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RESEARCH ARTICLE

The Impact of Climate Change on Agribusiness Commodity Productivity in the Tropics

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ABSTRACT

Climate change is a serious challenge for the agribusiness sector in the tropics, especially in Sulawesi. Rising temperatures, changes in rainfall patterns, and increasing extreme weather events threaten agricultural productivity, which has an impact on food security and farmers' economies. Major commodities such as rice, cocoa, oil palm, and horticulture experienced a decrease in crop yields and an increase in pest attacks due to increasingly unstable climatic conditions. Therefore, this study focuses on the impact of climate change on agribusiness and adaptation strategies carried out by farmers, agricultural extension workers, and policymakers. This study aims to evaluate the impact of climate change on the productivity of agribusiness commodities in the tropics, as well as identify adaptation and mitigation strategies that have been implemented to face these challenges. This study uses a mixed methods approach, with spatial and temporal analysis to map the affected areas based on changes in rainfall patterns, temperatures, and extreme weather events. Primary data was obtained through in-depth interviews with farmers, agricultural extension workers, agronomists, and policymakers, while secondary data was collected from official sources such as BMKG and BPS. The results of the study showed that 87% of farmers experienced changes in weather patterns, 75% experienced a decrease in crop yields, and 68% faced an increase in extreme weather events. Farmers have adopted adaptation strategies such as drought-resistant crop varieties, drip irrigation technology, and digital weather prediction applications. However, limited access to climate technology and information is still a major obstacle in the implementation of climate change mitigation.

INTRODUCTION

Climate change is one of the biggest global challenges of the 21st century affecting various sectors, including agribusiness in the tropics. The tropics play an important role in the production of various agribusiness commodities such as coffee, cocoa, and palm oil, which are the backbone of the economies of many developing countries (Awazi et al., 2021). However, rising global temperatures, changing rainfall patterns, and increasing frequency of extreme weather events threaten agribusiness productivity in the region. According to Kumar et al. (2022), climate change can cause a significant decrease in crop yields due to changes in environmental conditions that affect the planting cycle and plant growth patterns (Sharma et al., 2022).

Tropical agribusiness commodities are a key sector that makes a major contribution to the global and regional economy. Commodities such as coffee, cocoa, palm oil, rubber, and bananas are widely produced in tropical countries with climates that support the growth of these plants. According to research by Silva et al. (2022), tropical agribusiness not only contributes to export revenues but also plays an important role in improving the well-being of rural communities. The sector involves millions of smallholder farmers around the world who depend on the production and trade of the commodity.

However, the success of this sector is heavily influenced by global challenges such as market price fluctuations and the impact of climate change (da Silva Pinheiro et al., 2022).

Environmental sustainability is the main focus in the management of tropical agribusiness commodities. Valcin and Uchiyama (2021) highlight the importance of environmentally friendly agribusiness practices to reduce negative impacts on biodiversity and deforestation. Their study shows that integrated land management and the application of modern agricultural technologies can help increase productivity while protecting tropical ecosystems (Valcin & Uchiyama, 2021). Another study by Pratzer et al. (2023) confirms that the management of tropical commodities requires a community-based approach that involves local farmers in decision-making related to natural resource management. Thus, the synergy between technology and social approaches is the key to the sustainability of this sector (Pratzer et al., 2023).

From a socio-economic point of view, tropical agribusiness commodities also play a role in increasing economic inclusion in rural areas. According to Amanor (2019), strengthening the value chain of tropical commodities through technology integration and global market access can help smallholders increase their income and competitiveness (Amanor & Iddrisu, 2022). In addition, research by Cramb et al. (2019) highlights the importance of the role of government policies in supporting smallholder access to technology, credit, and training. With adequate support, the tropical agribusiness sector can become a pillar of sustainable development in the tropics (Kabir et al., 2019).

The impact of climate change is not only limited to a decrease in productivity but also affects the socio-economic stability of societies that depend on agribusiness. A study by Syed et al. (2022) shows that crop yield uncertainty due to extreme weather increases the economic vulnerability of smallholder farmers (Syed et al., 2022). This is exacerbated by a lack of access to adaptation technologies and relevant climate information. In addition, the potential for land degradation caused by changes in land use patterns further exacerbates the impact of climate change on tropical agribusiness (Saatchi et al., 2021).

Agribusiness resilience is not only important for local food security but also for global market stability, considering that the tropics are the main source of various strategic agribusiness commodities. Therefore, this study aims to fill the knowledge gap regarding how climate change affects agribusiness productivity and mitigation measures that can be applied (Thiault et al., 2019).

Previous research has explored the relationship between climate change and agricultural productivity. For example, a study by Shahzad et al. (2021) concluded that changes in rainfall patterns have a direct impact on plant productivity in the tropics (Shahzad & Amjad, 2022). Meanwhile, research by Su et al. (2021) shows that the adoption of agricultural conservation practices can increase the resilience of agribusiness systems to climate change. However, research specializing in community-based adaptation strategies for agribusiness in the tropics is still very limited (Su et al., 2021).

The purpose of this study is to evaluate the impact of climate change on the productivity of agribusiness commodities in the tropics. The study also aims to identify adaptation and mitigation strategies that can be applied to ensure the sustainability of the agribusiness sector in the midst of climate change. Thus, the results of this study are expected to provide relevant strategic insights for policymakers, the agribusiness community, and researchers in related fields.

METHODOLOGY

This research will be carried out in several tropical regions in Indonesia which are the main centers of agribusiness commodity production. The location of the research was conducted in Central Sulawesi. This region was chosen because of its significant agroecosystem diversity and the production of superior commodities such as rice, pepper, cloves, cane sugar, and tobacco that are vulnerable to the impacts of climate change. Changes in rainfall patterns in Sulawesi make it relevant for this study

(Sugiyono, 2015).

This study uses a mixed methods approach with a focus on spatial and temporal analysis to examine the impact of climate change on the productivity of agribusiness commodities in the tropics (Creswell, 2010). This approach was chosen because it allows for the integration between empirical data-based quantitative analysis and qualitative insights obtained through direct engagement with stakeholders. This method is designed to provide a deep understanding of climate change and its impact on agribusiness systems in tropical regions such as Indonesia.

This study is an explanatory research that aims to identify patterns of climate change impacts and analyze factors that affect the productivity of agribusiness commodities. The spatial approach is used to map the affected areas based on changes in rainfall patterns, temperatures, and extreme weather events. Meanwhile, temporal analysis was used to examine the long-term trend of agribusiness commodity productivity at the research site.

In this study, the population includes all farmers, agricultural extension workers, agronomists, and policymakers involved in the agribusiness sector in the Sulawesi region. Based on data from the Central Statistics Agency (BPS) and the Indonesian Ministry of Agriculture, it is estimated that there are more than 500,000 farmers involved in the production of major agribusiness commodities in these regions. In addition, there are around 5,000 active agricultural extension workers in the area where the research is located. The number of agronomists and relevant policymakers is estimated at around 500 at the regional and national levels. To determine the number of samples, the stratified random sampling method was used to ensure that each strata (farmers, extension workers, experts, and policy makers) was proportionally represented. The determination of the number of samples was carried out using the Slovin formula with a margin of error of 15%, resulting in the number of samples as follows:

Slovin formula:

$$n = \frac{N}{1 + Ne^2}$$

Where

n = sample size

N = total population

e = margin of error (15% atau 0,15)

Thus, the total number of samples to be studied is 120 respondents, consisting of:

- 50 farmers,
- 30 agricultural extension workers,
- 20 agronomists and climate researchers,
- 20 policymakers.

The data used in this study consists of two main types, namely secondary data and primary data. Secondary data includes information about climate, such as temperature, rainfall, and humidity, obtained from the Meteorology, Climatology, and Geophysics Agency (BMKG). In addition, global

databases such as the Intergovernmental Panel on Climate Change (IPCC) and the Food and Agriculture Organization (FAO) are also used to supplement information related to climate change trends at the global level. Other secondary data includes information on the productivity of agribusiness commodities such as rice, pepper, cloves, cane sugar, and tobacco, which is obtained from reports from the Ministry of Agriculture of the Republic of Indonesia and related agribusiness institutions. This data provides a strong foundation for analyzing the relationship between climate change and agribusiness commodity productivity. Meanwhile, primary data were collected through in-depth interviews with various stakeholders, including farmers, agricultural extension workers, and agronomists. This interview aims to explore an in-depth understanding of the direct impact of climate change on commodity productivity, the adaptation strategies that have been implemented, and the challenges faced in managing these impacts. In addition, direct observations in the field are also carried out to obtain a real picture of agroecosystem conditions, agribusiness practices, and specific phenomena that are not recorded in secondary data. With this approach, primary data provides a contextual dimension that complements and strengthens the results of secondary data analysis, thus supporting more comprehensive research.

Data collection is carried out through three main methods:

1. Document Analysis: Secondary data such as meteorological reports and agribusiness statistics are processed to obtain patterns of climate change and productivity.

2. In-Depth Interviews: Interviews are conducted with farmers, agricultural extension workers, and policymakers to gain an understanding of the direct impacts of climate change and the adaptation strategies that have been implemented.

3. Field Observations: Observations at the research site are used to verify spatial data and obtain additional information about environmental and socio-economic conditions.

The data in this study was analyzed using three main approaches, namely, spatial, temporal, and qualitative. Spatial analysis is carried out by utilizing GIS (Geographic Information Systems) software to map areas affected by climate change, resulting in a visualization of the geographical distribution of the impact on the productivity of agribusiness commodities. The temporal approach is used to analyze time series data over the past 20 years to identify trends in changes in commodity productivity. The relationship between climate variables such as temperature and rainfall and productivity was analyzed using regression and correlation techniques to evaluate the extent to which climate change affects crop yields. In addition, qualitative analysis was carried out by analyzing interview data thematically, aiming to understand the patterns, perceptions, and experiences of stakeholders, including farmers and extension workers, regarding the impacts of climate change and the adaptation strategies implemented. The results of these three approaches are integrated to provide a comprehensive understanding of the relationship between climate change and the productivity of agribusiness commodities in the tropics.

RESULTS

Agribusiness commodity production in Sulawesi

The productivity of agribusiness commodities in Sulawesi in recent years has shown diverse developments in various sectors, especially in rice production and smallholder plantations. Data from the Central Statistics Agency (BPS) of South Sulawesi noted that several smallholder plantation commodities experienced significant production in 2023. Among them, pepper production reached 3,742 thousand tons, while cloves were recorded at 21,688 thousand tons. Other commodities such as sugar, cane and tobacco also have a considerable contribution to the agribusiness sector in South Sulawesi with production of 3,699 thousand tons and 1,263 thousand tons, respectively (BPS South Sulawesi, 2024).

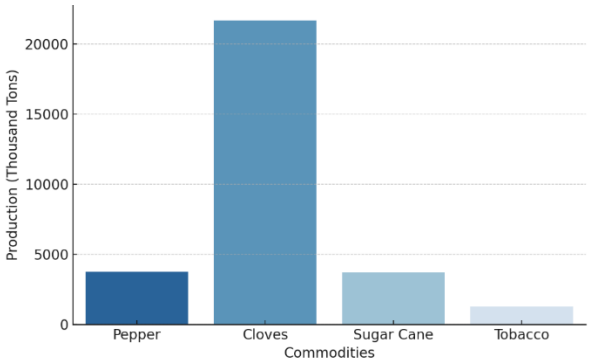

Figure 1. Production of Smallholder Plantations in South Sulawesi (2023)

In the food sector, rice productivity in recent years has increased even though the harvest area has decreased. Data from 2019 to 2021 shows that the rice harvest area nationally decreased from 10.68 million hectares to 10.41 million hectares. However, rice productivity increased from 51.14 quintals per hectare in 2019 to 52.26 quintals per hectare in 2021. This indicates improvements in cultivation techniques and better production efficiency despite the reduction of crop land (Secretariat General of the Republic of Indonesia, 2022).

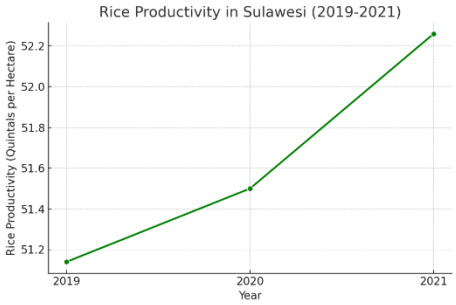

Figure 2. Rice Productivity in Sulawesi (2019-2021)

Meanwhile, the estimated rice harvest area in 2024 is estimated to reach 10.05 million hectares with a total production of around 52.66 million tons of dry milled grain (GKG). This data reflects a continuous trend of increasing productivity even though the area of land used has gradually decreased. This increase in productivity can be attributed to various factors, including the adoption of better agricultural technology and government policies in supporting the agricultural sector (BPS, 2024).

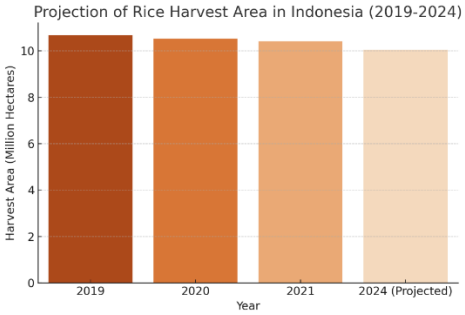

Figure 3. Projection of Rice Harvest Area in Indonesia (2019-2024)

Overall, agribusiness developments in Sulawesi, especially in the plantation and food crop sectors, show good resilience in facing the challenges of climate change and economic dynamics. Plantation commodities such as cloves and pepper remain mainstays for the regional economy, while increasing

rice productivity shows great potential for food security in the region. With the continued encouragement of innovation in agricultural practices and policies that support the agribusiness sector, Sulawesi has a great opportunity to maintain and increase its commodity productivity in the future.

Profile response

The speakers came from various backgrounds in the agribusiness sector, ranging from smallholders to large-scale agribusiness business managers, agricultural extension workers working at the village to provincial levels, agronomists who play a role in agricultural research, and policymakers who design agricultural regulations at the regional and national levels.

Most of the farmers interviewed are engaged in the rice, cocoa, oil palm, and horticultural sectors such as chili and tomato. The average agricultural extension worker has more than 10 years of experience in assisting farmers and providing solutions based on agricultural technology. Agronomists focus on the research and development of superior varieties, as well as the efficiency of land use and water resources. Meanwhile, policymakers are involved in the formulation of food security policies and farmer empowerment in Sulawesi.

Most of the farmers interviewed have been in the agricultural sector for more than 15 years, and many of them have experienced various environmental changes that affect agricultural production.

The Impact of Climate Change on Agriculture

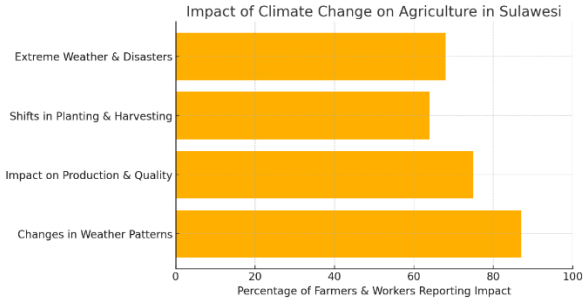

Figure 4. Impact of Climate Change on Agriculture In Sulawesi

The results of the interviews show that climate change has had a significant impact on the agricultural sector in Sulawesi, especially in terms of weather patterns, crop production, and the frequency of natural disasters. As many as 87% of farmers admitted to experiencing changes in weather patterns in the last five years, with shifts in the rainy season and erratic droughts. Agricultural extension workers also revealed that temperature anomalies and rainfall have increased the risk of pest and disease attacks, which have a direct impact on plant health.

In terms of production, 75% of farmers reported a decrease in crop yields due to higher temperatures and unstable rainfall patterns. Some leading commodities such as cocoa and palm oil have experienced a decline in seed quality due to prolonged drought, while high humidity further increases the risk of plant diseases such as fungi on rice and chili. In addition, 64% of farmers stated that their planting season no longer follows the traditional pattern, so they have to adjust the planting time so that they are not affected by extreme weather, and some even have to plant twice in one rainy season to avoid the risk of drought.

Extreme weather is also a big challenge for agriculture in Sulawesi. As many as 68% of farmers and agricultural extension workers reported that floods, storms, and droughts have become more frequent in the past five years. Some areas in South Sulawesi suffered heavy losses due to floods that damaged agricultural land, while in Central Sulawesi, changes in temperature and humidity have led to more

massive pest attacks. All of these factors suggest that climate change has created uncertainty for farmers and requires more strategic adaptation measures to maintain food security and agribusiness sustainability.

Adaptation and Mitigation

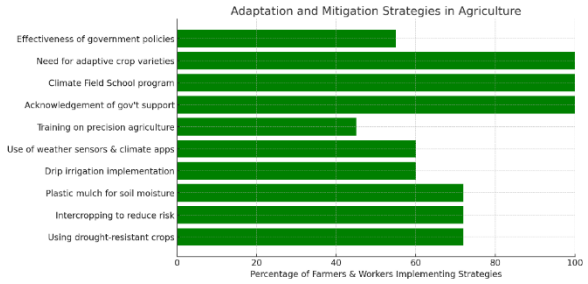

Figure 5. Adaptation and Mitigation Strategies in Agriculture

In response to climate change, farmers, agricultural extension workers, and agronomists in Sulawesi have implemented various adaptation and mitigation strategies to maintain agricultural productivity. As many as 72% of farmers have started using drought-resistant crop varieties, such as Inpari rice and hybrid corn, and implemented an intercropping system to reduce the risk of crop failure. Horticultural farmers also utilize plastic mulch to retain soil moisture and reduce water evaporation.

The use of technology is increasingly becoming a solution in dealing with climate change. About 60% of farmers have used drip irrigation technology to conserve water, especially in areas with low rainfall. In addition, agricultural extension workers and agronomists are starting to use weather sensors and climate prediction applications to provide recommendations related to planting and fertilization times. In fact, 45% of farmers have received training on precision agriculture and digital-based water management.

Government support is also an important factor in climate change mitigation. Farmers acknowledge the existence of seed and fertilizer subsidies, although aid distribution is often not timely. The Climate Field School (SLI) program has helped farmers understand the impacts of climate change and how to deal with it. Meanwhile, agronomists emphasized the need for further development of adaptive crop varieties, especially in coastal and highland areas.

However, 55% of policymakers admit that policy implementation is still lacking on the ground. They recommended increasing budgets for climate-based agricultural research and technology, as well as strengthening education programs for farmers to better prepare them for the challenges of climate change.

Sustainability and Long-Term Solutions

To increase agricultural resilience to climate change, the speakers emphasized the importance of adopting environmentally friendly agricultural technologies. Farmers are advised to be more active in using organic fertilizers and water-efficient irrigation systems, as well as to participate in training and discussion of farmer groups to share experiences in mitigating the impact of climate change. Agricultural extension workers consider that this approach can help farmers in implementing more effective adaptation strategies.

However, there are several key challenges in climate change mitigation efforts. The cost of investment in sustainable agricultural technology is still relatively high, which is an obstacle for smallholders. In addition, the lack of access to climate information and weather predictions makes it difficult for farmers to plan more adaptive planting patterns.

To address this problem, policymakers propose strengthening climate data-based assistance programs, especially for farmers in disaster-prone areas. In addition, agricultural infrastructure that is more resilient to climate change is needed, such as the construction of small reservoirs and modern drainage systems. Agricultural digitalization programs should also be expanded so that farmers have real-time access to weather data and market prices, so they can make better decisions in their agribusiness ventures.

Regarding the future of agriculture in Sulawesi, farmers hope for policies that are more in favor of food security and investment support for sustainability-based agribusiness. Agronomists are optimistic that with the adoption of the right technology, Sulawesi's agricultural sector can still develop and better face the challenges of climate change.

Figure 6. Affected maps

Rainfall Change Pattern

South Sulawesi, especially coastal areas such as Wajo and Luwu Regencies, experienced an increase in rain intensity that caused flooding on agricultural land and damage to irrigation systems. Central Sulawesi, especially in Poso and Parigi Moutong districts, has experienced a decrease in rainfall, which has an impact on cocoa and coffee productivity, forcing farmers to adjust planting schedules and look for additional water sources. Meanwhile, Southeast Sulawesi is facing shorter rainfall, causing drought in some agricultural lands. In response, farmers began to implement an intercropping system and use drought-resistant crop varieties such as hybrid corn and Inpari rice.

Changes in rainfall patterns in Sulawesi are increasingly erratic, causing challenges for farmers in determining planting and harvesting times. This uncertainty has a major impact on the agribusiness sector, especially food crops and plantations that depend on weather stability. In South Sulawesi (Gowa, Bone, Wajo), rice and maize production is disrupted by uneven rainfall, often causing floods that damage crops and hinder harvests. The cocoa and coffee sector is also affected by unstable moisture, reducing productivity and crop quality.

In Central Sulawesi (Poso, Sigi), the decline in rainfall triggered a prolonged drought, inhibiting the growth of chili peppers and tomatoes that require a steady supply of water. The irrigation system is disrupted, resulting in a decrease in agricultural yields and instability of food supply. In North Sulawesi (Minahasa, Bolaang Mongondow), unstable rainfall disrupts coconut and clove production. Longer rainy seasons increase air humidity, triggering plant diseases and pest attacks, which leads to a decrease in crop yields and the quality of plantation products (Upland Project, 2023).

Temperature Rise

Rising temperatures in Sulawesi have a significant impact on agricultural productivity, with 75% of

farmers reporting a decrease in crop yields. In Central and Southeast Sulawesi, temperatures increased by 1.5°C - 2°C, causing a decline in the quality of cocoa and oil palm, as well as accelerating the ripening of chili peppers and tomatoes which increased the risk of plant diseases. Meanwhile, in South Sulawesi, high temperatures accelerate water evaporation in rice fields, especially in Bone and Jeneponto districts, so farmers have begun to adopt drip irrigation technology to save water.

According to the United Nations in Indonesia (2023) report, the average temperature in Indonesia has increased by around 0.8°C in the last 30 years, having a significant impact on the agribusiness sector. Rising temperatures accelerate plant growth but also increase pests, lower soil quality, and disrupt microecosystems. In South Sulawesi (Enrekang & Sidrap), coffee and cocoa are affected by a decline in crop yields due to the loss of flowers before fruiting and an increase in pest infestation. Farmers face rising production costs for pest control as well as potential crop losses.

In Central Sulawesi (Donggala & Parigi Moutong), rice and maize are stressed by drought triggered by high evaporation. Production declined as the grains were smaller, and soil quality also deteriorated, hampering long-term agriculture. In North Sulawesi (Bitung & Sangihe Islands), coconut and nutmeg are experiencing a decline in production due to hotter temperatures that inhibit fruit growth and degrade oil quality. The shift in microecosystems also interferes with the adaptation of endemic plants, threatening the sustainability of production (PBB Indonesia, 2022).

Extreme Weather

As many as 68% of farmers and agricultural extension workers reported an increase in extreme weather events such as floods, storms, and droughts in the last five years. Areas at risk of flooding include Luwu, Wajo, and Sidrap Regencies in South Sulawesi, as well as Palu City in Central Sulawesi, which is often affected by high-intensity rains. Areas at risk of drought include South Konawe and Bombana in Southeast Sulawesi, as well as Poso Regency in Central Sulawesi, where rainfall has decreased dramatically, causing soil fertility to decrease. Meanwhile, climate anomalies in Central and South Sulawesi are increasing humidity that exacerbates pest attacks such as leafhoppers and armyworms, making farmers more likely to use pesticides to protect rice and chili crops.

In South Sulawesi, especially in Makassar, Maros, and Jeneponto, extreme rainfall that has occurred in recent years often triggers major floods. This condition causes damage to agricultural land, which leads to reduced crop yields, especially in rice and corn commodities. Floods not only submerge farmland, but also deteriorate soil structure, reduce fertility, and inhibit plant growth. In addition, in the Jeneponto region, rising sea levels have caused contamination of traditional salt ponds, resulting in a decline in salt production. For people who depend on salt pond businesses for their livelihoods, this condition is a big challenge in maintaining their economic stability.

In Central Sulawesi, especially in the Palu and Sigi regions, the impact of natural disasters is also felt very strongly. Earthquakes and liquefaction that occurred a few years ago had a major impact on the agricultural sector, with many lands suffering permanent damage. In addition, the region also faces drought problems due to climate anomalies, which have an impact on the decline in the production of horticultural crops, such as onions and chili peppers. These crops are highly dependent on the availability of sufficient water, so prolonged extreme weather conditions make it increasingly difficult for farmers to maintain stable production.

In North Sulawesi, especially in Bitung, Manado, and South Minahasa, tropical storms are becoming more frequent. Heavy rains and strong winds caused landslides, which not only damaged farmland but also hampered access to agricultural transportation and distribution of crops. When roads and infrastructure are damaged by disasters, farmers face great difficulties in delivering their crops to the market, leading to significant economic losses. In addition, coconut and clove crops, which are the main commodities of this area, have also suffered damage due to strong winds and rainfall that exceed normal limits. Crops that fall or are damaged by storms take a long time to recover, thus reducing production in

the long term (Upland Project, 2023).

DISCUSSION

The findings show how changes in rainfall patterns, rising temperatures, and extreme weather events have had a significant impact on the agribusiness sector in Sulawesi. Data from interviews with farmers, agricultural extension workers, and agronomists provide a clear picture of the challenges they face, ranging from declining crop yields to increasing pest attacks due to temperature and humidity changes. These findings support the premise that climate change has direct consequences on the productivity and quality of agribusiness commodities, as stated in the research objectives.

In addition, the study also succeeded in identifying various adaptation and mitigation strategies that have been implemented by farmers and the government. Various efforts such as the use of drought-resistant plant varieties, the application of water-saving irrigation technology, and the use of weather prediction applications show that adaptation to climate change has indeed been carried out, although there are still challenges in its implementation.

Further Limitations and Implications

Although this study has answered the main objectives that have been set, there are some limitations that need to be noted:

1. There is a lack of long-term data on commodity productivity that is more specific to each region, which can improve the accuracy of predicting the impact of climate change on agribusiness.

2. There is an imbalance between the adaptation strategies of smallholders and large-scale farmers, where smallholders have more difficulty accessing modern technology compared to large agribusiness companies.

3. Lack of coordination between farmers, agricultural extension workers, and policymakers, which leads to uneven mitigation and adaptation implementation in all regions.

Therefore, this research can be further developed by using more in-depth quantitative data on commodity productivity trends, as well as involving more stakeholders in the interview process to get a more comprehensive picture.

CONCLUSION

This study confirms that climate change has a significant impact on the productivity of agribusiness commodities in Sulawesi. Changing increasingly erratic rainfall patterns, continuous temperature rises, and increasing extreme weather events such as floods and droughts have caused major challenges for the agricultural sector. Major commodities such as rice, cocoa, oil palm, and horticulture experienced a decrease in crop yields due to disruptions in the planting cycle, increased pest attacks, and damage to agricultural land due to unstable weather conditions.

In facing this challenge, farmers have made various adaptation efforts, such as using plant varieties that are more resistant to drought, implementing water-saving irrigation systems, and utilizing digital technology for weather prediction to be able to adjust their planting patterns. However, the effectiveness of this adaptation strategy still faces various obstacles, especially related to the lack of access to climate information, limitations of agricultural technology, and lack of coordination between the government, agricultural extension workers, and farmers. These factors are obstacles in increasing agribusiness resilience to climate change in Sulawesi.

To ensure that the agribusiness sector can survive and thrive in changing climatic conditions, several

strategic steps need to be taken. Improving agricultural infrastructure and technology is urgent, especially in the form of the construction of small reservoirs and modern irrigation systems to overcome rainfall instability. In addition, the digitalization of agriculture needs to be expanded, so that farmers can have access to real-time weather prediction applications and market price data, which will help them in more effective decision-making.

In addition to the technological aspect, further research is needed to develop plant varieties that are more adaptive to temperature changes and extreme rainfall. Crops such as rice, cocoa, and oil palm must be adapted to increasingly unstable climatic conditions, so that agricultural productivity can still be maintained in the long term. Education and access to information for farmers must also be improved. The Climate Field School (SLI) program that has been running needs to be expanded so that more farmers can understand mitigation and adaptation strategies to climate change. Thus, farmers will be better prepared to face weather conditions that are increasingly difficult to predict.

In terms of policy, the government needs to take more responsive and data-based steps in designing agricultural adaptation regulations. The assistance and subsidies provided must be more targeted, especially for farmers who are directly affected by climate change. Clearer regulations and more concrete support from the government will help farmers in implementing mitigation and adaptation strategies more effectively.

With more integrated policies, improved agricultural infrastructure, and wider use of technology, the agribusiness sector in Sulawesi can be more resilient in the face of climate change. Thus, agriculture in this region can not only survive but also continue to contribute to maintaining food security and farmers' welfare in the future.

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