International Journal of Economic, Business, Accounting, Agriculture Management and Sharia Administration (IJEBAS)

International Journal of Economics, Business, Accounting, Agriculture Management and Sharia Administration (IJEBAS Journal) | ISSN(e): 2808-4713
Volume 6 No. 1 (2026)

ADAPTATION TO CLIMATE CHANGE THROUGH SUSTAINABLE RICE CULTIVATION INNOVATION

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Received : 15 January 2026 Accepted : 20 February 2026
Revised : 31 January 2026 Published : 28 April 2026

Abstract

This study aims to identify rice cultivation patterns and farmers' rice production responses to climate change by emphasizing the use of environmentally friendly technologies in Beringin District, Deli Serdang Regency, North Sumatra. A qualitative approach was conducted through interviews with ten farmers during the 2021–2023 period. The results show that all farmers have implemented the jajar legowo planting system—specifically the 4:1 pattern—as an environmentally friendly cultivation technology proven to improve land efficiency, lighting, and air circulation for plants. In addition, farmers consistently use organic fertilizers in the form of cow and goat manure, with doses adjusted annually to maintain soil fertility without polluting the environment. No use of inorganic fertilizers was found during the three years of observation. This strategy has proven effective, as indicated by an increase in yields from an average of 2.5 tons to 4.5–8 tons per farmer per planting season. These findings confirm that the application of environmentally friendly cultivation technologies not only increases productivity but also strengthens the resilience of agricultural systems in the face of climate change. This study recommends strengthening technical and policy support to expand the application of green technology in the agricultural sector.

Keywords: environmentally friendly technology, rice cultivation, jajar legowo, organic fertilizer, climate change, Beringin District

1. INTRODUCTION

Rice production, a primary food commodity, is highly dependent on water availability, especially in tropical agricultural systems like Indonesia. Rainfall and its distribution play a crucial role in determining the success of rice cultivation. Rice plants require optimal rainfall of around 150–200 mm per month or 1,500–2,000 mm per year, with even distribution (Paski et al., 2017). However, in recent years, global climate change has caused rainfall anomalies that have negatively impacted agricultural productivity. Beringin District, located in Deli Serdang Regency, is a rice production center using a technical irrigation system. However, extreme climate variability is suspected to impact harvest success. Therefore, this study aims to evaluate the effect of rainfall and rainy days on planted area, harvested area, and rice production in the region during 2020–2023. Global climate change has become a major challenge in the agricultural sector, especially for smallholder farmers in developing countries like Indonesia. Its impacts include increasing average temperatures, fluctuating rainfall, and shifting planting seasons, which directly impact the stability of food production. In Beringin Village, Beringin District, Deli Serdang Regency, North Sumatra Province, farmers are acutely affected by changes in extreme rainfall patterns.

According to data from the North Sumatra Meteorology, Climatology, and Geophysics Agency (UPTD) of the Meteorology, Climatology, and Geophysics Agency (BMKG), average rainfall in this region decreased from 2,750 mm per year in 2019 to around 2,320 mm in 2023, with uneven distribution and frequent short-term, high-intensity rainfall events that cause flooding and crop failure. This phenomenon has also had a significant impact on rice production. According to data from the Deli Serdang Regency Agriculture Office, rice production in Beringin Village has decreased from an average of 5.4 tons per hectare in 2020 to 4.7 tons per hectare in 2023. This decline is due to irregular planting seasons, increased attacks by plant pests (OPT), and limited access to adaptive technology. Smallholder farmers, who rely on planting seasons as the primary determinant of cultivation timing, now face high levels of uncertainty, increasing the risk of crop failure and decreasing household income. Beringin Village has begun adopting *the jajar legowo (sequence -based planting system)* and utilizing organic fertilizers from livestock waste and natural compost. The *jajar legowo system* , which provides wider spacing between rows of plants, has been shown to increase sunlight absorption and fertilizer efficiency. Data from the Beringin Agricultural Extension Center

(BPP) shows that farmers using this method were able to increase yields by up to 5.9 tons per hectare in the first planting season of 2024, higher than those still using conventional systems. Furthermore, the use of organic fertilizers has been shown to improve soil quality and reduce production costs. The implementation of environmentally friendly cultivation innovations in Beringin Village demonstrates that adaptation to climate change can be achieved through a local approach based on farmer knowledge and simple technological support. Training and mentoring efforts conducted by agricultural extension workers in conjunction with higher education institutions have successfully increased farmers' understanding of the importance of sustainable agriculture. A survey conducted in late 2023 recorded that more than 68% of farmers in the village have begun implementing sustainable agriculture principles. Beringin Village's experience can serve as a concrete example of how agrarian villages in Indonesia can build climate resilience in the agricultural sector through community-based strategies and local conditions.

2. RESEARCH METHOD

2.1 Location and Time of Research

The research was conducted in Beringin District, Deli Serdang Regency, North Sumatra. The location is 8–17 meters above sea level, with flat topography and a tropical climate.

2.2 Types and Sources of Data

The data used is secondary data obtained from:

- North Sumatra Central Statistics Agency (2020–2023)
- Department of Agriculture of Deli Serdang Regency
- BMKG Sampali Medan

Data includes: monthly rainfall, rainy days, planted area, harvested area, and rice production.

2.3 Data Analysis Techniques

The analysis was conducted using quantitative descriptive and correlational methods. The Pearson correlation test was used to determine the relationship between climate variables (rainfall and rainy days) and agricultural variables (planted area, harvested area, and production).

The approach used is **descriptive qualitative** , with data collection methods through **in-depth interviews** with **ten farmers** who have actively implemented environmentally friendly cultivation systems.

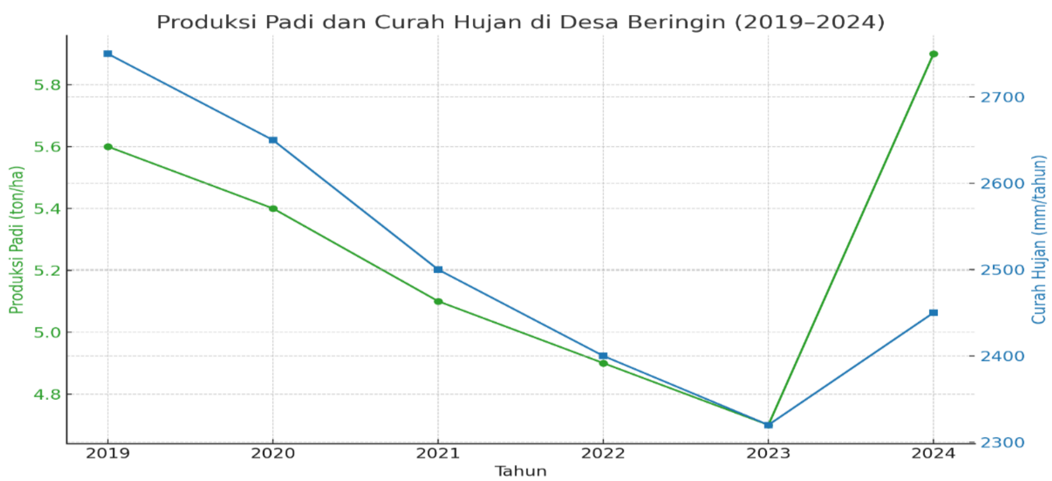
Aspects studied include:

- The planting pattern used (especially the legowo row system)
- Type and dose of fertilizer applied
- Yield trends over three growing seasons
- Farmers' perceptions of climate change

Data were analyzed descriptively by comparing farmer practices from year to year, as well as observing trends in changes in harvest yields as an indicator of successful adaptation.

3. DISCUSSION

3.1. PRODUCTION AND RAINFALL



The graph above shows the development **of rice production (tons/ha)** and **rainfall (mm/year)** in Beringin Village during the period 2019 to 2024. There is a fairly close relationship between the two variables.

In 2019, rice production reached approximately **5.6 tons/ha** , while rainfall peaked at around **2,750 mm/year** . However, between 2019 and 2023, there was a consistent decline in both rice production and rainfall. Rice production decreased to **4.7 tons/ha** in 2023, as rainfall declined to a low of around **2,325 mm/year** . Interestingly, rice production increased significantly in 2024 to **5.9 tons/ha** , even though rainfall increased less than in previous years, reaching only **2,450 mm/year** . This may indicate other factors contributing to the increase in rice production, such as the use of agricultural technology, high-yielding seeds, or improvements to irrigation systems. In general, this graph shows that rainfall influences rice production, but is not the only determining factor.

3.2. Characteristics of the Beringin District Area

Beringin District is one of the potential agricultural areas in Deli Serdang Regency, North Sumatra Province, with an area of 54.32 km². Geographically, this area is located at coordinates 3º54′–3º62′ N and 98º83′–98º88′ E, with an elevation ranging from 8 to 17 meters above sea level. The topography of this area tends to be flat and the climate is tropical, making it highly suitable for the development of food crops, particularly rice paddy. Three major rivers traverse this area: the Ular River, the Serdang River, and the Batu Ginging River, which contribute to the water supply for agricultural activities. Furthermore, most of the rice fields in this area utilize a technical irrigation system, which generally supports the sustainability of two annual rice crops.

3.3. Variability of Rainfall and Rainy Days (2020–2023)

Rainfall is a crucial climatological factor in determining the success of rice cultivation. Rainfall and rainy day data in Beringin District over the past four years (2020–2023) show significant variability. Average monthly rainfall (CH) ranged from 135.9 mm (2020) to 296.5 mm (2022), while the average number of rainy days (HH) per month ranged from 8.8 to 17.4. 2022 recorded the highest rainfall, exceeding the optimal monthly requirement for rice growth, which is between 200 and 300 mm (Paski et al., 2017). This high rainfall, coupled with an increased frequency of rainy days, can lead to excessive soil moisture, increase the risk of flooding, and reduce the intensity of sunlight, which is essential for plant photosynthesis.

3.4. Dynamics of Planted Area, Harvested Area, and Rice Production

Analysis of rice production data shows year-to-year fluctuations. The highest production occurred in 2021, at 38.11 tons/ha, along with the highest harvested area (6,097 ha). That year was characterized by relatively stable, near-optimal rainfall. Conversely, production decreased in 2022 and 2023 to 25.77 tons/ha and 26.32 tons/ha, respectively, despite an increase in planted area. The decline in production in those years is thought to have been caused by excessive rainfall, which led to waterlogging or even flooding in rice fields. This reduced the harvested area and affected the physiological health of the plants, such as reduced pollination intensity and impaired photosynthesis due to insufficient sunlight.

3. Productivity Trends

Average harvest yields have shown significant year-over-year increases. In 2021, the average yield per farmer was recorded at 2.5 tons per season. This figure rose sharply to 4.5 tons in 2022 and continued to soar to 6 to 8 tons per season in 2023. This increase is strong evidence that farmers' adaptation efforts, particularly through the implementation of the legowo planting system and the use of organic fertilizers, have had a significant impact on productivity. This sustainable agricultural strategy not only addresses the challenges of climate change but also directly improves farmers' resilience and well-being.

3.5. Correlation of Climate Factors to Rice Production

The correlation analysis results show that rainfall and rainy days do not have a positive correlation with increased production. In fact, a negative relationship was found between rainfall and rice production ($r = -0.883$), and between rainy days and production ($r = -0.475$). This correlation indicates that high rainfall actually has a negative impact on production, especially if rainfall exceeds the carrying capacity of the land and drainage system. A highly significant positive correlation was found between harvested area and production ($r = 0.998$), indicating that harvested area is the strongest indicator in determining the amount of production. Conversely, planted area showed a significant negative correlation with production ($r = -0.978$), indicating that increasing planted area does not guarantee increased yields if not accompanied by a successful harvest. These findings confirm that excessive water availability can inhibit plant growth. Prolonged waterlogging causes anaerobic conditions in plant roots, triggering tissue damage and increasing the risk of disease. Furthermore, during the rainy season, decreased solar radiation negatively impacts photosynthesis and photosynthates accumulation, ultimately reducing plant productivity (Chaniago, 2022).

4.5. Agronomic Implications and Strategic Adaptation

Use of Organic Fertilizer

During the three years of observation, no inorganic fertilizers were found on the respondents' farmland. Instead, farmers have switched entirely to organic fertilizers using readily available natural ingredients. The fertilizers used include cow manure at a dosage of 1–2 tons per hectare and goat manure at a dosage of 0.5–1 ton per hectare. The choice of organic fertilizer is not without reason. Farmers choose it because it is considered more environmentally friendly and able to maintain the balance of soil microbiota, which is crucial for long-term fertility. Furthermore, organic fertilizer is more economical than chemical fertilizers and can be produced locally, reducing dependence on external inputs. This step also represents a concrete example of sustainable agriculture, which is increasingly sought after by farmers amidst the challenges of climate change.

Implementation of the Legowo System

All respondents stated they had used the 4:1 legowo planting system, a planting pattern in which four rows of rice plants are interspersed with one empty row. This pattern has been shown to provide numerous tangible benefits in rice cultivation. First, this system improves land use efficiency by optimally utilizing the space between plants. Second, it improves air circulation and lighting between plants, thereby reducing the risk of disease. Third, the empty rows provide easier access for plant maintenance, such as fertilizing and weeding. With these various advantages, the 4:1 legowo row system has become the main choice for farmers to increase productivity while maintaining plant health sustainably. Farmers say this system is more resilient to both high rainfall and drought, making it a direct adaptation to climate change. Although most rice fields in Beringin District have been equipped with technical irrigation systems, rainfall remains a crucial factor in rice cultivation management. Excess rainfall not only causes physical damage to plants but also impacts physiological processes and generative development.

Therefore, climate adaptation strategies in rice cultivation are very necessary, including:

- Use of rice varieties that are resistant to flooding.
- Improvement of rice field drainage system.
- Scheduling planting times based on weather forecasts.
- Implementation of climate-friendly technologies and precision farming systems.

This strategy aims to increase the resilience of rice production to the dynamics of climate change and increasingly unpredictable rainfall variability.

4.6 Farmers' Response to Climate Change

The majority of farmers reported that climate change has had a significant impact on their cropping patterns. They experienced delayed rainy seasons, increasingly extreme weather conditions—both in the form of excessive heat and sudden downpours—and increased pest attacks, especially at the start of the planting season. These conditions undoubtedly pose a significant challenge to maintaining agricultural productivity. However, farmers also reported that after they began implementing environmentally friendly technologies, positive changes occurred in land conditions and agricultural yields. The land became more stable and fertile, while crop yields showed a significant increase. This demonstrates that adaptation through sustainable agricultural technologies can be an effective solution to address the impacts of climate change.

Conclusion

Research in Beringin District shows that the application of environmentally friendly cultivation technology—through the 4:1 legowo planting system, consistent use of organic fertilizers, and avoidance of inorganic fertilizers—successfully increased rice yields from 2.5 tons to up to 8 tons per season. This strategy is not only effective in increasing productivity but also contributes to environmental conservation, thus concluding that a sustainable cultivation approach is an effective adaptive solution to the impacts of climate change in the agricultural sector.

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