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Sustainable Rice Farming: Integration Strategy to Increase Rice Productivity in North Maluku Province, Indonesia

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ABSTRACT

Background: This study examines integrative strategies to increase sustainable rice production in East Halmahera District, North Maluku Province, Indonesia. Although the region has great potential in rice production, productivity instability and limited infrastructure are significant constraints.

Methods: The research method involved a qualitative approach through interviews, field observations and questionnaires with farmer group leaders and government officials. Data were analyzed using SWOT (Strengths, Weaknesses, Opportunities, Threats) and QSPM (Quantitative Strategic Planning Matrix) to generate strategy recommendations based on internal and external factors.

Result: The strategy that should be prioritized is to build collaborative programs between farmers and local governments to increase access to resources and technology while improving product quality through agricultural practices that are resistant to climate change and input price fluctuations so that they can compete with products from outside with a total alternative strategy (TAS) value of 3.75.

Key words: Agriculture, Integration, Rice, Strategy, Sustainable.

INTRODUCTION

Food crops are essential in agricultural development and they continue to grow and develop periodically. One such crop is rice (Fahrial, 2022). Paddy rice is necessary for food security in Indonesia, as it is the leading staple food for most of the population (Ekaria, 2023). Rice is cultivated in a wide spectrum of locations and under various climatic conditions, ranging from the wettest areas in the world to the driest areas (Nagarajan, 2024).

Rice production in North Maluku, Indonesia, has fluctuated over the past few years, raising concerns about the stability of the region's food supply (BPS-North Maluku, 2022). Previous literature studies show that the main challenges wet-rice farmers face in East Halmahera include the need to utilize modern agricultural technology more, limited access to adequate infrastructure such as irrigation networks and insufficient institutional support (Haryati La Kamisi, 2021). Sustainability in adaptive technological innovations, such as using rice varieties that are more resistant to extreme weather changes and applying appropriate planting methods, is very important because achieving and maintaining a certain level of productivity requires a balanced and proportional sustainable effort (Aurélie Perrin, 2023). The success of agricultural development programs is highly dependent on improving institutions' role, function and performance (Poppy Arsil, 2011). However, achieving these goals will be difficult without the support of adequate basic infrastructure, especially in agricultural areas spread across various sub-districts (Abdullah, 2018). Several factors affect rice production, including management practices such as using appropriate cultivars, planting timing, plant density, fertilizer application and irrigation systems (Saythong Vilayvong, 2015).

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The main research problem in this context is how to sustainably increase wet-rice production in East Halmahera Regency. The instability of wet-rice output in the area is often caused by reliance on less efficient traditional cultivation techniques and farmers' limited access to critical resources, such as business capital and information on modern agricultural technology (Ekaria, 2023). This problem is made more complex by the geographical condition of East Halmahera, which mainly consists of hilly areas and coastal areas, affecting the equitable distribution of water resources to all agricultural lands. In general, various policies implemented by the central and local governments, such as expanding paddy fields and providing superior varieties, have yet to be fully effective in overcoming these challenges. Typical solutions include providing farmers access to technology and training, improving farmers' institutional capacity through

strengthening farmer groups and developing irrigation infrastructure to support water needs in paddy fields.

Previous scientific literature has proposed some specific solutions to overcome this problem. The use of improved varieties has contributed substantially to the increase in average national rice production, reaching 4.5 tons/ha (Asnawi, 2014). Various studies have also focused on using more efficient irrigation methods, considering that water availability is one of the important factors in rice production. Implementing effective irrigation networks in paddy fields can increase productivity by 20-30% per growing season (Aprilia, 2023). The challenges faced by East Halmahera Regency related to limited labor and inadequate infrastructure require a more comprehensive approach focused not only on production aspects but also on empowering human resources and increasing institutional capacity (Abdullah, 2018).

One of the more specific approaches is strengthening farmers' institutions by forming farmer groups. There is a relationship between the role of farmer groups and the productivity of rice farming (Handayani, 2019). Strong farmer institutions not only increase farmers' access to capital and markets but also increase the adoption of agricultural technology (Agus, 1997). Empowering Gapoktan as a facilitator to connect farmers with the government and the private sector enables better access to technology and business capital (Hamid, 2018). However, previous literature has not detailed the effectiveness of this approach in infrastructure-limited areas such as East Halmahera. Improved varieties and structured irrigation utilization can increase yields, while strong institutions at the farm level can facilitate the adoption of these technologies (Abdullah, 2018). The literature on implementing this approach is still minimal and research has yet to precisely evaluate the effectiveness of this combination of techniques in the East Halmahera region. The limited irrigation infrastructure and lack of training and counseling for farmers indicate gaps in implementing strategies to increase rice production in this region.

A significant gap is a need for empirical studies that discuss internal factors, including strengths and weaknesses, external factors, including opportunities and threats and strategies for integrating adaptive technology with the institutional strengthening of farmers in increasing rice production in resource-limited areas such as East Halmahera. Previous studies have primarily focused on one aspect, either technology or institutions, without examining how the interaction between the two elements can have a more significant impact. In addition, most of the existing literature has yet to consider the specific challenges farmers face in rural areas, such as limited access to transportation and suboptimal market infrastructure. This research is expected to make a new contribution to developing a sustainable production improvement model in resource-constrained areas. The novelty of this research lies in the interactive analysis between technology and institutions in the context of regions with limited infrastructure, which has yet to be discussed in previous literature.

MATERIALS AND METHODS

Time of research and location

The research took place over two months, from February to March 2024, during the growing season in this region, making it easier to collect representative data on production and the challenges wet-rice farmers face during the growing season. This research was conducted in East Halmahera Regency, focusing mainly on the paddy rice production centers in the Wasile and East Wasile sub-districts. These two areas were selected based on their high land and production potential and have been administratively designated as rice paddy agricultural development areas by the local government. The research was carried out at the regent's office and the Agriculture Office of East Halmahera Regency.

Sampling

Deliberate sampling is called purposive sampling. In this study, informants or resource persons with expertise in agriculture were selected based on criteria relevant to the research objectives. The primary respondents included 11 heads of farmer group associations who have in-depth knowledge and understanding of the conditions and challenges in wet-rice production in their areas. In addition, the study involved five heads of local government agencies responsible for agricultural management: The head of the Regional Development Planning Agency, the Head of the Agriculture Office, the Head of the Food Security Office and the Head of the Wasile and East Wasile Agricultural Extension Centers. The combination of farmer group leaders and agency heads was chosen to provide a comprehensive perspective on agricultural policies, constraints and practices at the field level.

Data analysis methods

The collected data is analyzed using the SWOT analysis method (Strengths, Weaknesses, Opportunities, Threats). SWOT analysis is an ideal data analysis method because it can determine a product's strengths, weaknesses, opportunities and threats so that a development strategy can be made (Putra, 2019). The SWOT matrix is used to create ST (Strengths, Threats), SO (Strengths, Opportunities), WT (Weaknesses, Threats) and WO (Weaknesses, Opportunities) strategies. After developing several alternative methods, the organization must be able to evaluate and select the best plan that best suits the internal and external circumstances. This is referred to as the decision-making stage. The analytical tool used is QSPM (Quantitative Strategic Planning Matrix) (Putra, 2019).

RESULTS AND DISCUSSION

SWOT matrix (strength, weakness, opportunity and threat matrix)

The SWOT matrix is a chart designed to generate development strategies that combine four factors: strengths,

weaknesses, opportunities and challenges. These four factors are then divided into four strategies: SO strategy (strength-opportunity), WO strategy (weakness-opportunity), ST strategy (strength-challenge) and WT strategy (weakness-threat). The SWOT matrix can be seen in Table 1.

QSPM (quantitative strategic planning matrix) analysis

The results of the QSPM matrix analysis can be seen in Table 2, showing that the periodic strategy that should be prioritized is to build collaborative programs between farmers and local governments to increase access to resources and technology while improving product quality through agricultural practices that are resistant to climate change and input price fluctuations so that they can compete with products from outside with a Total Alternative Strategy (TAS) value of 3.75.

Integrative strategy recommendations for sustainable rice production improvement

Optimizing agricultural land, farmer institutions and skilled agricultural extension workers to implement adaptive agrarian technology innovations

The land area in East Halmahera Regency is the main potential for developing the paddy rice commodity. Paddy rice's total productive land area is approximately 5,024 hectares (BPS-North Maluku, 2022). The larger the land area, the greater the amount of production produced by the land (Abdul Rahim, 2008). Land area affects not only the level of farming efficiency but also the transfer and application of technology in agricultural development (Shinde, Kashid and Shende 2025)(Ara Anggar Andrias, 2017).

Strong farmer institutions are essential for farmers to access the technology, information and capital needed to increase productivity. Forming farmer groups, including rice paddies, significantly increases agricultural productivity. The role of farmer groups as a production unit is improved and the productivity of rice farmers will increase (Handayani, 2019). One of the main benefits of forming farmer groups is better access to agricultural resources and inputs. Farmer groups can purchase agricultural inputs such as seeds, fertilizers and pesticides by joint purchasing. This reduces production costs and ensures each participant can access the necessary inputs to increase crop yields.

Skilled extension workers can help farmers understand and implement the latest practices and technologies, such as improved seeds, contemporary irrigation techniques and efficient fertilization methods. Training provided to extension workers to enhance farmers' knowledge and skills improves their performance (Dewi Sahara, 2013). The training is divided into technical extension, management and agribusiness (Liani, 2013). Well-educated extension

Table 1: Matriks SWOT.

EFAS \ IFAS	Strength (S)	Weakness (W)
	1. Availability of agricultural land 2. Farmer institutions 3. Effective irrigation system 4. Skilled agricultural extension workers	1. Limited economic resources 2. Low product quality 3. Limited access to agricultural technologies
Opportunity (O) 1. Agricultural technology innovation 2. Regional Government policy support 3. High demand for rice	**Strategy SO :** 1. Optimizing agricultural land, farmer institutions and skilled agricultural extension workers to implement adaptive agricultural technology innovations. 2. Utilizing an effective irrigation system and local government support can increase production in line with market demand.	**Strategy WO :** 1. Utilize local government policy support to increase farmers' access to technological innovations, overcome limited economic resources and improve product quality according to market demand.
Threat (T) 1. Competition with external products 2. Climate/weather changes 3. Increase in the price of production inputs	**Strategy ST :** 1. Utilize the availability of farmland, farmer institutions and effective irrigation systems to increase resilience to climate change and rising production input prices and strengthen the competitiveness of local products by assisting skilled extension workers in implementing sustainable agricultural practices.	**Strategy WT :** 1. Establish collaborative programs between farmers and local governments to increase access to resources product and technology while improving quality through agricultural practices resilient to climate change and input price fluctuations to compete with products from outside.

workers strive to receive and carry out training well, which improves the quality of extension workers' human resources. Education is essential to improving the quality of extension operations (Peranginangin, 2016). Adaptive technology, such as high-yielding varieties and efficient irrigation techniques, is needed to increase land productivity. Using high-yielding varieties resistant to pests and extreme weather conditions is a solution to overcome the challenges of an uncertain climate (Abdullah, 2018). Farmers can reduce losses due to pest attacks and extreme weather using more adaptive rice varieties.

Land optimization strategies, farmer institutions and extension workers in adaptive technology innovation face challenges such as limited infrastructure, farmer resistance and suboptimal policy support. Emerging risks include failure to adapt technology, unequal access and negative impacts on the ecosystem and the socio-economic balance of farmers. Therefore, a participatory approach based on local research and sustainable policy support is needed for this strategy to be successful.

Utilizing an effective irrigation system and local government support can increase production in line with market demand

East Halmahera Regency has a high-potential natural irrigation network, one of the advantages of supporting rice cultivation. Natural irrigation from existing watersheds allows for wider water distribution. Water production is the economic or physical yield of each cubic meter of water used to produce grain or crops (Sukristiyonubowo, 2013). This network can support a more efficient irrigation system to increase rice productivity if managed well (Abdullah, 2018). Rotational irrigation systems involve setting schedules that alternate between farmers within an irrigation network, ensuring equitable water distribution and reducing wastage. The sustainability of production depends on developing more efficient and structured irrigation (Fadli, 2016). To increase the productivity and sustainability of wet-rice farming, collaboration between effective irrigation systems and proper guidance from extension officers will be essential.

Government support through conducive policies and capital loan facilities is essential to boost farmers' productivity. Local governments help farmers gain more comprehensive market access through the establishment of cooperatives, support in processing and marketing paddy products and setting minimum prices to protect farmers from adverse price fluctuations. The government also provides an agricultural insurance program to provide additional protection for farmers. Farmers say that joining the farm insurance program is very helpful when they experience crop failure; it makes them feel safe while farming and reduces loss (Nurilla Elysa Putri, 2019). Government support in marketing can help improve the sustainability of agricultural businesses, expand market access and provide stable price protection for farmers. An effective marketing system is indispensable in the agrarian goods market to increase producers' and consumers' added value and surplus (Akhmad Sutoni, 2021). The ever-increasing demand encourages farmers to increase rice production by increasing farmland, using superior varieties and applying modern technology in the cultivation process.

Implementing an effective irrigation system and local government support faces challenges such as budget limitations, inadequate infrastructure and suboptimal coordination between farmers and the government. Possible risks include imbalances in water distribution, farmers' dependence on unsustainable subsidies and conflicts in water resource management. If not managed properly, this strategy can lead to a mismatch between production and market absorption, leading to overproduction or price instability.

Utilize local government policy support to increase farmers' access to technological innovations, overcome limited economic resources and improve product quality according to market demand

Agricultural technology innovation aims to increase labor and land productivity and reduce production costs (Bahrul and Rusydi, 2022). Agricultural technology innovation is essential for advancing wetland rice farming as it helps farmers improve productivity, efficiency and sustainability. Economic resources include financial and human resources (capital) (labor, knowledge and skills). About 69.82% of wetland rice farmers use their limited capital (Ilma Satriana Dewi, 2015). Farmers struggle to obtain the necessary capital for investment in better technology and equipment due to a lack of access to financial resources such as banks and credit institutions in rural areas. Business capital derived from credit loans positively affects farmer happiness, with a regression coefficient of 0.29 (Nurmawati, 2016). Credit loans help farmers buy fertilizers, seeds and others related to agribusiness needs (Heri Susanto, 2021). Labor has a positive effect on the income/ income of farmers by looking at the need for labor on the land (Carmelo Tampubolon, 2024). Education plays a vital role in strengthening the labor force in the agricultural sector through increased knowledge and skills. Low levels of education can prevent group members from needing more ability to manage sustainable businesses (Mirza, 2017). A low education structure implies low literacy, limited insight and creativity, which in turn will reduce farmers' productivity in producing agricultural products and food crops (Aminah, 2015).

Lack of post-harvest processing technology, such as rice milling or mechanized drying, leads to decreased quality and added value of rice products. This reduces farmers' profits and affects competitiveness in the market. Farmers find it easier to store their harvest safely with adequate storage facilities, such as warehouses. As a result, agricultural products are often damaged or forced to be sold at a low price immediately after harvest. The lack of modern farm technology in paddy rice cultivation

Table 2: QSPM analysis results.

Critical factors for success	Bobot	Strategy alternative									
		Strategy 1		Strategy 2		Strategy 3		Strategy 4		Strategy 5	
		AS	TAS	AS	TAS	AS	TAS	AS	TAS	AS	TAS
Strength											
1. Availability of agricultural land	0.11	3	0.33	2	0.22	3	0.33	3	0.33	3	0.33
2. Farmer institutions	0.10	4	0.38	3	0.29	4	0.38	4	0.38	4	0.38
3. Effective irrigation system	0.11	4	0.43	3	0.32	4	0.43	3	0.32	4	0.43
4. Skilled agricultural extension workers	0.11	3	0.32	3	0.32	3	0.32	3	0.32	3	0.32
Weakness											
1. Limited economic resources	0.10	3	0.31	2	0.21	3	0.31	3	0.31	3	0.31
2. Low product quality	0.10	2	0.19	2	0.19	2	0.19	3	0.29	2	0.19
3. Limited access to agricultural technologies	0.11	2	0.21	2	0.21	2	0.21	2	0.21	2	0.21
Opportunity											
1. Agricultural technology innovation	0.09	2	0.18	2	0.18	3	0.27	2	0.18	2	0.18
2. Regional Government policy support	0.11	3	0.32	3	0.32	3	0.32	3	0.32	3	0.32
3. High demand for rice	0.10	4	0.40	4	0.40	4	0.40	4	0.40	4	0.40
Threat											
1. Competition with external products	0.10	3	0.31	3	0.31	3	0.31	3	0.31	3	0.31
2. Climate/weather changes	0.09	3	0.28	3	0.28	3	0.28	3	0.28	3	0.28
3. Increase in the price of production input	0.11	4	0.42	3	0.32	3	0.32	3	0.32	3	0.32
Total			3.35		3.74		3.64		3.65		3.75

practices also directly impacts production efficiency. To speed up the harvesting process, reduce grain loss during threshing and maintain old customs, farmers prefer to utilize hired labor (Sulha Pangaribuan, 2017).

Local government policy support in increasing farmers' access to technological innovation faces challenges such as budget constraints, low farmers' technological literacy and bureaucracy that can slow down the implementation of the program. Emerging risks include inequality in access to technology between small and large farmers, unsustainable reliance on government assistance and the possibility of low adoption of innovations if they do not match local conditions. If this strategy is not managed properly, the expected agricultural yield can be suboptimal, leading to production inefficiencies and inconsistencies with market demand.

Utilize the availability of farmland, farmer institutions and effective irrigation systems to increase resilience to climate change and rising production input prices and strengthen the competitiveness of local products by assisting skilled extension workers in implementing sustainable agricultural practices

Local farmers must increase productivity by utilizing available farmland, adopting modern agricultural technology and improving the quality of the rice they produce to face the competition. Climate change is causing increased weather, changes in rainfall patterns, rising temperatures and sea levels. One of the most impactful climate changes is the increased air temperature and humidity, leading to more pest and plant disease attacks, which can lead to crop failure due to unpredictable weather (Getmi Nuraisah, 2019). Climate change can impact water availability and trigger pest and disease attacks (Shanmugam *et al*., 2022) (Wiyono, 2010).

An increase in input prices directly increases the production costs of rice farming. This can reduce the profit margin earned by farmers, so they have a lower incentive to develop or scale up their farms. In the long run, high production costs can threaten the sustainability of rice farming. Farmers may reduce the use of inputs, such as fertilizers or pesticides, to reduce production costs. This may result in decreased land productivity and lower yields. With reduced productivity, rice yields are not optimal and farmers' income may decline.

Effective use of agricultural land, farmer institutions and irrigation systems to increase resilience to climate change and rising input prices face resource constraints, delayed technology adoption and poor coordination between stakeholders. Risks that can arise include inequality of access to resources and technology, over-reliance on government intervention and the possibility of land degradation if sustainable agricultural practices are not implemented correctly. If this strategy is not supported by adequate training for extension workers and farmers, the expected results may not be optimal, hindering the competitiveness of local products in the market.

Establish collaborative programs between farmers and local governments to increase access to resources and technology while improving product quality through agricultural practices resilient to climate change and input price fluctuations to compete with products from outside

Collaborative programs between farmer institutions and local governments through farmer group associations are a priority to encourage the adoption of modern technology and farmers' economic empowerment. Farmer group associations can facilitate training and counseling for farmers and be a key channel in the distribution of needed business capital. This support also enables farmers to manage their finances more effectively and strengthen marketing and distribution networks to ensure agricultural products can be sold in various markets. Create a digital-based platform that can be accessed by all parties involved in agriculture, including extension workers, farmers and other stakeholders. This platform could include a map of the region to enable the development of technology that suits the needs of the area and information that is disseminated thoroughly. It can also transmit information on each region's production assistance, marketing channels and climate change or rainfall. Digitization aims to make marketing channels more efficient and collect data on market conditions (Johan, 2022).

Establishing collaborative programs between farmers and local governments faces challenges such as differences in interests, budget limitations and low technology adoption due to a lack of understanding and training. Possible risks include inequality of access to resources, unsustainable reliance on government assistance and potential technological mismatch to local conditions that could hinder the effectiveness of agricultural practices. If this strategy is not managed properly, improving product quality and competitiveness against foreign products can be hampered, making it difficult for farmers to compete in the market.

CONCLUSION

Based on the study's results, building a collaborative program between farmers and local governments is the most important strategy to increase sustainable rice production in North Maluku. This strategy aims to increase access to resources and technology and improve product quality through agricultural practices that are adaptive to climate change and fluctuations in input prices. With a Total Alternative Strategy (TAS) value of 3.75, this finding confirms that the sustainability of rice production in North Maluku is highly dependent on synergy between various stakeholders. Implementing this strategy will increase the competitiveness of local products against rice from outside the region, strengthen regional food security and encourage agricultural economic stability in the area.

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Disclaimers

The integration strategy to increase rice productivity in North Maluku must prioritize sustainability. The use of environmentally friendly technologies, the wise management of natural resources and the enhancement of farmers' capacity through training are key factors in achieving this goal. Implementing sustainable rice farming in North Maluku is expected to improve agricultural yields, strengthen food security and maintain ecological balance. The article emphasizes that the success of this strategy's implementation highly depends on the support from all parties, including the government, local communities and the private sector.

Informed consent

The author did not use animal experiments.

Conflict of interest

The authors say that there is no conflict of interest.

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