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Analysis of Chemical Soil Properties and Social Economic Study of Swampland Rice Productivity

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ABSTRACT

Soil characteristics are a crucial matter in relation torice production in a swampland area. A study on chemical soil characteristics and economics of swampland rice production was carried out at a subdistrict of Rambutan and Banyuasin 1, Banyuasin, South Sumatera. Evaluation of soil organic matter in both locations foundcarbon content in Rambutan and Banyuasinto bemedium to high and medium to very high, respectively. In respect to nitrogen content, Rambutan had very low to medium, while Banyuasin 1 fell into the low to medium categories. Based on the average C/N ratio, both locations were considered to have a high accumulation of organic matter in the soil. In regard to macronutrient content, especially P and K, Rambutan and Banyuasin 1 fell into the low to medium category for P and low for K. Cost analysis of swampland rice production in both locations revealed the production processto be economically feasible. Linear regression analysis among pertinent factors in production improvement presented the positive impacts on rice productivity to be derived from Amount of planted seeds, phosphate fertilizer, return of straw to soil/organic matter and knowledge of the recommended fertilizer dosage.

Keywords: **Swampland rice production, soil chemical characteristics, cost analysis, regression equation**

INTRODUCTION

A freshwater swampland is naturally occurring soils or sediment formed between two rivers or lakes in a lowland. It is seasonally submerged and critically dependent upon rainwater and seasonal flooding to maintain natural water level fluctuation (Dodds *et al*. 2019). In Indonesia, the swampland area covers 34.12 million ha and is mostly located in Sumatera, Kalimantan and West Papua. Of this area, 25.2 million ha are non-tidal swamps while around 8.92 million ha are tidal swamps. According to records, the area of freshwater swampland utilised for agricultural activities is 7.52 million ha with the breakdown being 5.12 million ha for flooded/paddy rice, 1.47 million ha for horticulture and 0.93 million ha for perennial crops (Sulaiman *et al.* 2019). In Sumatera island, the largest swamp land area of 2.98 million ha is located in South Sumatera Province, of which only 368,690 ha have been utilised for rice which is cultivated in 70,908 ha of shallow swamp land, 129,103 ha in mid-swamp land and 168,670 ha in deep swamp land (Muhakka *et al.* 2019).

In many parts of the world, most swamplands do not actually function as an ideal land resource for agriculture. According to Susilawati *et al.*(2017), low optimisation of swamp land is due to its physical condition, mainly its fragile nature. Swamplands pose several obstacles to cultivation. These are suboptimal physical and chemical conditions with high acidity and erratic water logging and flooding in the rainy season withdrought in the dry season. Wetlands are also characterised by high concentrations of toxic elements such as iron (Fe), aluminium (Al), sulphur (S) and sodium (Na). Nutrient deficiency has also been reported, especially phosphorus (P), potassium (K), zinc (Zn) copper (Cu) and boron (B). Further, biological problems of a high level of weeds, pests and diseases are also present (Sulaiman *et al*. 2019). The continuing scarcity of arable land in Indonesia has led to wetlands being utilised as productive agricultural lands. Swamplands do offer advantages for agriculture such as abundant water, resilience to seasonal drought and support for longer cropping periods. Swamplands have great potential for an integrated farming system (food crops, estate crops and animal husbandry) (Wildayana and Armanto 2017). Based on these considerations, agriculture in swamplands should be directed to sustainability in terms of production and being environment friendly. The approaches to develop sustainable production should involve natural resources mapping, land suitability to crops, soil amelioration and improvement of the irrigation network, development of specific technology, empowerment of local communities and development of infrastructure and agribusiness (Ar-Riza and Alkasuma 2008).

Information related to soil characteristics and suitable crops in specific wetland locations are important considerations in the development of sustainable wetland productive areas. The province of South Sumatera has quite a large swampland area and several parts have been cultivated, mainly with rice/paddy (Purbiyanti *et al*. 2019). Rice cultivation starts in the dry season, when the submerged land is still under shallow conditions with the vegetative growth and harvest period occurring in the rainy season. Various varieties are observed to be cultivated in these areas, from local to improved varieties indicating farmers do select adaptive varieties (Irmawati *et al.* 2015; Kodir *et al.* 2016). Improvements in rice productivity in swampland areas could also be conducted through the implementation of specific procedures such as nutrient management. Proper evaluation of soil chemical properties is needed to determine level of soil fertility, nutrient status and other pertinent features that might directly or indirectly involve the availability of macro and micro nutrients and absorption capacity of the rice plant to the required nutrients. This paper elucidates the chemical soil properties of swampland in Banyuasin, South Sumatera in relation to rice productivity in the area. This information should serve as the basis for recommendations in nutrient management, a vital component of sustainable production strategy to improve and sustain rice production. An economic study of existing rice production systems was also carried out to obtain a socio-economic overview of swampland rice production in Banyuasin, South Sumatera.

MATERIALS AND METHODS

The study was carried out at the Subdistrict of Rambutan and Banyuasin 1, Banyuasin, South Sumatera (02°43'48"- 03°09'00" Sand 104°10'48" - 105°07'12" E)in 2012. The acreage of the freshwater swamplands was recorded as 624.55 km^2 in Rambutan, and 701.38 km^2 on Banyuasin 1. Administratively, the Banyuasin District is bounded by Muara Jambi Regency, Jambi Province and Bangka Straits in the North, East by Ogan Komering Ilir Regency, West by Musi Banyuasin Regency and South by Ogan Komering Ilir Regency, Palembang City, and Muara Enim Regency.

Collection of Soil Samples and Analysis

Each sub district of the study site was divided into six locations based on availability of cultivated swamplands. In each location, a composite soil sample was taken using a 5- point sampling technique from a depth of ±20 cm from moist to wet soil conditions. Subsequently, the soil samples were stirred evenly in a plastic bucket,cleared of roots, plants parts and animal debris. The soil samples were then brought to the laboratory for further assessment.

The soil analysis was conducted at the laboratory of Soil and Agroclimate Research Center, Bogor, Indonesia. The soil analysis included (1) pH extracted by H_2O and 1 M KCl measured with the pH electrode; (2) C-organic, wet digestion of $K_2Cr_2O_7$ using Walkley and Black method; (3) total-N content with Kjeldahl method; (4) available-P extracted by Bray-1 and total-P extracted by HCl 25% measured with a spectrophotometer; and (5) total-K extracted by HCl 25% measured with a flame photometer. Soil analysis data describes the current nutrient status of the freshwater swampland of the targeted locations.

Economic Assessment of Rice Production

The budgetary technique used for cost and return analysis is the gross margin. In 1 ha, the gross margin (GM) is the difference between Total Revenue (TR) and Total Variable Costs (TVC), expressed through the equation : GM =TR – TVC, and NFI = GM – TFC

where,

TR = Total Revenue (IDR/ha)
TVC = Total Variable Cost (IDR/ha)
TFC= Total Fixed Cost (IDR/ha)
NFI = Net Farm Income (IDR/ha)

Total Revenue (TR) is derived from TR = ∑QyPy - ∑XiPxi

where

TR = Total Revenue
Qy = Qutput (kg/ha)
Py = Unit price of the output (N)
QyPy = Total revenue derived ha^{-1}
Xi = Quantity of the ith input ha^{-1}
Pxi = Price $unit^{-1}$ of the ith input ha^{-1}
XiPxi = Total cost associated with input ha^{-1}

The relationship between input and output was analysed using linear regression equation (Paltasingh and Goyari 2018), Y = a + bX,

where

Y = Revenue, production costs, farm income
a = Constant
b = Regression coefficient
X = Planting area
The significance of regression coefficient was carried out by F test with $\alpha = 5\%$

RESULTS AND DISCUSSION

Organic Matter Content and Soil Acidity

Organic matter content represented by C/N ratio and soil pH from the sites of Rambutan and Banyuasin 1 sub districts are presented in Table 1. Carbon content in the soil from Rambutan ranged from 2.21 to 5.61%, while in Banyuasin 1,it ranged from 2.31 to 8.42%. Nitrogen content in Rambutan varied from 0.08 to 0.41% and in Banyuasin 1, it was found to be 0.14 to 0.48%. Based on the study by Prabowo and Subantoro (2008),the carbon content in Rambutan was categorised as medium to high, while in Banyuasin 1, it was categorised as medium to very high. In regard to nitrogen content, Rambutan was classified as very low to medium, while Banyuasin 1 fell into low to medium (Rusdiana and Lubis 2012). Based on the average C/N ratio, both locations were considered to have a high accumulation of organic matter in the soil (Rahmi and Biantary 2014).

TABLE 1
C/N ratio and pH of soil samples taken from six location points from sub-districts of Rambutan and Banyuasin 1, South Sumatera

Location	Organic matter (%)			pH (1:5)	
	C	N	C/N	H_2O	KCl
Rambutan					
1	4.58	0.24	19	3.73	3.45
2	2.52	0.09	26	4.04	3.75
3	3.80	0.23	17	3.61	3.32
4	5.62	0.08	27	3.68	3.37
5	2.21	0.41	14	3.83	3.55
6	2.76	0.12	22	3.81	3.44
Average	3.58	0.20	20.83	3.78	3.48
Banyuasin 1					
1	8.42	0.48	18	3.42	3.40
2	5.26	0.27	19	3.51	3.28
3	3.20	0.36	15	3.90	3.45
4	5.24	0.14	23	4.12	3.49
5	2.31	0.29	18	3.94	3.59
6	7.94	0.31	25	3.55	3.38
Average	5.40	0.31	19.67	3.74	3.43

Source : Processed primary data (2022)

Soil pH at Rambutan ranged from 3.61 to 4.04 when extracted using H_2O and 3.32 to 3.75 when extracted using KCl. Meanwhile in Banyuasin 1, soil pH when extracted with H_2O was recorded at 3.55 to 4.12 and 0.28 to 3.59 when extracted with KCI (Handayani *et al.* 2021).The soil pH range at both locations was considered low (very acidic) according to Prabowo and Subantoro (2008). Freshwater swampland as well as swampy tidal and peatland have high acidity with pH ranging from 2.9 - 3.9 when extracted with H_2O and 2.23 - 3.07 when extracted with KCI (Handayani and Maswar 2019). The acidic conditions are due to a high concentration of H^+ in the soil as a result of oxidation of the pyrite compound which is rich in iron, aluminum and sulphur (Stevanus *et al.* 2017; Priatmadi and Haris 2009). Several studies have indicated that high Fe^{2+} solubility, Al and S in soil solution might be toxic to plants (Shamshuddin *et al.* 2016; Elisa *et al.* 2016), restricting root growth and resulting in a stunted root system (Zhang *et al.* 2018), thus decreasing the capability of nutrient uptake (Marashi 2018).

Another adverse characteristics of acidic soils is the low availability of cations, especially P and K. These cations are known as macro nutrients essentially needed by plants (Han *et al.* 2019). The limited availability of these macro nutrients and toxicity effect of soluble Fe, Al and S have been reported to be the main obstacles to rice productivity in swampy acidic areas (Rusdiansyah and Saleh 2017; Halim *et al.* 2018). According to Masulili e*t al.* (2016), the effect of Fe, Al and S toxicity and the limited availability of macro nutrients in swampy acidic soils might decrease rice production from 30-100% depending on the variety and level of poisoning.

Phosphorus and Potassium Content

The P and K content of soil samples from the six studied sites of Rambutan and Banyuasin 1 sub districts are presented in Table 2. Total P content of Rambutan using HCl 25% method was observed at 11 – 66 mg/100 g soil and 3 – 25.01 mg/kg using Bray 1 methods. In average, the sub district of Rambutan hada total P of 23 mg/100 g soil (HCl method) and 11.08 using Bray 1 (Handayani *et al*. 2021), categorised as low to medium according to Bai *et al.* (2013) and Melese *et al.* (2015). The sub districts also have an average K_2O content of 11.67 mg/100 g soil, classified as low based on the study of Prabowo and Subantoro (2008). As in the case of Rambutan sub district, total P content at Banyuasin 1 sub district was observed at 29.17 mg/100 g soil and 25.29 mg/kg using HCl 25% and Bray1 methods, respectively, Meanwhile, K content in these areas averaged 13.17 mg/100 g soil. Therefore soil samples collected from Banyuasin 1 sub district were classified as low to medium for P content and low for K content (Bai *et al.* 2013; Melese *et al.* 2015; Prabowo and Subantoro 2008).

TABLE 2

Total P and K from soil samples taken from Rambutan and Banyuasin 1 sub districts

Location	Total P and K (HCl 25%) (mg/100 g soil)		P-available P_2O_5 (Bray 1) (mg/kg)
	P_2O_5	K_2O	
Rambutan			
1	11	14	5.75
2	12	10	3.51
3	14	11	25.01
4	12	12	9.79
5	66	12	19.44
6	23	11	3.00
Average	23.00	11.67	11.08
Banyuasin 1			
1	62	19	56.16
2	7	9	1.92
3	9	11	4.62
4	8	11	2.73
5	30	18	26.66
6	59	11	59.65
Average	29.17	13.17	25.29

Source : Processed primary data (2022)

The low level of P and K content in the soil of Rambutan and Banyuasin 1 sub-districts could be the limiting factors in increasing rice productivity. Phosphorus (P) or phosphate exists in the soil in the form of calcium phosphate, iron phosphate, aluminum phosphate and organic phosphate, etc. In swamp areas, rice plants are grown mostly in water-logged conditions in almost all planting cycles. The water logged conditions induce a reduction in soil quality (Nishigaki *et al.* 2019). When the soil pH is neutral, ferric phosphate is hydrolysed to form ferrous phosphate and the solubility of phosphorus is increased (Penn and Camberato 2019). In acidic soils, however, the process of Fe-phosphate hydrolysis is inhibited and the concentration of Fe^{2+} increases. These conditions might lead to reduced phosphate released into the soil solution, with less being available for plant uptake (Amirrullah and Prabowo 2017).

As in the case of phosphate, the availability of potassium (K) is affected by soil pH under acidic soil conditions. Acidification of rhizosphere can dissolve several low soluble macronutrients and micronutrients. H^+ is released from roots when plants take up lower anions than cations. This can promote the transformation of non-exchangeable K to exchangeable K and increase K^+ leaching in submerged conditions (Han *et al.* 2019). The loss of K from the rhizosphere due to leaching could be very high, especially in soils with porous drainage. The loss of K due to leaching might be as much as the amount of K in the harvested plants or equal to 25 kg per hectare or even more (Mendes *et al.* 2016).

Social Economic Characteristics of Swamp Rice Farmers

Surveys conducted on two study sites revealed the characteristics of respondents representing the swampland rice farmers. The data showed that farmers aged more than 45 yearswere more dominant and comprised 51.7% of all swamp rice farmers. In terms of formal education most farmers had only only elementary education followed by junior high school. Only 2% of the farmers had a bachelor‘s degree. Slightly more than two-thirds (67.2%) of the farmers had a family size of more than 5 members. From these figures, we can conclude that swamp rice farmers in Rambutan and Banyuasin 1 generally had less formal education and were of less productive age but had to financially support many family members.

The lack of young farmers in the rice production area indicates that productive-aged labour was less interested in the business of agriculture. A less formal education of the farmers could also be a constraint to technology adoption for improvements in rice production. Another constraining factor is that a large family size leads to financial support of family members which poses a limitation to the farmer’s ability to save or even access capital. This scenario of the farming community in the swampland area should become an important consideration in the dissemination of specific technology to the respektive areas. According to Alam (2015) and Sjakir *et al*. (2015), age, education, and the distance of agricultural land to the source of information technology are the key determinants of the adoptiveability of farmers to government programs in accelerating productivity of swamp rice cultivation.

In the case of production cost analysis of the farmers, the annual expenses for rice production in the swamp area was around 4.2 to 4.8 million IDR per hectare with the revenue reaching 12.2 to 17.7 million IDR (Table 3). Based on the annual scheme, farmers still get a net income of around 8.05 to 12.87 million IDR from a total production of 3,452 and 4,542 kg ha^{-1} in Banyuasin 1 and Rambutan sub-districts, respectively. The B/C ratio for swamp rice production was observed to be 1.9 in Banyuasin 1 and 2.65 in Rambutan, indicating an economically feasible production process (Suparwoto 2019). The profit margin of farming was derived from the higher ceiling price of 6,176 IDR kg^{-1} milled grains.

Agro-climate factors, biological (weed problems, pests, and diseases), agro-inputs and the cost of procuring agro-inputs, lack of credit facilities, and poor price incentives were found to be the factors affecting improvement in rice production in freshwater swampland areas. Linear regression analysis conducted on these factors revealed that positive impacts on rice productivity were derived from Amount of planted seeds (Seed), phosphate fertilizer (P_2O_5), the return of straw to soil/organic matter (Straw) and knowledge of the recommended fertilizer dosage (Dosage). The negative coefficient resulted from land area (Area), choice of variety (Variety), dose of nitrogen fertilizer(N), potassium fertilizer (K_2O), education level (Edu), farmers' preference for compound fertilizer (Com-fer), climate disturbance (Climate) and plant disease bearing pests (Pest).

TABLE 3
Financial analysis of rice farming based on research locations

Description	Distr cts		Average
	Banyuasin I	Rambutan	
Production cost (IDR/hectare)	1,519,678	1,315,775	1,417,726
-Seed	387,705	389,537	388,621
-fertilizer	717,829	711,772	714,801
-Pesticide	414,144	214,466	314,305
Hired labour (IDR/hectare)	2,457,878	2,667,778	2,562,828
Other costs (IDR/hectare)	266,846	876,321	571,583
Total production costs	4,244,402	4,859,873	4,552,138
Qutput (kg/ hectare)	3,452	4,542	3,997
Unit price of the output (N)	3,562	3,905	3,733
Revenue (IDR/hectare)	12,296,204	17,738,899	15,017,551
Income (IDR/hectare)	8,051,802	12,879,025	10,465,413
B/C ratio	1.90	2.65	2.30
Description	Favorable	Favorable	Favorable

Source : Processed primary data (2022)

The regression equation obtained is as follows:
Y = 3,573.3 -517.2 Area + 16.2 Seeds - 667.6 Variety - 1.4 N + 8.5 P_2O_5-16 K_2O - 76.5 Edu - 305 Com-fer + 832.8 Dosage + 252 Straw- 507.5 Climate - 69.2 Pest, with R^2 = 38.8%, F-count = 2.375 at α = 1.8%.
where

Y=Rice production
Area= Land area
Seeds = Amount of planted seeds
Variety= Impact of choice of existing variety
N = Nitrogen fertilizer
P_2O_5= Phosphate fertilizer
K_2O = Potassium fertilizer,
Edu = Education level of farmers
Com-fer = Compound fertilizer
Dosage= Knowledgeofrecommended fertilizer dosage
Straw = Return of straw to soil/organic matter
Climate= Climate disturbance
Pest = Pest and diseases

Based on the regression equation, rice productivity in the freshwater swampland could be improved through the addition of seeds, phosphate fertilizer, straw as organic matter, and increased knowledge on fertilizer recommendation. Improving capacity of farmers, reducing pesticide use, changing rice varieties and adapting to the effects of climate change were the factors that could be improved in the scale of farm management to increase productivity of rice cultivation. The increase in total planted seeds and straw return are dependant on the availability of resources. While the increase in phosphate fertilizer application could improve rice production and not potassium, though concentration of both nutrients was observed to be low in the studied area. Given the seconditions, improvement in rice productivity could be implemented through long and short term programs. Long term programs include the improvement of soil characteristics through the return of straw to the soil, increased farmer capacity and knowledge, including adapting to the effects of climate change, and government policy. While the short term program can be achieved through an increase in phosphate content in the soil. In increasing phosphate content, efficient and effective methods as well as the cost of new techniques of application should be thoroughly examined to ensure a significant increase not only in productivity, but farmers' income as well (Tashikalma *et al.* 2014).

The element P is a macronutrient needed by plants in large quantities but in smaller amounts compared to N, and K. Phosphate uptake by the rice plant through the root system ranges from 0.01 to 0.08%, and the optimal level of P in plants during vegetative growth ranges from 0.3 to 0.5% (Lan *et al.* 2012). The strategy to improve P content in swampland should involve various technological innovations. These includes the application of lime combined with organic fertilizer or other ameliorants (Azman *et al.* 2014), compost application (Barus 2012) or even phosphate fertilizers (Hubert 2018). The implication of these methods is that knowledge related to symptoms of nutrient deficiency and toxicity should be disseminated to farmers. It should include the standard fertilizer applications in specific locations, like dosage, time, application technique and type of fertilizers needed. Through these programs, farmer will learn how to manage fertilizer applications and other cultural practices based on their own production schedule (Arifin *et al.* 2018).

CONCLUSION

The carbon content in Rambutan was classified as medium to high, while in Banyuasin 1, it was medium to very high. With regard to nitrogen content, it was very low to medium in Rambutan, while it was low to medium in Banyuasin 1. Both locations also have almost similar soil acidity characteristics, with soil pH recorded inthe range of 3.48 – 3.78 in Rambutan and 3.43 – 3.74 in Banyuasin 1. Based on the average C/N ratio, both locations were considered to have high accumulation of organic matter in the soil. For P and K content, Rambutan fell in the low to medium category for P and low for K content. In the case of Banyuasin 1, P content was classified as low to medium and low for K. Cost analysis for swampland rice production in both locations revealed that the B/C ratio was 1.9 in Banyuasin 1 and 2.65 in Rambutan, indicating that the production process is economically feasible. Linear regression analysis among pertinent factors in production improvement showed that positive impacts on rice productivity could be achieved by a combination of (i) total seeds, (ii) phosphate fertilizer, (iii) return of straw to soil/organic matter, and (iv) knowledge of the recommended fertilizer dosage.

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