Sustainability of the Rice-Fish Farming System in Candibinangun Village Pakem Sub-district Sleman Regency

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Abstract. The increase in foodstuffs and the limited land for fish farming have caused a change in agricultural strategies that were originally monocultures to diversify crops through the rice-fish farming system. The rice-fish farming system is a combination of fish and rice farming in one field. The purpose of this research is to determine the level of sustainability of the rice-fish farming system in Candibinangun Village, Pakem Sub-district, Sleman Regency. Sustainability is seen from three perspectives; those are the economic dimension, the social dimension, and the ecological dimension. This research used a descriptive method with a quantitative approach by survey. The sampling technique used the census method, with a sample size of 36 people. Based on the results of the research, it shows that the level of sustainability of the rice-fish farming system in Candibinangun Village, Pakem Sub-district, Sleman Regency is high. The aspect value, including from the highest to the lowest, is the social dimension, ecological dimension, and economic dimension.

Keywords: Sustainability · The rice-fish farming system · Economic dimension · Social dimension · Ecological dimension

1 Introduction

The growth of global population has been rising. The population reached 7.7 billion in the mid 2019 after an increase of one billion since 2007 and two billion since 1994. The world's population is estimated to reach 8.5 billion of lives in 2030, 9.7 billion in 2050, and 10.9 billion in 2100 [1]. Meanwhile, the population in Indonesia in 2020 was 270.20 million of lives and it had increased for 32.56 million in the last 10 years [2]. The rise of population growth has its impact on the residential development which threatens the availability of agricultural land resulting in the decline of rice production [3]. According to [4] the national rice field transformation rate is estimated to be around 96,512 ha yr-1 in the period 2000–2015. With this conversion rate, the paddy field would undergo shrinkage from today's area, 8.1 million ha, to 5.1 million ha in 2045. This situation can endanger the amount national food production.

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In addition to the increasing demand for foodstuffs from the agricultural sector, demand from the fishery sector has also increased due to an increase in the level of fish consumption in the community. Based on data from the Ministry of Maritime Affairs and Fisheries (KKP), the number of fish consumption in 2014–2018 increased by 7.37% [5]. This increase in fish consumption has resulted in the increase in the amount of fish production. In 2017, the total production of cultured fish was 16,114,990.71 tons, the production increased as many as 112,671.62 tons from the total of number of 15,634,093.04 tons in 2015 [6]. The increasing need for foodstuffs and the demand for fish consumption are not in line with the total area of agricultural land, so an innovation is needed to optimize the land. One of the solutions is to integrate fish and rice cultivation in rice fields with the rice-fish farming system.

Rice-fish farming is described as a combination of paddy cultivation and fish farming in the same cultivation area simultaneously [7]. This practice becomes an alternative to provide animal-derived protein to fulfil family nutrition need. Beside that, this system also could be used to reduce pollution and sustain the continuity of living environment by lessening the use of chemical fertilizer and pesticide. Rice-fish farming can also be a solution to prevent agricultural land conversion into non- agricultural land. Rice-fish farming system has dual outputs as rice and fish which can minimize the risk of failure that may happen into one of the outputs.

The rice-fish farming system has been long practiced in Indonesia since around the 1970s. In fact, the rice-fish farming system has been known by the local community, especially in West Java since 1860 [8]. In 2014, Rice-fish farming was promoted again through the development of the rice-fish farming system in Sleman Regency. This development received appreciation from the World Food and Agriculture Organization (FAO). Since 2015, the government and FAO have developed the rice-fish farming through the "National Training on Promote Scaling-up of Innovative Rice-Fish Farming and Climate Resilient Tilapia Pond Culture Practice for Blue Growth in Asia" program which was carried on until 2018 [7].

Pakem is a sub-district in Sleman Regency which is still actively implementing the rice-fish farming system. This is due to its location on the slopes of Mount Merapi so that the water availability is very abundant. Candibinangun Village is one of the villages in Pakem Sub-District. Candibinangun village has several locations for the rice-fish farming system, including in Samberembe Hamlet and Kemput Hamlet. The rice-fish farming system was introduced in 2017. Currently, the two hamlets are well known to many people and have become a reference for several people to visit or learn about the cultivation of the rice-fish farming system. Therefore, as a land optimization step that still paying attention to the environment aspect through the rice-fish farming system, this is interesting to observe the level of sustainability of the rice-fish farming system in the Candibinangun Village will be in the future.

1.1 Sustainable Agriculture

The concept of sustainable development was first introduced by the economist Thomas Malthus in 1798, when he was concerned about the availability of land in England due to rapid population growth. A century and half later, Meadow in his book The Limit to Growth argued that economic growth would be severely constrained by the availability

of natural resources. The limited availability of natural resources will make it difficult to provide goods and services derived from natural resources continuously [9]. In other words, the supply of goods and services from natural resources has a limit so that it will affect the economy.

Sustainable agriculture can be defined as an agriculture that is managed with the basis to satisfy the needs without compromising the needs of others [10]. Sustainable farming systems are the management of agricultural resources to meet the needs of present and future generations without creating negative impact on the environment. The goal of sustainable agriculture is integrating the continuity of economic, ecological, and social benefits in land use [11]. The sustainability aspects include the use of energy sources, quality and quantity of production, and the environment. Sustainable agricultural production will lead to the use of organic products that are not harmful to the environment [12]. According to [13], the implementation of sustainable development is essentially the result of interaction between several sustainability aspects and the three important aspects commonly used as the reference namely economic, social, and environmental aspects.

According to [14], the concept of sustainable agriculture is oriented on the three aspects which are the sustainability of economic activity, the sustainability of human social life, and the sustainability of natural ecology.

1.1.1 The Sustainability of Economic Activity

The economic dimension refers to a concept of maximizing the cash flow, at least by preserving the productive asset which become the foundation of earnings. The main indicator of this aspect is the efficiency and competitiveness, the rate and growth of additional value, as well as economic stability. The economic dimension emphasizes on meeting the economic needs of current and future generation.

1.1.2 The Sustainability of *Human Social Life*

The social dimension is oriented on the people which comprises the need for social welfare embodied in a harmonious social life (including prevention of social conflict), preserving cultural diversity and socio-cultural capital, as well as protecting ethnic minorities. For this reason, poverty alleviation, income distribution and business opportunities, socio-political participation and socio-cultural stability are crucial indicators to be considered in the development process.

1.1.3 The Sustainability of *Natural Ecology*

Natural environments dimension emphasizes on the necessity of natural ecosystem stability including life system and natural materials. This includes maintaining biodiversity and biological carrying capacity, soil, water and agricultural resources, as well as environmental health and convenience. The focus is on maintaining the flexibility and dynamics of ecosystems to adapt to change, not maintaining unattainable static ideals.

1.2 Rice-Fish Farming System

The rice-fish farming system can be defined as a method of cultivating fish alongside the rice plants as a medium between two rice growing seasons or fish farming as a substitute for secondary crops in rice fields. The types of fish that are cultivated can vary from tilapia or mujair, pomfret or other types of freshwater fish [15]. The rice-fish farming system is an agricultural system that combines fish rearing and rice cultivation techniques simultaneously on rice fields [16].

The rice-fish farming system can be understood as the cultivation of fish and rice in one scope of rice fields area. The productivity of rice fields increases with the presence of the rice-fish farming system because other than not decreasing the rice production, it can also produce fish or shrimp [17]. The rice-fish farming system is a method of breeding fish among rice plants as a medium between two rice growing seasons or raising fish as a substitute for secondary crops in rice fields with a good irrigation system such as technical irrigation. There are various types of fish that can be bred such as carp, tilapia, mujair, catfish, and others. The purpose of fish culture in the exchange pattern of rice cultivation is to restore soil fertility [18]. The rice-fish farming system is a combination of farming that utilizes part of the rice field as a fishpond with the purpose of efficiency and optimization function of rice fields [19].

From some definitions above, it can be concluded that the rice-fish farming system is a combination of pisciculture and rice cultivation in fields. There are several types of fish that can be cultured such as goldfish, tilapia, mujair, catfish, and others. Fish farming in a rice crop rotation pattern has a goal to restore the level of soil fertility.

Some of the advantages of mina paddy are supporting increased land productivity, increasing farmers' income, and improving food quality [20]. The advantages of rice-fish farming system can also be viewed from three aspects, namely ecological, social, and economic.

1.2.1 Ecological Aspect

[21], explained that the cultivation of the rice-fish farming system can raise the productivity of rice fields, help to achieve ecological, economic, and social benefits. The interrelationships between biotic and abiotic components play an important role in the final product of the food chain. Biotic components include rice, invertebrates, weeds, and microflora. While abiotic components include light, soil, water, air, nutrients, etc. The rice-fish farming system can also reduce methane gas emissions [22]. According to [3], in the cultivation of the rice-fish farming system, there is a symbiotic relationship of mutualism between rice, fish, water, and soil so that ecological balance conditions are achieved. The rice-fish farming system can also increase soil fertility because pests on rice plants become fish feed and fish waste becomes natural fertilizer for rice [23, 24] states that the rice-fish farming system can reduce the amount of chemical pesticide and herbicide used in the process resulted in direct improvements to the environment and human health.

1.2.2 Social Aspect

According to [24], the rice-fish farming system cultivation can attract the younger generation and alleviate the intense growth of urbanization. The rice-fish farming system can also improve family dynamics and relationships owing to the involvement of all family members to manage the rice-fish farming system. Moreover, the rice-fish farming system can create harmonious relationships within groups and community empowerment because of a shared awareness to create an environment free of chemicals [25].

1.2.3 Economic Aspect

According to [3], the rice-fish farming system can escalate the source and distribution of farmers' income. This is because farmers are not only able to harvest rice but also fish. Beside increasing sources of income, the rice-fish farming system can increase the distribution of income suffice daily needs. The rice-fish farming system can increase labour efficiency such as at the stage of fertilization, spraying, and weeding.

2 Methods

This study employs a descriptive method with a quantitative approach. The technique used to conduct this research is by carrying out a survey using a questionnaire. This research was conducted in Candibinangun Village, Pakem Sub-District, Sleman Regency. The selection of two sample locations was deliberately determined, namely Samberembe Hamlet and Kemput Hamlet with the consideration that the two hamlets were still active in the rice-fish farming system in Sleman Regency and the higher number of farmers using the rice-fish farming system. Additionally, the village is quite well-known and successful in cultivating the rice-fish farming system.

The samples were taken from Mina Muda Farming Group in Samberembe Hamlet and Mina Maju Farming Group in Kemput Hamlet. These two hamlets were intentionally chosen based on their active engagement with the rice-fish farming system compared to other Rice-fish Farming Groups. Sampling of farmers was carried out using the census method, with a sample size of 36 people. The types of data used in this study are primary data and secondary data. Data collection techniques used in this study were observation, interviews, recording, literature study.

3 Result and Discussion

3.1 Result

Based on Table 1, it can be inferred that the sustainability of the rice-fish farming system in Candibinangun Village, Pakem Sub-District, Sleman Regency has an average of 78.63%. Based on these results, the sustainability of the rice-fish farming system belongs in the category of agree. This means that farmers in the Candibinangun Village agreed on the sustainability of the rice-fish farming system which includes three aspects, namely economic, social, and ecological dimensions. Each aspect of sustainability has

a different average percentage value. The highest percentage is in the social dimension, while the lowest percentage is in the economic dimension.

The economic dimension has an average of 72.55% and belongs in the category of agree. Therefore, the sustainability of the rice-fish farming system according to the economic dimension is considered sustainable. The percentage of 81.27% indicates that the rice-fish farming system is profitable from an economic point of view. This is because in one field the farmers get double yields which are fish and rice and save more expenses. Meanwhile, the response is 64.39% which illustrates that with the rice-fish farming system, farmers get income stability.

The social dimension has an average of 81.90% and belongs in the category of strongly agree. Hence, the sustainability of the rice-fish farming system according to the social dimension is considered sustainable. The percentage is 92.90% which indicates that farmers follow the agreements that have been made based on the consensus of the group, such as following the requirement to use jajar legowo planting system. Meanwhile, the percentage of 72.22% indicates that the farmers agreed that support from the family for the rice- fish farming system is quite important.

The ecological dimension has an average of 81.43% and is in the category of strongly agree. Based on the indicators, the sustainability of the rice-fish farming system according to the ecological dimension is considered sustainable. This is because, with rice-fish farming system, chemical fertilizers and pesticides are less used in the cultivation. The percentage of 91.10% indicates that the cultivation of the rice-fish farming system can increase soil fertility. This is due to the minimal use of chemical substances and more use of fish manure as a natural fertilizer. Meanwhile, the percentage of 74.99% indicates that the rice-fish farming system can reduce pest predators.

Based on the results of the research, the sustainability of the rice-fish farming system in Candibinangun Village, Pakem Sub-District, Sleman considerably quite sustainable. It signified a positive impact from the rice-fish farming system because there are still opportunities for this system to outlive in the future. The following table shows in the distribution of farmers on the sustainability of the rice-fish farming system in Candibinangun Village, Pakem Sub-District, Sleman Regency.

Based on Table 2, there are 17 farmers with a percentage of 47% who answered and strongly agree on the sustainability of the rice-fish farming system in Candibinangun Village, Pakem Sub-District, Sleman Regency. In addition, there are 2 farmers with a percentage of 6% answering doubtful. The results of this study indicate that the average farmers support the sustainability of the rice-fish farming system by considering the economic, social, and ecological dimensions. Farmer support is in line with the active participation of farmers in farmer groups. The more active farmers are in farmer group activities, the higher the level of sustainability of the rice-fish farming system in Candibinangun Village, Pakem Sub-District, Sleman Regency.

3.2 Sustainability of the Rice-Fish Farming System in Candibinangun Village Pakem Sub- District Sleman Regency

As the food demand increases and land for fish culture shrinks, the change in the agricultural strategy from monoculture to agricultural diversification is crucial. Therefore, the government is developing combined integrated farming or integrated agriculture

between crops and fisheries, namely rice and fish. One form of combined integrated farming being developed is the rice-fish farming system. The rice-fish farming system is the maintenance of fish and rice altogether in one field. Some of the advantages of the rice-fish farming system are reducing the use of pesticides and herbicides, increasing soil fertility, increasing income, and crop diversity.

Sleman Regency is the first sub-district to implement the rice-fish farming system. In 2015, the government, represented by the Ministry of Maritime Affairs and Fisheries (KKP) and the Regional Government of Sleman Regency in collaboration with the Food and Agriculture Organization (FAO) carried out a pilot project of rice-fish farming system. Currently, the rice-fish farming system in Sleman Regency has developed and expanded to other areas. One of the areas that implement the cultivation of the rice-fish farming is Pakem Sub-District. There are several several rice-fish farming system areas in Pakem.

Sub- District. One of them is in the Candibinangun Village, specifically in Samberembe Hamlet and Kemput Hamlet.

Village has substantial amount of natural resource to nurture the rice-fish farming practice. Today, the rice-fish farming system in the Samberembe Hamlet has developed into technology-based Edu-tourism. This vast development in the Candibinangun Village will certainly made an impact on the community and the environment. This cultivation system must be designed in a sustainable manner to maintain the existence of the rice-fish farming system. There are three aspects in the sustainability of the rice-fish farming system: the economic, social, and ecological dimensions. These three aspects must work together to maintain the existence of the rice-fish farming system.

The sustainability of the rice-fish farming is shown in Table 1. From the table, it could be inferred that the sustainability of the rice-fish farming system consists of three aspects. They are economic, social, and ecological dimensions.

Based on Table 1 through the interpretation of the aspects of the economic dimension, there is a percentage of 72.55% which belongs into the category of agree. In the aspect of the economic dimension, the indicator of profitability of the rice-fish farming system has a percentage of 81.27%. This shows that the rice-fish farming system is profitable because there is a double yield obtained: fish and rice, so that it can increase farmers' income. There are differences in farmer's income before and after implementing the rice-fish farming system. Before using the rice-fish farming system, the income obtained by farmers only came from one output, for example fish or rice only. Income for rice is approximately 1,050,000 rupiah and for fish is 6,750,000 rupiah. However, after utilizing the rice-fish farming system, the farmers' total income ranges from 6,000,000 to 13,000,000 rupiah. This increase in income was also due to reduced production costs, such as the use of chemical fertilizers and pesticides. In addition, farmers also have easy access to markets. The rice harvest is partly sold and partly consumed for household consumption. Meanwhile, the fish harvest is sold through collectors. The price of rice and fish can change or fluctuate depending on market demand. However, farmers can quickly find out updates or price updates through the Whatsapp group. In addition, today, farmers are also convenient in getting capital for rice-fish farming cultivation. The capital spent by farmers is obtained from the cooperation with financial institutions called BSI (Bank Syariah Indonesia). BSI provides capital assistance of 8,000,000 rupiah for each

Table 1. The sustainability of Rice-Fish Farming in Candibinangun Village, Pakem Sub-district, Sleman Regency in 2022

No	Indicator	Score Interval	Average Score	Response Rate (%)	Outcome Category
A. Economic Dimension					
1	The rice-fish farming cultivation system is profitable	0–5	4,06	81,27	Strongly Agree
2	Income increases due to rice-fish cultivation	0–5	4,04	80,77	Agree
3	The ease in obtaining capital	0–5	3,83	76,67	Agree
4	The ease in collaborating with the financial service provider to receive a funding assistance	0–5	3,84	76,85	Agree
5	The expenditure for rice-fish farming cultivation is reduced	0–6	3,92	65,40	Agree
6	There is income stability	0–6	3,86	64,39	Agree
7	The ease to market the products	0–5	3,99	79,86	Agree
8	The ease to access the market	0–5	3,98	79,68	Agree
9	The price of rice from the rice-fish farming is higher	0–5	3,87	77,36	Agree
10	The price of fish from the rice-fish farming is higher	0–6	3,94	65,70	Agree
11	The ease in acquiring information on prevailing rice and fish price	0–6	3,88	64,63	Agree
12	The ease in getting cultivation facility for rice-fish farming	0–6	3,92	65,39	Agree
13	Family well-being is improved due to rice-fish farming	0–6	3,91	65,12	Agree
	Total (A)	**0–71**	**51,06**		
	Average (A)			**72,55**	**Agree**
B. Social Dimension					
14	Communication among the farmers to improve farm production is well established	0–5	3,90	77,97	Agree
15	Being active in the rice fish farming system Farming Group	0–5	4,05	80,98	Agree
16	The establishment of the rice fish farming system Farming Group helps to coordinate the farmers	0–5	3,95	79,09	Agree

(*continued*)

Table 1. (*continued*)

No	Indicator	Score Interval	Average Score	Response Rate (%)	Outcome Category
17	Implementing the requirement and agreement made by the consensus of the rice fish farming system Farming Group	0–4	3,72	92,90	Strongly Agree
18	Taking participation in the communal work to build supporting facilities for rice-fish farming	0–5	4,12	82,39	Strongly Agree
19	Always attempt to improve the knowledge related to rice-fish farming	0–5	4,05	81,08	Strongly Agree
20	The role of community leaders promotes the success of rice-fish farming	0–5	3,88	77,57	Agree
21	Family support is important in the cultivation of rice-fish farming	0–4	2,89	72,22	Agree
22	Support from the surrounding community is important for rice-fish farming	0–4	3,60	90,00	Strongly Agree
23	The rice-fish farming increases young farmer's participation	0–5	3,85	77,05	Agree
24	The implementation of rice-fish farming system is supported by agricultural extension	0–4	3,59	89,67	Strongly Agree
	Total (A)	**0–51**	**41,60**		
	Average (A)			**81,90**	**Strongly Agree**
C. Ecological Dimension					
25	The rice-fish farming practice can conserve the environment	0–5	4,11	82,11	Strongly Agree
26	The rice-fish farming practice makes the water consumption become more efficient	0–5	3,93	78,58	Agree
27	The rice-fish farming practice reduces the growth of weed	0–5	4,09	81,81	Strongly Agree
28	The rice-fish farming practice can reduce the number of pest predator	0–5	3,75	74,99	Agree
29	The rice-fish farming practice can reduce the attack of Plant Pest Organism (OPT)	0–5	4,06	81,19	Strongly Agree
30	The rice-fish farming practice can reduce the usage of chemical fertilizer	0–4	3,63	90,66	Strongly Agree

(*continued*)

Table 1. (*continued*)

No	Indicator	Score Interval	Average Score	Response Rate (%)	Outcome Category
31	The rice-fish farming practice can reduce the usage of chemical pesticide	0–4	3,63	90,66	Strongly Agree
32	The rice-fish farming practice can improve soil fertility	0–4	3,64	91,10	Strongly Agree
33	The rice-fish farming practice can reduce open waste burning from plant residue	0–5	3,94	78,83	Agree
34	Farmers still need to add organic fertilizer into the cultivation	0–5	3,86	77,16	Agree
35	The rice-fish farming practice can reduce environmental pollution	0–5	3,95	79,01	Agree
36	Land productivity increases with the rice-fish farming	0–5	3,94	78,76	Agree
37	The rice-fish farming practice can conserve crop ecosystem	0–5	3,88	77,57	Agree
38	The rice-fish farming practice can reduce risk of soil erosion	0–5	3,88	77,63	Agree
	Total (C)	**0–67**	**54,28**		
	Average (C)			**81,43**	Strongly Agree
	Total (A + B + C)	**0–189**	**146,94**		
	Total Average (A + B + C)			**78,63**	Agree

Sourcer: The analysis of primary data, 2022

Table 2. Distribution of Farmers on the Sustainability of The Rice-Fish Farming System in Candibinangun Village, Pakem Sub-District, Sleman Regency in 2022

No.	Category (score)	Number (Person)	Percentage (%)
1	Strongly Disagree (0–37,8)	0	0
2	Disagree (37,9–75,6)	0	0
3	Doubtful (75,7–113,4)	2	6
4	Agree (113,5–151,2)	17	47
5	Strongly Agree (151,3–189)	17	47
Total		**36**	**100**

farmer. Although there is an increase in income, there are indicators that indicate that farmers still do not get income stability as much as 64.39%. This is due to the selling price of the harvest unstable or fluctuating. In addition, there are additional medication for the sick fish and the price of fish feed (pellets) is increasing day by day.

The second aspect is the social dimension. The social dimension has a percentage of 81.90% which falls into the category of strongly agree. The farmers strongly agree or have high sustainability of the rice-fish farming system in the Candibinangun Village, Pakem Sub- District. In the aspect of the social dimension, the indicator of implementing the requirement and agreement that has been made based on the consensus has a percentage of 92.90%. This shows that farmers always follow the agreements that have been decided by group members. The agreement such as the use of the jajar legowo planting system. The use of this planting system makes it easier for plants to carry out photosynthesis so it will produce more. Not only that, the use of the jajar legowo planting system can also ease the mobilisation of fish. Supervision of this planting requirement is quite strict. If there are farmers who violate, then the sanction to uproot the paddy must be accepted. Meanwhile, the indicator of the importance of family support for the rice- fish farming system has the lowest percentage, which is 72.22%. Family support can be in the form of being involved in the harvesting process to drying the rice harvest.

The third aspect is the ecological dimension. The ecological dimension has a percentage of 81.43% which belong in category of strongly agree. This aspect give a picture whether with the rice-fish farming system, farmers can preserve the environment. In the indicator of the ecological dimension, the highest percentage is 91.10%, which means, through the cultivation of mina paddy, soil fertility can increase. Thanks to the presence of fish among the rice plants has reduced the use of chemical fertilizers and pesticides. The naturally produced fish manure can be used as fertilizer for paddy. This increase in soil fertility can improve the balance of the ecosystem in rice fields so that natural sustainability is maintained. In addition, the rice-fish farming system can reduce the presence of weeds, reduce the burning waste of crop disposal to reduce the level of environmental pollution. However, farmers still add fertilizer. The types of fertilizers added are organic fertilizers and chemical fertilizers such as urea and NPK. Meanwhile, the lowest indicator is 74.99% in the ability of the rice-fish farming implementation to reduce pest predators. This proves that pest predators can be reduced, but there are still many pests which attack the rice-fish farming system such as rats, otters, crabs, snails, and birds.

4 Conclusions

According to the finding of the research, it can be concluded that farmers have a high level of sustainability of the rice-fish farming system in the Candibinangun Village, Pakem Sub-District, Sleman Regency. The highest score is achieved by the social dimension, then the ecological dimension, and finally the economic dimension.

The finding of the research suggests that the economic dimension of the of the rice-fish farming sustainability is quite low because it still lacks additional capital which actually obtainable through the collaboration with financial institutions, such as banks and cooperatives .

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