

Agribusiness Adaptation and Risk Management Strategy Based on Rice Prediction to Strengthen Sustainable Food Governance in Jember

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Keywords:

Adaptation strategies;
Agribusiness risk management;
Food security;
Food governance;
Paddy prediction

Submitted:

30-10-2025

Accepted:

11-03-2026

Published:

29-03-2026

ABSTRACT

Food security is a strategic issue prioritised in sustainable development. Jember Regency, as a rice production centre in East Java, faces various challenges in achieving sustainable food security. This research explores adaptation strategies and risk management in paddy agribusiness using a paddy prediction interpretation approach as the basis for food governance planning. The study employs a descriptive-exploratory qualitative approach with an interpretivist paradigm. Data were collected through in-depth interviews with 27 informants selected via purposive and snowball sampling, comprising rice farmers, farmer groups, Gapoktan administrators, agribusiness practitioners, Department of Agriculture officials, agricultural extension workers, and academics. Secondary data were obtained from the Central Bureau of Statistics and the Department of Agriculture of Jember Regency, and analysed using thematic analysis following Miles and Huberman. Importantly, this study does not develop a new predictive model but examines the utilisation and interpretation of existing prediction data in food planning and governance practices. Findings indicate that Jember Regency maintains a consistent paddy production surplus averaging 30,000 tonnes per annum. Agribusiness actors face production, price, institutional, financial, and personal risks. Adaptation strategies encompass technical, economic, social, and institutional dimensions, yet the utilisation of paddy prediction interpretation remains suboptimal, with significant information gaps between policy and operational levels. This research recommends developing an integrated food security information system, strengthening multi-stakeholder coordination, increasing investment in agricultural infrastructure, and establishing social protection schemes to reinforce sustainable food security in Jember Regency.

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1. Introduction

Food security is a critical global strategic issue and a major focus for numerous nations striving to achieve sustainable development objectives. The United Nations, through the Sustainable Development Goals (SDGs), ranks food security as a secondary priority, aiming to eradicate hunger, achieve food security and enhanced nutrition, and encourage sustainable agricultural practices. In this context, Béné *et al.* (2019) emphasized that food security is not only related to adequate food availability but also encompasses the dimensions of

accessibility, utilization, and long-term food stability. The challenges surrounding food security are becoming more complex, especially as the global population is expected to reach 9.7 billion by 2050. According to the Food and Agriculture Organization (FAO), worldwide food production must rise by 70 percent to satisfy the surging demand (World Health Organization, 2023).

Global climate change creates uncertain conditions for the agricultural sector and poses a serious threat to the stability of food production. Mbow *et al.* (2019), in their comprehensive study, found that climate change affects not only the quantity of production but also the quality of agricultural products, ultimately impacting the nutritional value and economic value of agricultural commodities. The Intergovernmental Panel on Climate Change (IPCC) states that climate change could reduce agricultural productivity by up to 25 percent by mid-century if adequate adaptation and mitigation measures are not implemented. In the context of rice production, Ray *et al.* (2019) found a significant impact of climate change on rice production in Thailand, with decreased productivity due to increasing temperatures and rainfall variability, creating uncertainty in production planning. More recent studies have further corroborated these findings. Iizumi *et al.* (2018) showed that climate variability has caused significant yield fluctuations in major rice-producing regions in Asia, with projected losses of up to 15 percent by 2050 under a high-emissions scenario.

Similarly, Arora (2019) emphasized that climate-induced agricultural risks disproportionately impact smallholder farmers in developing countries due to limited adaptive capacity and resource constraints. Furthermore, Rahimi-Moghaddam *et al.* (2018) found that integrated climate adaptation strategies combining technological innovation with institutional support significantly increased rice productivity resilience in the Southeast Asian context. Indonesia, as the world's fourth most populous country and an agricultural nation, faces unique challenges in achieving national food security. Although Indonesia achieved rice self-sufficiency in the 1980s through the Green Revolution program, Pingali *et al.* (2019) identified that this success has various limitations, including environmental degradation, dependence on external inputs, and socio-economic disparities that demand a transformation towards a more sustainable agricultural system.

East Java Province plays a strategic role as one of Indonesia's largest rice-producing provinces, accounting for approximately 15 percent of the nation's total rice production. (Reardon *et al.*, 2019) identified five major transformations in the Asian agrifood system that have significant implications for food security, including transformations in consumption patterns, transformations in value chains, and transformations in macroeconomic structures, all of which are also occurring in East Java. In the Indonesian context, Sari *et al.* (2024) and Ningsih *et al.* (2024) analyzed that food governance challenges extend beyond production issues to encompass complex supply chain management, institutional coordination, and data-driven decision-making, which require an integrated approach to sustainable food security planning. In addition, Oelviani *et al.* (2024) found that declining interest among the younger generation in the agricultural sector, coupled with pressure to convert land, poses a significant long-term threat to food security in rice-producing areas on the island of Java.

Jember Regency, in East Java Province, holds a strategic position in contributing to regional and national food security, with a rice-growing area exceeding 120,000 hectares per year and grain production exceeding 600,000 tons. However, consistent production surpluses do not automatically guarantee sustainable food security. The rice agribusiness system faces several structural issues identified in several studies. (Atasa *et al.*, 2022), Moreover, argue

that although small-scale farming faces various challenges in the context of globalization and modernization, this sector still plays a crucial role in food security and poverty alleviation, but requires appropriate policy support.

From an agribusiness risk management perspective, rice farmers face a variety of interrelated and complex risks. Hardaker *et al.* (1997) identified five dominant risk categories in their comprehensive framework for agricultural risk management: production risk, price risk, institutional risk, personal risk, and financial risk. In the context of developing countries, Dercon (2006) found that poor households employ various coping strategies to deal with income risks, including income diversification, asset accumulation, and the use of social networks as a safety net. Barrett *et al.* (2022) identified a feedback mechanism that reinforces the relationship between chronic poverty and low soil fertility in subsistence farming: when poor farmers are unable to invest in maintaining soil fertility, this worsens their economic conditions. A more recent study by Wauters *et al.* (2015) expanded the risk management framework by integrating behavioral dimensions, showing that farmers' perceptions and attitudes toward risk significantly influence the adoption of risk management strategies, a finding relevant to understanding adaptation behavior in Jember Regency. Furthermore, Komarek *et al.* (2020) presented a comprehensive review of agricultural risk management in developing countries, emphasizing the importance of a context-specific approach that accounts for local institutional environments and socioeconomic conditions.

Adaptation strategies are key to addressing high levels of uncertainty and risk in agribusiness. Momtaz & Shameem (2015) define adaptation as the process of adjustment within an ecological socio-economic system in response to actual or anticipated stimuli and their impacts, distinguishing between autonomous adaptation, which occurs spontaneously at the farmer level, and planned adaptation, which involves policy interventions. In their study in Ethiopia, Rodenburg *et al.* (2021) found that the adoption of adaptive agricultural practices, such as changing planting times, using drought-resistant varieties, and conserving soil and water, significantly increased productivity and stability of food production, demonstrating that farmer-based adaptation is an effective strategy in addressing climate uncertainty. A recent contribution by Omokpariola *et al.* (2025) further confirms that farmers' access to agricultural information and extension services significantly increases their adaptive capacity and willingness to adopt climate-smart agriculture practices, emphasizing the critical role of information dissemination in the adaptation process.

In the context of food governance, data-driven planning and prediction are crucial for ensuring food supply stability. The ability to accurately predict rice production and demand enables better decision-making on resource allocation, pricing policy, food stock management, and agricultural infrastructure development. Zilberman *et al.* (2018) used an economic approach to examine the trade-offs between the costs and benefits of various response options to climate change and found that cost-efficient adaptation strategies vary across agro-ecological and socio-economic contexts. A comprehensive interpretation of rice predictions can serve as a basis for formulating effective adaptation and risk management strategies at the farmer, agribusiness, and policy-making levels.

This research is relevant because in-depth studies on integrating rice prediction interpretation into risk management strategy formulation are still rarely conducted systematically. The literature review reveals a significant research gap: although previous studies have examined agricultural management Hardaker *et al.*, (1997); Komarek *et al.*, (2020), climate adaptation strategies Smit, (2018); Falco *et al.*, (2021), and food governance

planning Larasati, (2024) as separate domains, there is still a lack of studies that systematically integrate the interpretation of rice production prediction data with the formulation of risk management strategies within a food governance framework. Most existing research focuses on predictive modeling at the macro level or farmer adaptation behavior at the micro level, without bridging these two dimensions through an integrated analytical approach. Furthermore, studies specifically examining the use of predictive data in operational decision-making for food governance at the district level in Indonesia remain very limited. In the context of Jember Regency, although production forecast data is available from the Central Statistics Agency (BPS) and the Department of Agriculture, no previous study has systematically examined how this data is interpreted, disseminated, and used across stakeholder levels for risk management and governance planning. This study aims to explore and analyze adaptation and risk management strategies in the rice agribusiness in Jember Regency using a rice forecast interpretation approach as a basis for food governance planning. By utilizing a business administration perspective that emphasizes managerial, organizational, and governance aspects, this study is expected to provide strategic recommendations for various stakeholders in strengthening local food security and improving the sustainability of the rice agribusiness system in Jember Regency, while also contributing to the development of agribusiness risk management theory and practice within the context of sustainable food security.

The novelty of this study lies in its integrative approach, combining rice forecast interpretation with agribusiness risk management within a food governance planning framework. Unlike previous research, which tends to treat these elements separately, this study presents a holistic analysis of how predictive data interpretation can be used to formulate more effective, anticipatory risk management strategies, thereby contributing to evidence-based food governance planning. By examining the phenomenon from the perspectives of various stakeholders, including farmers, agribusinesses, policymakers, extension workers, and academics, this study offers a multi-layered understanding of the challenges and opportunities in integrating predictive information into risk management and food governance practices at the local level. The research findings contribute to the theoretical development of an agribusiness risk management framework and the practical improvement of food governance planning in rice-producing regions in Indonesia.

2. Methodology

This study employed qualitative, descriptive-exploratory methods and an interpretivist paradigm to comprehensively understand adaptation strategies and risk management in rice agribusiness in its natural context. It should be emphasized that this study does not develop a new predictive model for rice production; rather, it examines the use and interpretation of existing predictive data produced by institutions such as the Central Statistics Agency (BPS) and the Department of Agriculture in food planning and governance practices. The term "prediction interpretation" in this study refers to a qualitative exploration of how stakeholders understand, contextualize, and apply available production forecast data in decision-making processes.

The study was conducted in Jember Regency, East Java Province, for 4 months, from March to June 2025, covering the dry-season planting and harvesting periods. The location was selected because Jember Regency is a significant rice production center with relatively complete data availability and a diversity of rice production systems. The main data were

collected through in-depth interviews and field observations of respondents selected using targeted sampling and snowball sampling methods. A total of 27 informants were selected based on the following criteria: (1) direct involvement in rice agribusiness or related governance activities in Jember Regency for at least five years; (2) able to provide in-depth information regarding risks, adaptation strategies, and/or the use of predictive data; and (3) willing to participate voluntarily in the research. The informants included: rice farmers with at least 10 years of experience (12 informants), farmer group leaders and Gapoktan administrators (5 informants), rice agribusiness actors (3 informants), officials from the Department of Agriculture and Food Security (3 informants), agricultural extension workers (2 informants), and agricultural academics/researchers (2 informants). The informant selection process began with purposive sampling of key informants from each stakeholder category, followed by snowball sampling to identify additional informants with complementary perspectives. Secondary data were obtained from the Central Statistics Agency (BPS), the Department of Agriculture and Food Security of Jember Regency, and various related policy documents. Data analysis was conducted using a thematic analysis approach through three activity flows according to Miles *et al.*, (2014): data condensation (verbatim transcription, codification, categorization, and preparation of analytical memos), data presentation (descriptive narratives, comparison matrices, and direct quotes from informants), and gradual conclusion drawing with verification through data triangulation from various sources and methods. Data validity is assessed based on four criteria: credibility is ensured through triangulation of long-term investment, sources, and methods, and participant verification; transferability is ensured through detailed contextual descriptions; reliability is ensured through systematically documenting the research process and establishing a comprehensive audit trail; and verifiability is ensured through researchers' reflection and storing raw data for external auditing. This approach ensures methodological rigor and validity of the research findings in exploring the complexity of adaptation strategies and risk management of rice agribusiness in Jember Regency.

3. Results and Discussion

3.1. Dynamics of Paddy Production and Consumption

Data analysis shows that Jember Regency consistently recorded a rice production surplus, averaging around 30,000 tons per year from 2014 to 2026. Rice demand trends show a consistent increase, with an average annual growth rate of around 1.8 percent, in line with population growth and rising per capita rice consumption. Meanwhile, rice supply trends also show a relatively consistent increase, with an average annual growth rate of around 1.5 percent. Data show that in 2020, the harvested rice area reached 121,060 hectares, with a production of 590,026 tons, increasing to 124,028 hectares and 615,070 tons in 2021. In 2024, the harvested area reached 120,044 hectares with a production of 624,051 tons. Average rice productivity reaches 5.1–5.2 tons per hectare of dry milled grain, slightly above the national average. This production pattern is consistent with broader trends identified by Iizumi *et al.* (2018) regarding yield variability in Asia's rice-producing regions, where surplus production can mask underlying vulnerabilities related to climate variability and structural inefficiencies in the agrifood supply chain.

An informant from the Department of Agriculture stated: "Even though we have a surplus, this does not guarantee food security, because there are distribution issues, price

fluctuations, and the weak bargaining position of farmers.” This statement reflects the complexity of food security issues that go beyond production alone. Analysis shows that production patterns are influenced by seasonal factors, with peak production during the planting season at around 400,000 tons and during the dry season at around 220,000 tons. This condition causes seasonal price volatility, which impacts the economic stability of farmers and other agribusiness actors. This finding aligns with Pinstруп-Andersen, (2009) multidimensional framework for food security, which asserts that adequate production alone is insufficient without addressing the dimensions of access, distribution, and stability. The observed seasonal price volatility also aligns with Reardon & Timmer's (2014) analysis of the transformation of agrifood systems in Asia, where market imperfections and weak value chain integration exacerbate price transmission issues from producers to consumers.

3.2 Risk Identification in Paddy Agribusiness

The research findings identified five main categories of risks faced by rice agribusinesses in Jember Regency. First, production risks, including crop failure due to pests and diseases, extreme weather, and input availability. One farmer stated, “Last season, I experienced almost 30 percent crop failure due to planthoppers; this is becoming more frequent due to unpredictable weather”. Climate change increases production uncertainty. Extreme weather events are becoming more frequent. The implementation of technology and good agricultural practices (GAP) is suboptimal, with only around 40 percent of farmers consistently implementing GAP recommendations. The majority of farmers still rely on conventional cultivation practices and have limited knowledge of climate change adaptation. These findings confirm Arora (2019) observation that smallholder farmers in developing countries face increased production risks due to limited adaptive capacity, and extend Hardaker *et al.*, (1997) risk classification by showing how climate change strengthens the interrelationships between production risk categories in tropical rice farming systems.

Second, price risk is one of the most significant challenges. Sharp price fluctuations, especially during the peak harvest season, often harm farmers. A farmer group administrator explained: “During harvest time, the price of grain at the farm level can drop below the government purchase price; we have no bargaining power.” The asymmetry in price information between farmers and intermediaries creates an unfair bargaining position for farmers. The government’s reference purchase price is often not reflected in farm-level transactions due to difficult-to-meet quality requirements and farmers’ limited storage capacity. This price risk dynamic is consistent with the following results of Komarek *et al.*, (2020), who identified information asymmetry and weak market institutions as key drivers of price risk for smallholder farmers in developing countries. Farmers’ low bargaining power also reflects structural inequalities, as outlined by Poulton *et al.*, (2010) in their analysis of the livelihood strategies of poor groups, where limited market access perpetuates the poverty trap.

Third, institutional risk relates to the inconsistency and uncertainty of agricultural policies. Changes in subsidy policies, purchase prices, and agricultural programs often occur without adequate preparation and outreach. An agricultural extension worker stated: “Farmers are often confused when policies change suddenly; they have already made plans based on previous information.” Limited access to formal credit and complicated banking procedures force farmers to rely on informal lenders with higher interest rates. Farmer group institutions, while existing, have not yet functioned optimally as a buffer against various risks.

Fourth, financial risks stem from limited access to capital and farmers' debt burdens. Most farmers have limited capital and rely on debt to finance production. One agribusiness actor explained: "Rice farming is high-risk with thin margins; if one season fails, farmers can enter a cycle of debt." The absence of appropriate insurance schemes for smallholder farmers increases their vulnerability to production and price shocks. Existing agricultural insurance remains very limited in coverage and is not yet fully accessible to all farmers. Barrett & Bevis (2015) identified a similar mechanism linking low soil fertility to chronic poverty, in which financial constraints hinder investment in productivity-enhancing inputs, creating a cycle of vulnerability that is difficult to break without external intervention.

Fifth, personal risks relate to farmers' health, safety, and human resource capacity. The farming population is aging, with an average age of over 50, while younger generations are very interested in farming. One academic stated, "If there is no regeneration, future food security will be seriously threatened." Limited training and capacity-building for farmers in adopt technology and innovation further exacerbate this situation. This demographic challenge is reinforced by Okoth & Omar, (2025), who documented the declining interest of younger generations in agricultural work in Java, attributed to perceptions of low returns, physical work demands, and the limited social prestige of farming. An aging farming population has significant implications for the long-term sustainability of production and the adoption of innovative risk management strategies (Hazell *et al.*, 2010).

3.3 Adaptation Strategies of Agribusiness Actors

Rice agribusinesses in Jember Regency have developed various adaptation strategies to address risks. Technical adaptation strategies include adopting superior varieties resistant to pests and adverse climate conditions, adjusting planting and harvesting times based on weather predictions, and implementing integrated pest management (IPM). One farmer stated: Now we use varieties recommended by extension workers that are more resistant to drought and disease. Although still limited, the application of precision agriculture technology has shown positive results in increasing efficiency and reducing yield losses. The use of information systems for monitoring weather and plant health is increasingly adopted by advanced farmers and large-scale farmer groups. The adoption of these technical strategies aligns with the findings of Di Falco *et al.*, (2011) in Ethiopia, where farmers who adopted several adaptive practices, including variety selection and adjusting planting times, experienced higher productivity and production stability. However, the effectiveness of technical adaptation depends on farmers' access to timely and accurate information, as emphasized by Olarewaju *et al.*, (2025), who found a strong positive correlation between information access and the adoption of adaptive practices among smallholder farmers.

Economic adaptation strategies include income diversification through the integration of livestock and fisheries, and the development of added value through post-harvest processing. A farmer group administrator explained: "We do not rely solely on rice; some members raise cattle and fish in the rice fields to supplement income and reduce risk." Marketing strategies have also diversified, selling not only to middlemen but also directly to millers or through farmer-group-based collective marketing. Contract farming schemes have begun to be developed. However, their scope is still limited to providing price and market certainty. This economic diversification strategy aligns with Dercon, (2000) analysis of income risk-coping strategies, in which portfolio diversification is the primary mechanism for reducing income volatility among poor households. Dorward & Chirwa, (2012) also distinguish between

survival-oriented "hanging in" strategies and accumulation-oriented "stepping up" strategies. Therefore, economic adaptation in Jember encompasses both defensive risk mitigation and more proactive livelihood strengthening.

Social adaptation strategies emphasize strengthening farmer group institutions and collaborative networks among actors. Farmer groups function not only as a medium for extension and mentoring, but also as a forum for resource sharing and risk management. One farmer stated: In the group, we help each other; if someone is having difficulties, other members provide labor or capital. Developing social capital by strengthening trust and reciprocity among members is an important foundation for collective adaptation. Collaboration among farmer groups, local governments, the private sector, and universities is also being developed to increase adaptive capacity. This social mechanism reflects the emphasis of Smit & Wandel, (2006) that adaptive capacity is influenced by social capital, institutional support, and collective action. The role of farmer groups as risk-sharing platforms is crucial. Research by Wauters *et al.* (2014) shows that social networks and peer influence shape farmers' risk perceptions and the implementation of risk management strategies.

Institutional adaptation strategies include farmers' active participation in policy formulation processes and the strengthening of agricultural support institutions. Farmer involvement in the planning and evaluation of agricultural programs can increase policy relevance and effectiveness. An official from the Department of Agriculture stated: Now we involve more farmer representatives in program planning, so that policies are more grounded and aligned with farmers' real needs. The development of commodity information systems and agribusiness networks is also part of institutional adaptation to reduce information asymmetry and strengthen farmers' bargaining power.

However, this adaptation strategy still faces several obstacles. Limited access to technology and innovation, weak capital and infrastructure and a lack of coordination among stakeholders are the main obstacles. Furthermore, the adaptation strategies implemented are generally reactive and short-term, lacking proactive, long-term planning. Increasingly uncertain climate change and market dynamics demand more systematic, anticipatory adaptation strategies grounded in predictions and accurate data. This is important: the dominance of reactive adaptation strategies indicates that farmers in Jember Regency are engaging in more autonomous adaptation Smit & Wandel (2006) than planned, anticipatory adaptation. The transition to proactive adaptation requires the systematic integration of predictive data into decision-making processes, improved institutional coordination, and sustained investment in farmers' adaptive capacity, findings that underscore the importance of linking risk management with predictive governance planning, as discussed in the next section.

3.4 Utilisation of Paddy Prediction Interpretation in Food Governance Planning

An analysis of the use of rice prediction interpretation in food governance planning in Jember Regency shows that, despite the availability of various types of data and predictions, their use in operational decision-making is suboptimal. Production and demand predictions compiled by the Department of Agriculture and Statistics Indonesia (BPS) have not been fully disseminated or utilized by operational-level actors. One farmer stated, "We rarely receive information on production predictions or harvest estimates; we just rely on experience and habit." This statement reflects a significant gap in access to information between the policy and farmer levels. This gap aligns with a broader pattern identified by Olarewaju *et al.*, (2025),

which states that inadequate information dissemination mechanisms are a major barrier to the adoption of climate-smart agriculture in developing countries. The reliance on experiential knowledge rather than data-driven planning at the farmer level also illustrates the limitations of the current extension service model in bridging the science-practice gap.

At the policy level, predictive data is more commonly used in macro-level planning, such as setting planting area targets, supply and distribution planning, and stock management. An official from the Department of Agriculture explained: We use production predictions to plan procurement and logistics distribution programs, but dissemination to farmers is still limited. Integrated information systems linking production, price, stock, and distribution data are still under development and not yet fully functional. Limited information technology infrastructure in rural areas also hinders the dissemination and access to predictive information.

At the agribusiness level, some large-scale farmers and farmer groups are beginning to utilize predictive information for production and marketing planning. One farmer group administrator stated: If we know a region will have a bountiful harvest, we can prepare storage or seek alternative markets outside the region. Collaboration with research institutions and universities to develop predictive systems and decision-making tools is also underway, though it is still at the pilot project stage. Adopting this technology requires not only adequate infrastructure but also strengthening farmers' capacity and digital literacy.

Interpreting rice predictions goes beyond numbers; it requires a contextual understanding that encompasses local climate, land characteristics, social conditions, and agronomic practices. One researcher emphasized: Predictive data becomes meaningful only when correctly interpreted and contextualized to local conditions; numbers alone are not enough. Translating technical prediction data into information that is easily understood and applicable to farmers requires an effective communication approach and the strengthening of extension workers' capacity as information intermediaries. Developing a participatory early warning system that involves farmers in the monitoring and interpretation of predictions can increase their relevance and utility at the operational level. This finding is relevant to Zilberman *et al.*, (2018) argument that cost-efficient adaptation strategies are context-specific and require local interpretation of broader prediction data. A participatory approach to prediction interpretation also aligns with Okoth & Omar, (2025) emphasis on data-driven governance that accommodates stakeholder perspectives at multiple levels of the food system.

3.5 Integration of Risk Management and Planning

Effective integration of risk management and predictive planning requires a systemic approach involving all stakeholders in the rice agribusiness chain. The theoretical framework of adaptive governance, as proposed by Smit & Wandel, (2006), is relevant to the context of Jember Regency, where flexibility and responsiveness to change are key in policy formulation and implementation. Developing a multi-stakeholder platform that brings together farmers, farmer groups, agribusiness actors, government, researchers, and civil society can facilitate information exchange, coordination, and collective action in risk management and planning. Komarek *et al.*, (2020) also advocate a multi-stakeholder approach to agricultural risk management, emphasizing that effective risk governance requires integrating diverse knowledge systems, including scientific predictive data, local knowledge, and market intelligence, into a coherent planning framework.

The implementation of an integrated food security information system is a crucial prerequisite for supporting predictive risk management and planning. This system must be able to integrate various types of data and information, ranging from production, prices and stocks to distribution, climate and markets, in a format that is easily accessible and understandable to a wide range of users. An academic suggested: We need an integrated information system that can be accessed in real time by all stakeholders, from farmers to policymakers. Investment in information and communication technology infrastructure, especially in rural areas, is a prerequisite for the system's effectiveness.

At the policy level, integrating risk management and planning requires coordination among relevant institutions, including the Department of Agriculture, the Department of Trade, the Regional Development Planning Agency, and the State Logistics Agency (BULOG). An integrated approach to policy formulation can reduce overlaps and gaps in agricultural and food security programs. Developing contingency plans based on risk scenarios and predictions is also crucial for anticipating various possible conditions and determining appropriate responses. An official from the Department of Agriculture stated: We are developing a planning system that is more anticipatory, not merely reactive, based on risk mapping and production predictions.

At the farmer level, strengthening capacity in risk management and utilizing predictive information is essential. Training and mentoring related to the application of adaptive agricultural technology, financial management, and the use of information systems need to be carried out systematically and continuously. Strengthening farmer group institutions as platforms for collective learning and joint action can increase farmers' adaptive capacity. The development of farmer-to-farmer extension models and participatory innovation can accelerate the diffusion of innovations and good practices in risk management.

3.6 Challenges and Opportunities in Sustainable Food Governance

Sustainable food governance in Jember Regency faces various structural and operational challenges. Competition between agricultural and non-agricultural land uses continues to intensify, reducing rice paddy area and threatening long-term production sustainability. Land degradation due to intensive exploitation and excessive use of agrochemicals also poses a serious threat. Climate change, with its increasingly unpredictable variability, creates uncertainty in production planning and risk management. The aging of the farming population and the declining interest of younger generations in agriculture pose demographic challenges that require serious attention. These challenges not only occur in Jember, but also reflect a broader structural transformation in Asian agriculture, as documented by (Reardon & Timmer, 2014). The interaction between land conversion, demographic shifts, and climate change creates a "triple squeeze" that threatens the viability of rice-based food systems, demanding a comprehensive governance response that integrates the technological, institutional, and social dimensions of adaptation (Iizumi *et al.*, 2018).

However, there are numerous opportunities to strengthen sustainable food security. Advances in agricultural technology, including precision farming, digitalization, and automation, have the potential to increase efficiency and productivity. The development of value chains and agro industries can increase the added value of agricultural products and create jobs. Increased public and government awareness of the importance of food security and sustainable agriculture can support resource mobilization and political commitment.

Market opportunities for organic and sustainable products are also expanding, offering better incentives for farmers.

The development of innovative agribusiness financing and risk management strategies, such as microfinance schemes, crowdfunding, and parametric insurance, can improve access to capital and risk protection for smallholder farmers. Strategic partnerships among the public, private, and civil sectors can accelerate innovation and resource mobilization for sustainable agricultural development. Integrating local wisdom and traditional knowledge with modern science and technology can yield more contextually and culturally appropriate adaptation strategies.

Sustainable food governance demands a balance between meeting current food needs and preserving natural resources for future generations. The principle of sustainable intensification, as proposed by Mahon *et al.*, (2017), is relevant in the Jember context, where increased productivity must be accompanied by environmental conservation and improved social welfare. The implementation of good agricultural practices, efficient natural resource management, and agricultural waste reduction is crucial for achieving a sustainable production system. Social protection policies and farmer welfare programs also need to be strengthened to ensure the sustainability of the farming profession and food security.

4. Conclusion

This research shows that although Jember Regency maintains a consistent rice production surplus, food security is not automatically guaranteed due to the complexity of risks and structural challenges within the agribusiness system. Rice agribusiness actors face five main risk categories: production risk, price risk, institutional risk, financial risk, and personal risk, which are interrelated and impact the sustainability of farming businesses and food security. Various adaptation strategies have been implemented, encompassing technical, economic, social, and institutional strategies, but their effectiveness remains limited by barriers to access to technology, capital, information, and coordination among stakeholders. The analysis reveals that current adaptation strategies tend to be reactive and autonomous (Smit & Wandel, 2006), with limited integration with predictive, anticipatory planning. The transition to more proactive, data-driven adaptation requires systematic improvements to information systems, institutional coordination, and strengthening farmer capacity.

The use of rice prediction interpretation in food governance planning remains suboptimal, characterized by a significant gap in information access between the policy and operational levels. The development of an integrated food security information system, strengthening multi-stakeholder coordination, strengthening risk management capacity and utilizing predictive information are crucial for improving the effectiveness and integration of planning and risk management. Predictive interpretation requires not only accurate data but also contextual understanding and effective communication with all stakeholders.

This study recommends several strategic steps: (1) developing an integrated food security information system that can be accessed in real time by all stakeholders; (2) strengthening multi-stakeholder coordination and collaboration through the development of a participatory governance platform; (3) increasing investment in agricultural infrastructure and information technology; (4) developing social protection and risk insurance schemes for smallholder farmers; and (5) strengthening farmer capacity in technology adoption, risk management, and the utilization of predictive information. Implementing these recommendations requires commitment and synergy from various stakeholders to achieve

sustainable food security in Jember Regency. Future research is recommended to include longitudinal studies to assess the effectiveness of integrating risk management and predictive governance planning, as well as comparative analyses across rice-producing districts to increase the generalizability of the findings.

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