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Sustainability of the Different Rice Cultivation Practices in Yogyakarta, Indonesia

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Abstract

The current food crisis has become a serious threat to humanity. Other issues such as climate change, farmer regeneration, and excessive use of chemical inputs at the producer level threaten sustainability in agriculture. The sustainability of agricultural practices among farmers remains questionable due to the small number of organic farmers in Indonesia. The purpose of this study was to determine the level of sustainability of rice cultivation and the factors that influence the sustainability of rice cultivation in various types of cultivation in Yogyakarta. Research on farm sustainability that is analyzed in a multidimensional (5 dimensions) and compares 3 types of cultivation has not been widely carried out in Indonesia. This research was conducted in Bantul and Sleman with 90 respondents. The analysis method used Multidimensional Scaling-RAPFISH and Tobit regression. The results showed interesting findings where the 3 types of rice cultivation are in the sufficient (moderately sustainable) category even though the 3 have differences in the use of inputs, especially in the ecological dimension. The factors of education, frequency of attending extension and activity in farmer groups, the use of good agricultural practices, land ownership, and type of cultivation had a positive effect on increasing the sustainability of rice cultivation in various types of cultivation in Yogyakarta. The results of this research have an impact on agricultural extension field education provided by the government to increase the sustainability of rice cultivation in Yogyakarta. It is recommended that the 3 types of rice farmers to pay more attention to the use of Good Agricultural Practices (GAP) to increase sustainability.

Keywords: economic benefit; environmentally sustainable production; RAPFISH; rice farmer; Tobit regression

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INTRODUCTION

Today's challenge to society and the government is the slow food production capacity and rapid population growth. The increase in food production capacity is slower than the increase in food demand (FAO, 2015). This is partly because food production capacity is increasingly limited in some regions, such as Indonesia (Rozaki, 2021). At the same time, the high population growth rate is also a problem that must be addressed. On the other hand, the area of agricultural land is decreasing as the need for land for non-agricultural purposes continues to increase along with population growth (Eise and Foster, 2018).

In the current situation in dealing with the food crisis that may occur, there are several efforts that the government and the community must make. Solutions that need to be done are how to deal with climate change, fertilizer issues, and the issue of farmer regeneration. The current climate change is an obstacle in agriculture. Farmers also have other problems, one of which is using

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excessive inputs, such as chemicals (Li et al., 2022). With many farmers still applying chemical-based agriculture, only a few can escape this habit, and the current trend is that farmers are not confident if they do not use pesticides. Hence, farmers look "dependent" on the use of pesticides or chemicals (Wulansari, 2019). Farmers who apply non-organic farming systems will sooner or later cause serious problems, where the continuous use of inorganic fertilizers has a negative effect on the soil, such as a decrease in the content of organic matter and the activity of soil microorganisms, the soil becomes compacted, and damage occurs. In this case, farmers need to start switching from using chemicals to environmentally friendly organic materials. For example, research conducted in the Mount Ciremai National Park (TNGC) by Kurniawan et al. (2023) found that the application of organic fertilizer and plant growth-promoting rhizobacteria (PGPR) in the area around TNGC can improve soil physicochemical characteristics, which cause significant impacts on soil arthropod communities. These results explain that organic fertilizer and PGPR were successfully implemented by TNGC managers increasing the restoration of soil quality to support sustainable agriculture in the region (Kurniawan et al., 2023). On the other hand, organic farming will increase soil fertility and maintain the biological resources in the soil (Risdianto, 2015). This can be proven by comparing it with non-organic and semi-organic farming in terms of soil fertility. Research conducted by Supriyadi et al. (2021) shows that organic rice fields have the best soil quality with a soil quality index (SQI) score of 2.3, compared to the SQI of semi-organic rice fields (2.2) and SQI of inorganic rice fields (1.7) as measured by the total indicator microbes, base saturation, cation exchange capacity, and organic carbon.

This is the basis for the emergence of sustainable agriculture as one of the implementations of the concept of sustainable development, which includes 3 dimensions of development, namely economic, social, and environmental (Mulyadi et al., 2015). Sustainable agriculture not only provides benefits for the economic well-being but also for the good of socio-cultural humanity and the sustainability of the environment, which is known as the 3P (people, planet, profit) benefit (Fauzi, 2019). Analyzing the sustainability of organic farming practices among farmers then becomes one of the things that can be done.

The study was conducted to answer the above phenomenon which wanted to examine the sustainability of farmers' farms in various dimensions. The sustainability of organic farming practices among farmers needs to be assessed because there are still few organic farmers in Indonesia. Analysis of the sustainability of organic farming practices can be seen from the economic, socio-cultural, ecological, law-institutional, and technological aspects (Figure 1). Sustainability analysis can be carried out on farmers who have implemented an organic system or are in the transition period to organic (semi-organic) to see the level of sustainability and the evaluation that needs to be carried out by them. The actual aspects of sustainability analysis are closely related to the use of organic inputs to support sustainability.

The difference in each rice cultivation technique is an interesting topic, particularly to see how the sustainability of these farms in each cultivation technique is seen with the Multidimensional Scaling (MDS) analysis method. Each cultivation technique has the same problem, namely, farmers carrying out rice cultivation do not use existing good agricultural practices, so technical recommendations for rice cultivation from the government are not maximally implemented and only depend on habitual or hereditary patterns (Malia and Triana, 2015; Charina et al., 2018).

The application of Good Agricultural Practices (GAP) is very important, specifically to increase the productivity and quality of products produced by farmers to meet consumer requirements and have high competitiveness (Charina et al., 2018). GAP is a guideline for good horticultural practices that include farming practices ranging from pre-cultivation implementation to post-harvest handling with due regard to the preservation of natural resources and the preservation of biodiversity to achieve products that are safe for consumption of quality, have maximum benefits, are environmentally friendly and pay attention to aspects of safety, health, and welfare of farmers (Situmorang, 2022). This is in line with the notion of sustainability defined as development that meets current needs without compromising the ability of future generations to meet their own needs, considering environmental, economic, and social aspects in a balanced manner (Yusuf et al., 2021). Farmers who do not implement the standard operating procedures (SOPs) and GAPs should consider the sustainability of their farms.

Organic rice production currently faces various obstacles. The large gap in rice yields between conventional and organic production systems is one of the main factors hindering the implementation of this system on a large scale among farmers so not many farmers want to develop an organic system (Hazra et al., 2018). Moreover, in the cultivation process, farmers need to know about producing affordable organic fertilizer by composting all the materials needed and identifying local inputs that can be used as fertilizer. Farmers also need a better understanding of organic rice production which involves plant nutrient stress, soil nutrient dynamics, and soil-plant-microbe interactions. Pest dynamics are also important to produce maximum harvests while maintaining organic rice quality standards (Sujianto et al., 2024). Another problem is also related to productivity. The unavailability of rice varieties/genotypes specifically bred for organic farming is a major obstacle to realizing potential productivity. Therefore, organic responsive rice varieties that can excel in low input conditions are urgently needed to popularize organic rice production (Hazra et al., 2018).

Therefore, this study aims to analyze the level of farm sustainability, especially in each cultivation variety, and identify the factors influencing sustainability. Many domestic and foreign researchers have studied farm sustainability. For example, Purba et al. (2021) researched rice sustainability in tidal lands using Tobit regression analysis and Rice Check. Another study was conducted by Nurhidayat et al. (2022) on the sustainability status of organic rice in Jember and Bondowoso using MDS-Rapid Appraisal for Fisheries (MDS-RAPFISH) analysis. Based on research on the sustainability of rice cultivation, many studies only discussed the object of paddy field rice, but this present study compares cultivation techniques. Measurement of variables in the attributes of the sustainability dimension with MDS-RAPFISH apply variables that have not been widely used in previous studies such as local community wisdom (*pranoto mongso, wiwitan*, etc.), the influence of service programs, and how the level of information technology is utilized among rice farmers. This research is expected to impact farmers to pay attention to input usage in their farming. Agricultural extension workers through the government are also expected to provide advice or information that farmers need to pay attention to input usage and cultivation methods to maintain rice production and prices.

MATERIALS AND METHOD

Study location

The research was carried out in Yogyakarta, Indonesia, which has a diverse topography ranging from coastal sand, dry land, and rice fields to mountainous areas (Kurniawan and Sadali, 2018). This causes differences in rice cultivation, especially in high and low areas. For example, most areas of Bantul Regency are dominated by non-organic rice cultivation, and some farmer groups cultivate organic rice. At the same time, a type of rice is grown on fishponds (*minapadi*) in Sleman Regency, cultivated semi-organically. This research was conducted in Yogyakarta in early 2023, chosen because it is a province that has a variety of rice cultivation, such as paddy field, *minapadi* (rice grown on fishponds), coastal, rainfed, and upland rice. The research locations were 2 regencies, including Sleman and Bantul. Bantul Regency was selected because there are organic rice farmers with an organic certificate valid until 2026, especially in Gilangharjo Village, and non-organic rice farmers who are quite active in Bangunjiwo Village. Meanwhile, Sleman Regency was chosen because *minapadi* farms that are still active to date in Yogyakarta are only found in Candibinangun Village, which is located in Sleman Regency.

This research focuses on organic wetland rice, non-organic wetland rice, and semi-organic *minapadi* cultivation. Organic wetland rice is rice that has an organic certificate. In this research, farmer groups that already have this certificate are used, where they are inspected by private organic quality assurance institutions every 5 years. This organic rice farming group currently has a certificate valid up to 2026, making it eligible to be selected as a research sample. On the other hand, semi-organic *minapadi* is selected since farmers use natural/organic input in the production process but do not have an organic certificate because they have not passed the organic quality assurance process.

Data collection

The research was conducted by selecting farmers who had harvested their rice in early 2023 to obtain more up-to-date data. In the research process, if the rice farmer was in the initial cultivation process (not yet harvested) or failed to harvest, the farmer could not be interviewed, and the farmer would be replaced. The sampling technique used in this study was the non-probability sampling technique, particularly the quota sampling technique, which is a sampling method by considering the desired amount or following the desired quota (Sugiyono, 2006; Firmansyah and Dede, 2022). The number of respondent farmers was 90 (consisting of 31 organic, 31 non-organic, and 28 semi-organic rice farmers).

Data analysis

In this research, the data were analyzed with a multivariate MDS analysis technique using RAPFISH software, modified into the term RAP-RICE to measure the sustainability of rice cultivation. According to Fauzi and Anna (2005), RAPFISH is based on the ordination technique (placing something in the order of measurable attributes) using MDS. Furthermore, it states that MDS is a statistical technique that attempts to transform multiple dimensions into more dimensions. The 1st step was to determine the dimensions and attributes. The dimensions used in this study refer to the theory of agricultural sustainability and several experts in assessing agricultural sustainability. In 1990, Swaminathan (2010) proposed the sustainable agriculture matrix (SAM) (Figure 1). The SAM is a reference where stakeholders involved in agriculture can talk to each other about sustainability in the agricultural world.

The matrix displayed in Figure 1 includes 3 main categories: economic, ecological, and social. In each category, some problems can jeopardize sustainability and the 3 categories are interrelated. Dahuri et al. (1996) and Yusuf et al. (2021) added 2 aspects, namely law-institutional and technological aspects. This is in line with Brown (1991) who explains and re-conceptualizes the 3 pillars of sustainable development into 4, including ecological, economic, socio-cultural, and institutional politics. The technology pillar or dimension is also an important pillar in sustainable development in agriculture where Dumanski et al. (1998) further explain that the role of agricultural extension is significant in adopting technology for farmers. By referring to SAM (Figure 1) and the theories of some previous researchers, it was formulated that measuring the sustainability of rice cultivation on various practices of cultivation in Yogyakarta uses and examines 5 dimensions, namely, ecological, economic, socio-cultural, law-institutional, and technological. The attributes included in the dimensions follow the number and rules for determining attributes referring to the inventor of RAPFISH (Pitcher, 1999), which consists of 6 to 12 attributes, not a physical expression, and can be measured directly or indirectly. All attributes used are related to the dimensions studied and are based on theory or previous research results in Table 1.

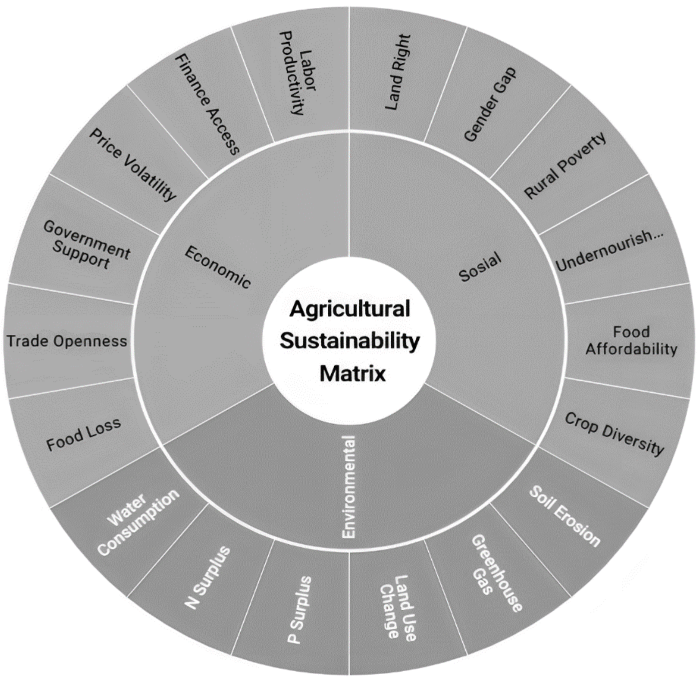

Figure 1. Sustainability agriculture matrix (Zhang et al., 2021)

Table 1. Different attributes used to measure the 5 dimensions of sustainability

Dimensions	Attribute	Source
Ecology	Waste pollution in rice fields	Hendri et al. (2020)
	Use of organic fertilizer	Dzikrillah et al. (2017); Yusuf et al. (2020); Rachman et al. (2022)
	Use of organic pesticides	Dzikrillah et al. (2017); Yusuf et al. (2020); Rachman et al. (2022)
	Planting pattern	Muksin et al. (2021)
	Utilization of livestock waste for fertilizer	Sulistyono et al. (2018)
	Irrigation network	Widiatmaka et al. (2015); Sulistyono et al. (2018); Hove et al. (2022)
	Use of superior quality seed varieties	Jha et al. (2020); Gharsallah et al. (2021)
	Use of certified rice seeds	Nurmalina (2008); Gunadi et al. (2019)
Economy	Profits from rice farming	Frimawaty et al. (2013); Muksin et al. (2021)
	Price of grain	Ekawati et al. (2019); Muksin et al. (2021)
	Stability of grain prices	Fitriani et al. (2021)
	Labor costs	Barchia et al. (2021)
	Income from rice farming compared to overall family income	Barchia et al. (2021)
	Availability of capital	Pitcher (1999)
	Marketing system	Pitcher (1999)
	Marketing institutions/agencies that accommodate production results	Widiatmaka et al. (2015)
Socio-cultural	Farmers' participation in farmer group activities	Rachman et al. (2022); Irianto et al. (2023)
	Social conflict	Pitcher and Preikshot (2001); Barchia et al. (2021)
	Local wisdom	Barchia et al. (2021)
	Farmers' knowledge of organic farming	Pitcher and Preikshot (2001); Irianto et al. (2023)
	GAP adoption rate	Pitcher and Preikshot (2001); Frimawaty et al. (2013)
	The main/basic motivation for farming	Afandhi (2020)
	Family participation in farming	Barchia et al. (2021); Irianto et al. (2023)
	Culture of collaborative work	Atmika et al. (2021); Hidayah et al. (2022); Ekopsi et al. (2023)
Law-institutional	Farmer participation in government extension activities	Rachman et al. (2022); Irianto et al. (2023)
	Existence of farmer groups	Pitcher (1999); Zuhdi et al. (2021); Irianto et al. (2023)
	The existence and role of local government extension agents	Irianto et al. (2023)
	Frequency of community service programs	Zuhdi et al. (2021)
	Farmer partnership network	Nugrahapsari et al. (2021)
	Ease of access to health facilities provided by the local government	Muksin et al. (2021)
	Access to credit service institutions	Muksin et al. (2021)
	Central/regional government subsidies	Muksin et al. (2021); Zuhdi et al. (2021)

Table 1. (*continued*)

Dimensions	Attribute	Source
Technology	Farmers' adoption of the *jajar legowo* system	Rachman et al. (2022)
	Technology adoption from local government	Pitcher (1999)
	Post-harvest processing (grain drying)	Irianto et al. (2023)
	Number of farming support equipment owned by farmers	Frimawaty et al. (2013); Linda et al. (2018)
	Pre-marketing technology (sales marketing strategy)	Frimawaty et al. (2013)
	Agricultural waste processing technology	Rohaeni et al. (2021)
	Pest and disease control	Rohaeni et al. (2021)
	Application of land management technology	Atmika et al. (2021); Ekopsi et al. (2023)

The sustainability index assessment looked at the output of the RAPFISH software, namely leverage of attributes. The following description of the resulting ordination index can be interpreted in 4 categories of sustainability status, as in Table 2.

Table 2. Sustainability index

Sustainability index	Status
0.00 – 25.00	Worst (unsustainable)
25.01 – 50.00	Lack (less sustainable)
50.01 – 75.00	Sufficient (moderately sustainable)
75.01 – 100.00	Good (sustainable)

Source: Kavanagh and Pitcher (2004); Yusuf et al. (2021)

Furthermore, regression analysis with the Tobit model was used to identify factors affecting the sustainability of rice cultivation. Tobit regression was used because this model can estimate and accommodate bias in censored data (Tobin, 1958; McDonald and Moffitt, 1980). The data structure of the sustainability index of rice cultivation practices or the dependent variable (Y) is known as censored data because there are several zero (0) values in the observation or index data. The dependent and independent variables are determined based on previous research in Table 3.

The independent variables consist of age, formal education, number of family members, frequency of attending extension services, a dummy for the use of GAP, a dummy for participation in farmer groups, a dummy for land ownership, and a dummy for cultivation variety. The regression with the Tobit model made in this study is presented as Equation 1.

$$Y = \beta_0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5D1 + \beta 6D2 + \beta 7D3 + \beta 8D4 + \beta 9D5 + \varepsilon \quad (1)$$

Where: Y = farm sustainability index (0 to 100), X1 = farmer age (years), X2 = formal education (years), X3 = number of family members, X4 = frequency of attending extension, D1 = dummy for the use of GAP (D = 1 if cultivation often uses GAP/guidelines, D = 0 if rarely uses GAP), D2 = dummy for participation in farmer groups (D = 1 if farmers are active in farmer groups, D = 0 if farmers are not active/not participating in farmer groups); D3 = dummy land ownership status (D = 1 if the land owned by the farmer is self-owned, D = 0 if the land used by the farmer is rented or profit sharing); D4 = dummy cultivation variety 1 (D = 1 if organic rice field cultivation, D = 0 if other than organic cultivation), D5 = Dummy cultivation variety 2 (D = 1 if semi-organic rice field cultivation, D = 0 if planted other than semi-organic), ε = error term.

RESULTS AND DISCUSSION

The sustainability of rice cultivation in different cultivation settings is the result of a results-oriented framework implemented in 5 dimensions of sustainability: ecological, economic, socio-cultural, law-institutional, and technological, the 5 dimensions being interrelated and interdependent. Each dimension includes a statement of objectives related to the mission of achieving farmers' economic prosperity, improving welfare, as well as nature conservation. The sustainability status of rice cultivation in the cultivation variety was analyzed using the RAPFISH technique, modified for rice into RAP-RICE. Statistical testing in RAPFISH software

Table 3. Factors that influence farming sustainability

Variable	Author	Research title	Research result
Farmer age	Purba et al. (2021)	The sustainability of rice farming practices in tidal swamplands of South Sumatra Indonesia	Age had a positive value (+) on sustainability
	Serebrennikov et al. (2020)	Factors influencing adoption of sustainable farming practices in Europe: A systematic review of empirical literature	Farmer age was found to be a significant determinant of organic farming adoption (+)
Formal education	Purba et al. (2021)	The sustainability of rice farming practices in tidal swamplands of South Sumatra Indonesia	Education had a positive and significant impact on sustainability (+)
	Sodjinou et al. (2015)	Socioeconomic determinants of organic cotton adoption in Benin, West Africa	Education had a significant positive influence on the adoption of organic farming (+)
Number of family members	Purba et al. (2021)	The sustainability of rice farming practices in tidal swamplands of South Sumatra Indonesia	The number of family members had a positive impact on the sustainability of rice farming practices in tidal swampland (-)
Frequency of attending extension	Prashanth and Reddy (2012)	Factors influencing the adoption of organic farming by the farmers of Karimnagar district of Andhra Pradesh	The higher the level of training received by a farmer, the more positive and significant relationship there is with farming sustainability (+)
	Métouolé Méda et al. (2018)	Institutional factors and farmers' adoption of conventional, organic and genetically modified cotton in Burkina Faso	Cotton production training also had a positive impact on the adoption of organic cotton and its sustainability (+)
Use of GAP	Bahar et al. (2019)	Study for evaluation of GAP implementation by farmers in Lembang vegetable production center	The implementation of vegetable GAP among farmers in Lembang Sub-district is categorized as quite sustainable (value 0.51)
	Shofi et al. (2019)	Implementation of good agriculture practices (GAP) in organic red rice farming	The relationship between the application of organic GAP variables and organic red rice production was a positive relationship with a strong relationship strength
Activeness in farmer groups	Sawitri and Nurtilawati (2019)	Capacity of paddy farmers in the application of integrated crop management technology in Tamansari District, Bogor Regency, West Java	The farmer group support variable had a significant (+) effect on the capacity of rice farmers in implementing integrated crop management technology
Land ownership status	Pratiwi (2022)	The impact of land ownership on the subjective well being of farming households in Indonesia	With a significance level of 1% and a positive effect (+), farmers with their own agricultural land status tend to be 1,034 times more likely to feel calm and profitable

uses 2 analytical techniques that indirectly become the output of the software, namely RAPFISH ordination to determine the picture of sustainability status and Leverage analysis to determine the effect of attribute sensitivity on sustainability status in each dimension.

The MDS method performs multidimensional transformation into lower dimensions, each dimension has attributes or indicators related to sustainability. The overall data from the attributes used are then analyzed multidimensionally to determine the point that shows the position of sustainability of rice cultivation.

Leverage of attributes of rice cultivation sustainability

Ecological dimension

Organic rice cultivation has 3 attributes with a high sensitivity value/root mean square (RMS) score (Figure 2). However, there are 2 that are the highest RMS, namely livestock waste and organic fertilizer. Based on conditions in the research location, many organic rice farms have cows and farmers use animal waste for basic fertilizer (livestock waste fertilizer). Animal waste is vital for farming because it can save the cost of purchasing fertilizers and utilize non-organic natural materials (Kurniati and Darus, 2019). Indirectly, the organic fertilizer attribute also has a high sensitivity value because by using livestock waste, organic rice cultivation indirectly uses it for natural organic fertilizer. In line with the research of Nugrahapsari et al. (2021), the ecological dimension of livestock waste and organic fertilizer use are the most sensitive attributes. The study also concluded that farmers could raise livestock and use livestock waste as crop fertilizer. Organic fertilizers can reduce environmental pollution due to the excessive use of inorganic fertilizers, increase crop productivity, and increase farmers' income (Thamrin et al., 2017).

Figure 2 depicts that the attribute of livestock waste in non-organic farming has similarities with organic rice, where farmers also utilize livestock waste in the rice cultivation process. However, the fact in the field that distinguishes between organic and non-organic rice cultivation is that non-organic farms still use chemical fertilizers in addition to fertilizers from cattle waste. The cropping pattern has a high sensitivity because some farmers use a polyculture system. In line with the research of Muksin et al. (2021), analyzing the status of post-disaster crop production sustainability in Sigi Regency, Central Sulawesi Province, in the ecological dimension, the garden pattern is the second largest attribute that has the highest RMS value, namely 3.08. Planting patterns are significant in the farming process because polyculture, by planting several types of plants in one area or a year, provides benefits in the form of biodiversity, natural pest control, and optimization of soil resource utilization (Arif, 2019).

Superior seed and irrigation channel conditions are the attributes with the highest RMS values in semi-organic cultivation. Based on the field study, semi-organic rice cultivation is very careful in using seeds, where the types of seeds used are mostly IR 64 and Inpari 32, known to be resilient to disease. Water inundation is quite a lot, considering that semi-organic rice is grown using the *minapadi* system (Department of Agriculture, Food and Fisheries, 2022; Nuraini, 2022). Irrigation networks are also essential in increasing the sustainability of semi-organic rice cultivation because it is grown on fishponds

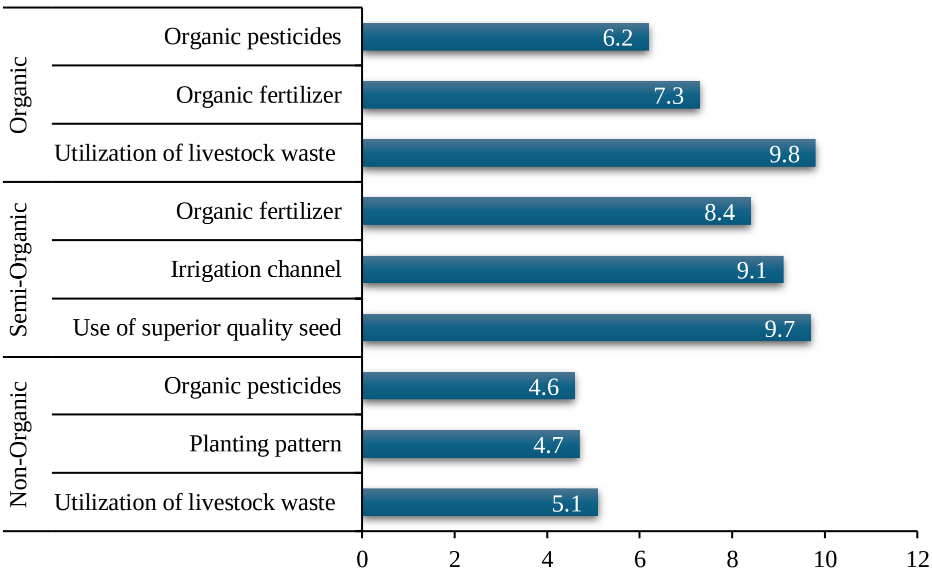

Figure 2. Leverage of attributes ecological dimensions

with fish, so irrigation network management must be good and organized. The results of the study are in line with Fitra and Sapanli (2019), in the ecological dimension of water quality and irrigation networks being the most sensitive attributes that affect the sustainability of semi-organic *minapadi* farming.

Economic dimension

The capital availability presented in Figure 3 is an attribute that affects sustainability where organic rice cultivation obtains capital from previous harvests and borrows from financial institutions so that capital in farming is not limited. The price of grain is also the most sensitive to farming sustainability, with the price of unhulled rice in Pandak, Bantul Regency, is 6,500 IDR, which is higher than the national price of 5,500 IDR (Statistics Indonesia, 2023). Fair and stable prices can provide incentives for farmers to increase production and implement more sustainable agricultural practices. Conversely, sharp price fluctuations or unfavorable prices can threaten the economic sustainability of rice cultivation, causing uncertainty and financial risk for farmers (Fitriani et al., 2021). The results of the RMS value of grain prices are not in line with the research of Hove et al. (2022) which is about the analysis of the sustainability of rice production in rice fields in the black water swamp irrigation area of Bengkulu where the price of grain is an attribute that does not affect sensitively due to the unstable price of grain in the Central Bengkulu Regency area.

The attributes of capital availability and income comparison in Figure 3 have the highest RMS values. The high value of capital availability attribute in influencing sustainability means that non-organic rice farms have no difficulty obtaining capital, which other non-organic rice farms also benefit from other crops because in the ecological dimension of farmers, planting patterns tend to be polyculture. For example, in the field results, some farmers have other land besides those planted with rice, namely farmers planting sugar cane and selling it to companies engaged in the sugar cane agro-industry (sugar factory) belonging to the Ngayogyakarta Hadiningrat Sultanate located in Bantul Regency. The farmers not only benefit from rice but also from the sale of their sugar cane farms. In line with the research of Rope et al. (2020) where the attribute of farm income from other crops has the 2nd highest value, the farmer's income is obtained from farming other food crops such as corn, bananas, and cassava.

The highest RMS value summarized in Figure 3 in the economic dimension of semi-organic rice is price stability and grain price. So far, the rice from semi-organic *minapadi* has a stable market price, ranging from 13,000 to 16,000 IDR kg^{-1}. This is because of the local government's attention in the form of routine counseling so that it can reduce the risk of crop failure and the price of crops can be maximized. Research by Atmika et al. (2021) on the sustainability status of upland rice farming in Bangli Regency, Bali Province, in the economic dimension of price stability is

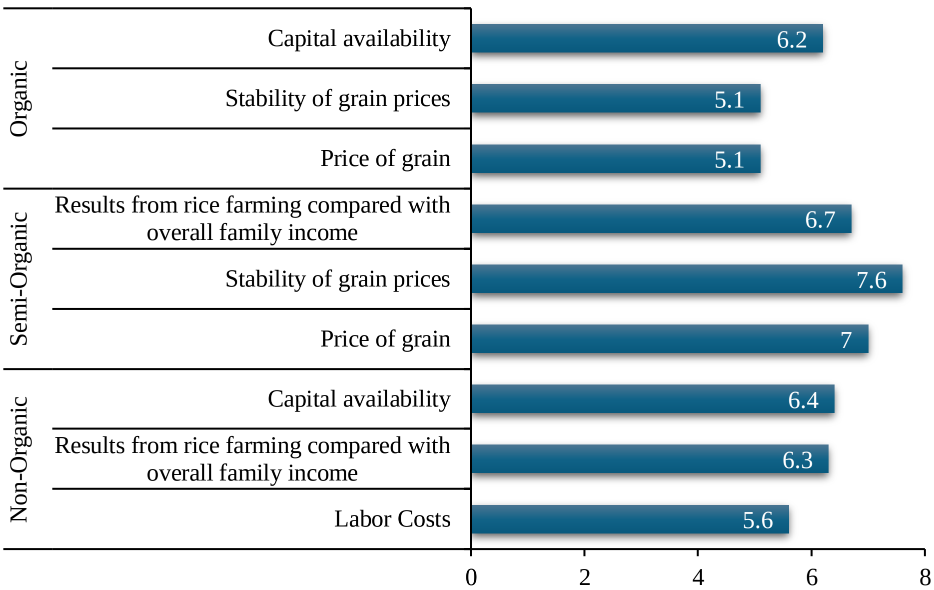

Figure 3. Leverage of economic dimension attributes

the highest attribute with an RMS value of 9.8 where the price of upland rice in the market ranges from 25,000.00 to 30,000.00 IDR kg^{-1}. This is because some areas in Bali only produce upland rice occasionally every year. After all, people always need rice for ceremonies and daily consumption.

Socio-cultural dimension

The highest attributes in Figure 4 are organic knowledge and farming motivation. The results of this study show that most farmers understand how to cultivate organic rice properly and the activeness of farmer groups supports this. Farmers who make farming their main job and farmers who make farming a side job have significant differences in the level of involvement, time dedication, and main source of income. These differences reflect the different levels of commitment and priorities between the 2 groups of farmers (Ittaqillah et al., 2020; Hidayah et al., 2022). In line with the research of Ristianingrum et al. (2016) which analyzed organic rice in Cianjur Regency, the results of the analysis carried out on the socio-cultural dimension of organic rice are: there are several attributes, namely farmers' knowledge level (RMS = 4.08) and farmers' skills in organic rice cultivation (RMS = 4.28). Farmers' skills in organic rice cultivation affect the sustainability of organic rice businesses because organic rice cultivation requires skills in making organic fertilizers and pesticides and intensive plant care to support the success of cultivation (Hadi et al., 2019).

The high local wisdom attribute in Figure 4 indicates that non-organic rice cultivation does not eliminate the cultivation. In the interview, the head of the farmer group, Mr. Sumiyanto, explained that the *wiwitan* tradition (prayer event together after harvest), which includes local wisdom culture, is still carried out today. He even has a *Pranata Mangsa* calendar, a calendar system or calendar associated with agricultural activities, especially for the benefit of farming. The relationship between the local wisdom of *wiwitan* tradition and the sustainability of rice cultivation reflects the integration of local wisdom in agricultural practices. The *wiwitan* tradition, which is a local cultural heritage, may include knowledge about cropping patterns that are compatible with natural cycles, the use of local rice varieties that are resistant to local environmental conditions, and sustainable land management techniques (Salim, 2013). These results are in line with research by Barchia et al. (2021) regarding the sustainability status of rice cultivation on marginal peatlands in Indonesia, particularly in the socio-cultural dimension, where local wisdom is the most sensitive attribute.

Organic knowledge is the attribute with the highest RMS value as presented in Figure 4, followed by the GAP adoption attribute. The high level of organic knowledge possessed by semi-organic rice farms is supported by the presence of extension workers living in the hamlet, so they often conduct counseling and share knowledge about organic farming. Indirectly, understanding organic farming helps farmers in applying or adopting GAP well, as evidenced by the high influence of GAP adoption on the sustainability of semi-organic farming. By applying GAP in

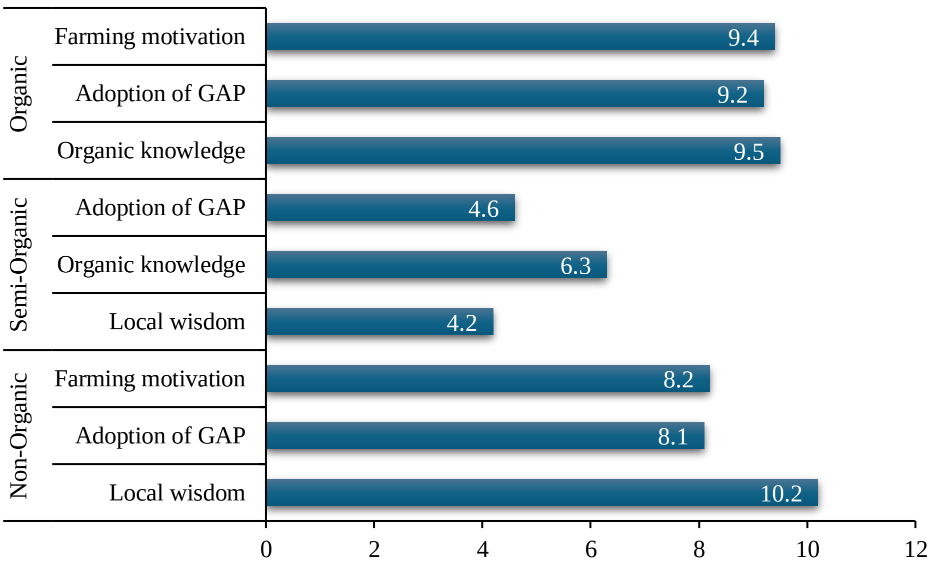

Figure 4. Leverage of socio-cultural dimension attributes

semi-organic rice cultivation, farmers can create an agricultural system that is resilient, profitable, and in line with environmental values (Shofi et al., 2019). In line with research on a case study on the sustainability of eco-farming-based rice farming in Jambi Province, Indonesia, by Frimawaty et al. (2013), the level of GAP adoption has an RMS value of 3.60 (3rd highest of 11 attributes) in the socio-cultural dimension.

Law-institutional dimensions

The role of extension workers and service programs (Figure 5) is attributed to high RMS values. Extension agents in organic rice cultivation, especially in Pandak, Bantul Regency, play an active role. They also invite farmer group leaders to become "double agents". This means that in addition to being farmers or producers, they are extension workers. Involved in the program, it becomes easier for extension workers to coordinate with farmers through farmer groups. One of the interesting aspects encountered is that the head of the farmer group, Mr. Mulyono (the head of Tani Rahayu farmer group), often conducts extensions to several areas in Bantul Regency about organic farming. According to Hadi et al. (2019), agricultural extension workers have an important role in increasing productivity, farmer welfare, and agricultural sustainability. They provide up-to-date information on agricultural techniques, plant variety selection, natural resource management, and marketing strategies. The research on the sustainability strategy for organic rice farming business towards the global market conducted by Irianto et al. (2023) revealed that on the results of sustainability analysis, especially the institutional dimension, the role of extension agents has the highest RMS value (6.16), signifying that the role of local organic rice extension agents affects the sustainability of rice cultivation.

There are 2 attributes in Figure 5 on the law-institutional dimension of non-organic rice institutions with high RMS values, including the role of extension workers and service programs. One of the interesting things that can be focused on is the service program where the sample location of non-organic rice farmers is in the college areas, which are Universitas Muhammadiyah Yogyakarta (UMY), Universitas Alma Ata, and Universitas Jenderal Achmad Yani Yogyakarta. Based on the information from the head of the farmer group, farmers are often invited to participate in counseling provided by UMY, such as a community service program in the form of training in making compost fertilizer in the middle of 2023. Yusran et al. (2019) said that the program offered to farmers is appropriate to overcome the problems faced by the community and relevant to the development programs of villages, sub-districts, and regencies. The same results were also identified in the research of Zuhdi et al. (2021) in the analysis of rice farming sustainability in Siak Regency in the dimension of institutional law. The attribute of a community empowerment program is one of the attributes sensitive to farming sustainability.

The role of extension workers and credit services presented in Figure 5 are attributes that influence sustainability. In the 3 cultivation practices, the role of extension workers always

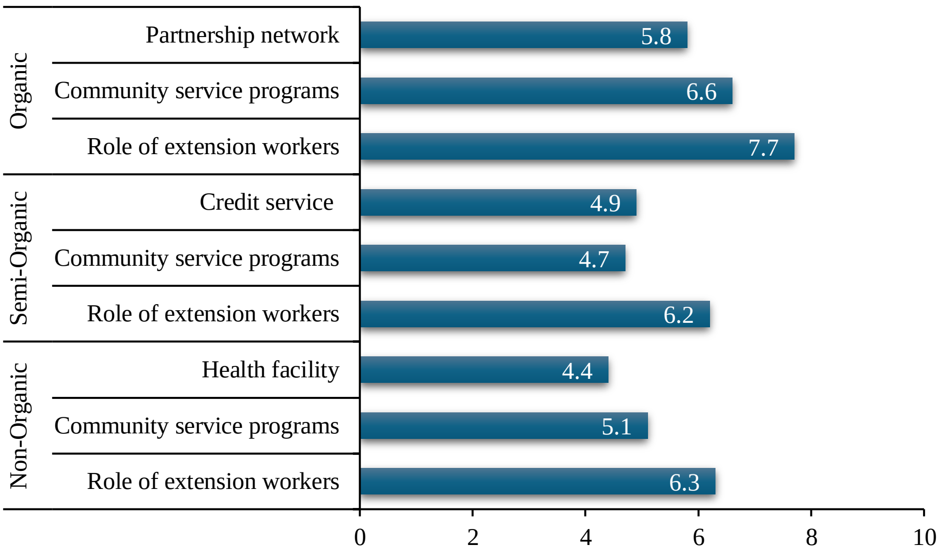

Figure 5. Leverage of law-institutional dimension attributes

has the highest value, meaning that extension workers affect sustainability in each cultivation variety. The extension workers in the semi-organic rice cultivation location are unique; where Mr. Frans, as an extension worker and facilitator of the Pakem area, Sleman Regency, was initially doubted by many farmers during the counseling and coaching. As an extension worker, he did not despair. He found a way to provide direct examples of planting rice cultivation, especially *minapadi*, properly and correctly. Hafsah (2019) explained that farmers face the most basic problem with capital, where farmers use their own capital to conduct farming to produce better results in terms of quality and quantity. To overcome this problem, the government provides facilities for the people's business credit program to help the agricultural sector obtain capital. The attribute of capital loans from financial institutions (banks or other capital assistance institutions) from the sustainability analysis results conducted by Wahyuni et al. (2023) has the highest RMS value of 4.78, which shows that capital support is significant for agricultural sustainability. In this case, the characteristics of capital are crucial for the sustainability of rice cultivation so that their farms are not disrupted. Local farmers with small capital need the support of financial institutions.

Technology dimension

Pest control and marketing technology as detailed in Figure 6 are 2 attributes that leverage the sustainability of organic rice cultivation. Pest and disease control is how farmers carry out various controls, where the more ways of control that farmers do, the better in overcoming pests. Organic rice pest control involves organic pesticides, manual weeding, and biological control. One of the strategies that farmers use in biological control is to extract plants such as papaya leaves (*Carica papaya* L.) and *bratawali* leaves (*Tinospora cordifolia*). Marketing technology, which is a leverage attribute, is quite influential for sustainability. For example, some farmers sell their crops via WhatsApp status and many collectors who see the status are interested in buying. Households with a considerable distance from the farmer's house are also interested because of their awareness of organic products, particularly organic rice. Rohaeni et al. (2021) explained that the utilization of technological information sources is a sensitive attribute for sustainability because it is closely related to the addition of insight or knowledge for human resources in the field of rice cultivation.

Plant disruptive organisms and waste technology are the main leverage attributes shown in Figure 6. Plant disruptive organisms carried out by non-organic rice farms are different from organic rice farms, where farmers focus on chemical pesticide use. In addition, they control pests using crop rotation in a year (rice - secondary crops - rice - secondary crops). They also do manual weeding with the help of agricultural tools such as sickles. An important point of concern in non-organic rice cultivation is how they process agricultural waste. The processing of straw waste is usually used to cultivate *janggel* mushrooms which utilize the remaining corn stalks combined with the

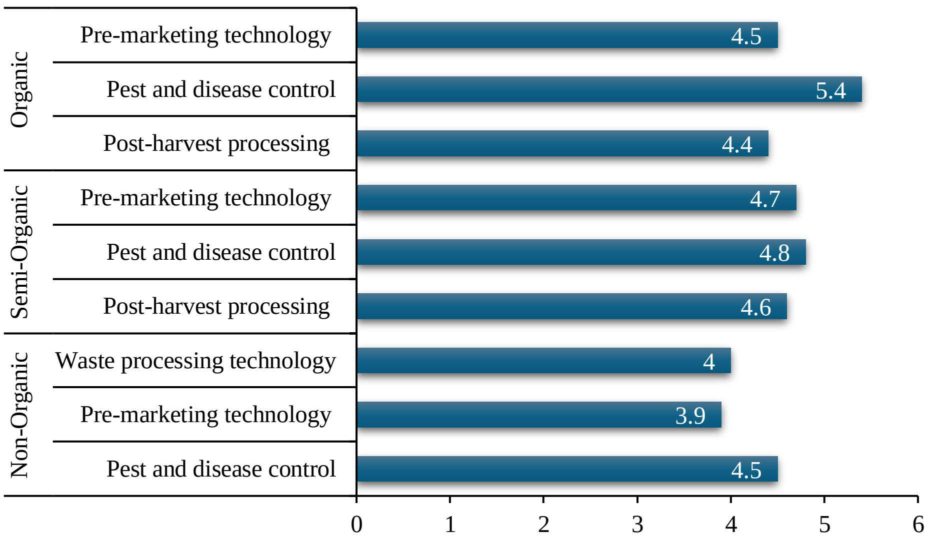

Figure 6. Leverage of technology dimension attributes

remaining straw waste from rice. Some farmers cultivate mushrooms in their respective homes based on the counseling conducted by the local government on the importance of processing waste. In line with the research of Rohaeni et al. (2021), the findings revealed that the dimension of waste treatment technology became a leverage attribute with the highest RMS value of 3.98. This signifies that the technology needs massive improvement and maintenance because waste treatment, both livestock waste and farm residues, positively impacts on the environment and land fertility. In addition, processing livestock waste will improve the quality of fertilizer.

Semi-organic rice in the technology dimension of the leverage of attributes (Figure 6) results in 2 leverage attributes that affect sustainability, namely the amount of equipment and marketing technology. The equipment of semi-organic rice farms tends to be more complete because *minapadi* farming requires much equipment to grow rice on fishponds. The difference with rice farming in paddy fields is that *minapadi* needs tools that can help control fish and rice, such as irrigation pumps to regulate the entry and exit of water into the pond. Farmers also need to buy fishing equipment such as nets or roads and fish mining equipment in the form of large tubs. Therefore, semi-organic *minapadi* farming requires sufficient equipment to support sustainability. Based on previous research by Linda et al. (2018), almost all attributes related to equipment, namely the number of rice harvesting, threshing machines, pest control, land processing, and harvesting tools all have RMS values above the threshold, which means that the equipment is not sufficient. It is important to carry out the cultivation process to maintain the farm's sustainability.

Sustainability index of rice cultivation

Table 4 presents the analysis results and the average value of the sustainability index of rice cultivation in Yogyakarta in 2023, which focuses on 5 dimensions, consisting of ecological, economic, socio-cultural, law-institutional, and technological. The sustainability index was measured for 3 practices of rice cultivation, including organic, non-organic, and semi-organic rice. In terms of ecology, organic rice scored the highest, with an average of 72.31, indicating a good level of sustainability. Meanwhile, non-organic and semi-organic rice scored lower, 42.14 and 52.84. Economically, organic rice also leads with an average of 52.22, indicating good sustainability, while non-organic and semi-organic rice score 52.59 and 49.56, indicating moderate and less sustainable levels.

The socio-cultural dimension shows that organic rice obtains the highest score with an average of 78.05, indicating good sustainability, while non-organic and semi-organic rice gets a score of 62.46 and 66.90, signifying a fairly good level of sustainability. In the dimension of institutional law, organic rice shows the highest score in both dimensions, but all 3 are still in the same category, which is sufficient (sustainable enough). The technology dimension of the 3 has a less sustainable category, but organic rice still has the highest value score of 48.43.

In Figure 7 we can also see how the graphic diagram shows that the red line (organic) is wider than the purple (semi-organic) and blue (non-organic) lines, which shows that the 5 dimensions of organic rice have a higher sustainability index. Organic rice is the only one that has a sustainability index value above 75, which is included in the sustainable category in the socio-cultural dimension. The ecological dimension has the largest sustainability index value because it contains attributes directly related to sustainability, such as the use of organic fertilizers and pesticides, irrigation networks, and the use of livestock waste. We can also highlight how big the influence of the use of natural fertilizers and pesticides is, as in Oco et al. (2024) regarding the use of *Nostoc piscinale* as a biofertilizer for rice plants producing quite interesting findings where rice grown using *Nostoc* was different from rice planted with

Table 4. Average value of rice cultivation sustainability index

Variety of rice cultivation	Dimensions					Multidimensional
	Ecology	Economy	Socio-cultural	Law-institutional	Technology	
Organic	72.31***	52.22***	78.05****	63.63***	48.43**	62.93***
Non-organic	42.14**	52.59***	62.46***	62.64***	41.33**	52.23***
Semi organic	52.84***	49.56**	66.90***	60.51***	44.68**	54.90***

Note: * = Bad (unsustainable); ** = Lack (less sustainable); *** = Sufficient (sustainable enough); **** = Good (sustainable) commercial fertilizer (CSF). The differences are in the content of nitrogen sources, plant development (root and shoot length), and chlorophyll content in leaf shoots. Irrigation also plays an important role in the sustainability process in the ecological dimension, apart from the importance of maintaining irrigation cleanliness, irrigation can help increase rice production. This is proven by Anshori et al. (2023) research in the dry land of Playen, Gunungkidul, Yogyakarta, supported by groundwater irrigation showing that rice productivity in the first planting season was 5,215 tons ha^{-1} with a profit of 12,288,000 IDR ha^{-1} and in the second planting season, productivity was 8,025 tons ha^{-1}, with dry straw of 8,049 tons ha^{-1}, with a profit of 20,700,000 IDR ha^{-1}. This shows the importance of an irrigation system so the construction of groundwater irrigation facilities must pay attention to safe aquifer yields and agricultural development plans to ensure the continued use of groundwater irrigation which can increase production results (Anshori et al., 2023).

The socio-cultural and technological dimensions also have quite a large sustainability index value with the same order of organic, semi-organic, and non-organic rice. In the other 2 dimensions, namely economy and institutionally, the 3 cultivation practices have almost the same sustainability index values, indicating that the attributes in the 2 dimensions are similar for the 3 cultivation practices.

The results of the sustainability index value of organic rice cultivation are in line with the research of Irianto et al. (2023), where analyzing organic rice in Ngawi Regency with 90 respondents resulted in the findings of environmental, economic, social, and institutional aspects obtaining MDS values of 72.10, 66.00, 66.29, and 65.00, respectively, which means quite sustainable. The similarity of the research is that the ecological dimension has the largest index value while the technological dimension has a relatively small index value among other dimensions. The ecological dimension in the theory of farm sustainability emphasizes the importance of maintaining ecosystem balance, biodiversity, natural resource management, adapting to climate change, reducing pollution, and balancing soil nutrients. This aspect ensures that agricultural practices do not harm the environment, maintain the sustainability of nature, and support long-term agricultural productivity (Yusuf et al., 2020; Rachman et al., 2022).

The results of the index value of non-organic and semi-organic rice are in line with the research of Linda et al. (2018) on the sustainability status of rice paddy farming in Denpasar City revealing that in non-organic rice in Denpasar, the socio-cultural and the law-institutional dimension of the institution have the highest score of 84.44 and 72.22, while the technology dimension has the smallest index value. The high value of the socio-cultural dimension in non-organic and semi-organic rice cultivation in Yogyakarta is also supported by the existence of local wisdom that is regularly carried out by farmers, such as the *wiwitan* tradition before rice harvest, where farmers wear clothes in the event. The socio-cultural dimension of farm sustainability highlights the importance of human aspects and

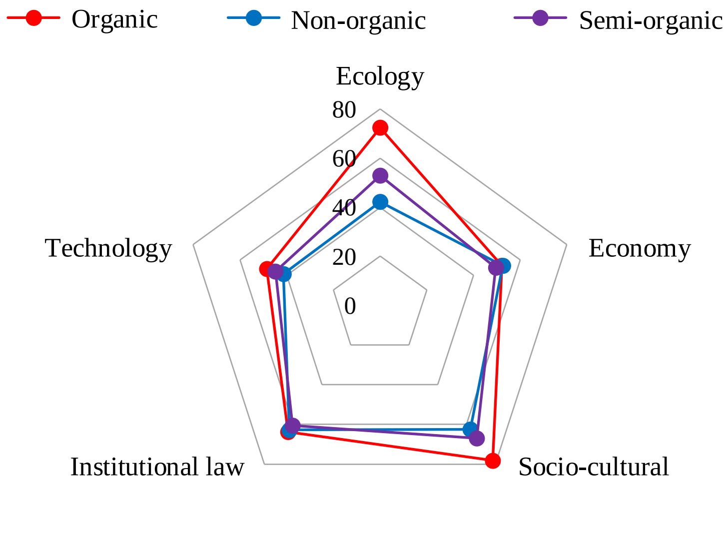

Figure 7. Rice cultivation sustainability index

cultural values in the context of agriculture. This includes farmers' social welfare, inclusiveness, empowerment of local communities, and understanding and respecting local cultural practices (Serageldin, 1993; Barchia et al., 2021; Fitriani, 2021).

Factors affecting the sustainability of rice cultivation in different cultivation practices

Pseudo R2 value on the equation of sustainability of rice cultivation on a variety of cultivation in Yogyakarta showed a value of 0.13, which means that the equation has a good model which is close to 0.2 to 0.4. This is in line with McFadden (1977) that the value of pseudo R2 between 0.2 and 0.4 is a "very good fit," and thus, it can be concluded that the factors of farm sustainability such as age, education, number of family members, frequency of attending extension, dummy GAP usage, dummy activity in farmer groups, dummy land ownership, and dummy cultivation are closely related to the sustainability of farming. The regression equation with the Tobit model based on analysis using STATA in this study is presented in Table 5.

As presented in Table 5, the age variable is not significant. Age only significantly affects the sustainability of rice cultivation in various types of cultivation in Yogyakarta. Age variable does not affect sustainability because the average age of rice farms of the 3 cultivation practices is in the elderly category. Farmers who are elderly certainly have limitations in terms of energy and the process of transferring technology, so this condition can threaten sustainability when there are no young farmers involved in agriculture practices. Based on the results of the study, many farmers' children prefer to work in offices such as in e-commerce companies (*Shopee*, *Gojek*, and *Tiktok*) (Erliaristi et al., 2022).

Education is one of the variables in the table above and is significant at the 10% error rate. The value can be interpreted as any increase in the education of rice farmers is likely to add a farm sustainability index of 1.70. Research conducted by Purba et al. (2021) shows the same results where education affects the sustainability of farming on tidal land in South Sumatra. Based on the research findings, rice farmers in Yogyakarta are dominated by farmers with a high level of education, mostly graduating from high school.

As summarized in Table 5, the number of family members shows no significant effect at the 1% error rate. This signifies that the number of family members does not significantly affect the sustainability of rice cultivation in various types of cultivation in Yogyakarta in production inputs such as labor, and farmers prefer to rely on labor outside the family, namely farm laborers rather than their own family members or labor within the family.

The frequency of attending extensions was a significant variable. The value can be interpreted that each additional frequency of counseling followed by rice farmers is likely to add a farm sustainability index of 0.22. Based on field results, rice farmers in Yogyakarta are close and closely related to extension workers, even some farmer group leaders are also (non-official) extension workers appointed by the local government.

Table 5. Factors affecting the sustainability of rice cultivation in different cultivation practices in Yogyakarta

Y (Sustainability index)	Expected sign	Coefficient	Std.err	t	P > t
X1 Age	+	-2.29	3.35	-0.68	0.495
X2 Education	+	1.70*	0.93	1.83	0.071
X3 Number of family members	+	1.06	0.88	1.19	0.236
X4 Freq. of attending extension	+	0.22*	0.12	1.85	0.068
D1 GAP usage	+	2.71**	1.23	2.20	0.031
D2 Activeness in farmer group	+	3.59*	2.13	1.68	0.096
D3 Land ownership	+	2.18**	1.03	2.11	0.038
D4 Organic cultivation	+	10.07***	1.28	8.65	0.000
D5 Semi-organic cultivation	+	-8.70***	1.35	-6.80	0.000
_cons	+/-	49.25*	14.90	3.31	0.001
LR chi^2 (9)		79.98			
Prob > chi^2		0.000			
Pseudo R2		0.13			

Note: *** = Significant at 99% confidence level (α = 0.01); ** = Significant at 95% confidence level (α = 0.05); * = Significant at 90% confidence level (α = 0.10)

According to Métouolé Méda et al. (2018), farmers who regularly attend extension programs have a greater chance of increasing productivity and implementing sustainable practices in their farms.

The GAP dummy or the level of GAP use by rice farmers in various cultivation practices means that farmers who apply GAP accordingly are likely to have a higher sustainability index compared to farmers who do not apply GAP. According to Bahar et al. (2019), the application of GAP can help produce competitive horticultural products, namely products that are safe for consumption, quality, and environmentally friendly production. GAP can also encourage farmers/horticultural producers to have a responsible mental attitude towards products, health, personal safety, and the environment.

The dummy of activeness in farmer groups affects the sustainability of rice cultivation in various types of cultivation in Yogyakarta at the 10% level. The result means that farmers who are active in farmer group activities will likely have a higher sustainability index value than farmers who are not active in farmer groups. In line with Sawitri and Nurtilawati (2019), the farmer group support has a significant effect on the capacity of rice farmers in the application of integrated crop management technology. The role of farmer groups in rice farming in Yogyakarta is supported by one important factor, which is the close relationship among the head of the farmer group, local government, and farmer group members. It was proven that the active role of farmer groups can be a lever for rice cultivation sustainability.

The land ownership dummy variable signifies that land owner farmers are likely to have a higher sustainability index than farmers who use rented or shared land. According to Latifah and Ekawati (2023), land ownership is a strength for farmers in terms of capital and has the potential to increase income. This is evidenced by the results of the analysis where the attribute of land ownership contributes significantly to sustainability.

The organic cultivation dummy in the farm sustainability equation has a positive coefficient value, which means that rice farmers who apply organic rice cultivation are likely to have a higher sustainability index than non-organic and semi-organic farmers. The semi-organic cultivation dummy has a negative coefficient. This suggests that rice farmers who implement semi-organic rice cultivation tend to have a lower sustainability index value than organic rice farmers.

CONCLUSIONS

Organic rice farming has the highest sustainability index value among the 3 cultivation practices. This can be seen from the ecological and socio-cultural dimensions, where the index values have a significant gap between semi-organic and non-organic farming. Based on the identified factors influencing sustainability, interesting findings indicate that the age variable did not affect sustainability, because the age of farmers can reduce sustainability. This statement can be supported by the results that for the 3 cultivation practices, the technological dimension index value is very small, meaning that the farmers in this study who are old have difficulty adopting technology. In the future, further research needs to consider relatively young farmers as samples to see how they assess the sustainability of farming.

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