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THE SUSTAINABILITY OF RICE FARMING PRACTICES IN TIDAL SWAMPLANDS OF SOUTH SUMATRA INDONESIA

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ABSTRACT
Tidal swamplands are considered the national food security platform in Indonesia. Residues from the excessive chemical input used in the rice production affecting the environment, farmers' health, and the safety of the product. Similarly, one can expect that excessive chemical use in tidal swamplands can also threaten rice production system sustainability. This study aimed to assess and identify factors influencing the sustainability of rice farming practices in tidal swamplands of South Sumatra, Indonesia. A survey was carried out to obtain information through direct interviews with 150 farmers in Muara Telang, South Sumatra, Indonesia. The Indonesia rice check was employed as indicators to assess the sustainability of rice farming practices in tidal swamplands. A percentage index was to categorize the sustainability status. A regression analysis with the Tobit model was applied to identify factors influencing the sustainability of rice farming practices. The result showed that the average sustainability index was 25.53%. It indicated rice farming practices in tidal swamplands tend to be unsustainable. The significant factors influencing the sustainability of rice farming practices were farmer's education and household size. A policy recommendation is proposed to enhance the implementation of sustainable agriculture practices by the rice farmers in tidal swamplands.

Keywords: index; rice check; rice farm; sustainable agriculture; tidal swampland

INTRODUCTION
Suboptimal lands have an essential role in the food security of Indonesia. One of the suboptimal land types in Indonesia is tidal swamplands. Tidal swamplands are located close to the sea or river such that water availability in tidal swamplands for rice cultivation depends on the tides. The difference between irrigated rice fields and tidal swamplands is water management. There are some primary, secondary, and tertiary canals to the rice field that has sufficient water availability **(Widjaja-Adi, Ratmini, and Swastika, 1997)**. Tidal swamplands are available in some regions of Indonesia such as Sumatra, Kalimantan, Papua, and Sulawesi only. The biggest area of tidal swamplands in Sumatra is in South Sumatra Province. Tidal swamplands were a government reclamation project in the 1970s. The project involved migrants from Java Island to Sumatra Island. The reclaimed area is cultivated for rice farming. The total area of tidal swamplands in South Sumatra is 266,674 hectares and 161,917 hectares are in Banyuasin Regency **(Statistical Center Bureau of Banyuasin Regency, 2018)**. It indicates that a potential exists for food security. Therefore, tidal swamplands are recognized as the food barn of South Sumatra. However, some problems such as pyrite or FeS_2, peat, soil acidity, salinity, and others threaten the productivity of tidal swamplands **(Wildayana and Armanto, 2018)**. Furthermore, the farmers in tidal swamplands still cultivate rice using chemicals such as pesticides, insecticides, and fungicides excessively, and intensively **(Roche, 1994; Zahri et al., 2018)**. It was caused by the label of chemicals stating the chemicals will not reduce rice production. The most used pesticide by the farmers is pesticide containing high toxicity **(Amir et al., 2012)**. Some factors influencing the excess chemical use are behavior, perception, and lack of knowledge **(Jallow et al., 2017)**. The problems can be threats to the ecology of tidal swamplands.

Many studies from some countries such as Australia **(Cohen, 2007)**, Kenya **(Tsimbiri et al., 2015)**, and Indonesia **(Mariyono, Kuntariningsih and Kompas, 2018)** stated that ecology degradation and decreased farmers' health occurred because of the chemical use such as pesticide, fertilizer, and others. The state is supported by a phenomenon in which farmers still use chemicals in higher doses than recommended **(Chauhan and Singhal, 2006)**. The impacts of excess chemical uses in the long-term are environmental degradation, CO_2 emission, health problem, externality, and others **(Yuan et al., 2017; Zeng et al., 2017)**. Therefore, preventive action should be taken.

In terms of food safety, excess chemical use affects rice quality **(Hong-xing et al., 2017)**. Many chemical residues are found in rice **(Añasco et al., 2010)**. So the food safety of rice is still in doubt. The case was caused by sustainable agriculture practices that have not been implemented properly. Therefore, it is also important to note that agricultural practices or agriculture production systems must be eco-friendly **(Mishra, 2013)**. So that the rice produced by farmers obtains a worthy price and good quality according to food safety criteria. Sustainable agriculture practices can improve yield and farmers' income. The recent studies investigated socio-economic factors influencing sustainable agriculture practices such as age, household size, education, farm size, and others **(Prokopy et al., 2008; Tey et al., 2014; Dessart, Barreiro-Hurlé and Bavel, 2019)**.

Based on the problems above, a study regarding the sustainability of rice farming practices in tidal swamplands is a concern to monitor the tidal swamplands' environment. One of the tools to assess the sustainability of rice farming practices is a rice check. The rice check first appeared in 1986 by the Department of Agriculture New South Wales, Australia. The goal is to improve the quantity and quality of rice production and as a recommendation and learning platform for farmers. The rice check helped the farmers to figure out when the crops must be provided fertilizer, chemicals, and others so that the chemicals do not damage the environment and agricultural resources in Australia. Furthermore, The Australia rice check includes the allowed pesticides, appropriate application methods of chemicals, and the proper doses accord to the recommendation. The document educated the Australian farmers not to use the chemical excessively. The Australia rice check is targeted to achieve rice production 6 to 8 $t.ha^{-1}$. **Singh, Brennan and Lacy (2007)** explained that the Australia rice check changed Australian farmers' behavior and agriculture practices. The Australian farmers also got the benefit through increasing rice production.

In Malaysia, the Malaysian rice check was introduced in 2002 by the Department of Agriculture Malaysia. The farmers were expected to pay attention to their rice farm. The chemical uses were regulated on the document as well. Furthermore, the sustainability indicator of rice farming practices in Vietnam was issued by The Ministry of Agriculture and Rural Development Vietnam in 2008. The document was well known as Vietnam Good Agricultural Practice (Viet GAP). The indicators emphasized chemical use, post-harvest process, and marketing of rice.

According to **Tilman et al. (2002)**, the sustainability of agricultural production practices needs to be assessed for food security and safety strategy. Thus, this study aimed to assess and identify factors influencing the sustainability of rice farming practices in tidal swamplands. Furthermore, research on the sustainability assessment of rice farming practices in tidal swamplands does not exist yet. So this study is necessary to be carried out.

Scientific hypothesis

This study had two hypotheses:

1. The rice farming practices are sustainable in tidal swamplands.
2. The socio-economic factors such as age, education, household size, farm size, and farming experience influence the sustainability of rice farming practices.

MATERIAL AND METHODOLOGY

Study area

This study was conducted in Muara Telang, South Sumatra, Indonesia (Figure 1). The location was considered because it is the biggest area of tidal swampland's agriculture for rice production. The total area of Muara Telang is 341.57 km^2. The location is also a production center of tidal swampland rice in South Sumatra Province. Muara Telang District is a tidal swamp area with an altitude of 0.5 m to 2.25 m above sea level. The average monthly temperature is 27 °C. The relative humidity is 87%. The average annual rainfall is approximately 2,400 mm. The region has a topography with a land slope of less than 3%. It is very potential for the development area of food crops, particularly rice.

Data Collection

The primary data were collected through face-to-face interviews with the farmers. The 150 farmers were chosen by a simple random sampling technique since the area is similarly affected by tidal water. Some questions regarding the farmers' socioeconomic situation were addressed, i.e., age, education, household size, farm size, and farming experience. This study also covered several agricultural input use information such as seed, fertilizer (nitrogen, phosphor, and potassium), and chemical (herbicide, pesticide, and fungicide).

Figure 1 Tidal swamplands in Muara Telang, South Sumatra, Indonesia.

Table 1 Sustainability assessment worksheet for rice farming practices.

Indicators of Rice Farming Practices	Amount or Frequency	Max Score	Min Score
Seedling (Rice check 1,2,3)			
Planting time	Not Following = 0, Oct-Dec = 1	1	0
Variety	Not Following = 0, Mekongga, Ciherang, Inpari 30 Ciherang Sub 1 = 1	1	0
Amount of seeds (80 $kg.ha^{-1}$)	<80 $kg.ha^{-1}$ = 0, 80 $kg.ha^{-1}$ = 1, >80 $kg.ha^{-1}$ = -1	1	-1
Land preparation (Rice check 4,6)			
Depth (20 – 40 cm)	Not Following = 0, within 20 – 40 cm = 1	1	0
Planting distance (20 × 20cm)	Not Following = 0, within 20 × 20 cm = 1	1	0
Fertilizer (Rice check 7)			
Timing 1st application (15 – 20 days after planting)	Not Following = 0, within 15 – 20 days = 1	1	0
2nd application (35 – 40 days after planting)	Not Following = 0, within 35 – 40 days =1	1	0
3rd application (50 – 55 days after planting)	Not Following = 0, within 50 – 55 days =1	1	0
Amount of N fertilizer (200 $kg.ha^{-1}$)	<200 $kg.ha^{-1}$ = 0, 200 $kg.ha^{-1}$ = 1, >200 $kg.ha^{-1}$ = -1	1	-1
Amount of P fertilizer (75 $kg.ha^{-1}$)	<75 $kg.ha^{-1}$ = 0, 75 $kg.ha^{-1}$= 1, >75 $kg.ha^{-1}$ = -1	1	-1
Amount of K fertilizer (50 $kg.ha^{-1}$)	<50 $kg.ha^{-1}$ = 0, 50 $kg.ha^{-1}$ = 1, >50 $kg.ha^{-1}$ = -1	1	-1
Organic fertilizer (Livestock dung, etc.)	No = 0, Used =1	1	0
Weed Control (Rice Check 9)			
Frequency (herbicide use)	2 times = 0, 0 – 1 = 1, over 3 times = -1	1	-1
Amount of herbicide (5 $L.ha^{-1}$)	<5 $L.ha^{-1}$ = 0, 5 $L.ha^{-1}$ = 1, >5 $L.ha^{-1}$ = -1	1	-1
Organic herbicide	No = 0, Used = 1	1	0
Pulling up weeds by hands	No = 0, Yes =1	1	0
Pest Control (Rice Check 10)			
Frequency (insecticide use)	2 times = 0, 0 – 1 time= 1, over 3 times = -1	1	-1
Amount of insecticide (5 $L.ha^{-1}$)	<5 $L.ha^{-1}$ = 0, 5 $L.ha^{-1}$ = 1, >5 $L.ha^{-1}$ = -1	1	-1
Organic insecticide	No = 0, Used = 1	1	0
Disease Control (Rice Check 10)			
Frequency (fungicide use)	2 times = 0, 0 – 1 time= 1, over 3 times = -1	1	-1
Amount of fungicide (5 $L.ha^{-1}$)	<5 $L.ha^{-1}$ = 0, 5 $L.ha^{-1}$= 1, >5 $L.ha^{-1}$ = -1	1	-1
Organic fungicide	No = 0, Used = 1	1	0
Water Management (Rice Check 8,12,13)			
Following irrigate and drainage schedule	Yes = 0, No = 1	1	0
Observing depth of water	Yes = 0, No = 1	1	0
Total Score		24	-10

Table 2 Sustainability index of rice farming practices.

Sustainability index value (%)	Category
>70.0	Sustainable
60.1 – 70.0	Somewhat sustainable
50.1 – 60.0	Intermediate sustainable
40.1 – 50.0	Possibly quite unsustainable
20.0 – 40.0	Possibly unsustainable
<20.0	Possibly very unsustainable

The Indonesia rice check was employed as indicators to assess the sustainability of rice farming practices in tidal swamplands. The rice check is a guideline document of sustainable rice farming practices. There were 24 rice farming practices used as indicators. The practices and indicators have been modified to be suitable for tidal swamplands. The sustainability assessment worksheet for rice farming practices was provided as a questionnaire in Table 1. The Indonesia rice check was presented by The Ministry of Agriculture Indonesia in 2017. It referred to the Australia rice check. It emphasized farmers to achieve optimal rice production. The document is a result of the agreement among researchers, farmers, and agricultural extension officers based on 3 aspects of sustainability which are social, economic, and ecology. By adopting the rice check, The Indonesia Government expected the farmers had adopted the best technology to achieve optimal and sustainable rice production **(The Ministry of Agriculture, 2017)**.

Data Analysis

The sustainability indexing of rice farming practices referred to **Taylor et al. (1993)**. The farmers applying practices based on the sustainability assessment worksheet or questionnaire would be given a score of 1. However, the farmers who do not apply practices based on the questionnaire would be given a score of 0 or negative. The sustainability index value of rice farming practices was built on a range of 0 to 100%. It was created to obtain tangible results and facilitate the comparison of numerical scales among the rice farmers.

Then, the values were categorized according to the sustainability index. The six categories for the sustainability index of rice farming practices are in Table 2.

Furthermore, regression analysis with the Tobit model was applied to identify the factors influencing the sustainability of rice farming practices. The Tobit model was applied because the model can estimate and accommodate bias on censored data. The data structure of the sustainability index of rice farming practices or dependent variable (Y) is known as censored data because there were some values of zero (0) on observation data or index. The independent variables (X) used were the socio-economic characteristics of the farmer. **Igbokwe (2000)** reported that the socio-economic characteristics of farmers influenced rice farming practices. Therefore, the independent variables used in this study were age (X_1), education (X_2), household size (X_3), farm size (X_4), and farming experience (X_5). A regression equation with the Tobit model created in this study was:

$$
\begin{aligned}
Y_i^* &= \alpha + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + u_i \\
Y_i &= Y^* \text{ if } Y^* > 0 \\
Y_i &= 0 \text{ if } Y^* \leq 0 \qquad (1)
\end{aligned}
$$

Where:
Y_i^* denotes the sustainability index of rice farming practices; α is the intercept of the model; $\beta_1 \ldots \beta_n$ (n = 1, 2, 3...) are estimated parameters; X_1, X_2, X_3, X_4, and X_5 represent age, education, household size, farm size, and farming experience respectively; u_i indicates an error term.

Statistical analysis

Two statistical analyses were used in this study. The descriptive statistics were performed in Microsoft Excel 2010. Furthermore, the data analysis for the parametric statistics which was regression analysis with the Tobit model was performed in STATA 15.1. The *p*-values used for this study were p <1%; 5% and 10%.

RESULTS AND DISCUSSION

Socio-economic characteristics and input uses of rice farmers in tidal swamplands

The socio-economic characteristics of rice farmers in Muara Telang can be seen in Table 3. The majority of farmers are still in productive age. Therefore, they are still able to cultivate rice and work on rice farms. The farmers' education in tidal swamplands is still low. The average farmers' formal education is to 7.72 years. It indicates that the farmers got an education in primary school only. The average household size is two or three people. A farmer's household usually consists of the farmer, his wife, and one child or two children (unmarried). However, some farmers have more than two children and the minority of them live alone since his wife passed away and his children married and moved to the city. Furthermore, the average farmers' farm size is 4.72 ha. The farmers got a grant which was 2 ha of rice farms from the government. However, some of them sold rice farms. Moreover, some of them have 8 ha or more. Consequently, some farmers have smaller rice farms. The average farming experience of farmers is over 20 years. Farming is the main job in Muara Telang. The farmers cultivated rice and worked in the rice farm or wetland before becoming migrants in the reclamation project of tidal swamplands in the 1970s.

This study found that excess agricultural input uses tidal swamplands (Table 4). The implication of the excess agricultural input uses is inefficient rice production in tidal swamplands **(Purba et al., 2020)**. The average seed use was 85.82 kg.ha^{-1}. The case was occurred due to the cultivation system in tidal swamplands. The cultivation system in tidal swamplands is direct seed spreading. It is well-known as *sonor*. It is carried out without seedling. The practice is also followed by burning the land for land clearing. It is one of the cases that trigger unsustainability **(Wildayana, Armanto and Junedi, 2017)**. The impact of the practice was no regulated depth and planting distance. Besides, some farmers still used the local variety with limited technology. It made the sustainability score of rice farming practices low.

Table 3 Socio-economic characteristics of rice farmers.

Variables	Mean	Std. Deviation
Age (year)	44.74	11.45
Education (year)	7.72	3.25
Household size (individual)	2.56	1.21
Farm size (ha)	4.72	3.93
Farming experience (year)	24.25	11.34

Table 4 Input use of rice farmers.

Input	Mean	Std. Deviation
Seed ($kg.ha^{-1}$)	85.82	20.94
Nitrogen fertilizer ($kg.ha^{-1}$)	239.09	120.05
Phospor fertilizer ($kg.ha^{-1}$)	149.20	76.39
Potassium fertilizer ($kg.ha^{-1}$)	132.95	73.28
Herbicide ($L.ha^{-1}$)	6.54	3.18
Insecticide ($L.ha^{-1}$)	5.34	3.27
Fungicide ($L.ha^{-1}$)	5.64	2.77

Table 5 Result of rice farming practices sustainability assessment.

Measure	Value (%)
Mean	25.53
Median	26.14
Mode	27.27
Min – Max	0.00 – 72.73

This study found that the fertilizer and chemical uses in tidal swamplands were still high. Based on the government recommendation, the fertilizer uses for nitrogen, phosphor, and potassium should be 200 $kg.ha^{-1}$, 75 $kg.ha^{-1}$ and 50 $kg.ha^{-1}$ respectively **(The Ministry of Agriculture, 2017)**. The case is in line with **Han and Zhao (2009)** that the farmers in China also use a higher amount of fertilizer than is recommended. The chemical uses for pest and disease control such as herbicide, insecticide, and fungicide are also higher than the recommendation. The recommendation of chemical uses is 5 $L.ha^{-1}$ for herbicide, insecticide, and fungicide respectively. **Abhilash and Singh (2009)** reported that chemical uses in India were higher than the recommendation. The chemical uses would be possible to increase and would threaten the sustainability of tidal swamplands.

Assessment of rice farming practices sustainability in tidal swamplands

The average index of rice farming practices sustainability in tidal swamplands was 25.53%. It means rice farming practices were in the category of possibly unsustainable. It occurred because some farmers indeed carried out sustainable agriculture practice but only the easy practices such as pulling up weeds by hands, the timing of fertilizer application, and others. The farmers disregarded the important practices in sustainable agriculture like the amount of fertilizer and chemicals **(Mishra et al., 2018)**. The maximum index was 72.73. Despite there was a farmer in the category of sustainable, no farmer has a perfect performance in sustainable agriculture practices with a score of 100% (Table 5).

Furthermore, over 50% of the farmers were in the category of possibly unsustainable. Moreover, 47 rice farmers (31.33%) were in the worst category, namely possibly very unsustainable. Then, 23 rice farmers (15.33%) had a sustainability index in the category of possibly quite unsustainable. There was one farmer in the category of intermediate sustainable, somewhat sustainable, and sustainable (Figure 2). The farmer in the sustainable category can be a role model for farmer-to-farmer learning so that the other farmers would adopt and apply sustainable agriculture practices. Farmer-to-farmer learning can improve social capital, income, and technology adoption **(Taweekul et al., 2010)**. The agricultural extension officers also are needed to enhance farmers' knowledge related to sustainable farming practices. The agricultural extension role is expected can improve the adoption of sustainable agriculture practices for the farmers **(Hosseini, Mohammadi and Mirdamadi, 2011; Anang, Bäckman and Sipiläinen, 2020)**.

Most of the farmers were in the possibly unsustainable category. The finding is supported by some studies in Malaysia. The studies explained that rice farming practices were possibly unsustainable in granary areas of Malaysia **(Mohamed et al., 2016a)** and Kelantan **(Terano et al., 2015)**. The majority of farmers were unsustainable for rice farming practices with a score of less than 40%. A study by **Roy, Chan and Rainis (2014)** showed that more than 50% of the rice farming were unsustainable in Bangladesh. The main cause of the case is excessive and intensively chemical use.

Factors influencing the sustainability of rice farming practices in tidal swamplands

According to **Veall and Zimmermann (1996)**, if the value of Pseudo R^2 is adequate (>50%), the Tobit model is fit. The value of Pseudo R^2 in this study was 69%. The result of the regression analysis with the Tobit model is provided in Table 6. The intercepts of the model were negative. It indicated the sustainability of rice farming practices in tidal swamplands is unsustainable. The result was supported by the previous finding revealing the sustainability of rice farming practices in tidal swamplands is possibly unsustainable with the score index range of 20 to 40%. Age had a positive value. However, it does not significantly influence the sustainability of rice farming practices in tidal swamplands. **Mohamed et al. (2016b)** also declared that age is not a determinant factor in the sustainability of rice farming practices in Malaysia.

Education was positive and significantly affected the sustainability of rice farming practices in tidal swamplands. It occurred since some farmers began to aware of the environmental issue and sustainability **(Francis and Porter, 2011)**.

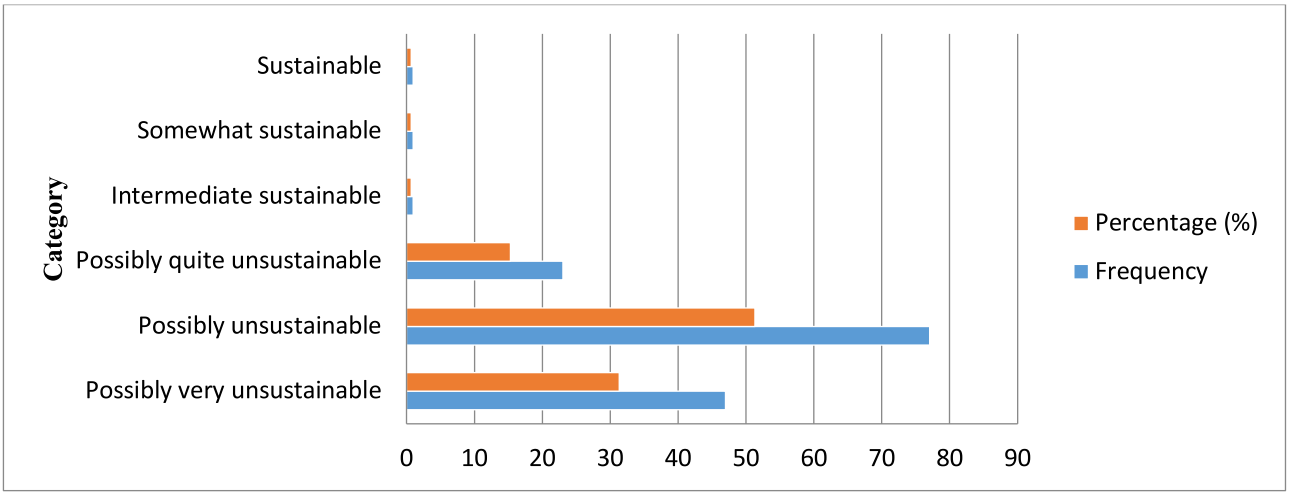

Figure 2 Categorization of the farmer sustainability index.

Table 6 Result of regression analysis with Tobit model.

Variables	Coefficient	Std. Error	t-stat	*p*
Constant	-5.14	1.87	-2.75	0.01**
Age	0.09	0.60	0.15	0.39
Education	1.70	0.20	8.50	0.00***
Household size	4.59	0.58	7.91	0.00***
Farm size	0.05	0.19	0.26	0.385
Farming experience	-0.28	0.15	-1.87	0.070*
Pseudo R^2			0.69	
p >Chi-square			0.00	

Note: ***= Significant at p <0.01; **= Significant at p <0.05; *= Significant at p <0.10.

The farmers got information from television or social media regarding sustainable agriculture. Currently, the role of electronic media is important to build the capacity of farmers **(Zeweld et al., 2017)**.

It is such an informal education that can improve the farmers' knowledge regarding sustainable agriculture. Education significantly influenced sustainable agriculture practices in Nigeria **(Omoare and Oyediran, 2020)**, Vietnam **(Thanh and Yapwattanaphun, 2015),** and the USA **(D'Souza, Cyphers and Phipps, 1993)**.

Furthermore, household size had a significant value on the sustainability of rice farming practices in tidal swamplands. The household size significantly influenced sustainable agriculture practices in the Philippines **(Mariano, Villano and Fleming, 2012)** and Ethiopia **(Kassie et al., 2009)**. The household size in agriculture is related to labor. Labor availability is important in sustainable agriculture **(Teklewold, Kassie and Shiferaw, 2013)**. The rice farmers in tidal swamplands employed family labor on the rice farm. The case occurred because sustainable agriculture required more labor than conventional agriculture **(Rigby and Cáceres, 2001)**. The most of inputs used for rice farms with sustainable farming practices must be made by own. Economically, the farmers can save some money to pay hired laborers if the farmers employed the family laborers. It is a reason why household size influences the sustainability of rice farming practices. However, the current case that occurred in the tidal swampland is the labor forces move to an urban area. The labor forces seek a job in the city as construction laborers or others. The decreasing force of labor in agriculture would threaten rural development **(Peng, Tang and Zou, 2009)**.

The other finding obtained that farm size did not influence the sustainability of rice farming practices in tidal swamplands. The tidal swamplands owned by farmers are fragmented. Therefore, the farmers are tough to manage and maintain their rice farms sustainably. The other reason is if a farmer carried out sustainable agriculture practices but the surrounding farmers did not; the surrounding farmers' chemical will pollute the rice farm with sustainable agriculture practices. This finding is also in line with **Terano et al. (2015)** and **Mohamed et al. (2016b)** that farm size did not affect the sustainability of rice farming practices significantly in Malaysia.

The farming experience negatively influences the sustainability of rice farming practices in tidal swamplands. The farming experience had a negative value on the sustainable agriculture practices of farmers in Bangladesh **(Ghosh and Hasan, 2013)** and Nigeria **(Oyewole and Sennuga, 2020)**. The experienced farmers were not willing to change their rice farming practices. They thought that sustainable rice farming practices are difficult and spend much of their time. On the other hand, they could buy the agricultural input without making it by themselves. It is required a way to change their paradigm to achieve sustainable agriculture. The ways are through training, field school, empowerment program, or others **(Berg et al., 2020)**.

CONCLUSION

This study concluded that rice farming practices in tidal swamplands were unsustainable. The majority of farmers had an average sustainability index of 25.53%. It indicated that rice farming practices in tidal swamplands were possibly unsustainable. The factors affecting the sustainability of rice farming practices in tidal swamplands were education and household size. In terms of policy recommendations, farmer-to-farmer learning and extension are considered to encourage and educate the farmers to implement sustainable agriculture practices. Also, an empowerment program for the young generation in tidal swamplands must be considered to prevent labor movement from the agriculture sector in the rural area to the industry sector in the urban area.

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The authors declare no conflict of interest.

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