This research was conducted in Lawele Village, Lasalimu District, Buton Regency, Indonesia, located at approximately 5°15'58" South Latitude and 122°56'10" East Longitude, with an altitude ranging from 10 to 12 meters above sea level. Lawele Village covers an area of 56.23 km² and is characterized by a combination of lowland areas, undulating terrain, and hilly landscapes that support diverse land uses, particularly agriculture. Administratively, the village is bordered by the Banda Sea to the north, Nambo Village to the east, Production Forest Areas to the south, and Benteng Village to the west (Fig. 1).

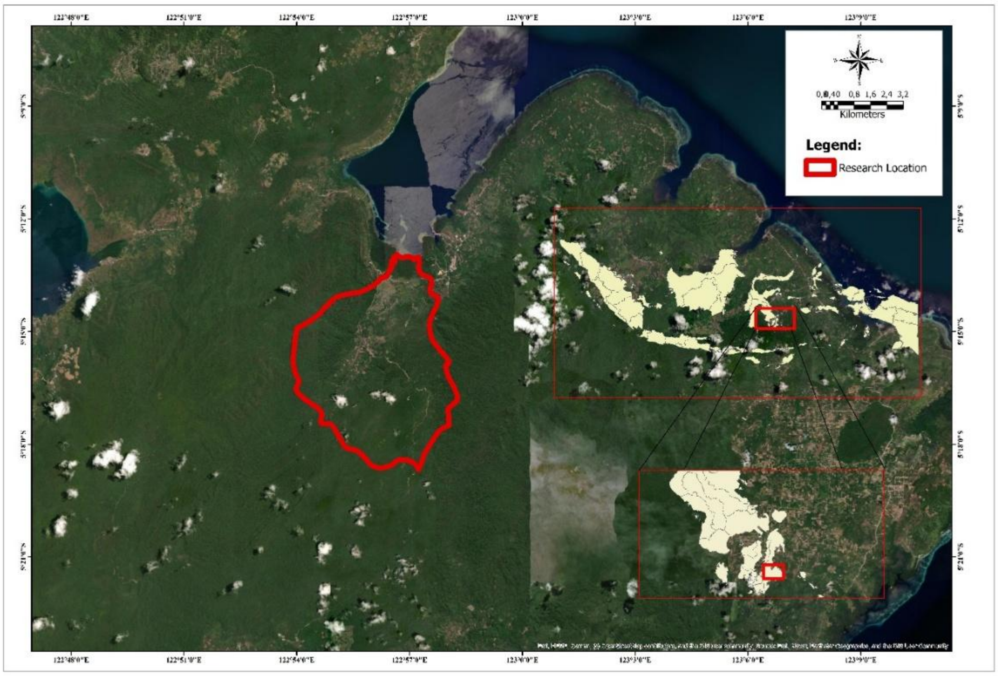

Fig 1. Research location

The region experiences a wet tropical climate, with average daily temperatures ranging from 24°C to 30°C and relatively high air humidity (Malino et al., 2021). Rainfall patterns show considerable interannual and seasonal variability. Based on climate data from 2020–2024, the highest average monthly rainfall occurred in May (486.04 mm), while the lowest was recorded in October (98.28 mm). Annual rainfall averages indicate that 2022 was wetter (301.2 mm) compared to 2020 (227 mm) and 2024 (242.9 mm), suggesting shifting rainfall patterns potentially linked to climate change (Anwar et al., 2015).

Average air temperatures during the same period ranged from 26.24°C to 28°C, with notable interannual fluctuations. The annual mean temperature in 2022 (26.98°C) was lower than in 2020 (27.23°C) and 2024 (27.49°C), reflecting an increasingly erratic temperature pattern consistent with climate change indicators in tropical regions (Sandy, 2017; Kandari et al., 2024). Air humidity also varied considerably, with the highest monthly average recorded in March (87.48%) and the lowest in August (77.68%), while annual averages peaked in 2022 (86.18%).

Sunshine duration exhibited strong variability, with the highest average occurring in October (77.02 hours/day) and the lowest in December (44.52 hours/day). The annual average sunshine duration declined in 2024 (53.66 hours/day) compared to 2020 and 2022, further indicating climatic instability (Pujiastuti, 2017).

Topographically, Buton Regency is dominated by mountainous, hilly, and undulating terrain, interspersed with lowland areas suitable for agriculture. Most areas fall within slope classes of 41–60%, while flat terrain (<2%) accounts for only 2.41% of the total area (Central Statistics Agency of Buton District, 2024). In Lawele Village specifically, fertile lowlands dominate the central area and are primarily used for rice cultivation, while gently rolling and rocky hills are utilized for coconut plantations. These topographic conditions strongly influence land use, accessibility, and agricultural practices.

2.2 Research design, data collection, data analysis

This study employed a qualitative descriptive research design to examine climate change indicators, their impacts on rice farming systems, and farmers' adaptation strategies. The study population consisted of all heads of households (HH) who owned rice fields in Lawele Village, totaling 50 HH. Samples were selected using purposive sampling, with the criteria that respondents had at least five years of experience in rice farming. Based on these criteria, 30 HH were selected as research respondents. Purposive sampling is a technique in which samples are chosen based on specific characteristics relevant to the research objectives (Sugiyono, 2015).

Climate data used in this study included rainfall, number of rainy days, air temperature, air humidity, and sunshine duration for the period 2020–2024. These data were used to identify climate change indicators and assess their variability over time. Primary data were obtained through interviews with farmers to capture perceptions of climate change impacts on rice production and adaptation measures implemented at the farm level. Data analysis was conducted using qualitative descriptive analysis. This approach was applied to analyze climate variability indicators, the perceived impacts of climate change on rice crops and farmers' livelihoods, and the adaptation strategies adopted by rice farmers in Lawele Village. The analysis emphasized pattern recognition and interpretation to explain relationships between climate variability and agricultural responses.

3. Results and Discussion

3.1 Climate change indicators

The research results contain a description of climate change indicators, the impacts of climate change, and the forms of adaptation by rice farmers in Lawele Village, Lasalimu District, Buton Regency. A detailed description of the findings in this study is provided as follows. Global warming over the last century has resulted in climate change that has greatly affected the agricultural sector because this sector is highly dependent on climatic conditions. In recent years, shifts in the rainy season have caused shifts in the planting season. Floods and droughts have caused crop failure and even harvest failure, which has led to a decline in production and farmer income (Rasmikayati & Endah, 2015).

Table 1. Climate change indicators

No	Climate Change Indicators	Respondent Answers			
		Yes	Percentage	No	Percentage
1	Unpredictable rainfall every year	30	100	-	-
2	The air temperature is getting higher and sometimes erratic	30	100	-	-
3	Relative humidity is high throughout the year	30	100	-	-
4	Intensity of prolonged exposure. The sun is high throughout	30	100	-	-

Climate change observed from records of the Southeast Sulawesi Meteorology, Climatology and Geophysics Agency/*Badan Meteorologi, Klimatologi, dan Geofisika* (BMKG) shows that rainfall, rainy days, temperature, and humidity have changed every year, prompting rice farmers to maintain production and income by adjusting planting times, planting patterns, and constructing irrigation channels. Based on observations by the Southeast Sulawesi Meteorology, Climatology and Geophysics Agency/*Badan Meteorologi, Klimatologi, dan Geofisika* (BMKG) from 2020 to 2024, the Lasalimu District in Buton Regency has shown fluctuating figures. Based on the data, the climate has changed over the past 5 years. The results of the study on climate change indicators among rice farmers based on data from all respondents are presented in Table 1. Table 1 shows that all (100%) of the rice farmers in Lawele Village responded to the climate change indicators. This was confirmed by field observations through interviews with 30 respondents.

3.2 Impact of Climate Change

Climate change has a significant impact on rice cultivation and is strongly dependent on climatic factors, especially rainfall and temperature. The impact of climate on rice crops in Lawele Village, Lasalimu Subdistrict, is that rice crops suffer from high pest attacks such as rats, borers, planthoppers, and other diseases, resulting in poor rice quality and yields, and even crop failure. The results of the analysis of the impact of climate change applied in this study involved 30 respondents with predetermined criteria. This description aims to provide an overview of the impact of climate change experienced by rice farmers in Lawele Village. The results of the study show that there are direct and indirect impacts.

3.2.1 Direct Impact

The direct impacts of climate change observed in the field include reduced crop yields, disruption of the planting season, crop failure, and pest attacks. The results of interviews conducted with 30 respondents are presented in Table 2.

Table 2. Results of observations of direct impacts of climate change on rice farmers

No	Direct Impact	Respondent Answers			
		Yes	Percentage	No	Percentage
1	Decrease in crop yield	30	100	-	-
2	Crop season disruptions	30	100	-	-
3	Crop failure	30	100	-	-
4	Pest attacks	30	100	-	-

Table 2 shows that all (100%) of the respondents experienced a decline in crop yield, disruption to the planting season, crop failure, and pest attacks as direct impacts on rice paddy crops. This was confirmed by field observations and interviews with 30 respondents.

Fig. 2. Rice attacked by rats (*Rattus argentiventer*) and green leafhoppers (*Nephotettix virescens*)

3.2.2 Indirect Impact

The indirect impacts of climate change observed in the field are a decrease in production costs and farmers' income. The results of interviews conducted with 30 respondents are presented in Table 3. Table 3 shows that all or 100% of farmers experienced increased production costs and decreased income as a direct impact on rice paddy crops. This was confirmed by field observations and interviews with 30 respondents.

Table 3. Results of observations on indirect impacts of climate change on rice farmers

No	Indirect Impact	Respondent Answers			
		Yes	Percentage	No	Percentage
1	Production costs are rising	30	100	-	-
2	Farmers' income decreases	30	100	-	-

3.3 Forms of adaptation by rice farmers

Based on the results of the survey conducted on respondents, it is known that farmers in Lawele Village, Lasalimu District, have made several forms of adaptation to the impact of climate change on rice crops. The forms of adaptation made by paddy field farmers in Lawele Village are divided into two, namely structural adaptation and non-structural adaptation.

3.3.1 Forms of structural adaptation

Structural adaptation was carried out through cooperation to repair irrigation channels for rice fields, where this cooperation was carried out by rice farmers, so that water could flow properly. Structural adaptation carried out by rice farmers in Lawele Village due to climate change, as observed in the field, included the construction of dams and irrigation channels. The results of interviews conducted with 30 respondents are presented in Table 4. Table 4 shows that all (100%) of the dam construction and irrigation channel construction projects were structural adaptations implemented by the government to address the impacts of climate change in Lawele Village. This was confirmed by field observations and interviews with 30 respondents.

Table 4. Results of observations on the forms of structural adaptation by rice farmers

No	Form of Structural Adaptation	Respondent Answers			
		Yes	Percentage	No	Percentage
1	Dam construction	30	100	-	-
2	Construction of irrigation channels	30	100	-	-

3.3.2 Forms of non-structural adaptation

Non-structural adaptation measures include adjustments to fertilizer use systems, planting patterns, and the use of pest-resistant (high-yield) rice varieties, as well as training/extension services, as presented in Table 5. Table 5 shows the use of fertilizers, adjustments to planting patterns, and the use of pest-resistant (superior) rice varieties. Respondents use locally grown varieties such as inpago and gogo rice, which are considered more suitable, and training/extension services are non-structural adaptations implemented by rice farmers in Lawele Village in response to climate change. This is confirmed by field observations through interviews with 30 respondents.

Table 5. Results of observations on non-structural adaptation measures by rice farmers

No	Form of Non-Structural Adaptation	Respondent Answers			
		Yes	Percentage	No	Percentage
1	Fertilizer use	30	100	-	-
2	Adjustment of planting patterns	30	100	-	-
3	Use of pest-resistant (high-yielding) rice varieties	30	100	-	-
4	Training/education	30	100	-	-

Climate changes continuously due to the interaction between its components. According to the results of the IPCC (2010) study, climate change can occur due to two factors, namely internal factors that occur naturally within the climate system, such as climate conditions over the last 5 years, including rainfall, air temperature, humidity, wind speed, and duration of sunshine, and external factors caused by human activities, such as illegal logging or deforestation, which can lead to flooding, landslides, drought, and climate change.

Rice paddies are not only seasonal crops that are highly dependent on climatic conditions, but also very susceptible to pest attacks. Based on research findings, several pests that attack rice paddies in Lawele Village are rats, stem borers, planthoppers, leafhoppers, and golden apple snails. The most dominant pest is rats. Rats can attack plants from the seedling stage to harvest, especially now that many rice fields in Lawele Village are not being used, making them a breeding ground for rats. Sodarmaji & Herawati (2017) explain that the important factors driving the growth of the rice field rat population are the availability of food, reproduction, and the availability of shelter. When food is not sufficiently available, rice field rats migrate in large numbers and can reach food sources that are 3-5 km away in one night.

Rice farmers in Lawele Village practice monoculture rice farming, meaning that after harvesting, they only plant rice and no other crops, leaving their fields empty. This creates an ideal breeding ground for rats, providing them with a safe hiding place close to their food source. The environmental impact of leaving farmers' land empty is that it can increase the rat population, which can spread to the active rice fields of surrounding farmers, spread weeds, and reduce soil quality.

Farmers plant rice twice a year, with the first planting season in January-April and the second planting season in July-October. Hijriah (2018) states that planting rice twice a year can cause several environmental problems, such as soil erosion, where the fertile topsoil can be lost, the proliferation of pests and diseases, where vacant land can become a breeding ground for rats, insects, and other pests because there is no agricultural activity, and a decline in soil fertility.

Climate change affects various sectors, one of which is agriculture, which is highly vulnerable to its impact. The agricultural sector is particularly susceptible to climate change as it can affect planting patterns, planting times, production, and crop quality. Agricultural production is influenced by climate change variables, namely rising temperatures, changes in rainfall, evaporation of water runoff, and soil moisture, which affect productivity (Harvian & Yuhan, 2020).

The issue of climate change is a global problem that will fundamentally affect human life. Several indicators of climate change that have attracted attention due to this issue have been detected, including warmer ocean temperatures, significant polar ice melt, and extreme weather events (Haryanto & Prahara, 2019). Climate change indicators are directly or indirectly related to pest attacks. The survival of pests depends on climatic factors such as rainfall, temperature, and humidity, which affect the life cycle and lifespan of pests. Climatic factors are also essential for the growth and development of plants such as rice paddies, which are a food source for pests.

Based on data observations Agency Meteorology, Climatology and Geophysics/*Badan Meteorologi, Klimatologi, dan Geofisika* (BMKG), Southeast Sulawesi, for the period 2020-2024, rainfall, rainy days, temperature, humidity, and duration of sunshine in Buton Regency have experienced significant fluctuations. Rainfall has undergone quite drastic changes, with the highest rainfall occurring in 2022 at 924.8 mm in June. There have also been changes in the number of rainy days, with the highest number of rainy days occurring in 2022 in March at 22 days. The next indicator is temperature, which has changed to a fairly low value (not extreme), with the highest temperature occurring in November 2023 at 29°C. Air humidity also changed, with the highest humidity occurring in April 2024 at 89.3%, while the duration of sunshine also changed, with the highest sunshine occurring in October 2023 at 97.7 hours/day.

Rainfall changes in Lawele Village over the past five years have shown significant fluctuations. Meteorology, Climatology and Geophysics Agency/*Badan Meteorologi, Klimatologi, dan Geofisika* (BMKG) data records the annual average, with 2023 having the lowest rainfall of 186 mm, while the highest annual rainfall occurred in 2022. Adequate and even rainfall is very important for successful rice cultivation. Therefore, farmers in Lawele Village choose planting times that coincide with the rainy season and use good irrigation systems as important strategies in rice farming. Respondents stated that high rainfall hinders rice growth, resulting in root rot, increased pest attacks, and a decline in quality and yield. Kandari et al. (2024) stated that climatic conditions are the most influential factor that influences agricultural production, especially during the growth and grain formation or production phases. Climate change and its variations, especially rainfall, affect crop productivity (Mulyono, 2017).

Changes in air temperature in Lawele Village over the past five years show significant dynamics, both in terms of data and respondents' perceptions. Meteorology, Climatology and Geophysics Agency/*Badan Meteorologi, Klimatologi, dan Geofisika* (BMKG) data records that the average annual temperature ranged from 26.98 to 27.55 °C, occurring in 2020-2023. This data indicates climate change in Lawele Village. Respondents mentioned that irregular air temperatures disrupt the rice crop cycle, reduce yields, prolong the planting period, and cause failures in important phases such as flowering and grain filling. (Kandari, 2024d) state that temperature is very important for plant growth and plays a role in almost all growth processes. Air temperature is an important factor in determining the suitable place and time for planting, and it can also be a determining factor in crop production. Air humidity is also closely related to air temperature; the higher the air temperature, the greater its capacity to hold water vapor, so the rate of transpiration is highly dependent on it, which in turn can affect the water potential of leaves.

The relationship between climate factors and rice growth is as follows: high rainfall can cause flooding and plant decay; low air temperature slows down rice growth and maturation; high air humidity accelerates growth but also increases the risk of plant disease; and if the amount of sunlight received by rice plants is reduced, it can inhibit photosynthesis, resulting in weak rice growth and a decrease in production.

According to Estiningtyas & Syakir (2018), climate factors greatly affect rice growth and production. Rising air temperatures will have an impact on crop productivity due to increased respiration at night and increased attacks by pests and plant diseases. Extreme climate events that often occur in the form of floods and droughts, as well as attacks by plant pests can lead to a decline in harvest areas due to crop damage.

The impacts of climate change felt by rice farmers in Lawele Village can be divided into two categories: direct and indirect impacts. Based on interviews with rice farmers in Lawele Village, as presented in Table 1, the direct impacts of climate change experienced by rice farmers in Lawele Village include reduced yields, changes in planting seasons, crop failures, and pest attacks, all of which greatly affect rice plant growth and production. Of the 30 respondents, 100% said that pest attacks such as rats, stemborers, planthoppers, leafhoppers, and golden apple snails were the most significant direct impacts they experienced. The most dominant pests attacking rice plants Rice farmers in Lawele Village are plagued by rats, and their rice production depends on rat infestations. The more rat infestations there are, the less yield there is, and even crop failure can occur. Conversely, the fewer rat infestations there are, the greater the yield. According to Kandari (2024b), the presence of pests, both in terms of number and type, needs to be monitored so that they do not interfere with crop production. Pest populations can increase or decrease depending on the availability of food in the field and a supportive environment, migration from other places with high populations, and a reduction in natural enemies (parasitoids and predators), thereby disrupting the balance of the ecosystem.

The area of rice fields also has a close relationship with rat infestation, where if there are no rice fields planted, rats have no food source or no rice to attack. The survival of pests depends on climatic factors such as rainfall, temperature, and humidity. Rats can reproduce well at suitable temperatures and humidity levels, namely 5-35°C and 50-95% (warm and humid). Rat infestations often occur when the rice begins to bear fruit until harvest. The more the water, temperature, and humidity requirements for the growth and development of paddy rice are met, the more food sources there are for pests and the greater the chance of pests attacking paddy rice crops (Hijriah, 2018).

Climate change hurts water availability and tends to reduce crop yields (Hidayati & Suryanto, 2015). The direct impact of climate change is increased production costs and decreased farmer income. Increased production costs and decreased income are caused by climate change factors such as rainfall, temperature, humidity, and duration of sunlight, which affect crop yields. The direct impact of climate change is increased production costs and decreased farmer income. Increased production costs and decreased income are caused by climate change factors such as rainfall, temperature, humidity, and duration of sunlight exposure, which affect crop production.

Based on the results presented in Table 2, all respondents from rice farmers in Lawele Village answered "yes" to each indirect impact with a percentage of 100%. The indirect impact experienced by farmers is increased production costs, which affect farmers' uncertain income. In addition, there have been changes in marketing, such as lower selling prices due to poor rice quality, fluctuations in supply and prices, and unstable production due to weather changes that can cause flooding, drought, and pest attacks due to climate change, resulting in inconsistent rice production.

The forms of adaptation used by rice farmers in Lawele Village to climate change are divided into two categories: structural adaptation and non-structural adaptation. Climate change adaptation is the ability of a system to adjust to climate change. This is done by reducing the damage caused, taking advantage of or overcoming the changes and all their consequences. Ecosystem-based rice adaptation strategies provide multiple benefits for both humans and nature (Kamaluddin & Kaimuddin, 2019).

Based on direct interviews with rice farmers in Lawele Village, structural adaptation for dam construction shows that 100% of rice farmers responded that the dam conditions are adequate so that rice fields do not experience drought due to climate change. Irrigation techniques are also a form of adaptation carried out by farmers because irrigation greatly affects rice growth, with 100% of rice farmers in Lawele Village using irrigation techniques. This irrigation must be monitored to ensure that the distribution of water to the rice fields is even. Rice farmers also work together to improve drainage channels for irrigation to the rice fields, a technique that is considered better. Good irrigation is very important for the growth and productivity of paddy rice crops. Some of the benefits of good irrigation for paddy rice growth include optimizing growth by maintaining water availability during the critical phases of early growth, reproduction, and grain filling. If paddy rice plants lack water at this stage, it can drastically reduce production. Other benefits include strengthening resistance to pests/diseases, improving fertilizer efficiency, and optimizing the absorption of nutrients from the soil. Therefore, irrigation management systems are very strategic in increasing rice productivity.

The water supply for farmers' rice fields in Lawele Village, which comes from a river collected in a dam, is still sufficient, even though during the dry season, the water in the dam has never experienced drought during its use to date. Therefore, farmers are not entirely dependent on rainfall, and it is hoped that water needs for irrigation can be met throughout the year. The problem is that irrigation water treatment and distribution management are still uneven across each rice field plot. Pest attacks, plant diseases, and unpredictable climate change are also challenges faced by agriculture in Lawele Village (Dairi & Kamhar, 2020).

Darmawan (2014) states that good irrigation water is water that can fulfill its irrigation function without causing side effects that can interfere with plant growth and damage soil structure and fertility. Irrigation built on agricultural land also functions as a guarantor of the continuity of plant physiological and biological processes, such as assimilation, nutrient dissolution, and transport of elements within the plant body. Irrigation water can also provide moisture and protect plants from drought during the dry season.

Community adaptation is divided into two forms: structural and non-structural adaptation. Structural adaptation involves physical improvements and construction aimed at reducing the long-term impacts of drought. Meanwhile, non-structural adaptation focuses on strengthening the community's resilience in facing drought without any physical construction; it is more characterized by changes in daily practices and capacity building. Community adaptation is also influenced by their preferences. Preferences refer to the tendency for free choices made individually toward certain likings, driven by supporting factors originating from both within the individual (internal) and input from others (external) (Sayoga & Artiningsih, 2023).

Non-structural adaptation is a form of indirect adjustment to the impacts of climate change. Climate change adaptation is aimed at utilizing the positive impacts and reducing the negative impacts of climate change. Adaptation activities can be carried out through the use of fertilizers, training/extension, and adjustments to cropping patterns, as well as capacity building for farmers and commodities (Perdinan et al., 2018).

Based on the results of the research conducted, rice farmers in Lawele Village have implemented non-structural adaptations to mitigate the impacts of climate change, such as the use of fertilizers, adjustments to cropping patterns, the use of pest-resistant (high-yielding) rice varieties, and training/extension services. Based on data, it shows that 30 respondents with a presentation of 100% use fertilizers to control pest attacks and improve rice quality. Farmers also adjust planting patterns by changing the planting time. According to Hasanah et al. (2017), adjusting planting patterns, such as changing planting times, is an effective method due to the current unpredictable and difficult-to-predict seasonal changes.

Another form of non-structural adaptation is the use of pest-resistant (superior) rice varieties, with 100% of respondents stating that not all or 17 people (57%) have implemented this, and 13 people (43%) have not implemented it. The superior variety used is Inpari, which is a seed provided by the local Department of Agriculture, but not all farmers have implemented it. This is due to the lack of technical assistance and the high cost of superior seeds. The local community complains about the lack of guidance from extension workers or the Department of Agriculture in selecting, obtaining, and implementing pest-resistant rice varieties. As a result, farmers in Lawele Village tend to plant local/old varieties because they are unaware of the advantages and cultivation methods of new varieties. The local varieties planted include Inpago and Gogo rice, which are considered more suitable for the conditions of the rice fields in Lawele Village.

Indrasari et al. (2024) states that the use of pest-resistant varieties can be an effective technology for reducing the risk of pest attacks, which are increasing in line with climate change dynamics. Although the use of pest-resistant varieties is very important to suppress pests, continuous planting of pest-resistant varieties will not be sufficient to stem pest attacks. This is because some Pests can adapt and form new biotypes/strains that can cause variety resistance to break down (Iswanto et al., 2015).

Another form of non-structural adaptation is training/extension. Based on the research results, 15 respondents (50%) said "yes" and 15 respondents (50%) said "no" to the lack of training/extension from the relevant agricultural agencies on adaptation to prevent the effects of climate change. This is because the farmers' houses are far from the center where training/extension is held, and some farmers are still in the fields, so they do not attend these activities. To increase farmers' acceptance of this form of adaptation, a more intensive socialization approach is needed so that farmers can prepare themselves for future events. Sunartomo (2016) states that the relationship between farmers and extension workers is related to how extension workers can change the level of knowledge, skills, and attitudes of farmers and their families to become independent. Extension/agriculture in an effort to increase agricultural productivity and formulate appropriate extension policy strategies to increase rice productivity

The relationship between structural and non-structural adaptation strategies among rice farmers in Lawele Village reflects a complementary and mutually reinforcing system. Field observations and interviews suggest that farmers who are actively involved in structural adaptation efforts such as the construction, maintenance, and monitoring of irrigation canals and dams—also tend to adopt non-structural measures more consistently. This pattern occurs because structural improvements provide a reliable foundation for implementing non-structural strategies, such as fertilizer management, cropping-pattern adjustments, and the use of pest-resistant varieties. Reliable irrigation, for example, increases farmers' confidence in investing in higher-quality seeds or intensifying fertilizer use, as water availability becomes more predictable throughout critical growth stages. Conversely, farmers who are less engaged in government-supported structural programs often demonstrate lower adoption of non-structural adaptations, partly due to limited access to information, lower institutional interaction, and reduced capacity to invest in additional inputs. This interdependence indicates that structural and non-structural measures are not isolated; rather, they form an integrated adaptation system in which physical infrastructure enhances the effectiveness of behavioral and agronomic adjustments. Strengthening this linkage through institutional support, coordinated extension services, and equitable access to resources can significantly enhance the community's overall resilience to climate change impacts.

4. Conclusion

Based on the results of the study on climate change impacts and adaptation strategies among rice farmers in Lawele Village, Lasalimu District, Buton Regency, the following conclusions can be drawn as follows. Climate change indicators observed in Lawele Village include increasingly unpredictable rainfall, gradual annual temperature increases, fluctuations in air humidity, and consistently high sunlight intensity throughout the year. These changing climatic conditions reflect a clear shift in the local microclimate.

Climate change impacts have resulted in more frequent pest attacks, disrupted planting seasons, and declining rice yields. These effects occur both directly—through crop damage and reduced productivity—and indirectly through rising production costs and decreasing farmer income. Changes in weather patterns have also affected market dynamics, further contributing to income instability. Adaptation strategies implemented by farmers consist of both structural and non-structural forms. Structural adaptations include the construction and maintenance of dams and irrigation systems to secure water availability throughout the growing season. Non-structural adaptations include fertilizer application to reduce pest pressure and improve crop quality, adjustments to planting schedules, the selective use of superior pest-resistant rice varieties, and participation in training or extension activities when accessible.

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During the preparation of this work, the authors used Grammarly to assist in improving grammar, clarity, and academic tone of the manuscript. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

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Biographies of Authors

Eka Tuwu, Department of Environmental Sciences, Faculty of Forestry and Environmental Sciences, Halu Oleo University, Kendari, 93231, Indonesia.

- Email: rosalianurma@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Aminuddin Mane Kandari, Department of Environmental Sciences, Faculty of Forestry and Environmental Sciences, Halu Oleo University, Kendari, 93231, Indonesia.

- Email: aminuddin.mane@uho.ac.id
- ORCID: 0000-0003-1526-2727
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: https://sinta.kemdiktisaintek.go.id/authors/profile/5975618

La Ode Muhammad Erif, Department of Environmental Sciences, Faculty of Forestry and Environmental Sciences, Halu Oleo University, Kendari, 93231, Indonesia.

- Email: laodemuhammad.erif@uho.ac.id
- ORCID: 0000-0001-9673-6482
- Web of Science ResearcherID: 4405217
- Scopus Author ID: 57226096320
- Homepage: https://sinta.kemdiktisaintek.go.id/authors/profile/6670981

La Gandri, Department of Environmental Sciences, Faculty of Forestry and Environmental Sciences, Halu Oleo University, Kendari, 93231, Indonesia.

- Email: lagandri@uho.ac.id
- ORCID: 0009-0004-9867-0105
- Web of Science ResearcherID: N/A
- Scopus Author ID: 59242105700
- Homepage: https://sinta.kemdiktisaintek.go.id/authors/profile/6739695

Arfiani, Department of Environmental Sciences, Faculty of Forestry and Environmental Sciences, Halu Oleo University, Kendari, 93231, Indonesia.

- Email: anhiedar@gmail.com
- ORCID: 0009-0001-8384-9813
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: https://sinta.kemdikbud.go.id/authors/profile/6927639/