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Assessing the Sustainability of Organic Rice Farming in Central Java and Yogyakarta: An Economic, Ecological, and Social Evaluation

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Abstract: The sustainability of organic rice farming has become a significant focus in agricultural development, as it addresses the interconnected challenges of economic viability, environmental preservation, and social equity. This study evaluates the sustainability of organic rice farming across five districts in Central Java and Yogyakarta, Indonesia, through a comprehensive assessment of economic, ecological, and social dimensions. A proportional stratified random sampling approach was employed, involving 150 farmer respondents, with 30 farmers selected from each district. Descriptive analysis revealed an average sustainability score of 2.94, indicating a moderate level of sustainability. In addition, the Rapid Appraisal for Sustainability (RAPS) tool yielded an average index score of 68.56, categorising the farming systems as "fairly sustainable." The model was further validated through a normalization test, which demonstrated strong consistency across the three sustainability dimensions, with a Standardized Residual Sum of Square (STRESS) value of 0.14 and an R-Squared (RSQ) value of 0.95, suggesting that the data were robust and the model reliable. Sensitivity analysis identified seven critical factors influencing sustainability: agricultural product prices, financial management, poverty alleviation, crop rotation, the involvement of women and young farmers, and preservation of tradition. The results of validation and stability tests indicated that the sustainability model was both stable and reliable across all three dimensions, with an overall sustainability score of 1. These findings underscore the importance of promoting sustainable agricultural practices in organic rice farming and highlight the need for enhanced government involvement in raising awareness, providing training, and fostering educational initiatives to support the economic, ecological, and social dimensions of sustainability in the region.

Keywords: Descriptive; RAPS; normalization; Sensitivity; Validation; Indonesia; Sustainability assessment

1. Introduction

Rice is a crop that is very easy to find in Indonesia, especially on the Java Island which is known as the largest rice producer in Indonesia (Fathonah & Mashilal, 2021). The majority of farmers in Java prefer to grow rice as their main commodity because it is easy to grow rice and this is in accordance with the geographical conditions in Java Island which is dominated by lowlands (Ani et al., 2023). In 2023, according to BPS, the rice yield was

30,158,079.3 tonnes in Java Island and 53,980,993.19 tonnes in Indonesia. In addition, the yield decreased by around 767,983.81 tonnes, mostly due to the application of a less sustainable agricultural system used by a large number of farmers, especially the use of less sustainable chemical fertilizers.

This problem of declining rice production encourages Indonesia to shift towards sustainable agriculture, which considers economic, social, and environmental factors to ensure that agriculture can continue without damaging nature (Prismantoro et al., 2024). Sustainable agriculture is an approach that focuses on not only short-term results but also the environment so that agriculture does not damage soil quality and other natural resources (Rustandi & Farid, 2023). This approach seeks to maintain ecological balance by reducing the negative impacts of chemical use, strengthening farmers' welfare, and promoting an economy based on environmentally friendly practices (Piash et al., 2023). Unfortunately, unsustainable agriculture can lead to soil degradation, water pollution, and adverse social impacts on farmers, such as increased dependence on expensive chemicals (Jha et al., 2023).

Since organic rice farming is part of sustainable agriculture, its implementation can be a good solution to overcome these problems (Prasetyo et al., 2022). Organic rice farming produces organic rice through rice cultivation that does not use chemical fertilizers and synthetic pesticides. Instead, it relies on natural ingredients that are more environmentally friendly (Srisawat et al., 2024). The use of natural fertilizers can increase soil fertility, improve soil structure, and increase crop productivity, especially in clay-rich soils (Li et al., 2024; Mabrouk et al., 2023). In addition, organic rice requires certification from a recognized institution, such as the Organic Certification Institute (LeSOS), to ensure that the product meets strict organic standards, which can increase the selling price and welfare of farmers (Krisna et al., 2023). While organic farming has the potential to bring economic and ecological benefits to sustainable agricultural development, its implementation in Indonesia is still constrained by various challenges, one of which is the high production costs associated with the transition from conventional to organic farming because farmers lack welfare, knowledge and understanding of the long-term benefits of sustainable farming caused by the lack of technological presence (Alla & Thangarasu, 2024).

In addition, Indonesia also faces a number of issues that hinder the progress of sustainable agriculture. One of the main problems is the reliance on chemical fertilizers that cause soil degradation and environmental pollution (Wang et al., 2024). Socially, the reliance on conventional farming methods leads to an imbalance in farmers' welfare, as farmers are often cash-strapped and have to go into debt to buy expensive chemical fertilizers (Nohara, 2024). The lack of information technology makes farmers have limited access to information on environmentally friendly agricultural technology, which also poses a major challenge in the implementation of sustainable agricultural development in Indonesia (Žukovskis et al., 2023). Therefore, it is crucial to conduct an in-depth evaluation of the sustainability of rice farming in Central Java and Yogyakarta by considering the social, economic and ecological dimensions, thereby identifying more effective solutions to increase agricultural productivity while preserving the environment.

2. Methodology

2.1 Research Location

By considering the large number of organic rice farmer groups, the area of organic rice land, and the availability of organic certification, three regencies in Central Java Province (Magelang Regency, Karanganyar Regency, and Sragen Regency) and two regencies in Yogyakarta (Bantul Regency and Sleman Regency) were chosen as the research location, as shown in Figure 1.

Figure 1. Research location

2.2 Sample Procedures and Data Collection

An interview research method was used in this study. Samples were taken from a population using a semi-structured questionnaire. Data was collected from farmers through questionnaires. Farmers were required to answer questions directly, individually and honestly at home, in fields and farmer group gatherings to ensure that they were not influenced by other farmers' answers. Proportional stratified random sampling was used as the sampling method to provide farmers with opportunities to be selected for interviews and facilitate the process of finding farmers. Using 150 farmer respondents as the sample size, the research location was divided into five districts, with 30 farmer respondents in each district, as shown in Table 1. The data collection focused on knowing the feasibility of organic rice farming in Central Java Province and Yogyakarta Special Region. Samples were taken to determine economic, ecological and social sustainability using farmer characteristics and sustainability statement attributes. Characteristics of farmers used as samples consist of age, gender, education, and farming experience.

Table 1. Location and number of samples

Research Location	Number of Respondents
Sragen, Central Java	30
Karanganyar, Central Java	30
Magelang, Central Java	30
Sleman, Yogyakarta	30
Bantul, Yogyakarta	30
Total	150

The statement attributes consist of 30 attributes, with 8 for economic attributes, 10 for ecological attributes and 12 for social attributes, as shown in Figure 2. These attributes were selected by Faried et al. (2021). Economic attributes were used to determine whether respondents are economically sustainable so that the selected attributes used can certainly determine economic sustainability. Income other than farming is an attribute to determining whether farmers have other income outside of farming so that they do not depend on farming, which can reduce their financial risk and make them not prosper. Poverty alleviation was used to determine whether farming can alleviate poverty, thereby determining the welfare of farmers and existing social equality. Financial management was rarely used by farmers, which made them wasteful. It should be used so that production costs can be met. Prices of agriculture are very influential in economic sustainability because the higher the incomes obtained, the more prosperous farmers can live. Infrastructure prices have an influence on rice paddies because high selling prices lead to high incomes. Use of machine tools during the production process makes farmers save time and energy. Processing results were used to find out whether they can make the selling value greater, thereby knowing whether respondents make sales through the process.

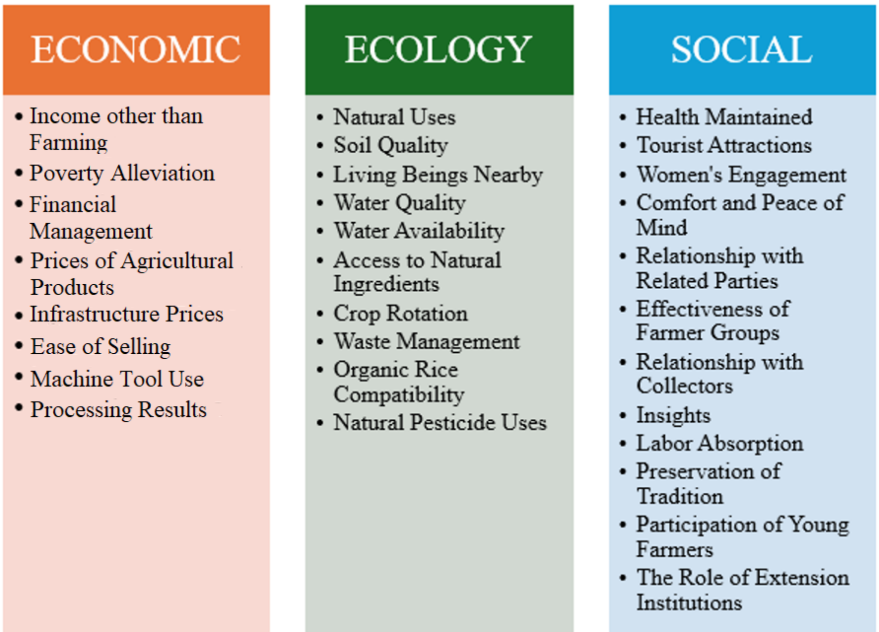

Figure 2. Sustainability attributes

The ecology attribute was used to determine whether respondents are sustainable in the field of ecology so that the selected attributes used can certainly determine the ecological sustainability of the respondents. Natural uses is a system that encourages sustainable agriculture because it uses natural and organic materials. Soil quality was used to assess whether the soil used is still fertile or not because soil with too much chemical fertilizer becomes infertile. Living nearby is a way to assess whether the ecosystem around the land is still natural or not. Water quality is a way to keep water suitable for agricultural use, and polluted water causes lethal consequences for plants. Water availability is a way to keep water available. Therefore, water management and wise use are needed. Access to natural ingredients is a way to find out whether the organic fertilizer used is homemade or bought from a store. Crop rotation is a change of crops planted in each season, which aims to maintain the fertility of the soil used. Waste management is a way of processing organic waste used as fertilizer, and the waste can improve soil structure and reduce dependence on chemical fertilizers. Organic rice compatibility is a way to determine whether the soil used is suitable for planting organic rice, and the soil that is suitable for organic rice must be truly organic for at least two seasons. Natural pesticide use is a way of reducing pests using natural means, such as natural enemies of pests.

Social attributes are a way to determine sustainability in accordance with social aspects for conflict prevention. Health maintained is part of sustainability because sick farmers can increase the risk when working and hamper agricultural production. Tourist attractions are very important to support the education of organic and sustainable agriculture and they can also increase the income of surrounding areas. Women's engagement is a way to assess the gender equality that occurs in agriculture so that farmers do not have to be men only. Comfort and peace of mind are a way to assess the welfare of farmers because farmers can feel comfortable and secure if they have equal access to resources. The relationship with related parties is a way of assessing the influence and participation of the government in supporting sustainable organic farming. The effectiveness of farmer groups is reflected in providing learning, guidance and supervision as well as being a direct link between farmers and the government. Relationships with collectors were used to determine the existing supply chain as desired and the ease of selling agricultural products. Insight is a way to find out the skills of farmers to innovate and adopt the knowledge provided. Labor absorption was used to determine the availability of jobs in agriculture and the feasibility of wages given to farmers. Preservation of traditions is one way to keep the culture alive so that agriculture in Indonesia still has characteristics. Participation of young farmers is a way to find out the interest of young farmers to become farmers and continue existing agriculture in the future. The role of extension institutions was used to determine the role of extension workers in supporting and accompanying farmers in every matter in sustainable agriculture.

2.3 Analysis Techniques

2.3.1 Descriptive analysis

Four categories with three different dimensions (economic, ecological, and social) adjusted to the questions in the interview were used for the analysis of sustainability research, namely unsustainable, less flexible, moderately sustainable, and sustainable. From these categories and aspects, the data was processed in a score scale. The following formula was used to determine the score value:

$$\text{Score} = \frac{(\text{Highest Score-Lowest Score})}{\text{Number of Categories}} = \frac{(4-1)}{3} = 1 \quad (1)$$

From the results of the formula above, three categories of scores are shown in Table 2.

Table 2. Results of score analysis and categories

Score	Category
1 - 2	Less
2.1 - 3	Enough
3.1 - 4	Good

The category for each attribute was determined using the average obtained from each attribute itself to ensure that each attribute is included in the category of less, sufficient or good.

2.4 MDS RAPFISH/RAPS

The RAPS/RAPFISH research method combined with the Multi-Dimensional Scaling (MDS) approach was used in this study. Rapid Appraisal for Fisheries (RAPFISH) is an analytical method for evaluating the sustainability of fisheries in a multidisciplinary manner based on an ordination technique (placing things in order of measurable attributes) with MDS (Nababan et al., 2017). RAPFISH with a MDS approach was used because this method helps in analyzing and understanding the relationship between sustainability indicators and selected attributes (Yusuf et al., 2021). Using MDS RAPS, key attributes that influence agricultural sustainability in Central Java and Yogyakarta can be identified. The sustainability index of each aspect was measured by category, as shown in Table 3.

Table 3. Sustainable category based on the index value

Index Value	Category	Description
0-25	Bad	Unsustainable
25.01-50	Less	Less sustainable
50.01-75	Enough	Quite sustainable
75.01-100	Good	Sustainable

A normalization test was also used in this study to find out whether the results of this analysis are accurate and in accordance with the actual conditions and whether the data can be explained well by the model produced, which was measured by RSQ and STRESS values. RSQ that is far from 1 shows that the data is difficult to explain; if it is close to 1, the data generated by the model is easier to read. The normalization test is considered feasible when the STRESS value is less than 0.20 and the RSQ is close to 1. The smaller the STRESS value, the more accurate and compliant with the actual conditions. The accepted STRESS score is usually less than 20% according to the five categories of the STRESS eligibility level (Yusuf et al., 2021), as shown in Table 4.

Table 4. STRESS value category

Score (%)	Category
0 - 2.5	Perfect
2.51 - 5.0	Very good
5.01 - 10.0	Good
10.01 - 20.0	Enough
>20	Less

In addition to these two analyses, leverage analysis was conducted to measure the most sensitive attributes in each aspect of its dimensions. The most sensitive attribute can be determined by determining the Root Mean Square (RMS) value. The Monte Carlo analysis was also conducted in this study. This analysis tests the validity and stability of the ordination results. Therefore, it determines that the ordination results can be considered valid and stable if there is no significant difference with the random values tested by Monte Carlo (Mahida & Handayani, 2019). The validity and stability of the ordination results can be said to be feasible if the results produced are not much different from the sustainability index value.

3. Results

3.1 Characteristics of the Farmers

3.1.1 Age and gender

Table 5 shows the characteristics of the farmers. Age is one of the measuring tools used to find out the farmers who are still productive, thereby finding workers who can work optimally (Idawati et al., 2024). Gender is a difference that exists between men and women, which often leads to disparities (Egyir et al., 2023). Organic rice farmers are dominated by men, with a total of 110 people. The most farmers are in the vulnerable age group of 54-66 years, with a total of 67 people accounting for 44.67%, as shown in Table 5. Organic rice farmers are at least vulnerable at the age of 28-40 years because there are only 11 people (7.33%). This has happened because Indonesia does lack young farmers to continue Indonesian agriculture

Table 5. Characteristics of the farmers

Characteristics		Number	Percentage (%)
Gender	Man	110	73.33
	Woman	40	26.67
	Total	150	100.00
Age	28-40	11	7.33
	41-53	42	28.00
	54-66	67	44.67
	67-79	30	20.00
	Total	150	100.00

Education	Elementary school	9	6.00
	Elementary school	51	34.00
	Junior high school	40	26.67
	Senior high school	46	30.67
	Diploma	2	1.33
	Bachelor	2	1.33
	Total	150	100.00
Farming Experience	1-20 years	60	40.00
	21-41 years	58	38.67
	42-62 years	32	21.33
	Total	150	100.00

3.1.2 Education

The education level of farmers affects the sustainability of production because farmers with higher education are more receptive to information (Abed & Al-Razaq Ahmed, 2024). The level of education most pursued by organic rice farmers is the senior high school level, which has 46 people (30.67%). In addition, there are a total of 4 people who have studied at universities with bachelor's (1.33%) and diploma (1.33%) degrees. Farmers with undergraduate education are very difficult to find in Indonesia because many graduates do not want to become farmers (Susanawati et al., 2021).

3.1.3 Farming experience

Farming experience is the length of time the farmer has been running the farm until now. The longer the farmer runs the farm, the more experienced the farmer is (Sina et al., 2023). Experience in farming affects the success of farming. Farmers who have a long experience tend to have abilities and skills compared to less experienced farmers. A total of 60 people have 1-20 years of farming experience, which is the majority and accounts for 40%. They just started their farming business compared to other vulnerable categories. Farmers in Indonesia have a long farming experience because the majority of farmers in Indonesia are old people and it is very difficult to find young farmers (Rustandi & Farid, 2023; Ardyanti et al., 2024).

3.2 Descriptive Analysis

3.2.1 Economic dimension

A sustainable economy is a development process in the economic sector, with attention to the future as its main goal. Therefore, increasing income plays a role in the long-term economy and eradicates poverty.

Table 6. Results of descriptive economic dimension analysis

Economic Dimension	Score	Category
Income other than farming	2.29	Enough
Poverty alleviation	2.6	Enough
Financial management	1.69	Less
Prices of agricultural products	2.77	Enough
Infrastructure prices	3.51	Good
Ease of selling	3.2	Good
Machine tool use	3.96	Good
Processing results	1.2	Less
Total	**21.22**	
Average	**2.65**	**Enough**

From the analysis results of the economic dimension aspect, the average score produced is 2.65. Therefore, the economic dimension is included in the sufficient category in its sustainability analysis. The attribute with the highest score is the use of machine tools and the one with the lowest score is the processing of results (Table 6). There are two prominent attributes, namely product processing and financial management. The processing of the results has a very low score because the farmers in this study hardly process their agricultural products first. Farmers sell in the form of grain, which is driven by weather factors that are difficult to predict (Chapman et al., 2021). Weather greatly affects the rice production process, especially in the drying process, which aligns with the research conducted by Mananohas et al. (2019). Financial management has a low score after processing the results because many farmers directly use the results of their farms to survive and there is no management of income for the next planting season. This prevents the yield in the next planting season from being optimal because the production cost is less (Liu et al., 2023). Financial management in farmers is still quite low and many farmers go into debt to get quick capital, which is the same as in the study by Rahmadi & Santosa (2018). The government and farming groups should collaborate to provide education on processing techniques to increase farmers' income. In addition, training and education on the importance of financial management are needed to ensure that the income from harvests is sufficient for use in the next planting season.

3.2.2 Ecological dimension

Sustainable ecology is a development process in the ecological sector that is principled in meeting current needs without sacrificing the fulfilment of needs for future generations by preserving nature without damaging it (Haloui et al., 2024).

Table 7. Results of descriptive ecological dimension analysis

Ecological Dimension	Score	Category
Natural uses	3.69	Good
Soil quality	3.42	Good
Living nearby	3.04	Good
Water quality	3.28	Good
Water availability	3.89	Good
Access to natural ingredients	3.83	Good
Crop rotation	2.29	Enough
Waste management	3	Good
Organic rice compatibility	3.26	Good
Natural pesticide uses	2.89	Enough
Total	**32.59**	
Average	**3.26**	**Good**

From the results of the descriptive analysis of the ecological dimension aspect, the average score produced is 3.26. Therefore, the ecological dimension is included in the good category in its sustainability analysis. The attribute with the highest score is water availability and the one with the lowest score is crop rotation (Table 7). The availability of water can be obtained by farmers because they manage water well so that there is no lack of water (Kumar et al., 2023). In addition, organic rice farming requires less water compared to conventional rice farming, as said by Johannes et al. (2019). Crop rotation has the lowest score in this ecological dimension, even though the score is still in the sufficient category. This happens because the availability of water is very abundant, and farmers do not need to replace the plants planted. In addition, replacement plants are more difficult to care. Therefore, farmers do not want to rotate their plants (Azeem et al., 2023). Crops are not substituted by most farmers and this causes the soil to run out of nutrients, which is similar to the research conducted by Gustaman (2020). Farmers currently have an abundant water supply, and they need to use it wisely. The government should educate farmers on using water sparingly and innovate by building water storage facilities and power generators to ensure that this abundant water remains available and beneficial. Crop rotation should be implemented to maintain soil fertility so that it can be planted every season.

3.2.3 Social dimension

Sustainable society is a development process in the social sector that is principled in meeting current needs without sacrificing the fulfilment of needs for the future (Javdan et al., 2023). From the results of the descriptive analysis of the social dimension aspect, the average score produced is 2.92. Therefore, the ecological dimension is included in the category of sufficient in its sustainability analysis (Table 8). The attribute with the highest score is the relationship with collectors and the one with the lowest score is the participation of young farmers (Table 8). The low participation of young farmers has become a problem in Indonesia because many young people now do not want to become farmers (Toumbourou et al., 2023). Young people consider farming to be disproportionate due to the low incomes and hard work (Widiyanti et al., 2020). The inequality of work has actually been overcome with technology that makes it easier to farm. If the decline of young farmers continues to occur, the future economy in Indonesia will decline (Riptanti et al., 2024). Farmers now have a good relationship with collectors, establishing a market chain. However, it would be better if farmers first processed their harvests into rice or other food products, which would allow them to earn a higher income. Indonesia is currently facing a shortage of young farmers (Dewayanti et al., 2022), young people in Indonesia are losing interest in becoming farmers. Therefore, campaigns are needed to show that farming is a profitable profession, ensuring that Indonesia does not lose its farmers in the future. The three aspects of the economic, ecological, and social dimensions resulted in an average score of 2.94, which is included in the category of quite sustainable. This aligns with the research conducted by Johannes et al. (2019).

Table 8. Results of descriptive social dimension analysis

Social Dimension	Score	Category
Health maintained	3.48	Good
Tourist attractions	2.2	Enough
Women's engagement	3.42	Good
Comfort and peace of mind	3.08	Good
Relationship with related parties	3.11	Good
Effectiveness of farmer groups	3.2	Good
Relationship with collectors	3.32	Good
Insights	2.83	Enough
Labor absorption	2.85	Good
Preservation of tradition	2.51	Enough
Participation of young farmers	1.84	Less
The role of extension institutions	3.22	Good
Total	**35.07**	
Average	**2.92**	**Enough**

3.3 Analysis Using MDS RAPS

3.3.1 Aspects of the economic dimension

The results of the analysis conducted using MDS-RAPS show that the average sustainability index in the economic aspect is 71.53. Therefore, it is included in the category of sufficient with a description of sufficient (Figure 3). This contrasts with the previous research conducted by Ruhimat (2015), which shows a less sustainable category with a score of 42.26%. It can be said that the sustainable status continues to increase every year.

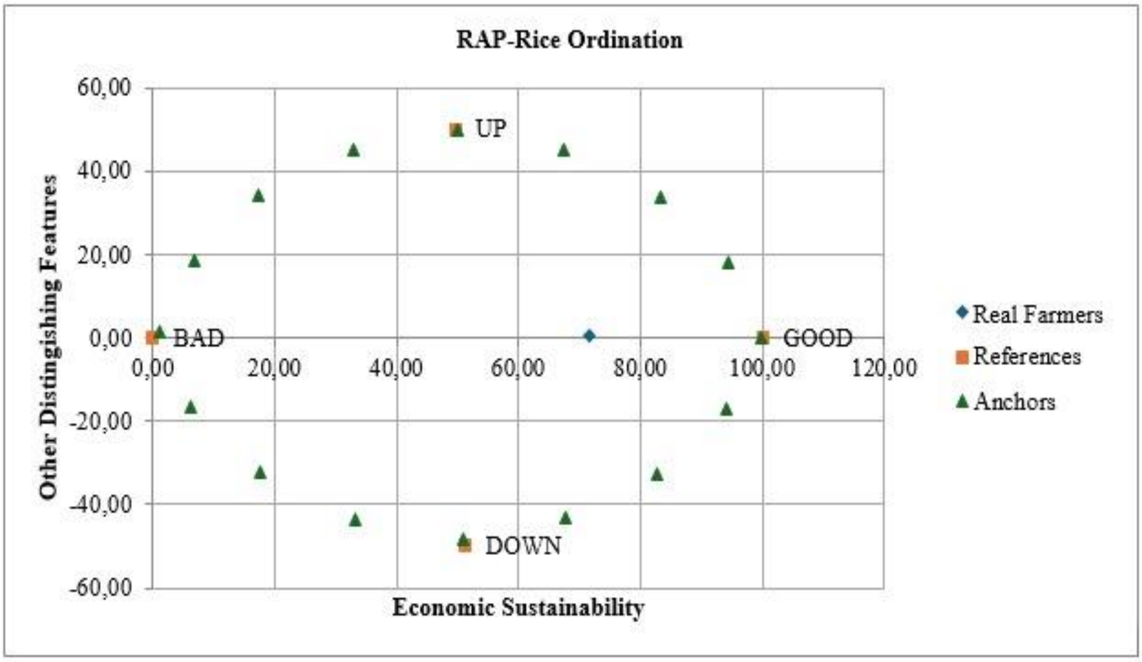

Figure 3. Average analysis results of sustainability in economic dimensions with RAPS

Table 9. Normalization test results of the economic dimension

Dimension	STRESS	RSQ
Economy	0.14	0.95

The results of the normalization test analysis show that the model displayed is considered feasible because the STRESS value is less than 0.20 and RSQ is close to 1 (Table 9). The STRESS value resulting from the normalization test is 0.14. Therefore, the number is included in the perfect category. The data displayed is significant and accurate with the actual conditions, which shows that the data obtained has small and reliable analysis errors. The resulting RSQ value of 0.95 shows that the data generated by the model is easy to read and indicates the significance and accuracy of the actual situation.

Three of the eight most prominent attributes are based on the RMS, namely the price of agricultural products, financial management, and poverty alleviation (Figure 4). This is in contrast to the previous research conducted by Nuraini (2022), showing that the sensitive attributes are market size and high income. The first highest attribute is the price of agricultural products, which is related to the selling price that farmers get. This can affect the welfare of farmers because it affects their economic conditions (Momeni et al., 2023). The second highest attribute is financial management, which affects their financial ability in the present and future and enhances their economic conditions (Muzekenyi et al., 2023). The third highest attribute is poverty alleviation, which is related to the results obtained. It greatly affects the welfare of farmers to live better if the income obtained is high (Nkoko et al., 2024). The government needs to provide a proper sales chain so that farmers get high income in each growing season. In addition, the government needs to socialize how to manage finance so that income from crops can be managed and production in the coming season can remain optimal without financial constraints, both of which must be done to alleviate poverty.

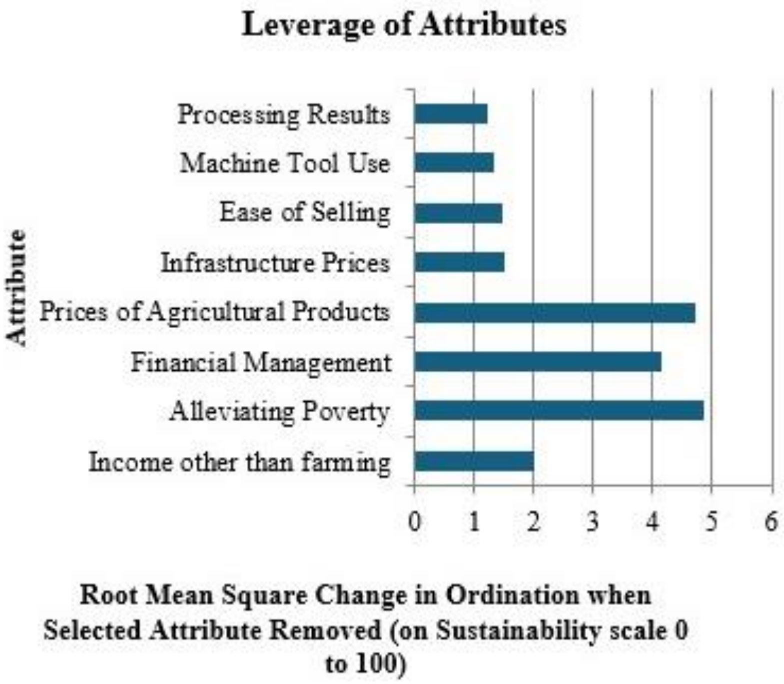

Figure 4. Results of sensitive attribute analysis of the economic dimension

Table 10. Validation and stability test results of economic dimension coordination

Sustainability Index Value	Monte Carlo	Difference
71.53	70.11	1.42

The results of the validation and stability test of coordination can be said to be feasible because the difference between the value of the sustainability index and Mote Carlo is only 1.42 and the value is below 5%. These results indicate that the data used has validity and stability with the actual situation (Table 10).

3.3.2 Aspects of the ecological dimension

The results of the analysis conducted using MDS-RAPS show that the average sustainability index in the economic aspect is 72.22, which is included in the category of sufficient with a description of sufficient sustainability (Figure 5). The sustainability category has similarities with the research conducted by Nuraini (2022) with a fairly sustainable category. However, the comparison of the scores produced is much different, with scores of 72.22 in this study and 51.03 in the research conducted by Nuraini (2022).

The results of the normalization test analysis show that the model displayed is considered feasible because the STRESS value is less than 0.20 and RSQ is close to 1 (Table 11). The STRESS value resulting from the normalization test is 0.14. Therefore, the number is included in the perfect category. Therefore, the data displayed is significant and accurate with the actual conditions, showing that the data obtained has small and reliable analysis errors. The resulting RSQ value of 0.95 shows that the data generated by the model is easy to read and indicates the significance and accuracy of the actual situation.

Table 11. Test analysis results of normalization of the ecological dimension

Dimension	STRESS	RSQ
Ecology	0.14	0.95

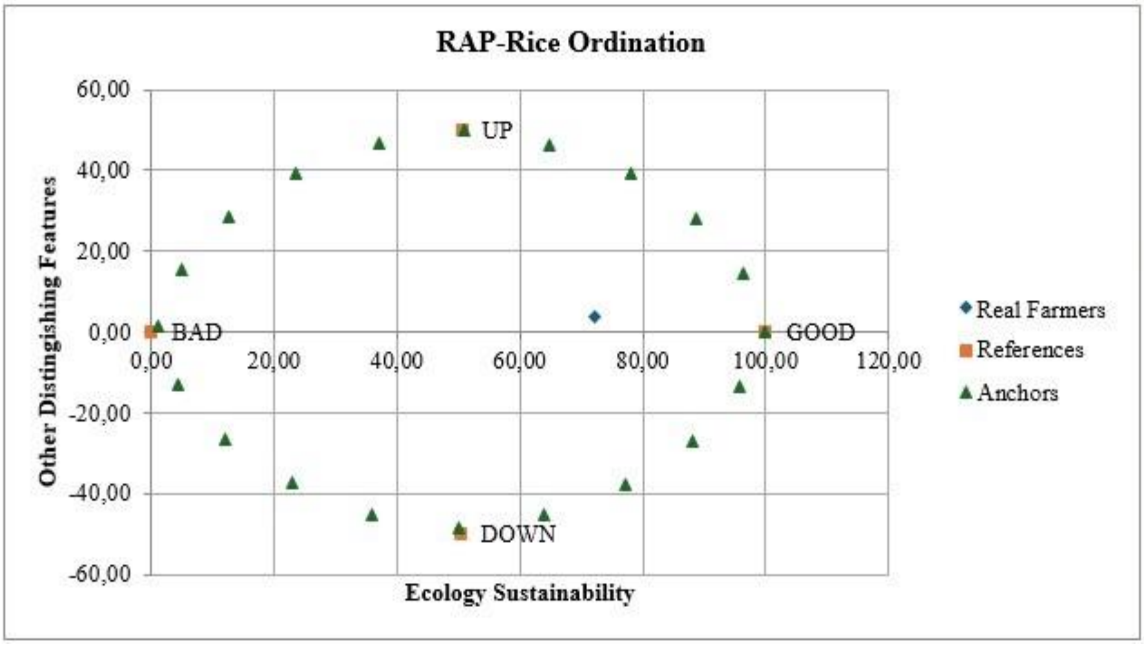

Figure 5. Average analysis results of sustainability of the ecological dimension with RAPS

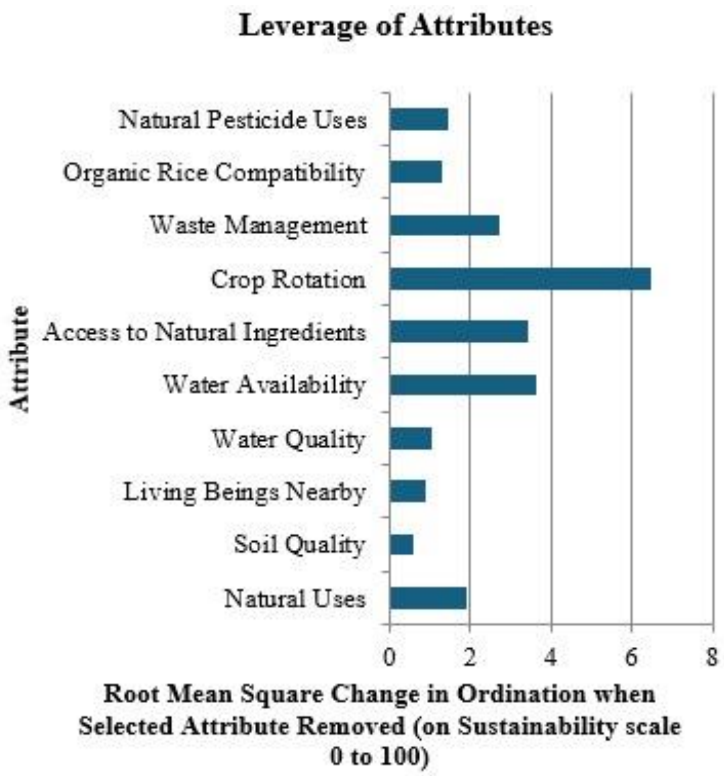

Figure 6. Sensitive attribute analysis results of the ecological dimension

One attribute out of ten attributes stands out the most based on its RMS, i.e., the planting rotation (Figure 6). The sensitive attributes in this study are in stark contrast to the research conducted by Nuraini (2022) with three sensitive aspects, namely maintenance, use of pesticide fertilizers and water quality. Planting rotation is related to the change of crops every season, which can maintain fertile soil to grow organic rice, resulting in abundant results. With fertile soil, ecological sustainability can run well (Dutta et al., 2024). Socialization and training on planting new or other crops are necessary to continue crop rotation, thereby maintaining soil fertility and planting in every season.

Table 12. Results of validation and stability test analysis of ecological dimension coordination

Sustainability Index Value	Monte Carlo	Difference
72.22	71.09	1.13

The results of the validation and stability test of coordination can be said to be feasible because the difference in the value of the sustainability index with Monte Carlo is only 1.13 and the value is below 5%. These results indicate that the data used has validity and stability with the actual situation (Table 12).

3.3.3 Aspects of the social dimension

According to the results of the analysis conducted using MDS-RAPS, the average sustainability index in the social aspect is 61.94, which is included in the category of sufficient with a description of being quite sustainable. The index number in this social aspect has the lowest value compared with the other two aspects (Figure 7). The sustainability index produced in this study has a considerable gap with the research conducted by Abdullah et al. (2015), with a less sustainable category with a score of 37.86.

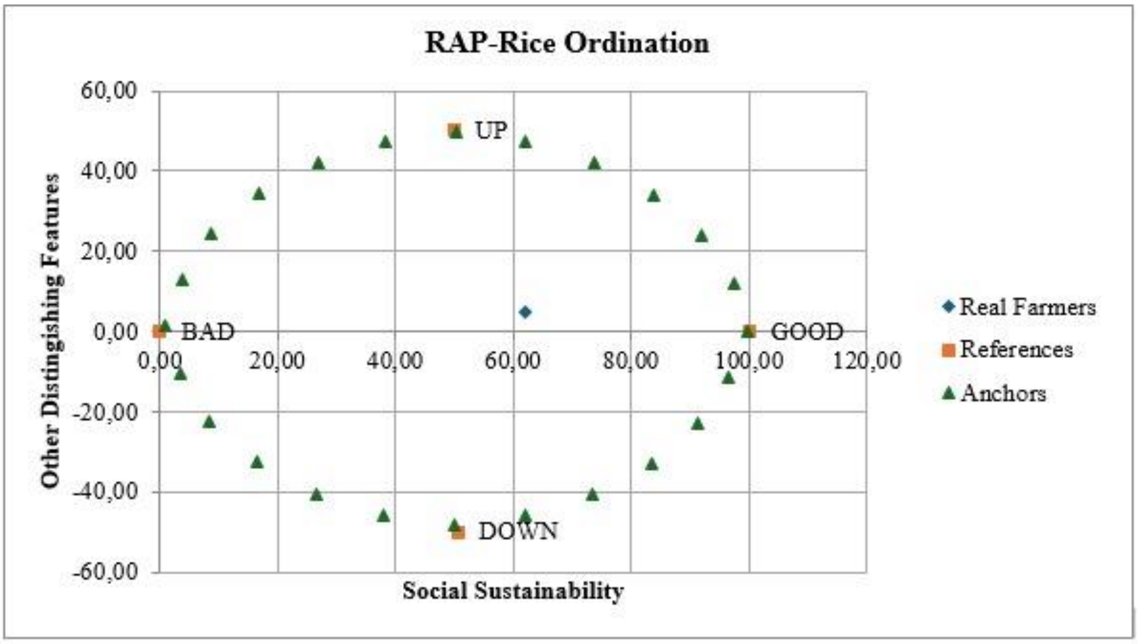

Figure 7. Average analysis results of sustainability of the social dimension with RAPS

Table 13. Results of the social dimension normalization test

Dimension	STRESS	RSQ
Society	0.14	0.95

The results of the normalization test analysis show that the model displayed is considered feasible because the STRESS value is less than 0.20 and RSQ is close to 1 (Table 13). The STRESS value resulting from the normalization test is 0.14. Therefore, the number is included in the perfect category. Therefore, the data displayed is significant and accurate with the actual conditions, showing that the data obtained has small and reliable analysis errors. The resulting RSQ value of 0.95 shows that the data generated by the model is easy to read and indicates the significance and accuracy of the actual situation.

Among the 12 identified attributes, three stand out the most based on their RMS, namely the involvement of women and young farmers and preservation of tradition. They greatly affect the sustainability of agriculture in the social field as well as agriculture at the time of planting. The majority of the workforce is women. If there are no young farmers from now, no one will continue farming in the future (Rahmawati et al., 2022). If tradition is not preserved in the present, agricultural traditions will not be found in the future (Askarova et al., 2023). Women's participation in agriculture is still considered very low because farmers think that women only need to be at home without doing work. The government needs to socialize the importance of gender equality in agriculture so that women can participate in improving agricultural sustainability. The preservation of traditions has now begun to be forgotten by farmers, leading to the loss of many traditions. The importance of traditions must be socialized and lost traditions must be introduced to farmers. The government needs support in terms of funds and introduction so that the characteristics of the nation are not lost. Indonesia is currently facing a shortage of young farmers; young people in Indonesia are losing interest in becoming farmers. Therefore, campaigns are needed to show that farming is a profitable profession, ensuring that Indonesia does not lose its farmers in the future. Figure 8 shows the results of the sensitive attribute analysis in the social dimension.

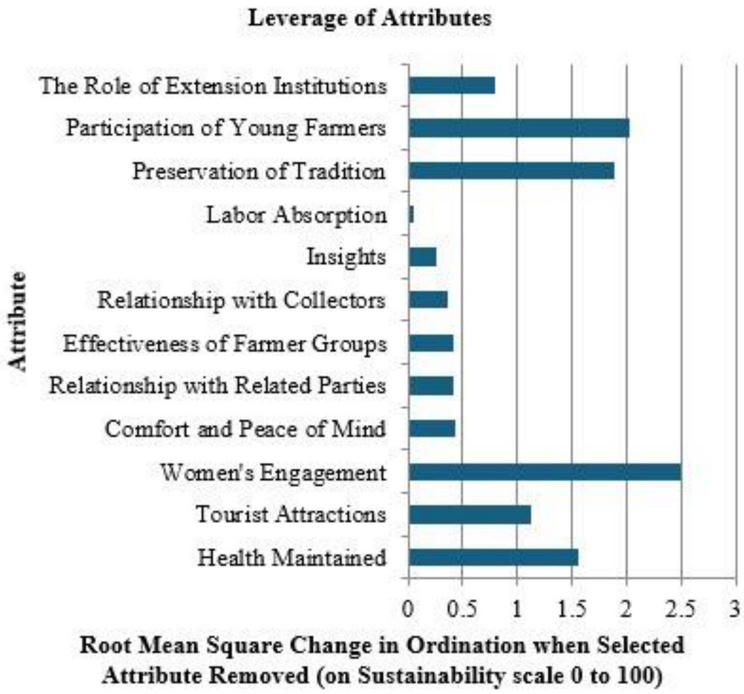

Figure 8. Results of the sensitive attribute analysis in the social dimension

Table 14. Results of the validation and stability test of social dimension coordination

Sustainability Index Value	Monte Carlo	Difference
61.94	61.49	0.45

The results of the validation and stability test of coordination can be said to be feasible because the difference between the value of the sustainability index and Monte Carlo is only 0.45 and the value is below 5%. These results indicate that the data used has validity and stability with the actual situation (Table 14).

4. Discussion

Sujianto et al. (2023) discussed sustainability categories in economic, ecological, and social aspects. In terms of the ecological aspect, the research results showed that organic rice farming consumes less water than conventional rice farming. In terms of economic sustainability, the research results showed that the high production of organic rice is of limited value due to the absence of a market. Organic rice farming in Sindangkerta Village, West Bandung, West Java, falls into the category of moderately sustainable, suggesting that it holds promise for achieving sustainable agriculture. The research results are relevant to the findings of this study in the ecological aspect by indicating that organic farming requires less water than conventional farming. In addition, the sustainability status found is also similar to that in this study, which is categorized as moderately sustainable. Similar discussions on organic farming also address the use of non-chemical fertilizers and other chemical-free methods to support sustainability in agriculture from an ecological perspective.

Gao et al. (2023) found that conventional rice farming in China has a higher negative impact on the environment and lower sustainability effects. Four types of rice systems were analyzed: green manure rice, duck rice, crayfish rice, and conventional rice. Duck rice demonstrated high energy use efficiency and the highest energy sustainability index, supporting the economic sustainability and viability of organic rice production. The relevance of the research lies in its insights into the fact that conventional and organic farming have lower negative environmental impacts, especially with the avoidance of chemical and synthetic pesticides. Economic sustainability was also assessed in the research by considering the cost-value ratio and high production costs. However, the research lacks relevance in the way it evaluates economic and ecological sustainability by focusing on only four types of rice without incorporating sustainability categories or considering the social aspect.

Salisa et al. (2023) proposed that the demand for organic rice is increasing so that it is necessary to increase the yield of rice farming. By comparing three planting techniques and four fertilizers used, it was found in this study that the transplantation technique and fertilizer use have a significant impact on organic rice production. Johannes et al. (2019) stated that Indonesia is still water scarce, with rice consuming the highest percentage of water at 69% and categorized as moderately sustainable. The research is relevant because it discusses the category of sustainability in economic, ecological and social aspects. This is also supported by the research conducted by (Kumar et al., 2023), that water availability can be obtained by farmers because farmers manage water well, which does not lead to a lack of water. Utilization of water by wise management can also improve water quality periodically (Irianto, 2015).

Phantha et al. (2021) said that the social sustainability produced by organic rice is better than conventional rice. It is relevant to this study because the social sustainability category is quite sustainable in this study. However, the research conducted by Ruhimat (2015) does not align with this study because it has a lower sustainability category in the final results. Organic farming produces less rice at a lower cost of production than conventional farming, but has a lower environmental impact (Dermiyati & Niswati, 2014). However, low rice production can also be affected by weather changes, such as rainfall, water availability and flooding (Mananohas et al., 2019). Farmers' lack of interest in changing crops in each season also depletes the soil of nutrients, resulting in decreased production (Azeem et al., 2023). Increased production can return if the soil can return to its maximum condition. Therefore, organic farming is recommended for sustainable agriculture (He et al., 2018).

5. Conclusions

The sustainability categories analyzed using Excel show varying results across each aspect. The economic aspect in this study yielded a score of 2.65, placing it in the moderately sustainable category. The ecological dimension aspect was the strongest, classified as sustainable with a score of 3.26. Meanwhile, the social dimension scored 2.92, also placing it in the moderately sustainable category. The average score for these three dimensions was 2.94, which falls within the moderately sustainable range. The sustainability analysis conducted using RAPS showed that these three dimensions were categorized as moderately sustainable, with index values of 71.53, 72.22 and 61.94 for the economic, ecological and social dimensions, respectively, resulting in an overall average of 68.56. This index falls under the moderately sustainable category. The normalization test results for the STRESS value indicated a perfect category with a value of 0.14 and RSQ of 0.95, meaning that for these three dimensions, the model data is easy to interpret and can accurately reflect the real situation. The sustainability category obtained in this study is significantly influenced by seven key attributes: agricultural product prices, financial management, poverty alleviation, crop rotation, involvement of women and young farmers, and the preservation of tradition.

Sustainable agriculture is essential for the future, and these seven important attributes require well-planned solutions and implementation. The governments of Central Java and Yogyakarta have already facilitated market access by connecting farmers with large companies and providing market spaces through the agricultural service department. Financial management training must be provided to farmers, as it directly impacts the capital needed for the next rice-growing season. If successful, these efforts can alleviate the poverty experienced by farmers. Crop rotation is rarely practiced, as observed in this study; thus, socialization and training by the government are necessary to optimize land use and prevent soil depletion, ensuring continued and increased rice production in the future. Socialization efforts regarding gender equality, fostering interest in farming, and preserving agricultural traditions for farmers, women, and youth should be conducted to raise awareness that farming requires regeneration. These socialization activities can be tailored to current community interests, such as through social media, direct meetings, and school visits. This study has implications for promoting sustainable agriculture in Central Java and Yogyakarta. The limited understanding of sustainable agriculture among the community and its potential impact on economic, ecological, and social aspects underscores the need for education on sustainable agriculture practices. In this way, farming in Indonesia can continue to develop while maintaining and enhancing its economic, ecological, and social aspects.

Author Contributions

Conceptualization, Z.R., T., N.R. and H.W.P.; Methodology, Z.R. and R.S.B.Y.; Writing—review and editing, Z.R. and R.S.B.Y.; Writing—original draft preparation, Z.R. and R.S.B.Y.; Investigation R.S.B.Y., S.A. and

R.A.A.; Funding Acquisition, Z.R. All authors have read and agreed to the published version of the manuscript. The relevant terms are explained at the Credit taxonomy.

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Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

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Conflicts of Interest

The authors declare no conflict of interest.

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