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Is it worth to integrate rice cultivation into catfish aquaculture system?: A case study in Kedah, Malaysia

(Kajian keberkesanan integrasi penanaman padi dan sistem akuakultur ikan keli di Kedah, Malaysia)

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Abstract

The agricultural policies of governments globally emphasise enhancing domestic production, productivity and sustainability, alongside addressing food security and resource limitations. One strategy gaining traction involves integrating rice and fish farming within a sustainable agricultural framework. This offers ecological and economic advantages like improved soil fertility, natural pest control and increased household income, while also creating agro-tourism opportunities. In Malaysia, catfish farming has notably expanded, significantly contributing to aquaculture production. Efforts are ongoing to integrate rice cultivation with catfish farming to optimise agricultural space and income generation. This study evaluates the monetary benefits of this integration, focusing on the Aquaculture Extension Centre or *Pusat Pengembangan Akuakultu*r (PPA) Jitra in Kedah Darul Aman. It employs experimental methodologies, assessing two scenarios involving rice production using a floating bed system. This method avoids conventional chemicals to minimise harm to aquatic life, especially catfish. The research presents two scenarios: The first is a rice production project at 3,624 kg/ha, and the second is a rice production project at 8,872 kg/ha, both integrated with catfish farming. A partial budgeting approach assesses financial viability, analysing net income alterations based on total revenue and costs. Scenario 1 displays a negative return due to escalating costs outweighing benefits. However, sensitivity analysis suggests Scenario 1's potential viability if rice yields reach 5,976.67 kg/ha. Scenario 2, though also showing a negative return, holds potential viability if rice yields increase to 9,814.44 kg/ha. The study evaluates the economic lifespan of catfish and rice cultivation, estimating catfish production at 1,700 kg/pond and rice production at 4.5 mt/pond. Break-even points for both components indicate when revenues equal costs. The integrated approach demonstrates a favourable Benefit Cost Ratio (BCR) of 1.27, indicating economic feasibility through integration. However, comprehensive environmental impact studies are vital to ensure sustainability, despite the promise of cost reduction through labor sharing. While aligned with promoting a circular economy and environmentally friendly agricultural practices, a thorough assessment of ecological implications is crucial. Integrated rice and catfish farming, if diligently executed, holds potential as a sustainable and environmentally responsible approach to agricultural development.

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Introduction

Governmental agricultural policies have consistently emphasised enhancing domestic production, productivity, and research and development, centred on innovation and technology (Serin et al. 2019). These initiatives extend beyond production phases to streamline marketing chains and diversify innovations, fortifying the agricultural industry (Trienekens 2011). A contemporary focus prioritises food security while highlighting the critical importance of environmental sustainability. Land use constraints in agriculture prompt exploration of adaptation strategies encompassing economic, sociological, and environmental facets (Ahmed et al. 2014). An emerging pivotal strategy involves integrating diverse agricultural commodities, particularly the integration of rice and fish farming, recognised as vital nutrient sources essential for human health (Nabi 2008). This integration has gained global attention, especially in regions where rice forms a dietary cornerstone, alongside the recognition of fish as a primary protein source across various economic strata (Nabi 2008).

Malaysia and other regions have witnessed rapid development in both marine and terrestrial fisheries, aligning with the prevalence of rice as a staple carbohydrate source, notably in Southeast Asia (Nabi 2008). The integration of rice cultivation within catfish farming ponds presents numerous advantages optimising resources and yielding significant benefits. This practice efficiently utilises space within catfish ponds, promoting resource efficiency by enabling rice crops, thriving in shallow water, to effectively use the pond's surface area. Consequently, farmers can cultivate two different products within the same space, enhancing overall productivity per unit area. Moreover, this integration enhances ecological balance within farming ecosystems. Rice plants provide shade and cover for catfish, fostering a conducive growth environment, while catfish waste serves as natural fertiliser, reducing reliance on external fertilisers and minimising environmental impact through reduced chemical inputs. Economically, integrating rice alongside catfish offers a dual-income stream for farmers, diversifying products and potentially increasing overall revenue.

Resource optimisation in water and land usage reduces operational costs, enhancing profitability and providing resilience against market fluctuations or specific crop failures, ensuring a more reliable income source. Expanding globally, Sub-Saharan Africa implements Integrated Irrigation Aquaculture (IIA), co-cultivating fish with crops, particularly rice (Koide et al. 2015). Similarly, Southeast Asian countries like Vietnam actively promote and harness integration potential between crops and livestock (Bosma et al. 2012). These initiatives aim to optimise input utilisation, enhance crop productivity, and transform traditional practices heavily reliant on chemical inputs, aligning with a global shift towards greener technologies in agriculture. Integrating agricultural commodities like rice and fish not only promises enhanced nutrition but also maximises resource utilisation and mitigates the environmental impact of conventional agricultural practices.

The concept of the green revolution, central to sustainable agricultural practices, has evolved further with the emergence of the blue-green revolution, integrating crops and livestock in agricultural systems (Ahmed and Turchini 2021). The integration of rice and fish in farming systems has been extensively documented for its considerable ecological and economic impacts. Various studies indicate that integrated rice-fish farming offers ecological benefits, with fish contributing to soil fertility by producing nitrogen and phosphorus (Lightfoot et al. 1992; Giap et al. 2005; Dugan et al. 2006). Moreover, certain fish species assist in pest control by biologically eliminating habitats of pests, such as aquatic weeds and algae, thereby indirectly reducing water-borne diseases and acting as a natural method for mosquito control (Matteson 2000), consequently benefiting human populations.

Economically, the integration of rice and fish cultivation demonstrates substantial revenue potential. Ahmed et al. (2010a) observed that integrated prawn-fish-rice culture in various farm sizes, small (> 0.2 ha), medium (0.21 – 0.4 ha), and large (> 0.4 ha), generated net returns of US$ 1,420, US$ 1,798 and US$ 2,426/ha annually, respectively. Diversifying agricultural crops and livestock through integration approaches has the potential to significantly increase average household incomes, a trend observed in various countries across the globe (Kazmina et al. 2020; Tugade 2020; Benignos et al. 2022). Additionally, by combining plant crops with livestock, opportunities for agro-tourism emerge, aiding in enhancing financial cash flows for farms while serving as a platform for marketing and promoting agricultural products (Wicks and Merrett 2003; Despotović et al. 2017; Khanal et al. 2019).

Furthermore, the integration of rice plants with fish contributes to the food sources available to fish, including planktonic, periphyte, and benthic resources (Mustow 2002). Rice plants positioned on water surfaces offer shade and regulate water temperatures, creating favourable conditions for fish, particularly during summer (Kunda et al. 2008). Numerous fish species favour paddy fields for breeding purposes (Fernando 1993; Little et al. 1996; Halwart 1998; Halwart and Gupta, 2004; Ahmed et al. 2011). When rice-fish integration occurs within rice cultivation areas, it offers numerous environmental benefits (Valdivia and Barbieri 2014) with direct implications for the environment. Similarly, introducing rice to fish ponds yields comparable benefits, potentially enhancing productivity for entrepreneurs and benefiting both rice and catfish farming (Gurung and Wagle 2005; Ahmed et al. 2011).

In the aquaculture landscape of Malaysia, the introduction of catfish as a non-native species stands as a pivotal moment, stemming from its initial importation from Thailand within the period of 1986 – 1989. The inception of catfish in Malaysian aquaculture was marked in 1987, recording an initial annual production of 6.46 mt. Since its introduction, the catfish industry has witnessed consistent growth, progressively expanding its output. Notably, within the last two decades, this sector has experienced rapid expansion, outpacing the production of red tilapia, which had previously held the foremost position in freshwater or brackish water fin-fish cultivation, as per the Department of Fisheries (DOF) Malaysia's annual statistics from 1995 – 2015.

According to the DOF statistics, the catfish industry has garnered substantial economic significance, contributing notably to the aquaculture sector. With a total value amounting to RM 223,056 (USD 51,271), catfish cultivation constitutes approximately 10% of the overall aquaculture production in Malaysia, marking an impressive 45.19% of freshwater aquaculture output (Dauda et al. 2018). However, the industry has encountered fluctuations over time. Presently, official records indicate an annual production of approximately 28,000 mt within the catfish farming sector. Notably, this figure likely underestimates the actual production value, hinting at an industry poised to surpass documented statistics.

For an updated overview of the landscape concerning the area and production data related to catfish in Malaysia as of 2019, *Table 1* offers a comprehensive reference point, delineating the latest basic information in this domain. This serves as a foundational resource for understanding the contemporary status and trajectory of the catfish farming industry within the Malaysian aquaculture landscape.

Efforts are underway to optimise agricultural space and enhance the economic returns of catfish farmers through the

Table 1. Basic information on the area and production of catfish in Malaysia

Catfish breeding area (ha)	Number of entrepreneurs (people)	
	Livestock	Seeding
154,354	162	5
	Number of ponds (unit)	
	1450	594
Total catfish production (mt)	28,473.91	

Source: Department of Fisheries (2020)

integration of rice cultivation with catfish farming. The documented array of benefits outlined in studies aims to materialise these advantages in practical terms. Consequently, a focused study has been formulated to delineate the advantages and ramifications associated with integrating catfish farming within rice production systems. Primarily, the research seeks to assess the financial performance metrics achievable through the integration of rice cultivation alongside existing catfish breeding ponds. The core hypothesis driving this investigation posits that entrepreneurs adopting a rice-catfish integration system will experience a discernible increase in income compared to those solely engaged in catfish farming. This study endeavours to quantify and validate the financial advantages inherent in this integrated approach, shedding light on its potential economic impact for agricultural entrepreneurs.

Materials and methods

This study was conducted using an experimental design by technical researchers who used two different scenarios at PPA, Jitra, Kedah. This is because controlled experiments in small squares show that there is potential for both categories of rice production which both use the floating bed system. The experiments exercises have been used as the basis of the assumptions and calculations made in the monetary benefits and implications of the study's valuation approach. The floating raft construction (1 x 1 x 0.2 m = length x width x height) is rectangular and triangular as described in *Table 2*, detailing the two scenarios involved. The rice cultivation procedure carried out is without the use of chemicals such as those contained in conventional fertilisers and pesticides with the use of environmentally friendly input materials to ensure minimal negative effects on the integrated aquatic life, catfish *Clarias gariepinus*.

Based on *Table 3*, the estimated revenue from catfish farming (soil pond) is MYR 13,600 for a pond area of 13,500 square meters with the integration of rice cultivation which is estimated to yield RM 4,348.80 for scenario 1 and RM 10,646.40 for scenario 2 after the 20% deduction. There are 2 scenarios as a result of rice cultivation using floating borders with catfish integration. The estimated yield from rice cultivation in scenario 1 is 3,624 kg/ha. As for scenario 2, it is estimated that rice production can reach 8,872 kg/ha per season (*Table 2*). In line with the increase in rice production, the cost of inputs is also recorded to increase with the increase in cups/tubes of rice plants.

Cost benefit approach using partial budgeting estimation

The details of the monetary benefits that will be shown are with the consideration of increased costs to integrate rice cultivation into catfish farming with a floating bed. The method used for this study uses partial budgeting estimates for both integrated rice cultivation systems and production viability for both. Net income is the value of money left after total costs are subtracted from total

Table 2. Differences in the rice production scenario in the floating bed system on the catfish pond

Item	Details	Yield	Deduction 20%
Scenario 1: Square planting system			
Planting distance	30 cm x 18 cm	4.53	3.624
Number of clumps in meter square m^2: 18	180,000 / ha		
Number of *perdu*/ha of rice fields (70%)	126,000 / ha		
Rice yield: 126,000 x 18 (stalk) x 2g (weight of rice stalks)	4,536 kg		
Scenario 2: Triangle planting system			
Planting distance	15 cm x 15 cm	11.09	8.872
Number of clumps in meter square m^2: 44	440,000 / ha		
Number of *perdu*/ha of rice fields (70%)	308,000 / ha		
Rice yield: 308,000 x 18 (stalk) x 2g (weight of rice stalks)	11,088 kg		

Table 3. Estimated costs of catfish livestock with rice cultivation integration

System	Area (m^2)	Estimated output (kg)	Cost (RM) tools & operational	Input cost (RM)	Price (RM)	Estimated yield (RM)
Earthen pond (Scenario 1)						
Catfish	13,500	1,700	860.00	1,800.00	8.00	13,600.00
Rice[a]	10,000	3,624	270.00	6,842.00	1.20	4,348.80
Earthen pond (Scenario 2)						
Catfish	13,500	1,700	860.00	1,800.00	8.00	13,600.00
Rice[a]	10,000	8,872	540.00	11,117.33	1.20	10,646.40

Nota: [a] = total rice yield after 20% deduction

revenue. In the partial budgeting approach, the change in net income is the difference between the change in total revenue (Benefits) and the change in total costs (Implications). The concept of the partial budgeting approach is simplified as been shown in *Table 4*.

On the left side, benefits consist of increased returns obtained from additional revenue while cost reductions are determined from reduced variable costs due to implemented changes (Soha 2014; Rahim et al. 2021). On the right-hand side, implications consist of diminishing returns and increasing costs to measure any reduction in revenue and increase in cost due to the change, respectively.

Results and discussions

Partial budgeting estimation of rice-fish integration potential scenarios

The partial budgeting calculation includes two estimated scenarios to demonstrate the benefits obtained for rice cultivation when integrated with catfish farming. By assuming the monetary income from catfish farming is equal, the surplus benefit/ha (-/+) from rice cultivation serves as a preliminary indicator to determine the viability of the rice-catfish integration initiative.

Scenario 1

Moreover, *Table 5b* offers a sensitivity analysis focusing on rice yields. It elucidates that a pivotal threshold exists wherein the monetary prospects of rice cultivation begin to shift. Specifically, augmenting the rice yield to a minimum of 5,976.67 kg/ha marks the turning point wherein the profitability of rice cultivation starts to exhibit positive monetary benefits. This analysis underscores the critical importance of rice yield enhancement in steering the financial viability of the integrated system towards a favorable trajectory.

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Table 4. The concept of the partial budgeting approach

Benefits	Value	Implications	Value
Return increase Increased income due to change:	MYRxx	**Return decrease** Reduced income due to change	MYRxx
Cost decrease Reduced costs due to change	MYRxx	**Cost increase** Increased costs due to change	MYRxx
Total benefits	MYRxx	Total implications	MYRxx
Net income (benefit or implication) = -(value) / +(value)			

Source: (Rahim et al. 2021)

Table 5a. Partial budgeting catfish-rice farming integration in earthen ponds with floating boundaries (Scenario 1)

Catfish farming -> Catfish farming + Rice cultivation (Floating boundaries earthen pond) Rice cultivation area = 10,000 m^2 / 1 ha			
Benefits (+)		Implications (-)	
Return increase (RM)		Return decrease (RM)	
Yield (kg) after deduction 20%	3,624		
Price (RM/kg)	1.20		
Price incentive (RM/kg)	0		
Total increase (RM)	4,348.80	Total decrease (RM)	0
Cost decrease (RM)		Cost increase (RM)	
i) Fix cost (depreciation cost)	0	i) Fix cost (depreciation cost)	5,600.00
ii) Variable cost	0	ii) Variable cost	1,572.00
Total decrease (RM)	4,348.80	Total increase (RM)	7,172.00
Total benefit	4,348.80	Total implication	7,172.00
Benefit per hectare (RM)			-2,823.20

Table 5b. Sensitivity analysis monetary benefit rice yield for catfish-rice farming integration with floating boundaries (Scenario 1)

Rice yield (kg)	3,624	4,500	5,500	5,976.67
Benefit per hectare (RM)	-2,823.2	-1,772	-572	0.0

Total benefit - Total implication = Benefit per pond
(Yield X Price) - (Fix cost + variable cost) = 0 (Break even point)
x (1.20) - (5,600 + 1,572) = 0
1.20x = 7,172
x = 7,172/1.20
x = 5,976.67

Scenario 2

The integration scenario involving rice cultivation spanning 10,000 m^2 and catfish farming employing a floating boundary in Scenario 2 yields a negative return, tallying RM 1,130.93. This adverse financial outcome results from the heightened benefit value of RM 10,646.40 being eclipsed by the consequential implications of additional costs amounting to RM 11,777.33. The incongruity between the amplified benefits and the accrued expenses underscores the negative financial implications evident within this integration scenario (*Table 6a*).

To delineate the threshold for achieving positive monetary benefits, a sensitivity analysis focusing on rice yields is presented in *Table 6b*. This analysis endeavours to pinpoint the critical juncture wherein the financial trajectory of rice cultivation shifts. Notably, elevating the rice yield to a minimum of 9,814.44 kg/ha emerges as the pivotal threshold, marking the point where rice cultivation attains positive monetary benefits. This emphasis on the requisite rice yield underscores its indispensable role in steering the integrated system toward financial viability and positive returns.

The viability of integrated production rice-catfish

An extensive viability analysis encompassing expenditures has been meticulously undertaken, offering a comprehensive breakdown of net income, production costs, and net profit concerning the implementation of integrated rice and fish farming. This analysis serves as a strategic tool, aiming to furnish stakeholders with invaluable insights into the financial landscape of the integrated rice-fish farming endeavour, thereby empowering informed decision-making. The detailed breakdown is bifurcated into distinct components for rice and catfish farming, while a prospective calculation is specifically tailored for the integrated cultivation activity of catfish and rice. Key economic lifespan assumptions and pertinent parameters are outlined in the accompanying table below.

Notably, Scenario 1 exclusively underwent analysis subsequent to meticulous technical research conducted by the research team during the experiment. However, a comprehensive analysis for Scenario 2 was omitted due to findings indicating a direct proportionality between input increments and yield increments. In the absence of any input savings attributed to innovative planting structures or alternative materials, significant disparities in rice yield are not anticipated. Notably, the economic lifespan estimation for catfish stands at approximately 90 days or three months. Accounting for a pond area spanning 13,500 m^2, the potential capacity reaches approximately 10,000 catfish at any given instance. Considering an average market weight of around 0.2 kg/catfish, the cumulative output from a single pond could potentially yield 2,000 kg, with an estimated net yield of 1,700 kg, accounting for the expected mortality rate (*Table 7a*).

Table 6a. Partial budgeting catfish-rice farming integration in earthen ponds with floating boundaries (Scenario 2)

Catfish farming -> Catfish farming + Rice cultivation (Floating boundaries earthen pond) Rice cultivation area = 10,000 m^2 / 1 ha			
Benefits (+)		Implications (-)	
Return increase (RM)		Return decrease (RM)	
Yield (kg) after deduction 20%	8,872		
Price (RM/kg)	1.20		
Price incentive (RM/kg)	0		
Total increase (RM)	10,646.40	Total decrease (RM)	0
Cost Decrease (RM)		Cost Increase (RM)	
i) Fix cost (depreciation cost)	0	i) Fix cost (depreciation cost)	8,633.33
ii) Variable cost	0	ii) Variable cost	3,144.00
Total decrease (RM)	0.00 (?)	Total increase (RM)	11,777.33
Total benefit	10,646.40	Total implication	11,777.33
Benefit/ha (RM)			-1,130.93

Table 6b. Sensitivity analysis monetary benefit rice yield for catfish-rice farming integration with floating boundaries (Scenario 2)

Rice yield (kg)	8,872	9,000	9,500	9,814.44
Benefit/ha (RM)	-1,130.93	-977.33	-377.33	0.0

Total benefit - Total implication = Benefit/pond

(Yield X Price) - (Fix cost + variable cost) = 0 (Break even point)

$$x (1.20) - (8,633.33 + 3,144) = 0$$

$$1.20x = 11,777.33$$

$$x = 11,777.33/1.20$$

$$x = 9,814.44$$

This meticulous analysis furnishes pivotal insights into the prospective catfish production and net yield, serving as a linchpin for evaluating the economic feasibility of the catfish farming component within the integrated system. Furthermore, it augments comprehension regarding revenue generation and profitability within the broader framework of the integrated rice-catfish farming venture.

This analysis delves into crucial insights regarding the rice cultivation facet within the integrated catfish-rice farming system, offering pivotal details on rice production and net yield pivotal for evaluating the comprehensive productivity and economic sustainability of the integrated farming endeavour. The average economic cycle attributed to rice cultivation stands at 3.5 months within this context. Within the integrated system harmonising catfish and rice cultivation, the rice cultivation area, utilising floating boundaries atop the pond's surface, spans 75% of the total pond area. The remaining 25% of space is strategically allocated for technical functionalities during catfish production, facilitating essential tasks like maintenance and fish harvesting.

Table 7a. Characteristics of catfish farming in the integrated production of rice-catfish

Item	Total	Unit
Economic cycle of catfish	3	month
Preparation time	0.01	month
Pond area (13,500 m^2)	1	month
Catfish distance	n.a.	-
Catfish density	10,000	fish
Number of pond	1	unit
Catfish density (total)	10,000	fish
Start selling period	90	DAS
Yield per fish	0.20	kg
Gross revenue	2,000.00	kg
Net yield (*estimated disposable yield*)	1,700.00	kg

Note: DAS = day after sowing
Source: Primary data, 2021

Remarkably, this system facilitates the production of approximately 126,000 rice seedlings, employing a planting spacing configuration of 30 cm X 18 cm, ingeniously designed within the allocated boundaries. Consequently, the average net yield of rice, factoring in an average loss of 20%, culminates in an estimated 4.5 mt/pond (*Table 7b*). This meticulous breakdown serves as a cornerstone in gauging the productivity and viability of rice cultivation within the integrated system, providing a comprehensive understanding of its potential economic impact and overall contribution within the broader context of the integrated catfish-rice farming initiative.

The comprehensive cost-benefit analysis unveils significant financial metrics regarding the catfish and rice components within the integrated farming system, prominently showcasing their break-even points and financial progression per cycle. For catfish, the break-even point stands at RM 776.40, equivalent to 97 kg/cycle. Considering the current average selling price of catfish at RM 8/kg and a variable cost of RM 6/kg, this metric delineates the threshold at which revenues from catfish cultivation offset the associated costs. Conversely, the break-even point for rice cultivation stands at 1.85 mt, equating to RM 2,220.97/pond/cycle. Notably, integrated rice cultivation incurs substantial fixed costs/pond due to the requisite initial capital investment in the floating boundary structure, essential for its proper design and functionality.

This meticulous financial analysis sheds light on crucial aspects pertaining to both catfish and rice components within the integrated farming system, particularly emphasising the break-even points. These points denote the critical junctures where revenues from each component align with their respective costs, ensuring a balance between revenue and expenditure without incurring net losses or gains. Evaluating these financial factors becomes imperative in making informed decisions concerning the implementation and management of the integrated catfish-rice farming initiative. However, it’s vital to recognise that the overall income generated operates on a combined basis, where surplus income from catfish farming supplements the potentially less competitive income from rice cultivation, as evidenced in *Tables 6a* and *6b*.

The integration of rice and catfish farming demonstrates positive returns, boasting a Benefit Cost Ratio (BCR) of 1.27. This ratio indicates that every RM 1 invested results in a return of RM 0.27. The estimated payback period falls within 3 to 4 cycles (*Table 8*), affirming the financial viability of this integrated approach. While

Table 7b. Characteristics of rice cultivation in the integrated production of rice-catfish

Item	Total	Unit
Economic cycle of rice	3.5	month
Preparation time	0.01	month
Pond area (13,500 m^2)	0.75	month
Plant distance	30cm x 18cm	-
Plant density	126,000	*perdu*
Yield	18	g/perdu
Livestock density (total)	2,268,000	*perdu*/pond
Start selling period	100	HLT
Yield per plant	0.00	kg
Gross revenue	4,536.00	Kg
Net yield (*Estimated disposable yield*)	3,624.00	Kg

Note: DAS = day after sowing, *Perdu* = like culm/shrubs/bunch of the rice grown from small group of seeds
Source: Primary data, 2021

Table 8. Breakeven point and indicator of financial viability of rice-catfish integrated production

Financial viability for catfish-rice integration	
Catfish integration farming	
Total fix costs (RM)	240.00
Average price (RM/kg)	8
Average variable costs (RM/kg)	6
Break-even point (producing unit by kg)	97.050
Break-even point (selling unit by RM)	776.40
Rice integration farming	
Total fix costs (RM)	1,587
Average price (RM/kg)	1.20
Average variable costs (RM/kg)	0.34
Break-even point (producing unit by kg)	1.85
Break-even point (selling unit by RM)	2,220.97
Indicators for financial viability	
Net present value (NPV) @5%	16,136.58
Internal rate of return (IRR)	0.76
Benefit cost ratio (BCR) @5%	1.27
Payback period (farming @ planting cycle)	3.24

individual profitability and competitiveness might vary between catfish and rice farming, the aggregate results showcase favourable economic returns and feasibility through their integration. This analysis underscores the financial benefits inherent in the integrated catfish-rice farming approach, contributing to long-term stability and advantages within the agricultural system.

Conclusion

The integration of rice and catfish farming using floating boundaries in earthen ponds faces cost challenges due to expensive input materials and moderate rice yields. Efficient management of input costs through innovation is vital for economic benefits in rice cultivation integration. However, analysis shows no significant positive impact of rice integration on catfish growth or substantial increase in monetary benefits. Addressing cost issues and optimising resource allocation are necessary for economic viability. Cost-effective approaches and better resource management can enhance financial outcomes and overall success.

While short-term evaluations don't demonstrate economic benefits, long-term financial analyses, such as NPV and IRR, suggest viability, albeit subject to risks like price fluctuations. Labor sharing between rice and catfish farming could reduce expenses if labour possesses the necessary skills for both. Innovative approaches in floating boundary design can significantly impact costs and improve financial feasibility. Integrating rice and catfish farming capitalises on reduced labour costs and improved rice yields, establishing a promising economic integration.

Further studies are needed to assess the environmental impact of integrating rice and fish farming as a mitigation approach for environmental changes. The restructuring of these agricultural commodities must prioritise environmental sustainability alongside income generation. Integrating rice and catfish farming can exemplify a circular economy, but evaluating environmental implications is crucial to prevent negative ecosystem impacts. In modern times, addressing climate change and adopting sustainable agricultural practices are crucial. Integrating rice and catfish farming can promote environmental stewardship. This approach showcases a sustainable model of economic development, harmonising agricultural activities with environmental preservation, ultimately embodying a circular economy with efficient resource use and ecological balance.

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Abstrak
Polisi pertanian di seluruh dunia menekankan peningkatan pengeluaran domestik, produktiviti dan kelestarian, sambil menangani keselamatan makanan dan keterbatasan sumber. Satu strategi yang semakin mendapat perhatian melibatkan penggabungan penanaman padi dan penternakan ikan dalam kerangka pertanian lestari. Hal ini menawarkan kelebihan ekologi dan ekonomi seperti kesuburan tanah yang lebih baik, kawalan serangga semula jadi, dan peningkatan pendapatan isi rumah, sambil mencipta potensi peluang agropelancongan. Di Malaysia, penternakan ikan keli telah berkembang pesat, memberi sumbangan yang ketara kepada pengeluaran akuakultur. Usaha sedang dijalankan untuk mengintegrasikan penanaman padi dengan penternakan ikan keli untuk mengoptimumkan ruang pertanian dan penjanaan pendapatan. Kajian ini menilai faedah kewangan dari integrasi ini, dengan kajian tumpuan di Pusat Pengembangan Akuakultur (PPA) di Jitra, Kedah Darul Aman. Ia menggunakan metodologi eksperimen, menilai dua senario yang melibatkan pengeluaran padi menggunakan sistem batas terapung. Kaedah ini mengelakkan bahan kimia konvensional untuk meminimumkan kerosakan kepada hidupan akuatik, terutamanya ikan keli. Penyelidikan ini menyajikan dua senario: Senario 1 meramalkan pengeluaran padi sebanyak 3,624 kg setiap hektar dan Senario 2 sebanyak 8,872 kg setiap hektar, kedua-duanya diintegrasikan dengan penternakan ikan keli sedia ada. Pendekatan perbelanjaan separa dalam menilai kebolehgunaan kewangan, menganalisis perubahan pendapatan bersih berdasarkan pendapatan dan anggaran kos keseluruhan. Senario 1 menunjukkan pulangan negatif kerana kos yang meningkat melebihi faedah. Walau bagaimanapun, analisis kepekaan menunjukkan potensi kebolehlaksanaan Senario 1 jika hasil padi mencapai 5,976.67 kg setiap hektar. Senario 2, walaupun juga menunjukkan pulangan negatif, mempunyai potensi kebolehlaksanaan jika hasil padi meningkat kepada 9,814.44 kg setiap hektar. Kajian menilai jangka hayat ekonomi penternakan ikan keli dan penanaman padi, dengan menjangkakan pengeluaran ikan keli sebanyak 1,700 kg setiap kolam dan pengeluaran padi sebanyak 4.5 tan metrik setiap kolam. Titik pulang modal untuk kedua-dua komponen adalah setara apabila pendapatan bersamaan dengan kos. Dapatan menunjukkan Nisbah Faedah Kos (BCR) yang menguntungkan sebanyak 1.27, menunjukkan kebolehlaksanaan ekonomi integrasi padi dan ikan keli. Walau bagaimanapun, kajian impak alam sekitar yang komprehensif adalah penting untuk memastikan kelestarian, walaupun memerlukan pengurangan kos seperti melalui perkongsian buruh. Sejajar dengan promosi *circular economy* dan amalan pertanian yang mesra alam, penilaian menyeluruh tentang implikasi ekologi adalah penting. Pertanian bersepadu padi dan ikan keli, jika dilaksanakan dengan teliti, mempunyai potensi sebagai pendekatan pembangunan pertanian yang lestari dan bertanggungjawab terhadap alam sekitar.