

SUSTAINABILITY EVALUATION OF MINA PADI FARMING IN LEBAK SWAMPS USING THE MDS METHOD



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ABSTRACT

This study aims to evaluate the sustainability of Mina Padi farming on wetlands in Epees Village based on five dimensions of sustainability: economic, social, ecological, institutional, and technological. The research was conducted in 2023 and involved 75 farmers and village heads, farmer group leaders, agricultural extension officers, and the agriculture office. Data analysis used the Multidimensional Scaling (MDS) approach with the Rapfish method to calculate the sustainability index in each dimension. The dimensions used are economic, social, institutional, ecological, and technological. The results showed that Mina Padi farming is quite sustainable, with an overall index of 69.58. The economic, social, and ecological dimensions are in the sustainable category, with an index of 76.59, 78.65, and 84.74, respectively. However, the institutional and technological dimensions are moderately sustainable, with indices of 57.44 and 50.49, respectively. These findings indicate the need for institutional strengthening and adoption of innovative technologies to support long-term sustainability. Efforts to strengthen inter-institutional coordination, improve decision-making capacity, and encourage technological innovation are important steps to improve the sustainability of this system. With these improvements, Mina Padi farming has the potential to become a sustainable agriculture model that can be applied in other regions to support sustainable development globally.

Keywords: lebak swamps; MDS Rapfish; mina padi; sustainability; sustainable agriculture.

INTRODUCTION

Agriculture is essential to support food security worldwide, especially in developing countries such as Indonesia, which has a large population and growing food needs (Rhofita, 2022; Rumawas et al., 2021). The Mina Padi integrated farming system, which combines rice cultivation with fisheries on the same land (Khoirunisa et al., 2024; Megasari et al., 2024), is a promising method to optimize land efficiency (Freed et al., 2020; Megasari et al., 2024) and support sustainable agriculture (Fyka, 2024; Goswami et al., 2024). Besides increasing land productivity, the system brings social, economic, and ecological benefits (Lestari & Bambang, 2017). This makes it an agricultural model with sustainable food production (Ahmed & Turchini, 2021; Amiruddin et al., 2024; Pratiwi & Budiasa, 2021), where the system optimizes resource use, increases productivity, and reduces environmental impacts (Jian et al., 2011).

Lebak swamplands, extensively found across Indonesia, provide considerable potential for agricultural and fisheries advancement (Sugiartanti & Sarah, 2020). These regions are distinguished by periodic waterlogging, diverse biodiversity, and plentiful water resources (Arsyad, 2014; Simatupang & Rina, 2019). The execution of the Mina Padi system in the Lebak swamplands encounters several obstacles. Seasonal water management challenges, such as floods in the rainy season and drought in the dry season, hinder agriculture efforts (Bobihoe et al., 2015). The distinctive properties of lebak swamp soils, including acid sulfate conditions, pyrite compounds, and variable groundwater levels, need suitable technologies to guarantee the viability and sustainability of rice



agriculture (Slameto et al., 2021). Consequently, evaluating the sustainability of these systems is crucial to discern variables affecting their effectiveness and formulate appropriate remedies.

Prior research underscores the need to assess technical, institutional, social, ecological, and economic dimensions for sustainable agricultural practices (Nuraini & Mutolib, 2023; Pawiengla et al., 2020; Ruhimat, 2015) and aquaculture (Wibowo et al., 2015). The multidimensional scaling (MDS) technique is extensively used to assess sustainability, offering insights into the interrelations among indicators and pinpointing features that want improvement. Nevertheless, current research primarily focuses on specific facets of sustainability, including social, economic, or ecological factors, and often lacks a comprehensive perspective. Research by Fathony et al. (2023), Kriska et al. (2022), and Junaidi et al. (2023) investigated the sustainability of the Mina Padi system using quantitative methodologies and SWOT analysis under constrained parameters. Likewise, research by Fitra and Sapanli (2019) and Nuaini (2021) confined their assessments to three dimensions: social, economic, and ecological. Despite its promise, a thorough multidimensional investigation of the sustainability of Mina Padi farming, specially adapted to the distinctive circumstances of lebak swamplands, is still lacking. The lack of studies using a five-dimensional assessment framework reveals a substantial research gap, emphasizing the need for this study.

This research seeks to thoroughly evaluate the sustainability of the Mina Padi system in the Lebak swamplands via the MDS approach. This project aims to identify the key drivers and obstacles to sustainability in the Mina Padi system by assessing five principal dimensions: ecological, economic, social, technical, and institutional, and to formulate customized solutions to improve sustainability in lebak swampland ecosystems. This research enhances the broader debate on agricultural sustainability by addressing identified gaps and using a multidimensional approach. It provides pragmatic insights for policymakers and stakeholders while presenting a global reproducible blueprint for analogous ecosystems.

MATERIALS AND METHODS

This research was undertaken in 2023 in Epeesi Village, located in the South Konawe Regency, which serves as a focal point for advancing Mina Padi cultivation in wetland areas. The sample comprised 75 respondents, including farmers employing the Mina Padi system, village leaders, farmers of farmer groups, agricultural and fisheries extension agents, and representatives from the ministries of agriculture and fisheries. The study assessed the sustainability of Mina Padi farming by examining five dimensions: economic, social, ecological, institutional, and technological. The data were obtained from both primary and secondary sources. Primary data were collected through structured interviews using questionnaires with respondents, while secondary data were obtained from statistical reports and relevant journals.

The analysis employed the Multidimensional Scaling (MDS) methodology utilizing the Rapfish (Rapid Appraisal for Fisheries) software. Rapfish has been extensively utilized in numerous studies about rice cultivation, fisheries, and Mina Padi farming (Ekopsi et al., 2023; El Kifaf et al., 2023; Fitra & Sapanli, 2019; Hidayah et al., 2020; Nuaini, 2021; Nugrahapsari et al., 2021). The method employs an ordination technique to position attributes/parameters into specific orders, then transforms multidimensional data into simplified dimensions using MDS (Fauzi & Anna, 2002).

To obtain comprehensive analytical results on the evaluation of the sustainability of Mina Padi farming on lebak swamp land, five dimensions were used: social, economic, ecological, institutional, and technological. The following are the stages of the Rapfish analysis for Mina Padi, namely:

1. Identification of Attributes: Sustainability attributes for Mina Padi cultivation were discerned across five dimensions. Each economic, social, ecological, institutional, and technological dimension encompassed between eight and nine attributes.
2. Scoring: Scores were allocated based on field observations and expert assessments, ranging from 0 to 2. Several 0 signifies poor sustainability, whereas a score of 2 denotes high sustainability. A higher score indicates a more significant contribution to the sustainability of Mina Padi agricultural practices in wetland environments.
3. Sustainability Index Calculation: The scores were evaluated utilizing the MDS program to ascertain the sustainability status, which is represented on a sustainability index scale as delineated in Table 1.
4. Leverage Analysis: Sensitive attributes that substantially impact sustainability were discerned through the application of leverage analysis. Attributes exhibiting more significant root mean square (RMS) variations significantly influenced the determination of sustainability.

5. Monte Carlo Analysis: To ascertain the model's reliability, a Monte Carlo analysis was conducted to evaluate the errors stemming from scoring discrepancies, data variability, and the consistency of inputs. The acceptable thresholds comprised a stress value of less than 20% and a deviation of under 5% between the Monte Carlo and Rappfish values.
6. The analysis findings were represented through kite diagrams, illustrating the sustainability index for each dimension. Moreover, sensitivity analyses were performed to ascertain the most significant attributes affecting sustainability. These measures facilitated a thorough assessment of the sustainability of Mina Padi cultivation within the study area.

Table 1. Categories of sustainability status based on the index value of mds analysis results

Index Value	Category	Description
0,00 - 25,00	Bad	Unsustainable
25,01 - 50,00	Less	Less Sustainable
50,01 - 75,00	Simply	Sustainable Enough
75,01 - 100	Good	Very Sustainable

Source: (Kavanagh & Pitcher, 2004)

RESULTS AND DISCUSSION

This study assessed the sustainability status of Mina Padi farming on wetlands in Basala Sub-district, South Konawe District, using the Rapid Appraisal for MinaPadi (RAP-MinaPadi) method based on multidimensional scaling (MDS). The five dimensions of sustainability used include ecological, economic, social, institutional, and technological, with 43 assessment attributes as primary indicators. These dimensions were selected based on direct observations in the field, literature review, and discussions with various stakeholders. This approach was taken to obtain a comprehensive picture of the sustainability of Mina Padi farming in the region. Each dimension has different attributes that reflect its level of sustainability, which were then analyzed on an ordination scale. The following are the results of the analysis of the sustainability status of Mina Padi farming on the lebak swamp land.

Sustainability Value of Mina Padi Farming on Lebak Swamp Land Based on Economic Dimension

Using swamp land for Mina Padi farming provides economic benefits derived from these farming activities. The attributes used in the economic dimension to assess the sustainability of Mina Padi farming on lebak swamp land are income diversification, farmer income, source of livelihood, ease of selling production, subsidy dependence, fulfillment of fish and rice food needs of the family, Mina Padi is more profitable than monoculture, dependence on external capital sources, and the existence of fishing. Based on the results of the MDS analysis with RAPPFISH for Mina Padi in the economic dimension, the sustainability index of Mina Padi farming on lebak swamp land is 76.59, which means it is sustainable.

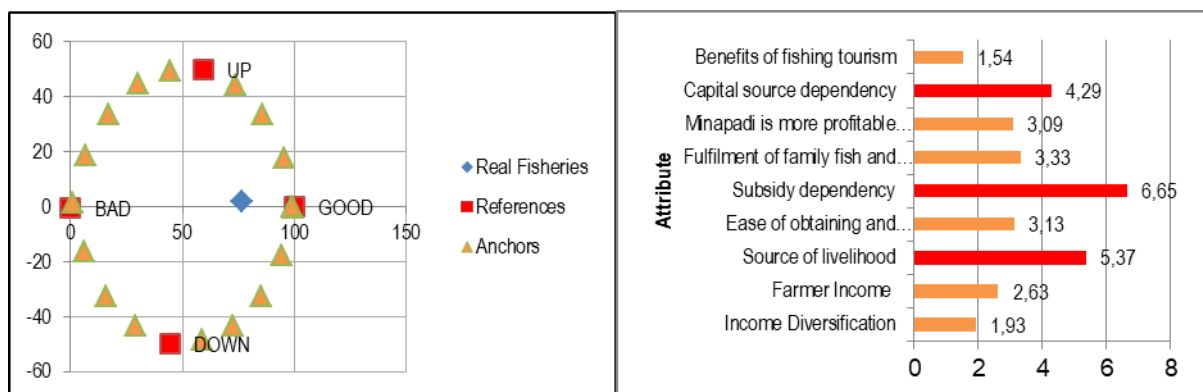


Figure 1. Rapfish-mina padi output and sensitivity analysis of economic dimension

This means that implementing Mina Padi farming in the lebak swamp land will benefit farmers economically. Based on research results and interviews with experts, respondents stated that implementing Mina Padi farming is more profitable than monoculture rice farming because Mina Padi

farming allows farmers to diversify their sources of income. Apart from the rice harvest, farmers can earn additional income from fish sales or fishing tours (Fyka et al., 2023; Sukri & Suwardi, 2016). Increasing the value of the sustainability index of the economic dimension of the development of Mina Padi farming on lebak swamp land needs to be done in the future by improving several sensitive attributes that affect the value of the sustainability index of the economic dimension. The results of the leverage analysis in the economic dimension (Figure 1) show that of the nine attributes analyzed, three sensitive attributes have the most significant influence on the sustainability index of the sustainable economic dimension. The three sensitive attributes are (1) subsidy dependency (6.65), (2) livelihood sources (5.37), and (3) dependency on capital sources (11.53). This means that to improve the sustainability status index value of the economic dimension, it is necessary to pay attention to and consider these three attributes.

The attribute with the highest sensitivity value to the sustainability status index of the economic dimension of Mina Padi farming on wetlands is dependence on subsidies, which is 6.65. Subsidies can help farmers access agricultural inputs, such as seeds, fertilizers, pesticides, and fish feed. The ease of obtaining fertilizer subsidies means that farmers can increase the productivity of their land in terms of yields (Adiraputra & Supyandi, 2021). Subsidies are given to help smallholder farmers who may not have much capital or resources. By providing financial assistance or agricultural input subsidies, the government can help improve the lives of smallholders and their farms (Sulaiman et al., 2023). Dependence on subsidies significantly affects the sustainability of Mina Padi farming in the lebak swamp. Subsidies such as assistance with fertilizers, seeds, and production tools can significantly help farmers lower production costs, allowing them to increase rice and fish yields.

With lower costs, farmers can earn better profits and maintain the economic stability of their families. However, if farmers rely too much on subsidies, problems can arise. If the subsidies are discontinued or the amount is reduced, they may find it challenging to run their farms due to a sudden spike in production costs. This can make their income uncertain and their farms vulnerable. Uncertainty about whether subsidies will continue to be provided also makes it difficult for farmers to plan for the future of their businesses.

On the other hand, dependence on subsidies can also make farmers less independent. They may be reluctant to seek other solutions, such as adopting new technologies or managing their businesses more efficiently. If subsidies are accompanied by training and mentoring, farmers can learn how to manage their businesses better and become more independent in the long run. To create better sustainability, subsidies should be provided with a clear strategy over some time. For example, the government could provide subsidies in the beginning to help farmers get back on their feet while providing training and access to other sources of capital. This way, farmers will have enough skills and resources to continue running their businesses even if subsidies are reduced or stopped. This will create a more stable and sustainable system for Mina Padi farming in wetlands.

Sustainability Value of Mina Padi Farming on Lebak Swamp Land Based on Social Dimension

The social dimension of sustainability refers to aspects that affect individuals' and communities' well-being and quality of life within an agricultural or fisheries system. Evaluation of the social dimension aims to understand how agricultural practices affect local communities, ensure active participation, improve living conditions, provide access to new knowledge and skills, and strengthen social networks. The attributes used to measure the sustainability of Mina Padi farming on lebak swamp land based on the social dimension are the level of education, age of farmers, land status, family participation, development of the number of Mina Padi farmers, cooperation and cooperation, frequency of conflict, frequency of counseling and local wisdom in Mina Padi cultivation. The results of MDS analysis with RAPFISH for Mina Padi in the social dimension show that the sustainability index of Mina Padi farming on wetlands has a value of 78.65, which means it is sustainable.

Increasing the value of the sustainability index of the social dimension of the development of Mina Padi farming on wetlands needs to be done in the future by improving several sensitive attributes that affect the value of the sustainability index of the social dimension. Based on the results of the *leverage* analysis in the social dimension (Figure 2), it shows that of the nine (9) attributes used in the analysis, three sensitive attributes have the most significant influence on the sustainability index of the social dimension of sustainability. The three sensitive attributes are (1) land status (6.29), (2) education level (4.59), and (3) frequency of counseling (4.33). This means that efforts to improve the sustainability status of the social dimension need to pay attention to and consider these three attributes.

Research shows that the main attribute that strongly influences the sustainability index of the social dimension of Mina Padi farming is land status, with the highest sensitivity value of 6.29. Clear

land status provides legal security to farmers, strengthens socio-economic stability, and encourages long-term investment (Siata & Nurfathiyah, 2014). Legal land ownership also increases farmers' autonomy in decision-making and reduces the potential for future agrarian conflicts (Manatar et al., 2017). Therefore, strengthening the legality of land tenure is crucial to support the sustainability of Mina Padi farming.

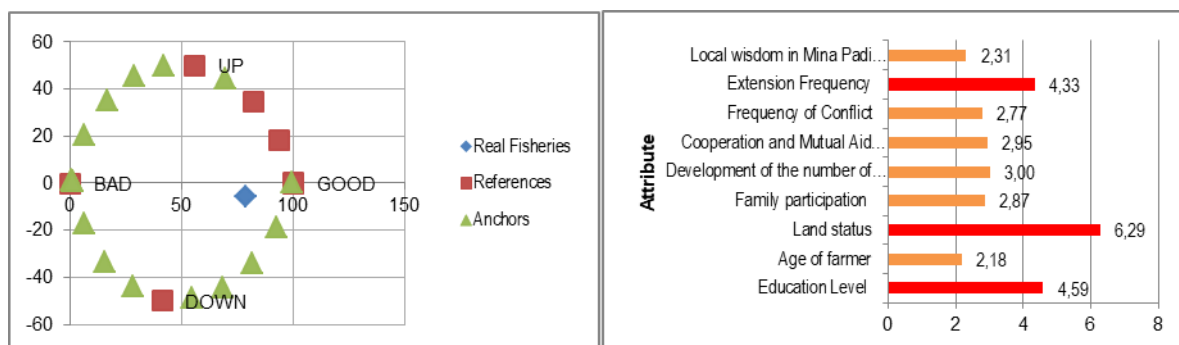


Figure 2. The output of Rapfish-mina padi and sensitivity analysis of social dimension

Another significant attribute is the farmers' education level, with a sensitivity value of 4.59. Most farmers only have basic education (SD and SMP), which limits their ability to adopt sustainable agricultural technologies and practices. The higher the farmer's education level, the more the farmer's ability to adopt technology for the development of his farm (Wibisonya, 2023). Higher education can improve technical literacy, managerial skills, and adaptation to environmental or policy changes (SDGs). Therefore, increasing farmers' access to education is a priority in supporting social sustainability and more efficient agriculture.

In addition, the low frequency of extension services (sensitivity value 4.33) exacerbates the impact of limited education. Regular and quality extension services are important in bridging knowledge gaps, providing practical training, and strengthening farmers' social networks. Extension as a motivator and facilitator can improve farmers' ability to develop their farms (Latif et al., 2022). Therefore, it is necessary to strengthen the role of extension to farmers to improve and support the sustainability of farming (Anwarudin et al., 2020). In addition, it will also increase farmers' ability to adapt to changes in markets, policies, and new technologies, which in turn will support the social and economic sustainability of Mina Padi farms. These three attributes indicate that the sustainability of the social dimension of Mina Padi farming is highly dependent on strengthening land status, improving farmer education, and optimising extension programmes. These strategic measures are in line with the sustainable development goals (SDGs) to holistically improve farmers' welfare and food security.

Sustainability Value of Mina Padi Farming on Lebak Swamp Land Based on Institutional Dimension

The institutional dimension plays a significant role in the sustainability of Mina Padi farming. Institutions refer to the structures, rules, and relationships that regulate interactions among farmers and between farmers and external parties in the future development of Mina Padi farming on lebak swamp land. In this study, the sustainability analysis of the institutional dimension used eight attributes, consisting of (1) the existence and role of farmer groups; (2) the role of government agencies (fisheries/agriculture); (3) the existence and role of extension workers; (4) the participation of farmers in farmer groups; (5) the role of formal institutions (researchers/PT/BPTP); (6) the existence and role of financial institutions (formal/non-formal); (7) support from the village government and (8) the existence of agricultural input providers.

Based on the results of the MDS analysis with *RAPFISH for MinaPadi* on the institutional dimension, the sustainability index of Mina Padi farming on wetland swamp land is 57.44, which means it is quite sustainable. The index value and sustainability status of the institutional dimension of Mina Padi farming on wetlands in South Konawe District can be seen in Figure 23. Several important attributes need to be considered in the institutional dimension. The first is the role of formal institutions such as researchers/PT/BPTP with a sensitivity value of 6.85, which shows their contribution to research and technology development that supports sustainability. Second, the role of government agencies (agriculture/fisheries), with a value of 5.36, indicates the need for government support and regulations to direct and optimize sustainable farming practices. Third, the presence and role of

extension workers, with a score of 3.41, indicate that extension workers play a role in providing technical guidance and counseling to farmers, which is also a crucial factor in achieving sustainability. Therefore, to improve the sustainability status of Mina Padi farming, special attention and consideration must be given to these three institutional attributes.

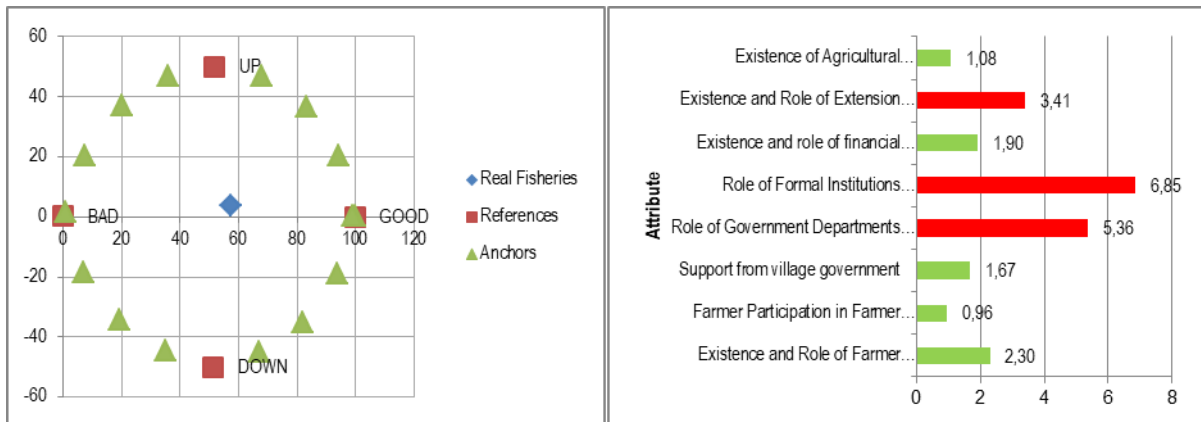


Figure 3. Output of rapfish-mina padi and sensitivity analysis of institutional dimensions

The sustainability of Mina Padi farming in lebak swamp land is a complex challenge and requires inter-institutional cooperation. The results show that coordination between the government, formal institutions, extension workers, and farmers is still not going well. One of the main constraints is the limited number of field instructors, who play an important role in introducing technologies and innovations to farmers. Without adequate extension services, many farmers do not receive the necessary information and assistance to support sustainable agricultural practices (Danapriatna et al., 2023; Naipospos & Martini, 2021). In addition, the participation of research institutions such as universities or BPTP in this region is still very low. Many farmers do not realize the potential benefits of working with these institutions, and the lack of trust-based relationships hampers collaboration (Anantanyu, 2011). This makes knowledge and technology transfer difficult. Farmer groups, which are supposed to be a platform for strengthening networks between farmers and related institutions, also have a limited role. Currently, the function of farmer groups is to focus more on routine activities, with no specific priority being given to Mina Padi development. Farmer groups have great potential as a link between farmers and financial institutions, research, and the government (Lestari et al., 2023; Nikoyan et al., 2020). Therefore, to improve the sustainability of Mina Padi farming in lebak swamplands, extension officers must provide technical guidance and facilitate access to resources and technology. In addition, farmer groups need to be empowered to become strategic coordination centers for farmers and related parties. Better synergy between various parties will be an important step in supporting sustainable agriculture, which is in line with the sustainable development goals (SDG 2, SDG 6, and SDG 15).

Sustainability Value of Mina Padi Farming on Lebak Swamp Land Based on Ecological Dimension

The ecological dimension plays an important role in the sustainability of Mina Padi cultivation. Agricultural practices that pay attention to ecological aspects will help maintain the balance of the ecosystem. Mina Padi cultivation can be sustainable by protecting biodiversity and reducing negative environmental impacts. In this study, the ecological dimension of sustainability was analyzed using nine attributes, consisting of (1) soil quality, (2) water quality, (3) fertilizer/pesticide use rate, (4) water availability, (5) Mina Padi mutualism; (6) land use rate for Minapadi; (7) natural weed and pest control; (8) frequency of drought; (9) frequency of flood.

The results of the RAPFISH For MinaPadi analysis in the ecological dimension show that the sustainability index of Mina Padi farming on the wetland has a value of 84.74, which means it is sustainable. Increasing the value of the sustainability index of the ecological dimension of the development of Mina Padi farming on wetlands needs to be done in the future by improving several attributes that are sensitive to affect the value of the ecological dimension sustainability index. A leverage analysis was conducted to determine the sensitive attributes that contribute to the sustainable value of the ecological dimension.

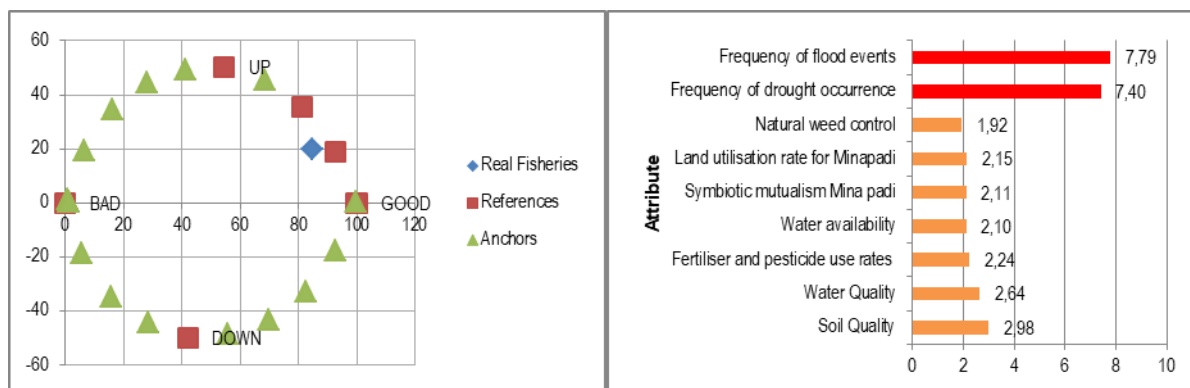


Figure 4. Rappfish-mina padi output and sensitivity analysis of ecological dimensions

Based on the RAPPFISH analysis, the sustainability index of the ecological dimension of Mina Padi farming in the wetland swamp reached a value of 84.74, which indicates a sustainable category. This indicates that managing natural resources in the Lebak swamp area supports ecosystem stability, including water balance, biodiversity, and land productivity. This sustainability is determined by two sensitive attributes: the frequency of flooding, with a sensitivity value of 7.79, and the frequency of drought, with a value of 7.40. The frequency of flooding is a key factor because the dynamics of the lebak swamp ecosystem are strongly influenced by water conditions. Excessive flooding can disrupt soil aeration, damage rice plants, and reduce land quality.

On the other hand, the frequency of drought can reduce the availability of water, which is crucial for plant productivity and biodiversity (Dewandini, 2020; Naufal & Chofyan, 2022). To address these challenges, good water management, including improved drainage systems and water suction technology, is an important solution. This strategy not only reduces negative environmental impacts but also supports Sustainable Development Goals (SDGs) targets, especially those related to sustainable water management (SDG 6) and ecosystem preservation (SDG 15). These results differ from Fitra and Sapanli (2019) study in Pacet District, Bandung Regency, which showed an index of 50.87 (moderately sustainable). Different ecosystem characteristics, levels of agricultural intensification and local environmental pressures can explain this difference. Thus, this study confirms that the ecological sustainability of farming is highly contextual, depending on ecosystem characteristics and local management practices. Lebak swamplands show higher potential in supporting sustainable agriculture if water resources are managed effectively.

Sustainability Value of Mina Padi Farming on Lebak Swamp Land Based on Technology Dimension

The technological dimension plays a significant role in maintaining the sustainability of Mina Padi cultivation. Appropriate technology can increase land productivity, reduce losses due to pests and diseases, and optimize the use of natural resources. Thus, the technological dimension plays a crucial role in supporting the sustainability of Mina Padi cultivation by applying sustainable and future-oriented innovations in agricultural practices. In this study, the technology-infrastructure dimension of sustainability was analyzed using eight attributes, consisting of: (1) water pump/alkon; (2) use of superior seeds/seedlings; (3) water wheel; (4) drainage channel; (5) harvesting technology; (6) farm road condition; (7) rice planting technology; (8) internet network access.

The results of the RAPPFISH For MinaPadi analysis on the technology-infrastructure dimension show that the sustainability index of Mina Padi farming on the wetland has a value of 50.49, which means it is quite sustainable. Increasing the value of the sustainability index of the technological dimension of Mina Padi farming development on the wetland needs to be done in the future by making improvements to several sensitive attributes that affect the value of the sustainability index of the technological dimension. The results of the leverage analysis in the technology dimension (Figure 5) show that of the eight attributes analyzed, three sensitive attributes have the most significant influence on the sustainability index of the technology dimension. The three sensitive attributes are: (1) waterwheel (3.51); (2) use of superior seeds/seedlings (2.51); (3) water pump/alkon (3.56).

The analysis results show that technology is important in supporting the sustainability of Mina Padi farming in lebak swamp land, which faces challenges such as water stagnation and fluctuations in water availability. The availability of waterwheels is the technology attribute that has the most

influence on sustainability, with a sensitivity value of 3.51. The presence of waterwheels will help improve water circulation, reduce inundation, and provide sufficient oxygen to support the health of rice and fish. In addition, this technology also prevents eutrophication and maintains water quality, thus supporting a more environmentally friendly farming system (Li et al., 2023; Ogawa et al., 2022; Setyowati et al., 2022).

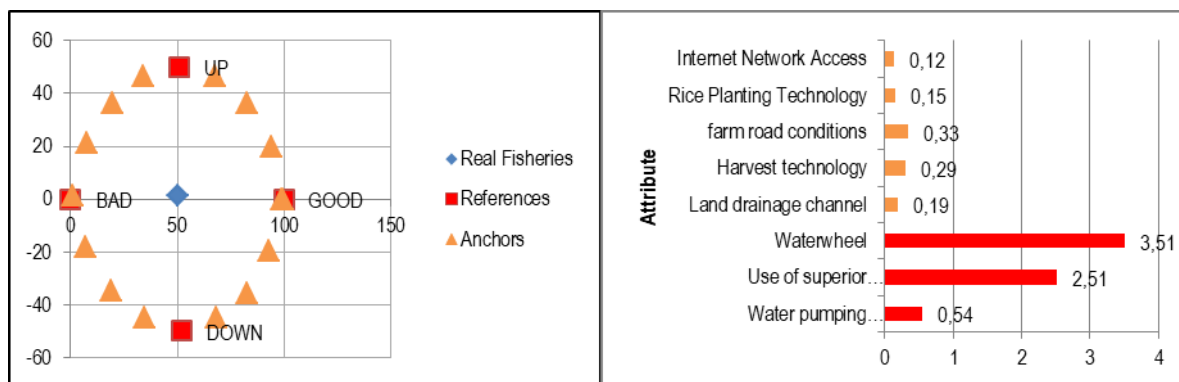


Figure 5. Rapsfish-mina padi output and sensitivity analysis of technology dimensions

In addition, the use of superior seeds and seedlings is also a key factor. Superior seeds resistant to disease and adaptable to environmental conditions have been shown to increase rice and fish productivity while reducing negative environmental impacts (Hu et al., 2023; Suriadikarta, 2012). However, interviews with farmers show that their knowledge in selecting improved seeds is still limited. This shows the importance of training and counseling so farmers can understand the long-term benefits of using high-quality seeds (Setyowati et al., 2022).

Another important technology is the water siphon (alkon), which helps farmers manage water fluctuations in their fields. They enable waterlogging control during the rainy season and replenishment of water during droughts. By managing water availability more effectively, they support ecological, social, and economic sustainability while helping farmers adapt to climate change (Pauzi et al., 2020).

This combination of technologies shows great potential to support the sustainability of Mina Padi farming in lebak swamp land. With the support of training, extension, and inter-agency synergy, the sustainability of this system can be further enhanced in line with the sustainable development goals (SDG 2, SDG 6, SDG 13, and SDG 15).

Based on the results of the analysis of the sustainability of Mina Padi farming on wetland swamp land using five dimensions, namely economic, social, ecological, institutional, and technological, it is known that the sustainability status of Mina Padi farming on wetland swamp land multidimensionally is 69.58 (quite sustainable). This follows research conducted by Fitra and Sapanli (2019), which states that the sustainability status of Minapadi farming in Pacet District, Bandung Regency, is in the moderately sustainable category. The following is the sustainability index value of Mina Padi farming on lebak swamp land in South Konawe District.

Table 2. Sustainability index value of mina padi farming on wetland in South Konawe District

No.	Dimensions	Value	Description
1	Economics	76,59	Sustainable
2	Social	78,65	Sustainable
3	Institutions	57,44	Sustainable enough
4	Ecology	84,74	Sustainable
5	Technology	50,49	Sustainable enough
Average		69,58	Sustainable enough

The comparison of the average results of the analysis of the sustainability of Mina Padi farming on wetlands in Konawe Selatan District on these dimensions is then visualized in the form of a kite diagram, as presented in Figure 6.

This study found that Mina Padi farming in Epeesi Village, South Konawe, has varying levels of sustainability across five dimensions: economic, social, ecological, institutional, and technological. The economic, social, and ecological dimensions are in the sustainable category, with index values of

76.59, 78.65, and 84.74, respectively. In contrast, the institutional (57.44) and technological (50.49) dimensions fall into the moderately sustainable category. These findings indicate that Mina Padi farming has successfully applied sustainable agriculture principles, which pursue productivity, community welfare, and environmental sustainability.

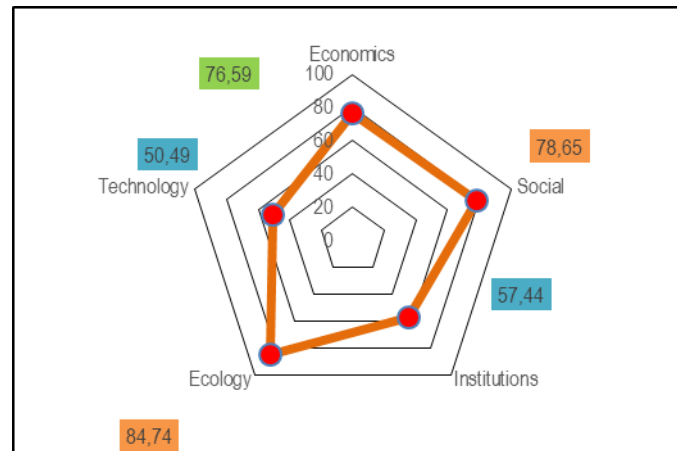


Figure 6. Kite Diagram of sustainability index of mina rice farming on flat swamp land

The economic dimension, which has a high index, reflects the important role of the Mina Padi system in increasing farmers' income through business diversification, namely the combination of rice and fish farming. This diversification increases yield per land and reduces the economic risks farmers face. Previous studies, such as those conducted by Pengseng (2013), support these results by stating that Mina Padi provides better returns than monoculture, even in crop failure. This is relevant to sustainable development goals, especially those focusing on poverty alleviation and inclusive economic growth.

Meanwhile, the social index 78.65 describes various factors that support sustainability, such as education levels, intergenerational knowledge transfer, and family participation in agricultural activities. High community participation also contributes to increased social cohesion and harmony. Research by Dewandini (2020) and Lestari and Bambang (2017) states that Mina Padi encourages positive social dynamics and improves the quality of education of the younger generation, especially in agriculture and fisheries.

On the ecological dimension, the highest index of 84.74 indicates that Mina Padi farming supports environmental conservation through reduced chemical use and increased biodiversity. The presence of fish in the system serves as a natural pest controller, helps improve soil structure and fertility, and increases water use efficiency. The symbiotic relationship between fish, rice, soil, and water creates a better ecological balance, as Sukri and Suwardi (2016) described.

However, on the institutional dimension, the index value of 57.44 highlights the need to strengthen the capacity of institutions that support farm sustainability. Better institutional support is needed to optimally manage resources and create policies that support sustainable farming practices. On the other hand, the technology index of 50.49 indicates that adopting more innovative technologies such as windmills, water pumps, and adaptive seeds is urgently needed to improve efficiency and productivity, particularly in lebak swamplands. These innovations provide economic benefits and help reduce negative impacts on the ecosystem (Najafabadi & Masjedi, 2011).

The results of this study show that Mina Padi farming on lebak swamp land plays a significant role in supporting the achievement of sustainable development goals (SDGs), such as poverty alleviation, improved food security, sustainable economic growth, and environmental conservation. By strengthening institutions and improving technology applications, Mina Padi farming can become a better model for sustainable development in the future.

Validation Analysis of Mina Padi Farming Sustainability Model on Lebak Swamp Land

Model validation serves as a standard to determine the feasibility and accuracy of the results of studies in each dimension and multidimensionality that have been carried out in the study area. The statistical parameters used are contained in Table 3.

This study validated the sustainability model of Mina Padi farming in the lebak swamp land using the Multidimensional Scaling (MDS)-based RAPFISH method. The validation results showed

that the difference between the MDS and Monte Carlo index values for the five dimensions of sustainability was less than 3%. This slight difference indicates a high level of confidence in the model used to describe the sustainability of Mina Padi farming (Kavanagh & Pitcher, 2004). In addition, the resulting stress values ranged from 13-15%, well below the tolerance threshold of 25%, indicating that the model configuration was accurate enough to represent the actual conditions. The coefficient of determination (R^2) value of 0.94-0.95 also confirmed that the model could explain most of the variation in the data well. The economic dimension has the highest validation, with a difference of 1.56% between the MDS and Monte Carlo indices, while the technology dimension has the lowest difference of 0.15%. This indicates that the attributes used in the model can accurately describe each dimension. Thus, RAPFISH for Mina Padi proved to be an efficient and quick evaluation method to measure the sustainability of Mina Padi farming in swamps.

Table 3. Results of statistical parametric validation of the sustainability index value of mina padi farming on lebak swamp land

No.	Dimension	Statistical Parameterisation Validation (%)				
		MDS	Monte Carlo	Difference	Stress	RSQ (R^2)
1	Economics	76,59	75,03	1,56	0,13	0,95
2	Social	69,59	68,98	0,61	0,14	0,95
3	Institutions	38,39	39,31	0,92	0,14	0,94
4	Ecology	63,74	62,65	1,09	0,14	0,95
5	Technology	50,49	50,34	0,15	0,14	0,95

This research provides evidence that the validated model is relevant for lebak swamp areas and can be applied in other locations with different ecosystem characteristics. These results provide a strong basis for further development in sustainable farming management.

CONCLUSIONS

According to the findings of this study, Mina Padi cultivation on lebak wetland lands in Epeesi Village exhibits a sustainability index of 69.58, which is classified as moderately sustainable. Among the five assessed dimensions, the economic (76.59), social (78.65), and ecological (84.74) dimensions demonstrate sustainable conditions, signifying the effective integration of sustainable agriculture principles. These dimensions facilitate enhanced productivity, the betterment of livelihoods, and the preservation of the environment. Nevertheless, the institutional dimension, with a score of 57.44, and the technological dimension, with a score of 50.49, are classified within the moderately sustainable category, signifying the necessity for focused enhancements in these areas. Enhancing institutional capacity through the augmentation of inter-institutional coordination and the refinement of decision-making processes is paramount. Furthermore, fostering innovation in agricultural technology—such as implementing advanced irrigation systems, utilizing disease-resistant seedlings, and enhancing water management technologies—is imperative to overcome existing technological constraints. Targeted interventions in these domains will guarantee the long-term viability of Mina Padi farming while simultaneously augmenting its capacity to serve as a paradigm for sustainable agricultural practices in analogous ecosystems.

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