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# TECHNICAL EFFICIENCY AND FARMER DECISION-MAKING IN INTEGRATED RICE-FISH FARMING IN FLOOD-PRONE AREAS: A CASE STUDY OF PASURUAN REGENCY, EAST JAVA

# EFISIENSI TEKNIS DAN PENGAMBILAN KEPUTUSAN PETANI UNTUK PERTANIAN PADI-IKAN TERINTEGRASI DI DAERAH RAWAN BANJIR: STUDI KASUS DI KABUPATEN PASURUAN, JAWA TIMUR

Wenny Mamilianti[*1)], Ary Bunayya Saifuddin[1)], Kelvin Angga Pramadani[1)], and Kresno Aji Bayu Samudro[1)]

[1)] Department of Agribusiness, Faculty of Agriculture, Universitas Yudharta Pasuruan, Purwosari, Pasuruan, East Java

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## ABSTRACT

Flooding occurs almost annually in Kedungboto Village, Pasuruan Regency, Indonesia, restricting farmers to a single rice-growing season due to prolonged field inundation. As an adaptive strategy, some farmers integrate fish farming during the rainy season; however, its contribution to farm efficiency remains insufficiently examined. This study aims to evaluate the technical efficiency of rice farming in flood-prone areas and to analyze the factors influencing farmers decisions to adopt rice-fish farming systems. A total of 120 farmers were surveyed, comprising 60 rice-fish farmers and 60 rice-only farmers. Technical efficiency was measured using Data Envelopment Analysis (DEA), while logistic regression was employed to identify the determinants of adoption. The results indicate that rice-fish farmers achieve higher average technical efficiency (0.82) than rice-only farmers (0.67). Technical efficiency, landholding size, farm income, knowledge of fish farming, and access to freshwater fish markets significantly influence adoption decisions. An odds ratio of 1.054 suggests that higher technical efficiency increases the likelihood of adopting rice-fish systems. These findings highlight the role of rice-fish integration in enhancing farm performance and resilience. Strengthening extension services and improving flood control infrastructure are essential to support sustainable and wider adoption.

Keywords: farmer decisions, flood prone, pasuruan, rice-fish system, technical efficiency.

## ABSTRAK

Banjir terjadi hampir setiap tahun di Desa Kedungboto, Kabupaten Pasuruan, Indonesia, yang membatasi petani hanya pada satu musim tanam padi karena genangan sawah yang berkepanjangan. Sebagai strategi adaptasi, beberapa petani mengintegrasikan budidaya ikan selama musim hujan; namun, kontribusinya terhadap efisiensi pertanian masih kurang ditinjau. Penelitian ini bertujuan mengevaluasi efisiensi teknis pertanian padi di daerah rawan banjir dan menganalisis faktor-faktor yang memengaruhi keputusan petani untuk mengadopsi sistem pertanian padi-ikan. 120 petani disurvei, terdiri dari 60 petani padi-ikan dan 60 petani padi saja. Efisiensi teknis diukur menggunakan Data Envelopment Analysis (DEA), sedangkan regresi logistik diterapkan untuk mengidentifikasi penentu keputusan adopsi. Hasil menunjukkan bahwa petani padi-ikan mencapai efisiensi teknis rata-rata yang lebih tinggi (0,82) dibandingkan dengan petani padi saja (0,67). Efisiensi teknis, luas lahan padi, pendapatan pertanian, pengetahuan tentang budidaya ikan, dan akses ke pasar ikan air tawar ditemukan secara signifikan memengaruhi keputusan adopsi. Rasio peluang sebesar 1,054 menunjukkan bahwa efisiensi teknis yang lebih tinggi meningkatkan kemungkinan adopsi sistem pertanian padi-ikan. Temuan ini menjelaskan bahwa integrasi budidaya padi-ikan meningkatkan efisiensi pertanian dan strategi adaptasi di daerah rawan banjir. Oleh karena itu, penguatan layanan penyuluhan pertanian dan peningkatan infrastruktur pengendalian banjir penting untuk mendukung keberlanjutan dan adopsi yang lebih luas dari sistem pertanian ini.

Kata kunci: keputusan petani, rawan banjir, pasuruan, sistem padi-ikan, efisiensi teknis.

[*] *Corresponding author: Wenny Mamilianti, wennymfp@yudharta.ac.id*
*Institution and its address*: *Department of Agribusiness, Faculty of Agriculture, Universitas Yudharta Pasuruan, Purwosari, Pasuruan, East Java*

## INTRODUCTION

Agriculture remains a leading sector in Indonesia, as reflected in the government's continuous efforts to strengthen and develop this sector. Its contribution to the national economy is widely recognized as a strategic pillar for supporting food security programs, enhancing competitiveness, generating employment, and improving farmers welfare (Chandio et al., 2016). Agricultural activities are predominantly concentrated in rural areas, where they continue to serve as the primary source of household income. According to the 2023 agricultural census conducted by the Central Bureau of Statistics of Indonesia (BPS), the total number of individuals engaged in food crops, horticulture, plantations, and livestock farming reached 28,191,747, while 27,802,434 individuals were directly involved in land-based agricultural activities.

As a key sector in ensuring national food security, agriculture faces substantial challenges, particularly under the increasing pressures of climate change (Ahmad & Afzal, 2022; Guo et al., 2022; Habib-ur-rahman et al., 2022; Malhi & Kaur, 2021; Rio et al., 2023). Dependence on nature causes the agricultural sector to have a high risk and uncertainty. As argued by Aldosari et al. (2019) uncertainty and risk are intrinsic characteristics of agriculture as a complex system. Current environmental conditions are increasingly unpredictable, characterized by extreme climate variability, erratic rainfall patterns, shifts in seasonal cycles, rising temperatures, and changing wind dynamics. Climate change has been identified as one of the most significant environmental threats of the 21st century (Ha et al., 2021; Handoko et al., 2018; Hultgren et al., 2025). Recent studies indicate that climate change has altered seasonal patterns, often resulting in delayed onset and earlier cessation of the rainy season, thereby extending periods of climatic instability (Ferijal et al. 2022; Wagner et al. 2021). These changes directly affect agricultural production and rural livelihoods (Chen & Gong, 2021; Guo et al., 2022; Yuan et a., 2024; Thi Lan Huong et al., 2017). Moreover, intensified rainfall, seasonal shifts, and the increasing frequency of extreme weather events heighten the vulnerability of agricultural systems to production shocks (Akmalia, 2022; Guo et al., 2022; Sekaranom et al., 2021). Ensuring stable agricultural production is therefore critical for achieving food security. Therefore, the success of agricultural production is important, so a strategy and technology are needed to face climate change.

Climate change has also increased the likelihood and severity of natural disasters in the absence of effective management practices. Flooding is among the most frequent climate-related disasters, primarily driven by high rainfall intensity and excessive precipitation. Such flood events cause significant damage to agricultural land, particularly for staple crops such as rice. Prolonged inundation often prevents farmers from achieving multiple planting cycles within a year. The resulting losses are not only borne by farmers through reduced yields and income but also have broader implications for national food security due to disruptions in the supply of strategic commodities. Data from the National Agency for Disaster Management (BNPB) in 2023 indicate that floods affected approximately 110,383.80 hectares of agricultural land, with 54,442.42 hectares experiencing crop failure. Furthermore, flood events during the January-March 2023 planting season resulted in

estimated economic losses of 412 billion rupiahs and affected around 52,053 farmers (BPS, 2023). Therefore, climate-adaptive agricultural management, including effective flood risk mitigation, is essential to sustain production and safeguard farmers livelihoods.

In flood-prone areas, the efficiency of input allocation requires careful attention, as nutrient composition may decline due to reduction processes triggered by prolonged inundation. Empirical studies examining technical efficiency in such environments remain limited and predominantly focus on monoculture rice systems, with relatively little attention given to integrated farming practices (Mamilianti et al., 2025**;** Ramadani et al., 2024; Saeri et al., 2024). Furthermore, the integration of efficiency analysis with farmer behavior and location-specific environmental conditions such as flood-prone ecosystems has not been extensively explored in the literature. Research on farmers adoption decisions regarding rice-fish systems is also still limited, particularly in relation to variations in technical efficiency (Fernandez-zatrate et al., 2025; Rahman et al., 2022; Sathoria & Roy, 2022).

Technical efficiency in agriculture reflects the optimal utilization of production inputs. For instance, fertilizer application must be carefully calibrated to match crop nutrient requirements in order to enhance efficiency (Saeri et al., 2024). Key agricultural inputs include land, seeds, fertilizers, pesticides, and labor (Asmara et al., 2022; Dewanti et al., 2024). Lands are the planting medium that provides nutrients needed by the plants. The use of high-quality, stress-tolerant seed varieties can improve adaptability and mitigate yield losses associated with climate variability. In addition, the appropriate selection and application of fertilizers and pesticides can reduce plant stress, thereby enhancing both productivity and cost efficiency (Kharisma & Mamilianti, 2026). Labor, as a component of human resources, plays a critical role throughout the production process, from land preparation to harvesting. Ultimately, the appropriate combination of input dosage, timing of application, and cost management determines overall farm efficiency. Consequently, farmers in flood-prone areas must make strategic decisions regarding input use to achieve optimal production outcomes.

East Java is one of Indonesia’s key rice-producing provinces and serves as a national food granary, while also facing significant disaster risks associated with climate change. Pasuruan Regency is among the major rice-producing areas within the province. Rice production in this regency is influenced by multiple factors, including land availability, land-use change, climate variability, irrigation conditions, pest and disease pressures, technical aspects of farming, and broader socio-economic conditions. Monitoring of extreme weather events indicates that East Java experienced unusually high rainfall in 2016, with precipitation levels reaching approximately twice the normal rate. Average monthly rainfall exceeded 500 mm, which is considered abnormal, and the onset of the rainy season occurred 1-2 months earlier than the typical seasonal pattern. Pasuruan Regency is classified as a flood-prone area, as illustrated in Figure 1. Flooding that affects rice fields occurs frequently, particularly in the northern part of the regency, including Beji District. In Kedungboto Village, Beji District, rice fields are inundated almost every year. As a result, farmers

typically cultivate rice only once annually and subsequently shift to fish farming during the following season when fields remain flooded.

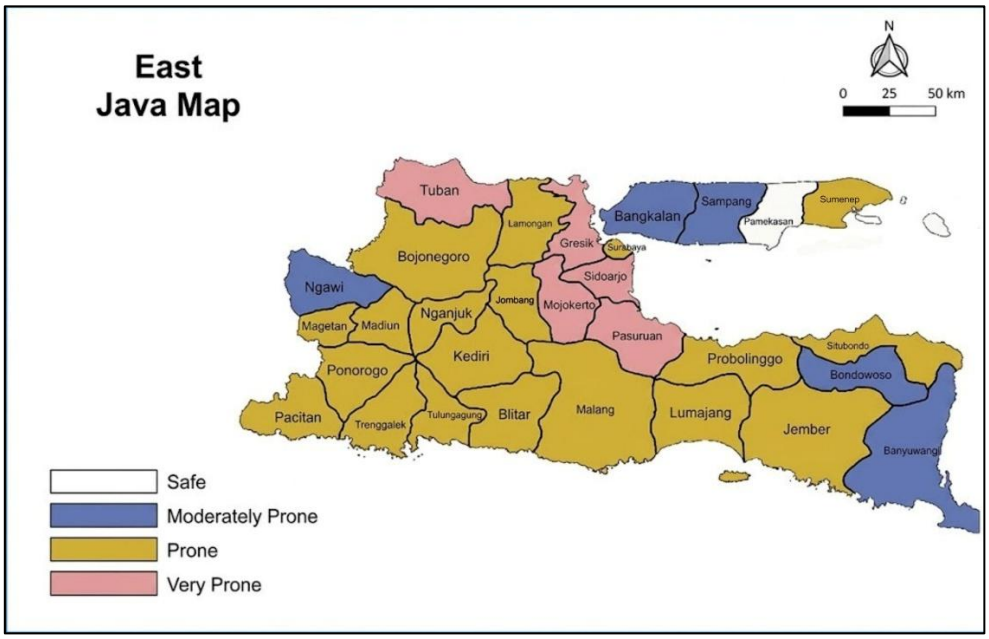



**Figure 1. Map of Rice Submerged by Floods in East Java**

Recurring floods in Kedungboto Village, Beji District, Pasuruan Regency, pose significant challenges for farmers in managing their agricultural activities to achieve targeted production and income levels. Income earned from the previous planting season serves as the primary source of capital for subsequent cycles. As emphasized by Dash dan Ashraful (2023) and He and Ahmed (2022), farm income is a key determinant of agricultural sustainability, as it underpins input procurement, maintenance of production assets, and improvements in farm efficiency and productivity. However, farmers in this area face a major constraint: rice cultivation is limited to a single cropping season per year due to prolonged flooding during the rainy season. Continuous inundation not only restricts cropping intensity but also reduces land productivity. Moreover, flooded conditions promote the accumulation of reduced metal compounds, such as iron (Fe), manganese (Mn), and cadmium (Cd). When present in excessive concentrations, these elements can become toxic and adversely affect rice growth and yield (Niki et al., 2022).

Rice farmers in Kedungboto Village, Beji District, Pasuruan Regency, operate under conditions that require continuous adaptation to environmental stress. To cope with recurrent flooding, farmers implement various adaptive strategies. These include selecting flood-tolerant rice varieties, adjusting cropping patterns to align with flood cycles, and strengthening collective action through farmer groups. In addition, the efficient use of inputs—such as applying fertilizers and pesticides at appropriate dosages and timing—plays a crucial role in maintaining productivity. Farmers also develop simple irrigation channels and advocate for government support in constructing flood control infrastructure, such as dams (Dewa et al., 2023; Salampessy 2018; Yulinar & Virianita 2021). Furthermore, farmers diversify their livelihoods by integrating rice cultivation with fish farming, allowing inundated fields to remain productive and providing an alternative source of income. These

adaptive measures help mitigate production risks and support the maintenance of land productivity under flood-prone conditions (Fernandez-zatrate et al., 2025; Nurhidayati et al., 2020; Sathoria & Roy, 2022).

Farmers in Kedungboto Village transition to fish farming during flood events, as inundated rice fields cannot be used for cultivating rice or other crops. Under these conditions, the use of flooded land for aquaculture represents a more viable and economically beneficial alternative. Flooding in the area typically persists for nearly one month, rendering rice cultivation infeasible during this period. In addition, farmers face challenges related to the rapid proliferation of snails, with populations estimated to reach up to 12 tonnes per day (Amalijah et al., 2023). These constraints necessitate a reduction in dependence on rice farming and encourage the exploration of alternative livelihood strategies. Integrating fish farming into flooded fields provides both an additional source of income and a means of enhancing household food security. Furthermore, fish production in inundated areas benefits from the natural availability of feed within the flood ecosystem, resulting in relatively low production costs. This adaptive strategy not only enables farmers to cope with recurring floods but also strengthens their economic resilience by leveraging opportunities arising from uncertain environmental conditions.

Therefore, assessing the technical efficiency of rice farming in flood-affected areas alongside fish cultivation during flood periods and the determinants of farmers adoption decisions is essential for understanding the sustainability of rice-based farming systems in flood-prone regions. This study integrates technical efficiency analysis with farmers adoption behavior in rice-fish systems under flood-prone conditions and proposes a multi output framework that more accurately captures the complexity of integrated farming systems. Accordingly, this research aims to (i) evaluate the level of technical efficiency in rice farming in flood-prone areas and (ii) identify the factors influencing farmers decisions to adopt fish farming during the rainy season.

The expectation of the rotating system between rice-fish in this farming business is reaching increasing efficiency and sustainability in the business, where the rice field can be utilized throughout the year without having to wait for a season to completely end. By planting rice during the dry season and farming fish during the rainy season or floods, the farmer can receive income from two different sources at the same time, so that the risk of loss due to crop failure can be reduced (Galarza-villamar et al., 2024; Sudirah et al., 2020). Moreover, the fish waste can be used for organic fertilizer that fertilizes the soil, while the rice residue becomes the natural feed for the fish. Hopefully, these patterns not only increase the farmer's income and food security, but also sustainably maintain the ecosystem balance of the ricefield.

## RESEARCH METHODS

The research was conducted in Kedungboto Village, Beji District, Pasuruan Regency, East Java, Indonesia. The location selection was done purposively, considering that the location is one of the flood-prone areas, where the ricefields are flooded annually, and some farmers practice

freshwater fish farming when floods hit. The research data were collected through interviews, field observations, focus group discussions, and structured questionnaires administered to farmer respondents. The respondents were rice farmers in Kedungboto Village, Beji District, Pasuruan Regency, who are members of the Kedungboto Makmur Farmer Group and the Subur Farmer Group. These two farmer groups were purposively selected because their members are affected by flooding, and a proportion of them practice rice-fish farming. The Kedungboto Makmur Farmer Group consists of 134 members, while the Subur Farmer Group has 107 members. Approximately 50% of the total farmers were selected as respondents, resulting in a total sample of 120 farmers. The sample comprised 60 rice farmers who cultivate rice only and do not engage in fish farming during the rainy or flood season (hereafter referred to as "rice farmers"), and 60 farmers who practice integrated rice-fish farming on the same land using a rotational system (hereafter referred to as "rice-fish farmers"). The sampling method was simple random sampling of the farmers in the research area who cultivated rice only or rice and fish alternately on the same land.

The data analysis method to measure the technical efficiency level of rice and freshwater fish farming was done using the Data Envelopment Analysis (DEA). The DEA approach used for this research is appropriate because the data used is in the form of non-parametric, deterministic data. Moreover, the DEA approach helped to find the causes of inefficiency and determine the results of relatively efficient input use. The rice farming business was said to be relatively efficient if the value of efficiency equals one, where it would be less effective if the value is less than one. Fundamentally, the DEA model compares input and output data sourced from an organization and from another decision-making unit. The research also utilizes the variable of return into scale (VRS) as the farmers in the research location have yet to achieve the optimum scale. This study adopts the variable returns to scale (VRS) assumption, as it generally yields higher efficiency scores compared to alternative specifications (Banker, Charnes & Cooper, 1984). The model of this research uses input and output variables. The input variable includes the land, seeds, laborers from family or outside of the family, fertilizer, and pesticides, while the output of this research is the rice production. Mathematically, the DEA model can be written as follows:

$$\begin{gathered} Min_{\theta\lambda}\ \theta \\ s.t. -y_i + Y\lambda \geq 0 \\ \theta_{xi} - X\lambda \geq 0 \\ N1'\lambda = 1 \\ \lambda \geq 0 \end{gathered} \tag{1}$$

where: $\lambda$ = constant vector; $x_i$ = i-th DMU non-negative input vector; $\theta$ = the efficiency value that resulted from the i-th DMU ($0 \leq \theta \leq 1$); $N1'\lambda$ = convexity constraint

The analytical method to measure the factors that influence rice farmers to switch to freshwater fish farming during the floods is the logistic regression. This research looks at the factors that influence the selection of freshwater fish farming during floods by the rice farmers in the flood-prone area, where the farmers decision (FD) becomes the dependent variable. Factors that were analyzed include the level of technical efficiency (TE), farmers age (AGE), education level (EDU),

the amount of family members (FAM), land area (LAND), farming income (INC), fish farming knowledge (FISH), freshwater fish market (SALE), non-agricultural job (OFF), and farmer participation in a cooperative or a farmers group (COOP). The logistic regression model is written as follows:

$$log\left(\frac{\pi j}{\pi l}\right) = \beta 0j + \beta 1TE + \beta 2AGE + \beta 3EDU + \beta 4FAM + \beta 5LAND + \beta 6INC + \beta 7FISH + \beta 8SALE + \beta 9OFF + \beta 10COOP \quad (2)$$

**Table 1. Dependent Variable**

| Variable | Description | Value |
|---|---|---|
| FD | Farmers decision to alternately cultivate rice–fish or rice-only systems on the same plot of land. | 1 = utilizing the flooded land for fish farming<br>0 = did not do fish farming during floods |

**Table 2. Independent Variables**

| Variable | Description | Measurement | Direction |
|---|---|---|---|
| TE | Technical efficiency | The value of technical efficiency is Continuous (0-1) | + |
| AGE | Farmer age | In year | - |
| EDU | education level | 0 = did not finish;<br>6 = finished elementary school,<br>9 = finished middle school,<br>12 = finished high school,<br>16 = finished tertiary education | + |
| FAM | The number of family members who become the farmers responsibility | In the number of people | + |
| LAND | The rice field areas | In hectare | + |
| INC | The income from the rice farming business in a planting season | in millions of rupiah | ± |
| FISH | Farmers knowledge regarding freshwater fish farming | 5 = very aware; 4 = aware;<br>3 = adequately aware;<br>2 = lacking awareness; 1 = not aware | + |
| SALE | The market of freshwater fish, the ease of sale, and the price of the fish are advantageous, according to the farmers. | 5 = very agree; 4 = agree; 3 = sufficiently agree; 2 = less agree; 1 = disagree | + |
| OFF | Non-agricultural job. The farmer has a job other than farming or working on their land. | 1 = have a job outside farming,<br>0 = did not have a job outside farming | - |
| COOP | The participation in an organization or a farmers group | 1 = participate, 0 = did not participate | + |

## RESULT AND DISCUSSION

### Floodplain Rice Cultivation in Kedungboto Village, Beji District, Pasuruan Regency

### Land Characteristics

Rice cultivation in the flood-prone areas of Kedungboto Village, Beji District, Pasuruan Regency, represents a farming system strongly influenced by seasonal hydrological dynamics. The area is characterized by lowland topography situated near river systems and industrial zones, rendering the rice fields particularly susceptible to inundation during the rainy season. Consequently, paddy fields are frequently exposed to flooding with varying depths and durations.

Rice fields in Kedungboto are generally classified as either fully irrigated or semi-technical irrigation systems. However, during periods of intense rainfall, drainage capacity is often insufficient to accommodate surface runoff, resulting in water stagnation at depths ranging from 20 to 70 cm. The duration of inundation typically varies from 3 to 14 days, depending on rainfall intensity, and is often accompanied by significant sediment deposition. Prolonged flooding can lead to root damage due to oxygen deficiency, a reduction in the number of productive tillers, and an increased risk of crop failure (puso), particularly during the early vegetative stage. Figure 2 illustrates rice fields inundated by floodwater, which are subsequently utilized for integrated fish cultivation.



**Figure 2. Rice Fields at the Research Site Inundated by Floodwater and Utilized for Integrated Rice–Fish Cultivation**

Farmers in Kedungboto Village implement several adaptive strategies to mitigate the impacts of flooding on their agricultural land. These measures include adjusting the planting calendar by initiating cultivation prior to the peak of the rainy season, thereby preventing the generative growth stage from coinciding with periods of high flood risk. In addition, farmers adopt flood-tolerant rice varieties, such as Inpari 30 Ciherang, which are better suited to withstand temporary submergence. Furthermore, efforts are made to improve field drainage systems to enhance water outflow and reduce the duration of inundation. Farmers also diversify their production systems by integrating rice and fish cultivation (rice-fish farming) within the same plots. This diversification strategy serves to minimize potential economic losses due to flooding while simultaneously creating opportunities for supplementary income generation.

**Technical Efficiency of Rice Farming Business**

The analysis of technical efficiency in rice farming in Kedungboto Village, Beji District, Pasuruan Regency, indicates that farmers practicing rice-fish systems across different seasons achieve a higher average technical efficiency score (0.82) compared to monoculture rice farmers (0.67). This finding suggests that production inputs in rice-fish systems could be reduced by approximately 18% without compromising output, whereas monoculture rice systems exhibit a

potential input reduction of up to 33%. The distribution of technical efficiency scores among farmers is presented in Tables 3 and 4.

According to the result of data analysis using DEAP, among the respondents, 11 rice-fish farmers are deemed as fully efficient or having the technical efficiency value of one. It made up 18.33% of the total respondents of 60 farmers. The remaining 49 farmers or 81.67% have efficiency scores below one, indicating suboptimal input use. The lowest observed technical efficiency score among rice-fish farmers is 0.33. Overall, the results demonstrate that farmers who adopt rice-fish farming during flood periods achieve better technical efficiency performance compared to those engaged solely in rice cultivation.

**Table 3. The Distribution of Technical Efficiency with the VRSTE Assumption in the Research Location**

| Efficiency value | Rice-Fish Farmers (n=60) | | Rice Farmers (n=60) | |
|---|---|---|---|---|
| | Amount (people) | Percentage | Amount (people) | Percentage |
| < 0,5 | 3 | 5 | 4 | 6.67 |
| 0,5 – 0,7 | 9 | 15 | 25 | 41.66 |
| 0,71 – 0,9 | 22 | 36.67 | 17 | 28.33 |
| 0,91 – 0,99 | 15 | 25 | 10 | 16.67 |
| 1 | 11 | 18.33 | 4 | 6.67 |
| The sum of farmers with an efficiency value of 1 | 11 | 18.33 | 4 | 6.67 |
| The sum of farmers with an efficiency value less than 1 | 49 | 81.67 | 56 | 93.33 |
| Average efficiency value | 0.82 | | 0.67 | |
| Maximum value | 1 | | 1 | |
| Minimum value | 0.33 | | 0.39 | |

Source: Processed Data (2024)

Based on the technical efficiency analysis of rice farmers, only 4 out of 60 respondents (6.67%) are classified as fully efficient, achieving a score of one. The remaining 56 farmers (93.33%) exhibit technical efficiency scores below one, indicating suboptimal use of production inputs. These findings confirm that rice farmers have lower technical efficiency compared to those adopting rice-fish systems. The minimum technical efficiency score observed among rice farmers is 0.39, which is slightly higher than the lowest value recorded for rice-fish farmers. However, despite this difference, the overall efficiency level of rice farmers remains relatively low on average.

The result of this study is in accordance with several previous studies done by multiple researchers. Ahmed et al. (2011), who conducted a study of rice-fish farming in Bangladesh, mentioned that the farmers who do rice-fish farming are more efficient in rice farming compared to the monoculture farmers or those who only work on rice farming, as the rice production is higher, even though the cost of production is higher. Fernandez-zatrate et al. (2025) explain that rice-fish farming is a sustainable farming system that pushes for the continuity of ecology, food security, and the farmers socio-economics. It is further explained that as the rice production is bigger than that of the monoculture farmers, it will help the farmers economy. Nurhidayati et al. (2020) explained that the farmers who carried out rice-fish farming in Lamongan, East Java, have not reached the technical efficiency level of 100%, with the allocation of inputs, such as fertilizers and pesticides, having

different dosages between farmers, and the average efficiency reaches 78.05%. Ahmadian & Yustiati (2021) mentioned that rice-fish farming can increase rice productivity and increase the farmers income from the fish farming. Moreover, it also has a positive impact on the ecology, social, and economic aspects of the farmers.

According to the calculation result by using the DEA model, most of the farmers in Kedungboto Village, Beji District, Pasuruan Regency use excessive inputs on their rice farming business, so it's not technically efficient. This is causing the value on slack for all variables not to be met. Table 4 shows the excessive use of inputs by the rice farmers.

**Table 4. Average Input Slack Values for Rice–Fish and Rice-Only Farmers**

| Variable | Rice-Fish Farmers (n=60) | | | Rice Farmers (n=60) | | |
|---|---|---|---|---|---|---|
| | Average slack value | Amount (people) | Percentage | Average slack value | Amount (people) | Percentage |
| Seeds (kg) | 1.89 | 17 | 28.33 | 3.22 | 21 | 35 |
| Urea Fertilizer (kg) | 6.48 | 8 | 13.33 | 10.66 | 23 | 38.33 |
| NPK Fertilizer (Phonska) (kg) | 3.34 | 13 | 21.67 | 7.94 | 18 | 30 |
| Pesticides (kg) | 5.77 | 9 | 15 | 11.28 | 5 | 8.33 |
| Labor (HOK) | 7.36 | 11 | 18.33 | 3.56 | 13 | 21.67 |

Source: Processed Data (2024)

Farmers who used excessive inputs value is 34 people or 56.67% of the total rice-fish farmers respondents, where the excessive inputs that were used are seeds at 1.89 kg, urea fertilizer at 6.48 kg, NPK fertilizer (Phonska) at 3.34 kg, pesticides at 5.77 liters, and labor at 7.36 work days. To increase the technical efficiency and achieve zero slack, the rice-fish farmers can reduce the composition of inputs, as explained in Table 4. Moreover, there are farmer respondents in Kedungboto who have been efficient in the usage of input. Efficient farmers are 26 people or 43.33 percent of the total rice-fish farmer respondents. The efficient farmers have achieved the zero-slack assumption across all variables of production inputs used.

The number of farmers among the rice farmers respondents who used excessive inputs is 46 people, or 76.67% of the total. Generally, the condition is the same as that of rice-fish farmers, where the excessive use of inputs indicates that part of the rice farming business is technically inefficient due to the slack value across all the variables used not being fulfilled. On the rice farmers, the excessive input values are on the seeds at 3.22 kg, urea fertilizer at 10.66 kg, NPK fertilizer (Ponska) at 7.94 kg, pesticides at 11.28 liters, and labor at 3.56 work days. To increase the technical efficiency and achieve zero slack, the monoculture farmers, who only do rice farming, can reduce the composition of production input, as explained in Table 4. The efficient "rice-only farmers" in terms of the input aspects among the respondents are 14 people, or 23.33 percent of the total respondents. Efficient farmers have achieved zero slack assumptions across all the variables of production input used.

**Factors That Influence the Farmers Decision to Do Fish Farming During Floods**

Logistic regression analysis was employed to identify the independent variables influencing farmers decisions to adopt a particular farming system. Table 5 presents the estimated effects of

these variables, expressed as odds ratios. The likelihood ratio Chi-square statistic is 44.79 with a p-value of 0.000, indicating statistical significance at the 1% level. This result suggests that at least one independent variable has a significant effect on the adoption decision. Furthermore, the Pseudo R-squared value of 0.3601 indicates that the model explains approximately 36.01% of the variation in farmers adoption decisions. Table 5 also reports the factors influencing rice farmers decisions to switch to freshwater fish farming during flood periods. The estimated odds ratio of 1.054 for technical efficiency implies that an increase in efficiency slightly raises the likelihood of farmers adopting rice-fish farming systems.

**Table 5. The Result of the Analysis of the Factors That Influence Rice Farmers to Switch to Freshwater Fish Farming During Floods**

| Variable | Coefficient | Probability | Odd ratio |
|---|---|---|---|
| Constant | 5.416 | 0.000 | 0.055 |
| The value of technical efficiency (EF)* | 0.049 | 0.016 | 1.054 |
| Farmer's age (AGE) | -0.312 | 0.547 | 1.029 |
| Farmer's education level (PDK) | 4.836 | 0.849 | 0.793 |
| The number of farmers family members (FAM) | 0.443 | 0.742 | 3.607 |
| The rice field area (LAND)* | 0.062 | 0.000 | 1.154 |
| Income of the farming business (INC)* | -0.042 | 0.000 | 1.022 |
| Knowledge regarding fish farming (FISH)** | 0.110 | 0.067 | 5.959 |
| The market of freshwater fish (SALE)* | 0.015 | 0.129 | 3.233 |
| Farmer's non-agricultural job (OFF) | 0.673 | 0.259 | 7.122 |
| The participation in a cooperative or farmers group (COOP)* | 0.399 | 0.001 | 1.098 |
| *Log likelihood* | -98.34 | *LR Chi-Square* | 44.79 |
| *Prob > Chi-Square* | 0.000 | *Pseudo R2* | 0.3601 |

Notes: *significant at α=1%, **significant at α=5%
Source: Processed Data (2024)

The choice of farming systems and input allocation is critical for farmers, particularly smallholders with limited resources. These decisions directly influence production costs, input requirements, output levels, and ultimately farm income. Farmers adoption of rice-fish farming systems, especially under flood-prone conditions, is shaped by a combination of social, economic, and ecological factors. Table 5 presents several key determinants that significantly influence farmers decisions to shift to fish farming during flood periods, including technical efficiency, rice field size, farm income, knowledge of aquaculture practices, and the availability of freshwater fish markets.

Farmers decisions to shift to fish farming when rice fields are flooded are influenced by a combination of land, economic, knowledge, and market factors. Land area is a key consideration: larger flooded areas entail greater risk of loss, incentivizing farmers to use the land for fish production (Nurhayati et al., 2020). The income from the farming business also plays a role, where diversification by fish is seen as a strategy to stabilize or increase the income when the yield of the rice is threatened with failure (Ahmed et al., 2011). Moreover, the knowledge and the skill in fish farming directly influence the level of confidence of the farmer in managing that system, so that the farmers who have experience or access to information find it easier to decide to switch to fish farming (Yulinar & Virianita, 2021). The external factor, such as the availability of freshwater fish market, is also becoming the driving force, as the existence of stable demand ensures the marketing of the

result and increases the incentive of the farmers to switch. Thus, the interaction of internal and external factors determines the likelihood of farmers adopting fish farming as a flood adaptation strategy.

Social factors, such as the availability of technical knowledge, the support of the farmers group, and access to the fish or rice market, also strengthen the farmers decision to adopt the rice-fish system. The land factor also becomes the main factor in the farmers decision, where a vast land area will be a consideration for the farmer in fish farming. The vulnerability of the land to floods causes losses in monocultural rice farming, so that the integration with the fish farming becomes the adaptation strategy to reduce the risk of failed crops (Yulinar & Virianita, 2021). Moreover, the consideration of the economic advantage of business diversification, the utilization of the abundant water resource, and the increase in consumable fish also push the farmer to choose this system (Sudirah et al., 2020).

## CONCLUSION AND SUGGESTION

### Conclusion

In general, the rice farmers in the flood-prone ricefield in Kedungboto Village, Beji District, Pasuruan Regency have a low average technical efficiency, as shown by the fact that the farmers who reached full efficiency only around 18.33% for rice-fish farmers and 6.67% for rice farmers. The farmers in the two groups can still increase their technical efficiency by paying attention to the utilization of the excess production inputs. The low technical efficiency indicates that there's still inefficiency in the input allocation among farmers, as shown in the usage of production factors that is excessive and not in accordance with the intended usage of the two farmer groups that became the respondents for this research. The rice farmers who did the fish farming during the floods (the rice-fish farmers) showed a higher technical efficiency compared to the farmers who only do rice farming (the rice farmers). The factors that influence the farmers decision to switch to fish farming during the rainy season and floods are the value of technical efficiency, the rice field area, the income from the farming business, the knowledge regarding fish farming, and the market for freshwater fish. The level of technical efficiency in rice farming increases the likelihood that farmers will adopt fish farming during the rainy or flood season, indicating that farmers are more productive and innovative in managing their farming systems.

### Suggestion

This study has several limitations. First, the use of cross-sectional data does not capture the dynamics of technical efficiency and farmers behavior over time. Second, the analysis of farmers decision-making does not fully account for non-economic factors, such as risk perception and socio-cultural influences. Third, the study is geographically limited to Pasuruan Regency, which constrains the generalizability of the findings. Therefore, future research is recommended to employ panel data and to expand the scope of variables and study areas in order to obtain a more comprehensive understanding of efficiency and decision-making in integrated farming systems in disaster-prone

areas. In terms of implications, farmers are encouraged to enhance their knowledge and skills in rice–fish farming as an adaptive strategy to flooding. Extension services should strengthen technical assistance and the dissemination of integrated farming innovations tailored to local conditions. Policymakers are expected to support these efforts through the provision of flood control infrastructure, improved access to financing, and the strengthening of agricultural and fisheries markets to promote the sustainability of farming systems.

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