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Land optimization using two rice-fish planting patterns for environmental benefits and farmer welfare

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ABSTRACT

One of the ways to optimize the potential of land to increase the income of lowland rice farmers is to engineer land from a monoculture system to a diversified rice-fish cultivation system. The study aimed to compare the feasibility of farming for three growing seasons using cropping pattern 1 with the Rice-Fish – Rice-Fish – Rice-Fish sequence and cropping pattern 2 with the Rice-Fish – Rice – Rice sequence and see which composition of the cropping pattern is the most profitable between the two. The research was conducted in Tasikmalaya Regency, West Java Province, Indonesia, using the survey method. The population consisted of 49 farmers; using the Slovin technique, a sample of 33 farmers was taken. The sample was taken using the simple random sampling technique. It was carried out during the 2020-2021 planting period. The results showed that farming using both cropping patterns is feasible because it has an R/C ratio > 1 (Revenue is higher than costs). Cropping pattern 1 shows greater farming profits compared to pattern 2. The difference in profits may be due to the income from fish planted in addition to rice yields. Planting with the Rice-Fish cropping system provides significant additional income for farmers, risk mitigations and improve environment.

Keywords: Crop pattern, food risk, integration, optimization, rice-fish.
Article type: Research Article.

INTRODUCTION

In general, farmers in developing countries, including Indonesia, tend to be subsistence (Utami & Harianto 2021). Especially rice farmers who grow crops only to meet their daily needs due to limited knowledge, modern technology and lack of agricultural land they own. This causes the low income of farmers. Therefore, the agricultural sector is required to make a breakthrough. One way to optimize land potential and increase farmer income is to engineer land with appropriate technology (Sudiarta *et al.* 2016). The way that can be done is to change the agricultural strategy from a monoculture system to an agricultural diversification system by implementing a rice-fish cultivation one (Hikmasari *et al.* 2013). Rice-fish cultivation system is an agricultural activity that combines fish farming with rice cultivation in paddy fields. In this system, water has two functions, i.e., as part of the rice plant and as a living medium for (Hasbi & Tunggal 2021; Nurhidayati *et al.* 2020). The water productivity of rice-fish cultivation also increases much higher compared to rice monoculture, because of double planting (Ahmed & Turchini 2021). It is one type of integrated farming systems and the most feasible solutions to increase sustainable or diversified food production as well as encouraging the efficient use of production resources to deal with the problems of an increasing population (Ahmed *et al.* 2011; Olabode *et al.*

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2021). Fish-rice cultivation can also play an important role in coping shrinking size of farmland and aim of increasing farmland productivity as well as income and household food production (Ahmed *et al.* 2011; Dwiyana & Mendoza 2006). Rice-fish farming should be implemented, because it has the advantage of producing two outputs or two harvests at the end of the season, i.e., harvesting rice and fish, so that the income is higher and more profitable (Dwiyana & Mendoza 2006; Hikmasari *et al.* 2013; Hasbi & Tunggal 2021). In addition, as a complement in the event of a rice crop failure, farmers still have fish yields that can cover rice farming losses.
Integrated rice-fish farming is better than rice monoculture in terms of resource use, plant abundance, diversity, productivity, efficiency or agricultural economy, as well as the quality and quantity of food products (Rahman 2016). In addition, monoculture crop production systems are vulnerable to various risks and uncertainties, such as seasonal, discontinuous, income and employment uncertainties, for farmers calling for the implementation of effective integrated farming systems (Shefat *et al.* 2018). It is also one of the most important agricultural systems and is an environmentally friendly system (Luo *et al.* 2020). The rice and fish integration system has been practiced by Indonesian farmers, especially farmers in rural areas (Hasbi & Tunggal 2021). Likewise, in Tasikmalaya Regency, one of which is in Sirnasari Village, Sariwangi with a potential area of 3,045.41 ha consisting of 33.43% of paddy fields and 66.57% of land. The one-third of paddy fields, 678 hectares are provided with technical irrigation to ensure the sustainability of rice-fish farming in the area. In general, there are three rice-fish integrated cultivation systems known in this region, i.e., the Penyelang cultivation system, the intercropping cultivation, and the palawija cultivation ones. If these three systems are combined, it will create a variety of cropping patterns. The cropping pattern is defined as the proportion of land planted with different crops/commodities, usually indicating the time and arrangement of the layout and sequence of plants in a certain area of land, including during tillage and fallow during a certain period. In the research area, rice-fish integrated farming is more popularly called rice-fish and has long been carried out by rotating different cultivation systems in each planting season so as to produce different cropping patterns for each season and each year. The most frequently implemented in this research area are intercropping cultivation, monoculture cultivation and variations between the two. The number of farmers who implement rice-fish in the area under study varies from period to period on the grounds that planting rice-fish in fact has never been known for its economic benefits. In this regard and looking at the existing documents, until now there has been no information or research results that specifically examine the extent to which the rice-fish farming integration system is based on a cropping pattern in three planting seasons to increase farmers' income, for this reason this research was carried out.

MATERIALS AND METHODS

The method applied in this research is survey. Survey is a research method that takes samples from one population and uses a questionnaire as a primary data collection tool (Sugiyono 2013). The research location was chosen purposively in Sirnasari Sariwangi Village, Tasikmalaya Regency, West Java Province, Indonesia. The criteria for the farmer population were farmers who cultivate rice-fish using the Jajar Legowo spacing system in the 2020-2021 planting period. The population was 49 farmers. The sampling method uses simple random sampling technique, i.e., sampling based on the area where each part is randomly sampled (Sugiyono 2013). Sampling from the population used the Slovin technique so that a sample of 33 farmers was obtained. The type of data used was primary data obtained from interviews with respondent farmers, while secondary data was obtained from related offices/agencies, journals and other documents relevant to this research.

Definition of research variables

The definitions of the variables observed in this study include the following:

1) Rice-fish farmers are farmers who cultivate rice with fish using the Jajar Legowo spacing system and apply a minimum of the rice-fish system in one of the growing seasons in the 2019-2020 period.
2) Planting season, is the time used by farmers from land preparation, planting, maintenance to harvest. Planting season 1 begins in October 2019, second planting season in February 2020 and third in June 2020.
3) Planting pattern is a pattern of crop rotation cultivated by farmers on a plot of land by arranging the arrangement/layout and sequence of plants over a certain period of time, including the tillage period and the fallow period for a certain period.

4) Rice-fish Farming System is the cultivation of fish and rice plants at once. The duration of maintenance is from the time the rice seeds are planted until the second weeding or until the rice plants flower around the age of rice 50 days after planting.
5) Rice Monoculture System, is the cultivation of only one commodity (rice) in a certain growing season.

Variable Operationalization

Serves to direct the variables used in research into indicators that will be used in the discussion, as follows:

1) Fixed costs are costs whose size is not affected by the size of production and are not used up in one production process. The results of calculating the average fixed cost are converted into a unit area of land into one hectare for three planting seasons. The calculated fixed costs consist of: (i) Land and Building Tax, (ii) Traktor rental, (iii) depreciation of equipment and (iv) interest on capital.
2) Variable costs are costs whose size is determined by the size of production and its use is used up in one planting season or one production process. The results of calculating the average variable cost are converted into one hectare of land area for three planting seasons. Including variable costs are: (i) Rice seeds, (ii) Fish seeds, (iii) Organic fertilizers, (iv) Urea fertilizers, (v) SP36, Ponska, KCl, TSP, NPK and ZA fertilizers, (vi) Botanical pesticides, (vii) Fish feed, (viii) Medicines, (ix) Agricultural lime, labor and capital interest.
3) Total costs are costs incurred for the entire production process (fixed costs plus variable costs). The final result of the average total cost is converted into units of hectare area.
4) Productivity is the result of kg per hectare unit
5) Revenue, is the product multiplied by the selling price calculated in units of hectares for three planting seasons.
6) Income is the difference between revenue and total costs, calculated in hectares for three planting seasons.
7) R/C Ratio, a comparison between revenue and total costs, at the same time states whether the business is feasible or not.

Analysis framework

1) Revenue analysis

   Revenue is the sum of the receipts from rice and fish. Revenues from fish will be converted into rice revenues by dividing fish revenues in rupiah units by the selling price of rice commodities. In general, Revenue is calculated by the formulation:

   $$TR = \sum_{i=1}^{n} Y.Py$$

Description: TR = Total Revenue
Y = Yields
Py = Price y
n = Number of commodities cultivated

2) Revenue Analysis

   Income is calculated for one year for the combination of cropping patterns cultivated. In rice-fish farming, the income is the sum of the income from each commodity cultivated. Farming income is the difference between receipts and all calculated costs as follows:

$$\pi = TR - TC$$

   Description: π= Income
   TR = TotalRevenues
   TC = Total Cost

3) Total Cost is the entire cost used for rice-fish farming, calculated by the following formula:

   $$TC = FC + VC$$

Description: TC = Total Cost
FC = Fixed Cost
VC = Variable Cost
Note: All cost, revenue and income calculations will be converted to average per hectare.

4) Farming Feasibility Analysis
The feasibility of the farming carried out will be calculated by the R/C Ratio. R/C ratio is the comparison between Revenue and Cost, calculated by:

$$R/C = \frac{TR}{TC}$$

TR = TotalRevenues
TC = Total Cost

Decision making with this R/C analysis is as follows:
R/C > 1, then farming is feasible to continue
R/C = 1, then the farm is break even (no profit/no loss)
R/C <1, then farming is not feasible to continue

RESULTS AND DISCUSSION

A. Characteristics of the research area

The research area was located at an altitude of 500 – 550 m above sea level, with an average temperature of 33 ℃ – 37 ℃. The total area was 207.195 ha consisting of 61.195 ha of land, 101 ha of paddy fields, 15 ha of rainfed paddy fields, 20 ha of ponds and 10 acres yard. Most of the soil type was Andosol reddish brown. Based on this data, it is known that most of the land (55.99 percent) in the study area is for paddy fields. In 2018, there were 1,404 heads of households or a total of 5,343 people. As much as 37.15% were residents of productive age while 62.85% were residents who were not yet productive and are no longer productive. The population density was around 2,579 people/km$^{2.}$ The level of education taken by the community varied, as many as 2,201 people graduated from elementary school, while the rest were between secondary and higher education. The livelihood of 326 people or around 6.10% was as farmers, the rest were entrepreneurs and other professions.

B. Characteristics of respondents of rice-fish farmers

The characteristics of rice-fish farmers that were studied in this study included age, recent education, and farming experience. More details can be seen in the image below.

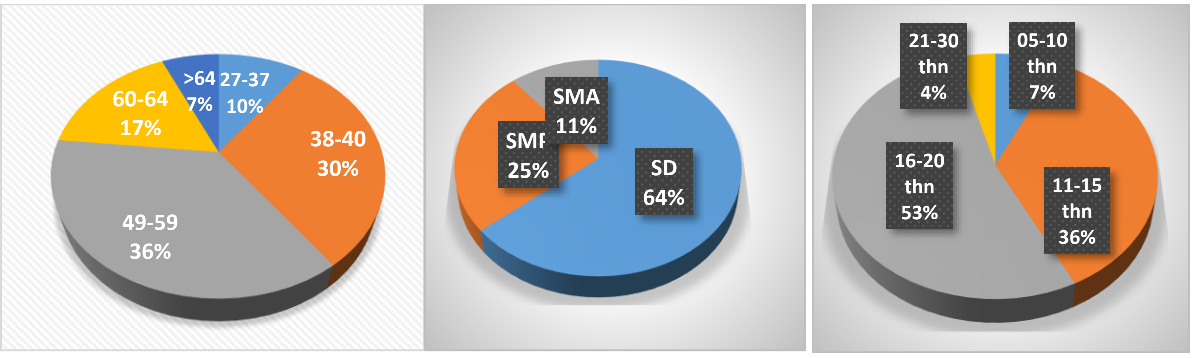

Fig. 1. Age of Respondents; **Fig. 2.** Education of Respondents; **Fig. 3.** Experience in farming.

Based on Fig. 1, it is known that the majority of rice-fish farmers, i.e., 30 people (93%) are in the productive age (between 27 and 64 years), and 3 people (7%) are at an age that is no longer productive, i.e., over 64 years. This is in accordance with what was conveyed by Goma *et al.* (2021) that between 27 and 64 years is considered productive age and over 64 years is considered unproductive age. This implies that the majority of respondents are young and productive. This is an important asset for production efficiency and has a vulnerability to change for the better (Olabode *et al.* 2021). Therefore, people of productive age tend to have enthusiasm for using new agricultural technologies (Onoh *et al.* 2020). As many as 24 people (64%) graduated from Elementary School (SD), 6 people (25%) from Junior High School (SMP) and 3 people (11%) from High School (SMA). These results indicate that even though the majority of farmers only graduated from elementary school, at least they already have the minimum provisions, i.e., literacy and a sense of responsibility which affect perceptions in adopting the Rice-Fish business (Olabode *et al.* 2021). Most of the respondents, i.e., 15 people (53%) had farming experience between 16 and 20 years, 10 people (36%) between 11 and 15 years, 3 people (7%) between 21 and 30 years and the smallest was 2 people (4%) between 5 and 10 years exhibiting that rice farming is a long-term and cultural profession among respondents. This means that respondents are familiar with the ins and outs of the rice-fish farming that they manage (Olabode *et al.* 2021).

C. Planting pattern

Cropping pattern means the proportion of planting on a plot land at a point in time by arranging the layout and order of the plants (Murugesan *et al.* 2018; Murni & Purnama 2020). There were two cropping patterns during the year: Cropping Pattern I: Rice-Fish– Rice-Fish– Rice-Fish (3 plantings) and Planting Pattern II: Rice-Fish– Rice – Rice (3 plantings).

D. Farming analysis

Farming analysis was carried out by comparing the first cropping pattern in a year (3 growing seasons) successively planting rice-fish – rice-fish – rice-fish with cropping pattern II which cultivates rice-fish – rice – rice. The analysis is carried out by calculating fixed costs, variable costs, revenue, income and the feasibility of farming.

1) Fixed cost

Fixed costs are cost whose size is not affected by the size of production and are not used up in one production process. Based on Table 1, it is known that the total fixed cost of Rice-Fish farming on average per hectare according to planting pattern I in 2020-2021 is IDR 4,687,297.39, while for Planting Pattern II it is IDR 4,199,013.98. This fee is used for Land and Building Tax (PBB), tractor rental, equipment depreciation costs and fixed capital interest. In cropping pattern I, what distinguishes the amount of fixed costs for each season is the cost of renting a tractor and has implications for the amount of interest on fixed capital that should be issued. The cost of renting a tractor increases every season, since the cost of rent is increased by the owner of the tractor, and also at the time of the study there was an increase in fuel prices. In cropping pattern II, apart from the above reason, costs for rice-fish require relatively higher costs compared to other planting seasons, because during rice-fish there are special land preparation activities including making "caren" for the gathering place for planted fish, so that the rental costs the tractor is bigger. Meanwhile, for the next planting season, the fixed costs are smaller than for the first planting season.

Table 1. Average Fixed Costs of rice-fish Farming Based on Planting Patterns for One Year for the 2020-2021 Period.

No	Planting Pattern	Fixed Cost of Farming			
		Season Plant I	Season Plant II	Season Plant III	Total
1.	rice-fish – rice-fish – rice-fish	1,549,855.52	1,567,294.35	1.570.147.52	4,687,297.39
2.	rice-fish – rice – rice	1,422,261.05	1,385,822.63	1,390,930.30	4,199,013.98

2) Variable cost

Variable costs are cost whose size is determined by the size of the production and is used up in one planting season or one production process. The total variable costs used in farming I cropping pattern during the three growing seasons is IDR 48,913,511.22, while for cropping pattern II is IDR 23,903,550.70. This amount is used to expend production inputs consisting of fish seeds, rice seeds, organic fertilizers, Urea fertilizers, SP 36, Ponska, KCl, TSP, NPK, pesticides, fish feed, medicines, agricultural lime, in addition to labor costs for ditching activities, land preparation, initial fertilization, seedbed making, rice planting, fish stocking, weeding, follow-up fertilization, spraying, weeding, fish feeding, fish harvesting, rice harvesting and post-harvest (Table 2). In cropping pattern I, there was a decrease in the total variable costs incurred from planting seasons 1, 2 and 3, since during planting season 1, a lot of labor activity was needed to start a Rice-Fish business, while in the following season labor costs could be reduced. Likewise, for spending on the use of production inputs, there is a tendency to decrease spending on variable costs from season to season.

Table 2. Average Variable Costs of rice-fish Farming Based on Planting Patterns for One Year for the 2020-2021 Period.

No	Planting Pattern	Variable Cost of Farming (IDR)			
		Season Plant I	**Season Plant II**	**Season Plant III**	**Amount**
1.	Rice-Fish – Rice-Fish – Rice-Fish	16,528,926.32	16,253,805.72	16,130,779.18	48,913,511.22
2.	Rice-Fish – Rice – Rice	10,890,828.35	6,424,056.13	6,588,666.22	23,903,550.70

In cropping pattern II, the total variable costs of planting season 1 are greater than those of the following planting seasons, since in the 1st planting season, farmers carry out rice-fish planting which requires higher variable costs including for the costs of fish seeds, labor costs for making ditches / "caren ", feeding, ditch maintenance. Meanwhile for planting seasons 2 and 3 it was smaller. Most of the work during these seasons included returning the rice fields that were previously used for rice-fish to monoculture rice fields. The reason for the farmers changing the cropping pattern from rice-fish to planting rice monoculture is mainly because they are worried about limited water from the irrigation they use, while for rice-fish, its availability determines the cultivation of fish. As stated by Ahmed *et al.* (2022), drought, irregular rainfall, and lack of water can have a serious impact on fish growth. Fish become more stressed at lower water depths affecting its survival, growth, and reproductive performance. The difference that is quite striking between the variable costs for cropping patterns I and II: in cropping pattern I each season uses the rice-fish Padi pattern for three seasons, so that it requires higher variable costs compared to pattern II which only plants once with rice-fish and subsequently Paddy Monoculture. Variable costs for rice farming show a tendency to increase over time. Increased production costs for rice monocultures and concerns about the food security of farming households have motivated farmers to adopt integrated rice-fish farming (Arunrat & Sereenonchai 2022).

3) Total cost

Total costs are costs incurred for the entire production process. This fee is obtained from the sum of fixed costs and variable costs. The final result of the average total cost is converted into units of hectare area.

Table 3. Average Total Cost of rice-fish Farming Based on Planting Patterns for One Year for the 2020-2021 Period.

No	Planting Pattern	Total Cost of Farming			
		Season Plant I	**Season Plant II**	**Season Plant III**	**Amount**
1.	rice-fish – rice-fish – rice-fish	15,065,665.56	14,568,850.80	13,865,500.80	43,500,017.16
2.	rice-fish – rice – rice	12,313,089.40	7,809,878.76	7,979,596.52	28,102,564.68

Based on Table 3, it is known that the average total cost of Rice-Fish farming based on cropping pattern I for one year is greater than pattern II. The cropping pattern with three times the Rice-Fish does require a greater cost, especially the contribution from the "Variable Costs" used for fish farming including for fish seeds, fish feed and labor. Whereas for pattern I, only planting season 1 requires costs for fish seeds, fish feed and labor, while planting seasons 2 and 3 require costs for rice cultivation only.

4) Revenue, income and business eligibility

The full amount of revenue, income and feasibility of rice-fish farming based on the cropping pattern for one year for the 2020/2021 period can be seen in Table 4. Increased water table and reduced rice arable area, the two main requirements for rice-fish farming, result in lower/decreased rice yields in rice-fish systems compared to monoculture systems (Cahyanti *et al.* 2017; Vromant *et al.* 2002).

Table 4. Average total cost of rice-fish farming based on planting patterns for one year for the 2020-2021 period.

Description	Farming revenue			
	Planting Season I	**Planting Season II**	**Planting Season III**	**Total**
Planting Pattern I: Rice-Fish – Rice-Fish – Rice-Fish:				
1. Total Revenue (a+b)	31,017,600.00	29,037,050.00	28,946,400.00	89,001,050.00
a) Rice yield (tonnes × selling price)	20,700,000.00	20,600,000.00	20,250,000.00	61,550,000.00
1) Rice productivity (tonnes/ha)	4.14 tonnes	4.12 tonnes	4.05 tonnes	
2) Rice selling price (Rp/kg)	5000.00	5000.00	5000.00	
b) Fish Yield	10,317,600.00	8,437,050.00	8,696,400.00	27,451,050.00
1) Fish yield (kg)	515.88	421.85	434.82	
2) Selling price of fish/kg	20,000.00	20,000.00	20,000.00	
2. Total cost	15,065,665.56	14,368,850.80	13,865,500.80	43,500,017.16
3. Income	15,951,934.44	14,668,199.20	15,080,899.20	45,501,032.84
4. R /C ratio	2.05	2.02	2.08	2.04
Planting Pattern II: Rice-Fish–Rice–Rice:				
1. Total revenue (a+b)	28,968,200.00	21,550,000.00	21,100,000.00	71,618,200.00
a. Rice yield (tonnes × selling price)	19,500,000.00	21. 5 50.00 0.00 _	21,100,000.00	62,150,000.00
b. Rice productivity (tonnes/ha)	3.90	4,31	4,22	
c. Rice selling price (Rp/kg)	5000.00	5000.00	5000.00	
b) Fish Yield	9,468,200.00	-	-	9,468,200.00
3) Fish yield (kg)	473,41	-	-	
4) Selling price of fish/kg	20,000.00	-	-	
b. Total Cost	14,313,089.40	13,560,564.88	12,856,544.67	40,730,198.95
c. Income	14,655,110.60	7,989,435.12	8,243,455.33	30,888,001.05
cR/C ratio	2.02	1.58	1.64	1.75

This can be seen in Table 4 that the productivity of rice per ha of cropping pattern II, i.e., in the first planting season, is smaller (3.90 tons/ha) compared to the productivity of monoculture rice in the second (4.31 tons/ha) and the third (4.22 tonnes/ha). Likewise, the productivity of rice in cropping pattern I, in all planting seasons I (4.14 tons/ha), II (4.12 tons/ha) and III (4.22 tons/ha) were lower than the monoculture rice planting season of cropping pattern II. Even though rice yields in Rice-Fish have decreased, the net economic benefit of the rice–fish system enhanced obviously due to the high value of aquaculture animals (Zhao *et al.* 2021). The average productivity of fish in rice-fish cultivation per hectare/planting season (Table 4) is between 421.85 kg and 515.88 kg. These results are almost similar to those obtained by Ahmed *et al.* (2022) who reported that the average fish yield per planting season in fish-rice cultivation is 485 kg/ha. These results fluctuate according to suitability of environmental conditions, as well as the frequency and feeding of fish. In general, if we look at the productivity produced in cropping pattern I, in which Rice-Fish was planted in all three growing seasons, higher productivity is observed compared to cropping pattern II, which only planted Rice-Fish once and then planted rice monocultures. These results are in accordance with the opinion of Cahyanti *et al.* (2017) and Freed *et al.* (2020)

who reported that implementing an integrated and agroecological Rice-Fish system will contribute to land productivity, and apart from the rice produced, farmers can also benefit from the results of raising fish. The price of grain per quintal at the time of the study was IDR 1.000,000.00/ton, while the price of fish per kg was IDR 20,000.00. Revenue is calculated based on the multiplication of the productivity per hectare and the selling price. Based on this data, the total revenue for the first cropping pattern, which cultivates three times of rice cultivation, is IDR 89,001,050.00. This result is obtained from the sale of rice and fish. Whereas in cropping pattern I, with a planting season of I Rice-Fish and planting seasons II and III of only planting rice monoculture, an income of IDR 71,618,200.00 was obtained. So, it can be concluded that planting with cropping pattern 1 which has three seasons of Rice-Fish is more profitable than cropping pattern 2 which only plants 1 time of Rice-Fish and other seasons monoculture rice. It is also stated by Lestari & Bambang (2017) that by the rice-fish planting system, land efficiency and productivity will increase, since farmers can get results from two products, i.e., rice and fish. The income earned is the difference between the total revenue and total costs. In the cropping pattern I, the revenue obtained is IDR 45,501,032.84, while in the second, IDR 30,888,001.05. The conclusion is that farmers who use cropping pattern I with three Rice-Fish plantings earn 32% higher income than using cropping pattern II with one Rice-Fish planting and two rice monocultures. In accordance with the results of Cahyanti *et al.* (2017), Freed *et al.* (2020) and Lestari & Bambang (2017), using the right technology, integrated and agroecological Rice-Fish can provide quite high income for small-scale food production. In addition, Rice-Fish can be a wise choice for optimizing rice farming land, maintenance and capacity of ecosystems to adapt to extreme climate change like today. In fact, according to research by Liu *et al.* (2021), agricultural income comes from rice-fish cultivation increased by 177.33% compared to rice monoculture plants. The two cropping patterns cultivated for 3 growing seasons are feasible and profitable to implement, since their R/C ratio is higher than 1 according to the decision-making criteria used in this study. However, when compared, cropping pattern I with 3 times Rice-Fish shows a larger R/C ratio (2.04), while planting season II with one Rice-Fish and two times monoculture rice shows a smaller R/C ratio (1.75). Then when looking at the R/C ratio of Rice-Fish in all cropping patterns, it is evident that the R/C ratio of Rice-Fish is greater (above 2.0) compared to the R/C ratio of monoculture rice with a value below 2.0. This is in accordance with the results of research by Lestari & Bambang (2017) and Triyanti *et al.* (2021) who reported that Rice-Fish cultivation provides greater revenue for the costs of farming compared to rice monoculture business.

Environmental impact

Integrated rice-fish farming is a sustainable agricultural practice that offers several environmental benefits:

1) Increase farm productivity both in terms of biomass and economics (Rahman *et al.* 2016) and also can lead to increas rice yield (IRRI, 2023) and fish at once in their stages.

2) Resource optimization and maintain sustainable environmental condition (Sathoria & Roy 2022). It is an efficient farming practice in terms of resource utilization, diversity, productivity, production efficiency and food supply (Rahman *et al.* 2016).

3) Pest Control: The presence fish in rice field helps control harmful insects (Agriculture Farming 2018). This also reduce the need of pesticide even chemical pesticide which can have adverse environmental impact.

4) Weed Control: Fish activity in the fields can also helps control weed (Agriculture Farming, 2018), reducing need for herbicides.

5) Soil Nutrient Stirring: Fish stir up soil nutrients, which are beneficial for rice crop (Agriculture Farming 2018), reducing the need for chemical fertilizer replaced by organical fertilizer of excess fish.

6) Reduce bad environmental impact especially lowers methane gas emission compared to monoculcute farming (IRRI, 2023). This can contribute to efforts to combat climate change.

7) Risk mitigation of crop failure by providing a more stable source of income. The income of integrated crop pattern reached IDR 45,501,032.84 for Rice-Fish – Rice-Fish – Rice-Fish in a year and IDR 30,888,001.05 for Rice-Fish – Rice – Rice in a year, and also increase the farming feasibility to R/C ratio 2.04 from 1.75.

CONCLUSION

The results showed that farming using both cropping patterns is feasible because it has an R/C ratio > 1 (revenue is greater than costs). Cropping pattern 1 showed higher farming profits compared to pattern 2. The difference in profits is due to the income from fish planted in addition to rice yields. Planting with the Rice-Fish cropping system provides significant additional income for farmers.

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REFERENCES

Agriculture Farming 2018, Integrated Rice and Fish Farming Information | Agri Farming. Agri Farming. https://www.agrifarming.in/rice-fish-farming.

Ahmed, N, Hornbuckle, J & Turchini, GM 2022, Blue–green water utilization in rice–fish cultivation towards sustainable food production. *Ambio*, 51: 1933-1948, https://doi.org/10.1007/s13280-022-01711-5.

Ahmed, N & Turchini, GM 2021, The evolution of the blue-green revolution of rice-fish cultivation for sustainable food production. *Sustainability Science*, 16: 1375-1390, https://doi.org/10.1007/s11625-021-00924-z.

Ahmed, N, Zander, KK, & Garnett, ST 2011, Socioeconomic aspects of rice-fish farming in Bangladesh : Opportunities, challenges and production efficiency Socioeconomic aspects of rice-fish farming in Bangladesh: opportunities, challenges and production efficiency. https://doi.org/10.1111/j.1467-8489.2011. 00535.x.

Arunrat, N & Sereenonchai, S 2022, Assessing ecosystem services of rice–fish co-culture and rice monoculture in Thailand. *Agronomy*, 12(5), https://doi.org/10.3390/AGRONOMY12051241.

Cahyanti, W, Prakoso, VA, Arifin, OZ & Kusmini, I I 2017, Intensive production of superior fish in Minapadi Land. *Jurnal Sains Natural*, 4(1): 26, https://doi.org/10.31938/jsn.v4i1.72.

Dwiyana, E & Mendoza, TC 2006, Comparative productivity, profitability and efficiency of rice monoculture and rice-fish culture systems. *Journal of Sustainable Agriculture*, 29: 145-166, https://doi.org/10.1300/ J064v29n01_11.

Freed, S, Barman, B, Dubois, M, Flor, RJ, Funge-Smith, S, Gregory, R, Hadi, BAR, Halwart, M, Haque, M, Jagadish, SVK, Joffre, OM, Karim, M, Kura, Y, McCartney, M, Mondal, M, Nguyen, VK, Sinclair, F, Stuart, AM, Tezzo, X, … Cohen, PJ 2020, Maintaining diversity of integrated rice and fish production confers adaptability of food systems to global change. *Frontiers in Sustainable Food Systems*, 4: 1-17, https://doi.org/10.3389/fsufs.2020.576179.

Goma, EI, Sandy, AT & Zakaria, M 2021, Distribution analysis and interpretation of data on Indonesia's productive age population in 2020. *Jurnal Georafflesia: Artikel Ilmiah Pendidikan Geografi*, 6: 20. https://doi.org/10.32663/georaf.v6i1.1781.

Hasbi & Tunggal, T 2021, Paddy-fish integrated agricultural system to increase income and food security. IOP Conference Series: Earth and Environmental Science, 782(2). https://doi.org/10.1088/1755-1315/782/2/ 022019.

Hikmasari, R, Muhaimin, AW, Setiawan, B, Pasca, P, Fakultas, S, Universitas, P, Sosial, J, Fakultas, E & Universitas, P 2013, Efisiensi Mina Mendong farming techniques with the stochastic production frontier approach (Case study in Blayu Village and Wajak Village, Wajak District, Malang Regency). *Habitat*, 24: 1-9.

IRRI 2023, Rice-fish culture helps make rice production sustainable. Rice Today. https://ricetoday.irri.org/rice-fish-culture-helps-make-rice-production-sustainable/.

Lestari, S & Bambang, AN 2017, Application of Minapadi to support food security and improve community welfare. Proceeding Biology Education Conference, 14: 70-74.

Liu, D, Feng, Q, Zhang, J, Zhang, K, Tian, J & Xie, J 2021, Ecosystem services analysis for sustainable agriculture expansion: Rice-fish co-culture system breaking through the Hu Line. *Ecological Indicators*, *133*: 108385. https://doi.org/10.1016/j.ecolind.2021.108385.

Luo, W, Wang, D, Xu, Z, Liao, G, Chen, D, Huang, X, Wang, Y, Yang, S, Zhao, L, Huang, H, Li, Y, Wei, W, Long, Y & Du, Z 2020, Effects of cadmium pollution on the safety of rice and fish in a rice-fish coculture system. *Environment International*, 143 (December 2019), 105898. https://doi.org/10.1016/j.envint. 2020.105898.

Nurhidayati, DR, Huang, W & Hanani, N 020, Rice-fish farming system in Lamongan , East Java , Indonesia: *SWOT and Profit Efficiency Analysis*, 20*:* 311-318.

Olabode, D, Omotesho, K, Olabanji, O, Ogunlade, I & Adebisi, O 2021, Rice farmers' perception and knowledge of integrated rice and fish farming in selected local government areas of Kwara State. *Cercetari Agronomice* *in Moldova*, 53: 368-383, https://doi.org/10.46909/cerce-2020-032.

Onoh, AL, Onoh, CC, Onoh, PA & Ukpongson, MT 2020, Adoption of integrated rice-fish farming technology in Ebonyi State Nigeria: Socio-demographic characteristics and availability of technology. *Asian Journal of Fisheries and Aquatic Research*, 7: 29-38, https://doi.org/10.9734/ajfar/2020/v7i230116.

Rahman, MA 2016, Integration of aquaculture with rice farming: A way to increase farm productivity, food security, livelihood improvement and better environment. 6th International Conference on Agriculture, Environment and Biological Sciences (ICAEBS'16), pp. 149-151, https://doi.org/10.15242/iie.a1216044.

Rahman, MA, Parvez, MS & Marimuthu, K 2016, Prospects, potentials, practices and benefits of integrated rice-fish farming in Bangladesh. *International Journal of Biological, Ecological and Environmental Sciences*, 5: 46-49, http://journalsweb.org/siteadmin/upload/2803EAP816236.pdf.

Sathoria, P & Roy, B 2022, Sustainable food production through integrated rice-fish farming in India: a brief review. *Renewable Agriculture and Food Systems*. https://doi.org/10.1017/S1742170522000126

Shefat, SHT, Rahman, A & Chowdhury, M A 2018, Integrated aqua-farming in Bangladesh : SWOT Analysis. *Acta Scientific Agriculture*, 2(12): 112-118.

Sudiarta, IM, Syam'um, E & Syamsuddin, R 2016, Growth and production of rice plants and tilapia fish production in the Jajar Legowo Planting System. *Jurnal Sains & Teknologi*, *16*(1), 70–80.

Sugiyono 2013, Metode Penelitian Kuantitatif kualitatif dan R&D (19th ed.). CV. ALFABETA.

Triyanti, R, Suryawati, SH, Wijaya, RA, Wardono, B & Hafsaridewi, R 2021, Assessment of the success factors influencing of rice-fish farming innovation village to support food security. IOP Conference Series: Earth and Environmental Science, 892(1). https://doi.org/10.1088/1755-1315/892/1/012052.

Utami, A & Harianto, H 2021, Farmers' subsistence in indonesian rice farming. *Jurnal Agribisnis Indonesia*, *9*(2), 79–87. https://doi.org/10.29244/jai.2021.9.2.79-87.

Vromant, N, Duong, LT & Ollevier, F 2002, Effect of fish on the yield and yield components of rice in integrated concurrent rice-fish systems. *Journal of Agricultural Science*, *138*(1), 63–71. https://doi.org/10.1017/s0021859601001642.

Zhao, Z, Chu, C, Zhou, D, Wang, Q, Wu, S, Zheng, X, Song, K & Lv, W 2021, Soil bacterial community composition in rice–fish integrated farming systems with different planting years. *Scientific Reports*, 11: 1-10, https://doi.org/10.1038/s41598-021-90370-9.

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