(RESEARCH ARTICLE)

Sustainable wetland rice farming in Kutai Kartanegara district

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Abstract

Sustainable agriculture is the management of food production resources using environmental principles so that future generations can enjoy agriculture. The problem of declining production can be influenced by improper management, which impacts the sustainability of paddy rice farming. This research analyzes the following: 1) the sustainability status of wet-rice farming in Kutai Kartanegara Regency based on five dimensions: ecological, economic, institutional, technological and social. 2) Analyzing sensitive attributes that influence the sustainability status of wet-rice farming in Kutai Kartanegara Regency. The research method used descriptive qualitative. Samples in this study were farmers and key informants. Sampling research uses the Slovin formula with a cluster sampling method and purposive techniques. Based on the results of Multidimensional Scaling (MDS) analysis, the sustainability status of rice paddy farming in Kutai Kartanegara Regency with a multidimensional index value of 52.37% (Sustainable). There are five dimensions with three sustainable dimensions, namely economic, ecological, technological, and less sustainable, ecological, and social. Of the 30 sustainable attributes, six are sensitive and affect the sustainability of rice paddy farming in Kutai Kartanegara Regency.

1. Introduction

In early 2022, a law was passed that regulates the relocation of the capital city of the Republic of Indonesia to the province of East Kalimantan. East Kalimantan Province has several regencies, one of which is Kutai Kartanegara Regency. Kutai Kartanegara Regency is one of the pillars of Indonesia's future capital city. Large-scale migration will occur in the coming decades. Population migration will impact a region's progress, and one of the sectors that must be prepared to ensure food availability is the agricultural sector.

The agricultural sector in Kutai Kartanegara Regency ranks second as a producer of gross regional domestic product (GRDP) of 25,777.34 (10.72%) from a total of 240,402.39 (BPS Kukar, 2023). Based on production data 2018, it amounts to 144,048 thousand tons, a productivity of 46.33 quintals/ha, and a harvest area of 31,094 ha. In 2019, production was 121,203, productivity 38.65 Kuintal/ha, and harvest area 31,358 ha. 2020 production 110,940, productivity 31.953 Kuintal/ha, harvest area 34.72 ha, 2021 production 104,442, productivity 37.79 Kuintal/ha, harvest area 27.365 ha, 2022 production 106,117, productivity 37.86, and land area 28,028 ha. Rice production in Kutai Kartanegara Regency has experienced dynamic fluctuations for several decades. The decline in rice farming productivity is caused by several factors: limited resources, climate change, pests and diseases, environmental degradation, and non-synchronized planting. Therefore, until now, the agricultural sector's decline in production and productivity has been inevitable.

Global dynamics challenges require sustainable agriculture due to increasing population growth and environmental degradation (Cai et al., 2022; Nam et al., 2024). Farming activities carried out by farmers are expected to align with the objectives of sustainable agricultural development to maintain environmental quality and improve farmers' welfare

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(Sari et al., 2020). The objectives of sustainable agriculture are to avoid environmental degradation, maintain productivity, increase income, and change farming patterns (Zabadi et al., 2022).

Sustainable agriculture relies on three indicators: social, ecological, and economic (Fikriman et al., 2022). Food crop production must be sustainable to overcome the challenges of climate change, water scarcity and others (Mucharam et al., 2022). Implement sustainable agriculture to optimize social, economic and environmental impacts (Kharel et al., 2022). Technology is essential for sustainable agriculture (Gaffney et al., 2019). Uncertain challenges requirestakeholders or policymakers to intervene for promotion, and sustainable agriculture practices can be applied worldwide (Swami & Parthasarathy, 2024). Sustainable agriculture emphasizes the value of farmer welfare (Grigoroudis et al., 2024).

Based on the background description, the author chose the title analysis of sustainable rice farming in Kutai Kartanegara Regency with the research objectives 1) Analyzing the sustainability status of rice paddy farming in Kutai Kartanegara Regency based on five dimensions: ecological, economic, institutional, technological and social. 2) Analyzing sensitive attributes that influence the sustainability status of paddy rice farming in Kutai Kartanegara Regency.

2. Material and methods

The research was conducted in Kutai Kartanegara Regency, East Kalimantan Province. The research was conducted from April - June 2023. The research used descriptive qualitative. The sample of this research was paddy rice farmers and critical persons. The research sample was determined using the Slovin formula, and there was a total sample of 54578 rice farmers (Dinas et al., 2023). Based on the Slovin formula with an error rate of 10%, then, to get the sample results using the Slovin formula according to Sugiyono (2021), as follows:

$$n = \frac{54578}{1 + 54578\ (10\%)^2}$$

n = 99,81 (rounded to 100)

The research location was carried out purposively. It was done purposively because of the food estate development area in Kutai Kartanegara Regency. The area comprises sub-districts, Tenggarong Seberang, Loa Kulu, Tenggarong, Muara Kaman, and Marang Kayu. Cluster sampling is a method of determining a population divided into groups, and all members of each cluster can be selected as respondents to find the sample in each sub-district (Nazrin et al., 2023). As for determining the sample in each sub-district with the following steps:

$$n_h = \frac{N_h}{N}\ n$$

meaning :

nh = Number of selected samples
Nh = Total research population
N = Total research population
n = Number of Samples

After obtaining the number of samples from 100 rice paddy farmers in Kutai Kartanegara Regency, Then the next step is to determine critical informants (Key person), as many as seven people consisting of 1 Kutai Kartanegara district government, 3 Gapoktan heads, 1 East Kalimantan Food, Crops and Horticulture Office, 1 Kutai Kartanegara Agriculture and Livestock Office. 1 Academician and farmer respondents who master the problem so that they can provide information and answer the research problems needed.

The analysis method used was Analysis (Rap-farm), modified from multidimensional scaling (MDS) Rapfish, which the University of British Columbia developedthe University of British Columbia developed. MDS analysis is a statistical analysis that transforms each dimension into a multidimensional one (Rao & Rogers, 2006). According to (Nurmalina, 2008), MDS is one way to bring two points that are far apart closer together. Conversely, points or objects that are not the same are depicted with dots far apart. These dots will also be handy in regression analysis to calculate this "Stress," which is part of the MDS method. The score values for each attribute will form a matrix X (n x p), n being the number of regions and their reference points and p being the number of attributes used. Then, standards are set for the score

values of each attribute so that the attributes have uniform weights, and differences between measurement scales can be eliminated. The standardization method is:

$$X_{ik}\,sd = \frac{X_{ik} - X_k}{S_k}$$

Keterangan :

X_ik sd = Standard score value of the area (including the reference point) to i = 1, 2, . . . n, for each attribute to k = 1, 2, . . . p;
X_ik = Standard score value of the region (including its reference point) to i = 1 ,2, . . . n, for each attribute k = 1, 2, . . . p;
X_k = Center value score on each of the kth attribute = 1, 2, . . . p;
S_k = Standard deviation of the score on each attribute to k = 1,2, . . . p;

According to (Fauzi & Anna, 2002), the Rapfish MDS analysis can be done by calculating the closest distance from the euclidian distance, which can be written in the formula equation:

$$d_{12} = \sqrt{(y_{1-}y_2)^2 + (x_1 - x_2)^2 + \cdots}$$

The Euclidean distance between the two points (D_ij) is based on the following formula:

$$d_{ij} = a + bD_{ij} + e \text{ adalah eror}$$

ALSCAL algorithm is used in raffish with the principle of iteration to produce a limit stress value smaller than 0.25. ALSCAL algorithm for optimizing squared distance against squared data based on the formula:

$$d_{ij} = bD_{ij} + e.$$

The iteration process will stop when the "goodnes of fit" measured through s-streesss if it reaches the minimum limit value of 0.005 The stress value is obtained based on the formula:

$$Stress = \sqrt{\frac{1}{m}\sum_{k=1}^{m}\left[\frac{\sum_i\sum_j(d^2_{ijk} - d^2_{ijk})^4}{\sum_i\sum_j d^4_{ijk}}\right]}$$

According to (Dzikrillah et al., 2017), several things can cause errors in MDS analysis, including

- Errors in determining scores due to errors in understanding attributes,
- Variations in values due to differences in researchers' views,
- Repetitive mds analysis processes that cause data entry errors or loss of data and high-stress values.

The process of repeating the stress value will stop at the value of 0.25, so the stress value < 25% is an acceptableacce error tolerance limit. Furthermore, the influence of errors that can affect ordination values can be evaluated using Monte Carlo analysis.

3. Results and discussion

3.1. Economic Dimension

Based on the results of the Multidimensional Scaling analysis of the economic dimension, the index value is 70.24% (Moderately Sustainable), in the value range of 50.01 - 75.00. The information on the sustainable value of the economic dimension can be seen in Figure 1. Five research attributes are observed in the sustainable analysis of the economic dimension; based on the results of the leverage analysis, one attribute is the most sensitive. Leverage analysis results can be seen in Figure 2.
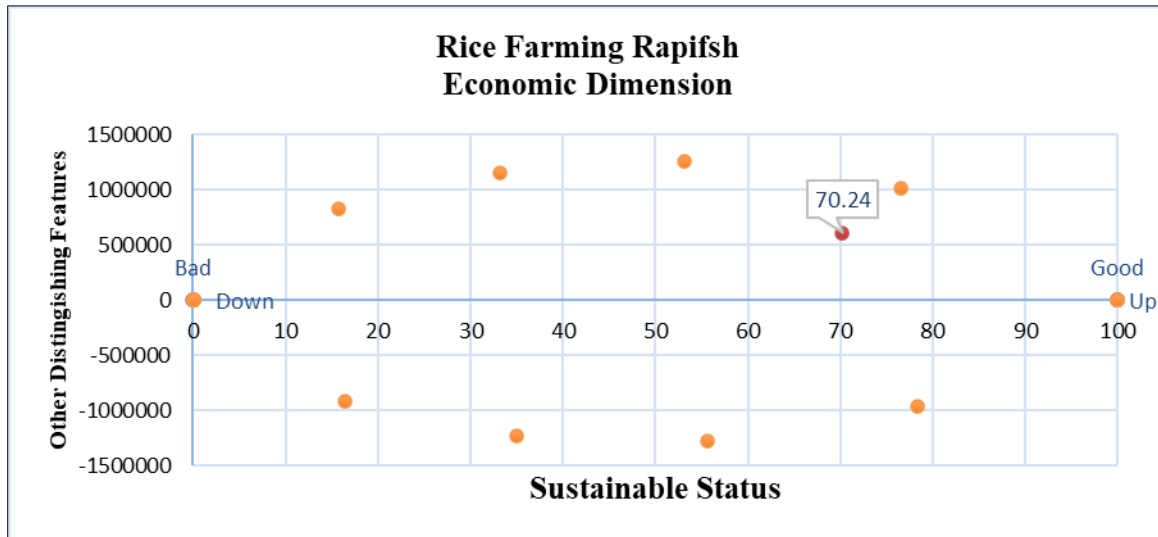
Source: Data processed by researchers, 2023.

Figure 1 Economic dimension of the Sustainability Index**.**
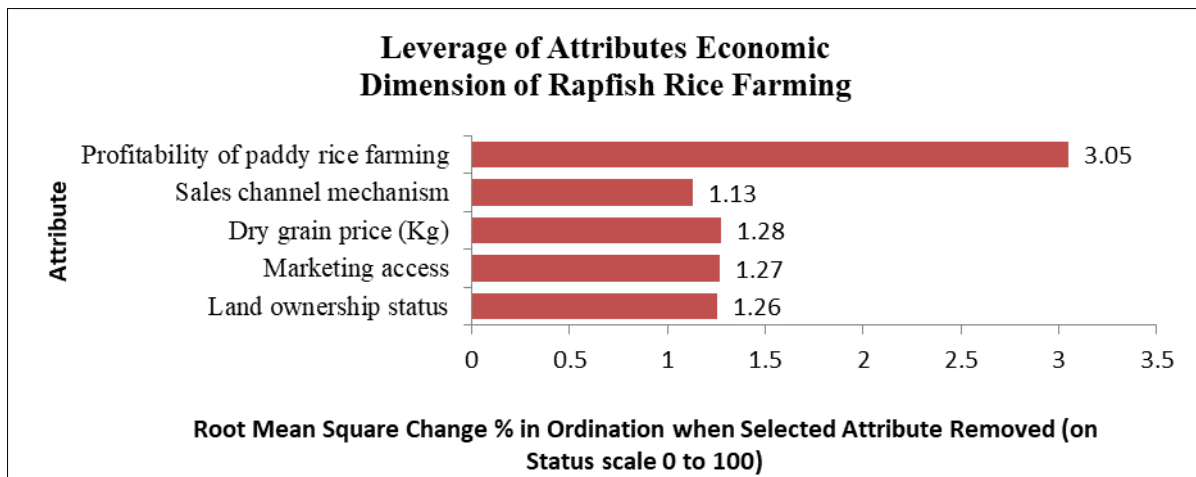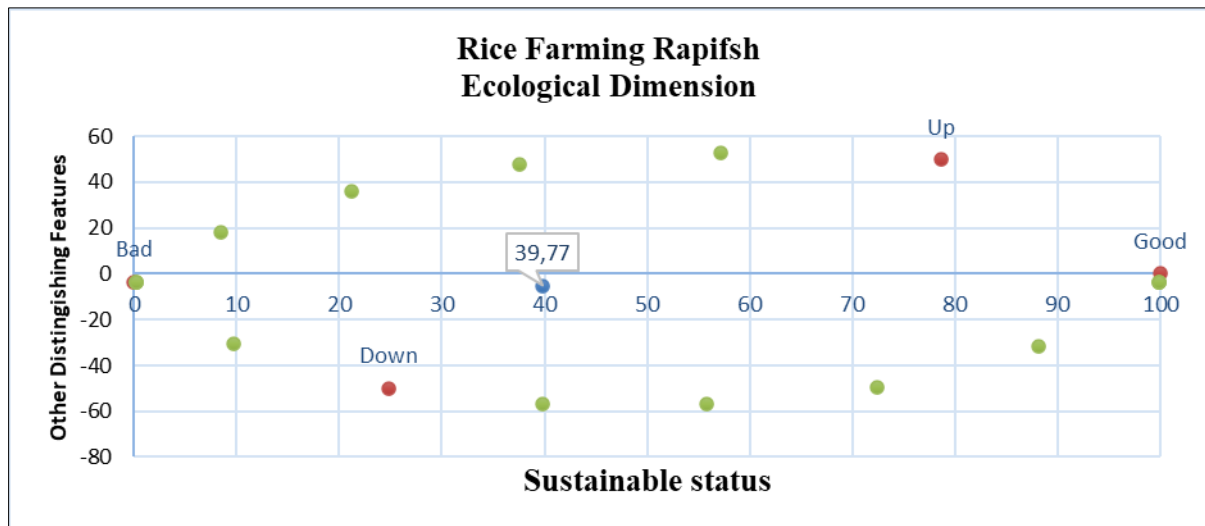

Source: Data processed by researchers, 2023.

Figure 2 Lever attributes of the economic dimension of rice farming.

Running farming aims to obtain maximum profit, but in reality, the welfare level of rice farmers in Indonesia is still low (Zuhdi et al., 2021). Farmers' income is the main factor in farming activities every harvest season. The research results show that in one harvest, the average farmer sells dry grain for IDR 5,000 (Farmer, 2023). Farmers' expenses are not proportional to the income earned due to the weak bargaining position of farmers to traders, middlemen, and brokers who make farmers the leading producers and do not have the power to play the value of the selling price of their products (Jahidah et al., 2023). Low-income farmers will affect the costs of production facilities for labour rent, buying fertilizers, pesticides, seeds, equipment, and other costs. Production facilities are crucial in supporting farming activities that aim to increase production. Using seeds, fertilizers, and labour significantly increases production (Alamri et al., 2022; Ifgayani et al., 2019; Sukmayanto et al., 2022).
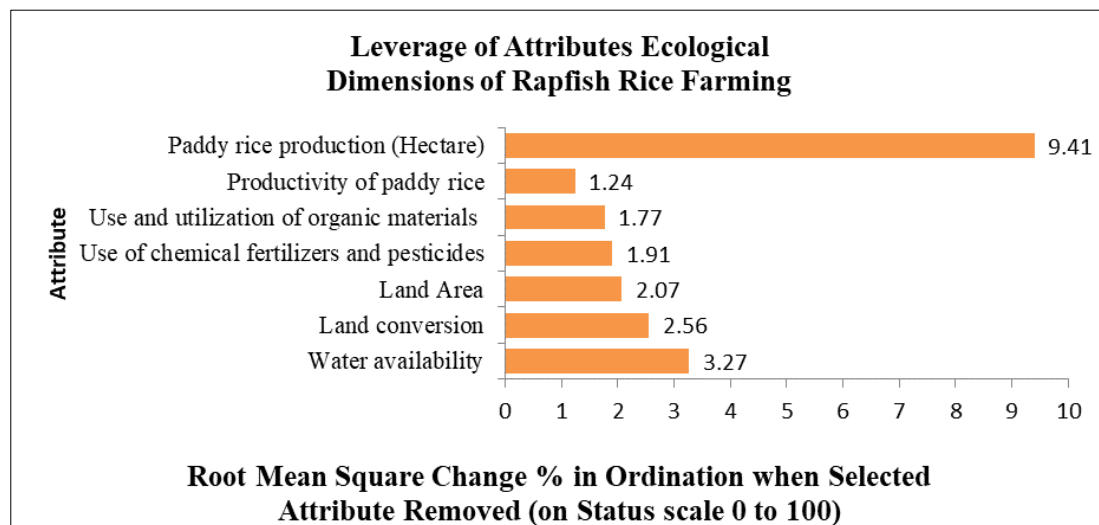
3.2. Ecological Dimension

Based on the results of the Multidimensional Scaling analysis on the ecological dimension, the index value is 39.77% (Less sustainable), by the value range of 25.01 - 50.00. The ecological dimension sustainable index information can be seen in Figure 3. In the sustainable analysis of the ecological dimension, seven research attributes are observed, and based on the results of the leverage analysis, one attribute is most sensitive, namely the production of paddy rice. Leverage analysis results can be seen in Figure 4.

Figure 3 Sustainable Index of ecological dimension.

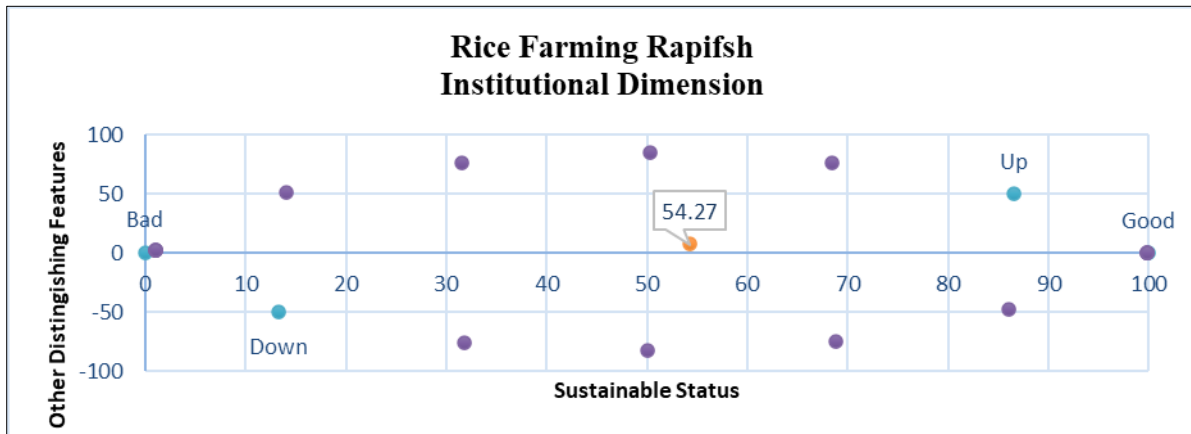**Figure 4** Leverage attributes of the ecological dimension of rice farming.

Based on the research results, the average farmer's land area is 0.6 hectares, with an average production of 2.6 tons (Farmer, 2023). Climate change that occurs significantly affects crop production, pest attacks, floods, and droughts that reduce the amount of production. Damage and decline in ecological quality caused by resource management are not used wisely and wisely. Therefore, water has a vital role in the ecological dimension. Without water, crops cannot grow optimally, and water availability is an essential indicator in supporting the sustainable ecological dimension of the agricultural sector.

Rainfed systems are very vulnerable to climate change; climate change causes the instability of water tides, temperature increases, temperature decreases, and erratic rain (Ninuk & Amelia, 2020). Water availability is a vital object in sustainable rice farming activities. The impact of environmental damage and degradation caused by resource management is not wisely used. Moreover, climate change significantly affects the carrying capacity of agricultural land, causing drought, flooding, decreased production, and decreased farmer welfare (Hussain & Qamar, 2020).
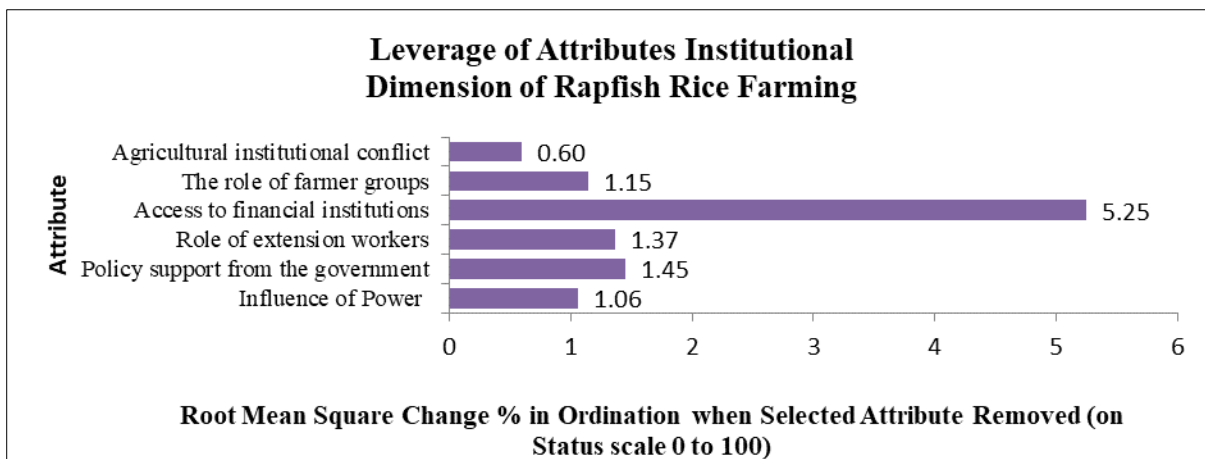
3.3. Institutional Dimension

Based on the Multidimensional Scaling analysis results on the institutional dimension, the index value is 54.27% (Moderately sustainable), in the value range of 50.01 - 75.00. The institutional dimension index can be seen in Figure 5 In the institutional dimension sustainability analysis, six research attributes are observed; based on the results of the

leverage analysis, one attribute is included in the sensitive category, namely access to financial institutions. Leverage analysis results can be seen in Figure 6.

Source: Data processed by researchers, 2023.

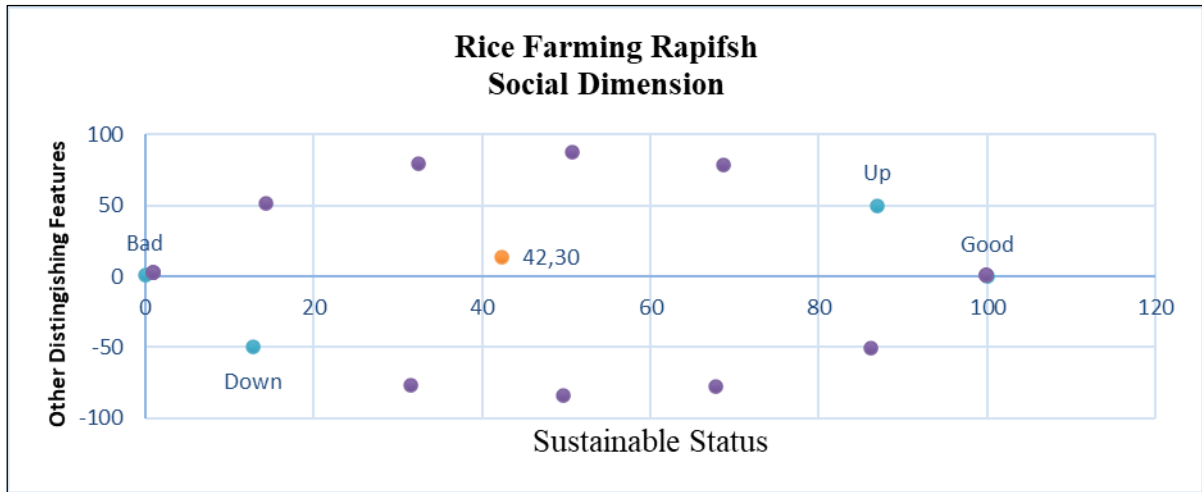**Figure 5** Sustainable index of institutional dimension

Source: Data processed by researchers, 2023.

Figure 6 Leverage attributes of the institutional dimension of rice farming.

Agricultural institutions are financial institutions and institutions in general. The advancement of financial institutions plays a role in driving development and the economy (Baajike et al., 2022). Institutional strengthening is needed to solve fundamental problems in agricultural issues, and the solutions provided can provide favouritism and protection to the main actors, namely farmers (Holle, 2022). Financial institutions offer money loans and insurance, savings, and other services not offered by conventional financial institutions (Naz & Doneys, 2022). In general, rice paddy farming activities are still carried out on a small scale, which makes it difficult to access financial institutions because agricultural activities have risks. Hence, the risk of payment failure is higher (Lu et al., 2024). Agricultural insurance can help deal with climate change and risks from financial institutions' credit pressure (Ma et al., 2024).
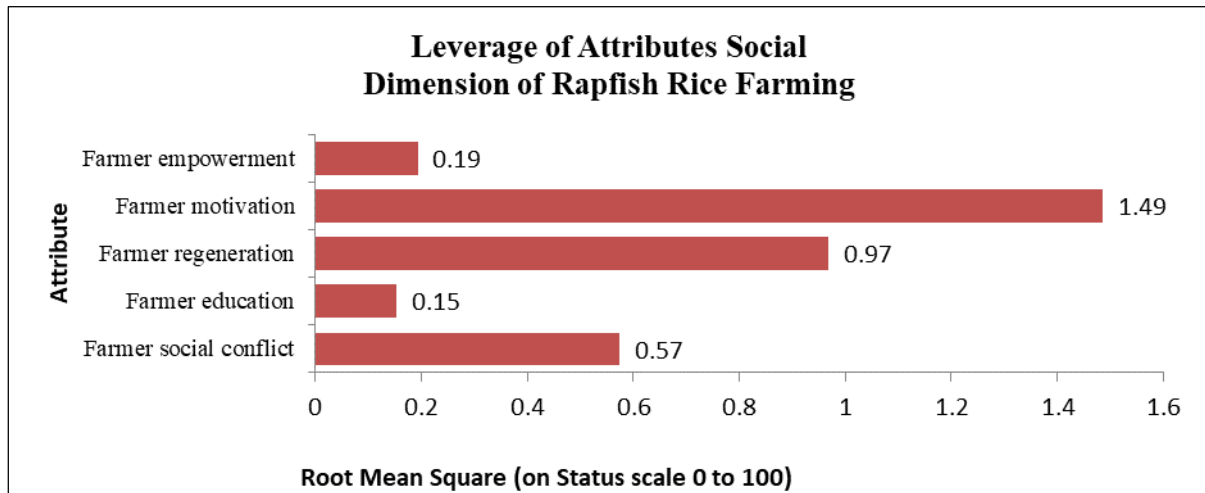
3.4. Social dimension

Based on the results of the Multidimensional Scaling analysis on the social dimension, the index value is 42.30% (Less sustainable), by the value range of 25.01 - 50.00. The social dimension index can be seen in Figure 7. In the sustainable analysis of the ecological dimension, six attributes are were observed; based on the results of the level analysis, two attributes fall into the sensitive category: Education level and farmer empowerment. Leverage analysis results can be seen in Figure 8.

Source: Data processed by researchers, 2023.

Figure 7 Social dimension sustainability index, 2023.

Source: Data processed by researchers, 2023.

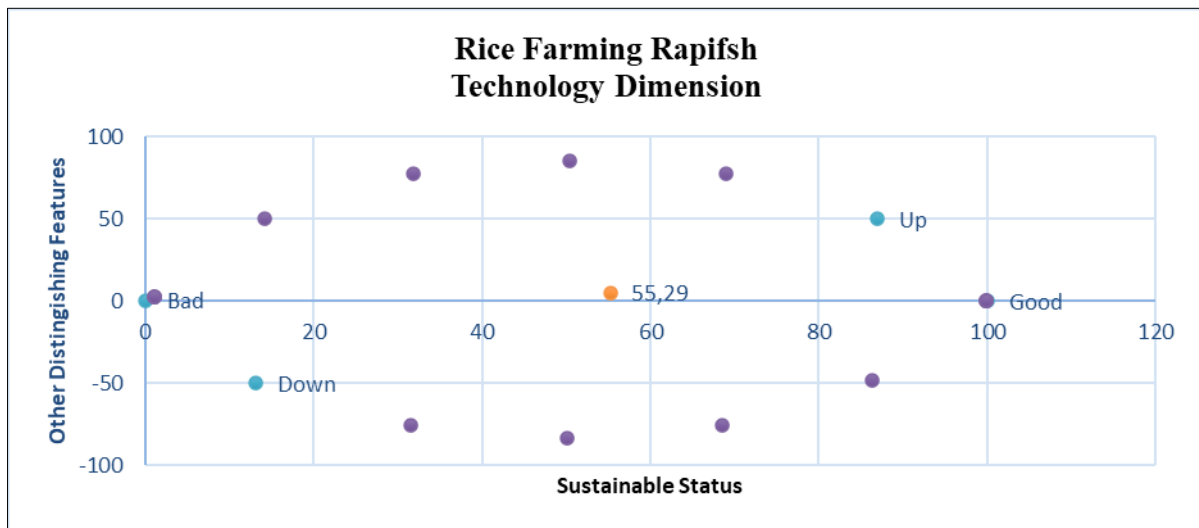**Figure 8** Leverage attributes of the social dimension of rice farming.

In order to achieve the success of sustainable agricultural development, quality human resources are needed. Currently, the low level of education minimizes the regeneration of farmers and makes the agricultural sector unpromising for the future. In addition, there is still a lack of use of technology in the agricultural sector, which makes it different from the service industry sector, where technological infrastructure is developing rapidly so that many young people work in the industrial sector (Salamah et al., 2021). Farmers' social behaviour is strongly influenced by education; if a farmer has limited education, it will have an impact when looking for access to information and technology, and the implementation of farm management will still be low (Aminah et al., 2023).

The state must protect and empower farmers in Indonesia because, politically, agricultural development must continue to be carried out by the government to realize food security and self-sufficiency (Permatasari & Wahyudi, 2022). Increasing the capacity of farmer resources requires empowerment, collaboration, stakeholder collaboration, and involvement (2018). Empowerment is a form of absorbing aspirations from the lower level, and empowerment is essential to present solutions to the problems faced (Mudege et al., 2015). When paying attention to the aspirations of farmers so that agricultural activities can run according to their needs. But in reality, the expectations and desires are inversely proportional to what farmers want with the assistance that has been provided (Firdaus, 2020).
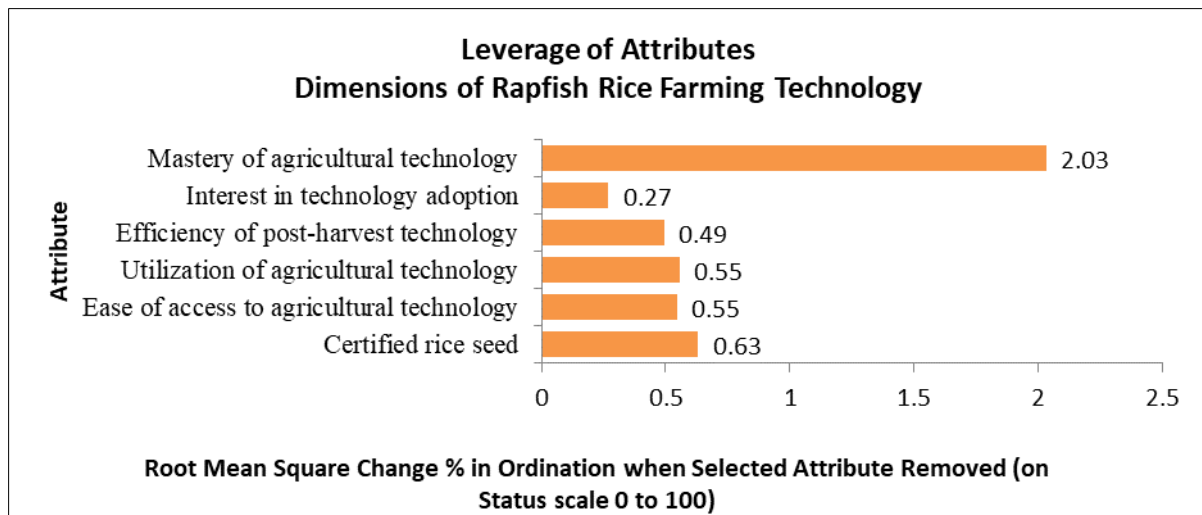
3.5. Dimensions of technology

Based on the Multidimensional Scaling analysis results on the technological dimension, the index value is 55.29% (Quite Sustainable), by the value range of 50.01 - 75.00 in Figure 9. Six attributes were observed in the sustainable analysis of

the technological dimension; based on the level analysis, one attribute is included in the sensitive category: mastery of technology. Leverage analysis results can be seen in Figure 10.

Source: Data processed by researchers, 2023.

Figure 9 Technology dimension sustainability index.
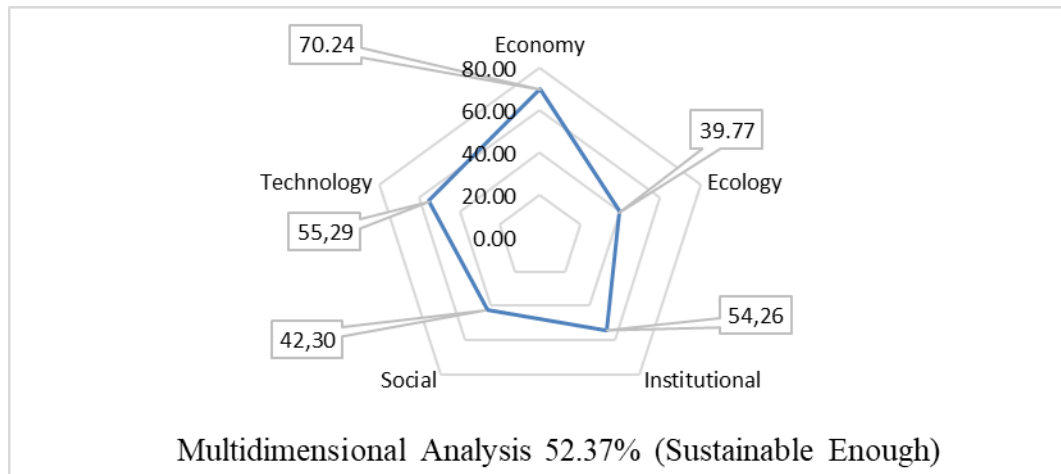

Source: Data processed by researchers, 2023.

Figure 10 Leverage attributes of the technology dimension of rice farming.

In recent decades, agricultural technology development has been rapid (Javaid et al., 2022). The quality of farmers' human resources plays a vital role in facing the challenges of the changing times of the agricultural sector (Leonardo et al., 2021). Knowledge transfer is essential to acquisition, exchange and implementation (Mwantimwa & Ndege, 2024). Extension activities are expected to accelerate agricultural dissemination (Morgan et al., 2020). Although the high intensity of extension to farmers has not seen too maximum results, it is suspected that many factors are interrelated, including socio-economic, cultural, and ecological behaviour, so farmers have not been able to leave the old pattern of farming (Riyadi, 2020). Infrastructure and access limitations make technology optimization unable to run well, so commitment, support and concrete actions from policymakers are needed (Saraan & Rambe, 2022).

3.6. Multi Dimensional Analysis of Sustainable Status

The results of Rapfish analysis showed that the multidimensional value of the sustainable index of wet-rice farming in Kutai Kartanegara Regency was 52.37% (Figure 11). Based on the multidimensional value, the sustainable status of paddy rice farming in Kutai Kartanegara Regency is quite sustainable. There are economic, institutional, and technological dimensions that show a positive trend (sustainable), but there are two dimensions that are still low status

(less sustainable), namely the ecological dimension and the social dimension. These two dimensions require a focus on management in the future so that their status can be raised to moderately sustainable.

Source: Data processed by researchers, 2023.

Figure 11 Multidimensional Analysis

The Monte Carlo analysis results show that the smallest difference in each value between the multidimensional scale and the Monte Carlo Index value is at the 95% confidence interval, corresponding to the average value. The slight difference in index values between MDS and Monte Carlo can prove that errors can be avoided. The results of the continuous index can be seen in Table 1.

Table 1 Results of continuous index analysis.

Sustainability Index Value				
Dimensions	MDS (Rapfish)	Monte Carlo	R2 value	Stress Value
Economy	70,24	69,17	0,98	0,13
Ecology	39,77	39,51	0,97	0,16
Institutional	54,26	53,42	0,95	0,14
Social	42,30	41,86	0,95	0,14
Technology	55,29	54,95	0,94	0,16
Multidimensional	52,37	51,78	0,95	0,14

Source: Data processed by researchers, 2023.

The results of the analysis obtained a Stress value smaller than 0.25, namely 0.14, so it can be concluded that the attributes or indicators used in the study are feasible and recognized. The results of the research analysis were that R2 was close to 1 and that stress values were less than 0.25 (Fauzi & Anna, 2002).

4. Conclusion

Based on the results of the discussion, it can be concluded as follows:

- The results of the analysis of the economic, ecological, institutional, social and technological dimensions show there are two dimensions that are less sustainable, namely: The social dimension is 42.30% (Less sustainable), and the ecological dimension is 39.77% (Less sustainable). While the institutional dimension is 54.26% (Moderately sustainable), the technological dimension is 55.29% (Moderately sustainable), and the economic dimension is 70.24% (Moderately sustainable). The social dimension has the lowest score, and the economic dimension has the highest score.

- The results of the analysis of the economic, ecological, institutional, social, and technological dimensions there are attributes that are most sensitive and influential on sustainable rice paddy farming in Kutai Kartanegara Regency, namely the attributes: profit of rice paddy farming, rice paddy production, access to financial institutions, education level, farmer empowerment, and mastery of agricultural technology.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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