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Rice Fertilization Based on Soil Nutrient Status in Tidal Lowland Agriculture in Delta Saleh, South Sumatra, Indonesia

A. MADJID, MOMON SODIK IMANUDIN*, M. EDI ARMANTO, WARSITO, MAWARDI ABI SAHIL, VIRA HERLIANA, AND ELISA WILDAYANA

Faculty of Agriculture, Sriwijaya University, Inderalaya (30862), South Sumatra, Indonesia

ABSTRACT

The research was to look at the diversity of soil nutrient status that supports soil fertility to formulate fertilization recommendations for rice plants and to relate water status to available nutrient status on land with type C water inundation in two villages (Sri Katon and Damar Wulan), South Sumatera. Soil samples were taken in the two villages and brough to laboratory for determination of pH values (Electrometry), total-N (Kjeldahl), available-P (P-Bray 1), and available-K (Ammonium Acetate 1 N). Water table were measured in the field at the same time with soil sampling. The results showed he nutrient status in the two villages did not have significant differences in N, K contents, and pH. For the P contents, however, there were differences between Sri Katon village which had an average of 29.75 ppm (with high criteria) and Damar Wulan village (P value of 6. 30 ppm; very low). Therefore, the average fertilization in Sri Katon village needs small addition of urea fertilizer and P, except in the T1S5 point which needs 779.73 kg ha $^{-1}$ of SP-36. Meanwhile, in Damar Wulan Village, the addition of urea fertilizer (average of 51.63 kg ha^{-1}) and P (1110.74 kg ha-1 SP-36) are recommended. The K did not require the addition of fertilizer in all observation sites. Groundwater table observations indicated a potential contamination of sulfidic elements as a result of pyrite mineral oxidation when the groundwater table goes lower than the sulfidic layer. This further can cause N, P, K contents decrease.
Keywords: Tidal Lowland, Nutrient Status, Rice

INTRODUCTION

There are four types of tidal lowland, namely types A, B, C, and D. Type C is not inundated by tides, but the groundwater level is less than 50 cm (Nazemi *et al.* 2012). Imanudin *et al.* (2017) stated that tidal lowlands are an area whose productivity can be affected due to a problem of physical and chemical conditions, which include other water status and soil fertility, because each type of water status can have differences even though the land type is the same. However, South Sumatra has a large area of tidal lowland reclamation (more than 350.000 ha) was potentially suitable for rice cultivation (Armanto *et al*., 2013). Some areas of tidal lowland were good for rice production, where rice production was about 6-7 t ha^{-1} (Imanudin *et al*., 2024).

Micro water management is a way of managing water by controlling the water so that it can function to meet the water needs of plants, therefore Karolinoerita *et al.* (2021) stated that determining the success of planting and harvesting yields, micro-water management is very determining the level of success because there are wet months with high rainfall so that when the tide rises, thanks to this arrangement, water will not enter from the canals or culverts. During the dry season, the water table must be able to be diluted for the needs of cultivated plants so that it can become a sufficient supply of water for plant needs. Water management, especially macro, can aim to function more as drainage and irrigation channels or areas that can accommodate it, while micro or small water management can be applied at the farmer level (Septinar and Putri, 2018).

Corresponding author: Dr. Momon Sodik Imanuddin, Faculty of Agriculture, Sriwijaya University, Inderalaya (30862), South Sumatra, Indonesia; E-mail: momonsodikimanudin@fp.unsri.ac.id

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One way to increase N, P, and K nutrients in the soil can be done by applying Urea, SP-36, and KCl fertilizers. According to Suarjana *et al.*, (2015), fertilizer is an important factor in increasing the productivity of rice plants. Fertilization is an effort to increase soil fertility so that good conditions will be created for rice plants. In addition, the use of fertilizers that exceed the needs of rice plants can also cause a decrease in soil quality. Fertilization following the dose is the most important effort in increasing the production of rice plants. Bustami (2012) also stated that nutrient availability is very important to help the growth and development of rice plants. Nutrients N, P, and K are three nutrients whose availability is needed by rice plants. Sukmawati *et al.* (2021) added that the application of NPK fertilizer to rice plants can help the way rice photosynthesis works. This is due to the function of the N nutrient, which helps increase chlorophyll in rice leaves so that the process of photosynthesis will become more efficient. However groundwater depth determines the nutrient status in the root zone in swampy agriculture, especially nitrogen nutrient status. This macro element is very important for plant growth (Chen *et al*., 2024). In Indonesia, research on nutrient status in wetland areas that have groundwater level fluctuations is still rare and for this reason, research is needed.

Air Salek District is a sub-district in Banyuasin Regency, South Sumatra Province, which is a tidal land area that has the potential to be exploited for rice fields. According to Anisah *et al.* (2015) in Air Salek District. There must be efforts that can increase the utilization of tidal lowlands, especially in the diversification of recommendations developed by the government, which can have a real impact on increasing farmers' income. The purpose of this study was to examine the diversity of soil nutrient status that supports soil fertility in order to formulate recommendations for rice plant fertilization and to relate water status to available nutrient status on type C land that cannot be irrigated by tidal water.

METHODOLOGY

Research Sites

This research activity was conducted in August-October 2022 in the paddy fields of Sri Katon Village, which can be seen in Figure 1 and November 2022 - January 2023 in the paddy fields of Damar Wulan Village, which can be seen in Figure 2. Air Salek District, Banyuasin Regency, South Sumatra, and continued with soil analysis conducted at the Chemistry, Biology, and Soil Fertility Laboratory, Department of Soil, Faculty of Agriculture, Sriwijaya University.

Research methods

The method used in this study was a field survey using a map of 1: 10,000 scale. Soil sampling points were taken randomly, as well as observing groundwater levels and collecting rainfall data from the nearest climatology station. The implementation of this research was carried out in several stages, including initial preparation, field activities, analysis in the laboratory and data analysis.

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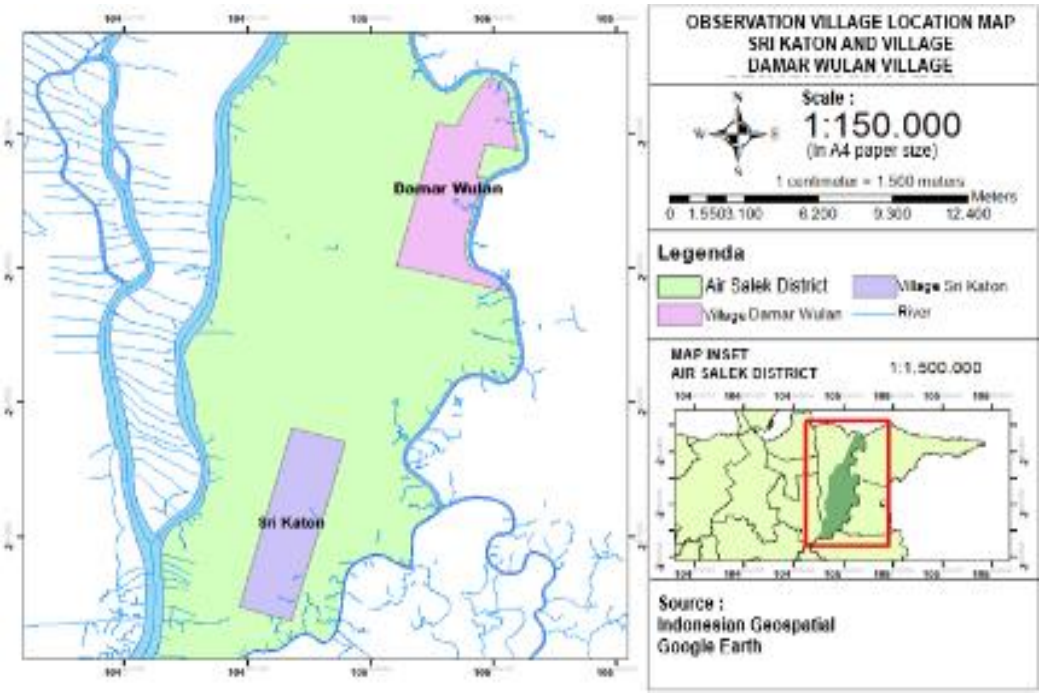

Figure 1. The research locations

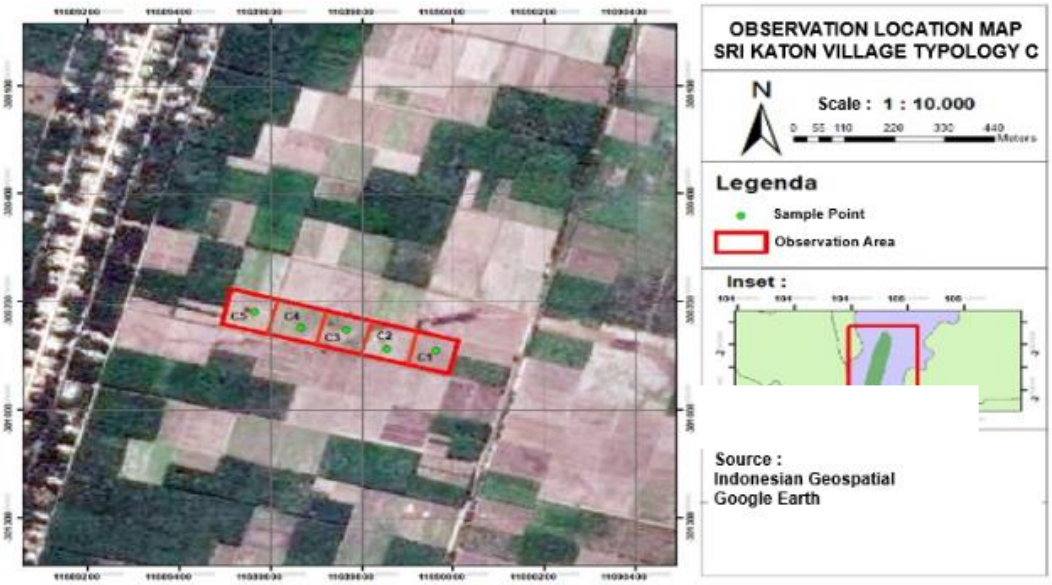

Figure 2. Sampling plots in Srikaton Village, Air Saleh Sub-district.

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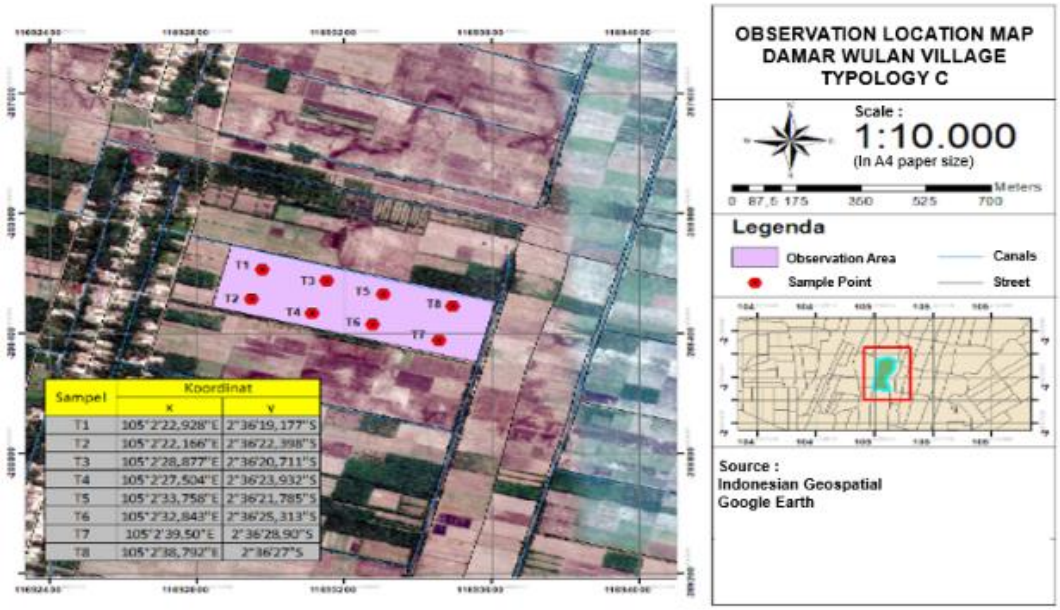

Figure 3. Sampling plots in Damar Wulan Village, Air Saleh Sub-district

Initial Data Collection

At this stage, data collection was carried out to support the research by interviewing rice farmers and observing the land based on the Types of land that have the potential to receive tidal irrigation

Observation and sampling were conducted in Sri Katon Village on an area of 10 ha and Damar Wulan Village with an area of 16 ha. The observation area is classified into the land class typology C (rainfed)

Sampling Points and Soil Sampling

In this study, two soil sampling locations were made. From one research location, 1 soil sample representing 2 ha was taken and from 1 soil sample 4 sampling points were taken randomly to take composite soil samples with 5 soil samples from Srikaton Village and eight soil samples from Damar Wulan Village, a total of 13 soil samples for each sample taken (Tabel 1). Then, the soil samples were analyzed in the laboratory. The soil samples taken are soil samples at a depth of 0-30 cm. Soil sampling was taken using auger while simultaneously drilling to check the groundwater level. Coordinate points for each soil sampling location are presented in Table 1.

Soil Analysis

The analysis included pH values (Electrometry), total-N (Kjeldahl), available-P (P-Bray 1), and available-K (Ammonium Acetate 1 N). These analyses were carried out at the Laboratory of Chemistry, Biology and Soil Fertility, Faculty of Agriculture, Sriwijaya University.

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Table 1. Soil sample codes and GPS coordinates of soil Sampling locations

Sample codes	Coordinates	
	X	Y
Katon Village		
T1S1	02˚43'05.62"S	105˚00'33.64"E
T1S2	02˚43'06.46"S	105˚00'36.26"E
T1S3	02˚43'07.41"S	105˚00'39.80"E
T1S4	02˚43'07.21"S	105˚00'42.39"E
T1S5	02˚43'08.98"S	105˚00'45.05"E
ıar Wulan Village		
T2S1	105°2'22.928"E	2°36'19.177"S
T2S2	105°2'22,166"E	2°36'22.398"S
T2S3	105°2'28.877"E	2°36'20.711"S
T2S4	105°2'27.504"E	2°36'23.932"S
T2S5	105°2'33.758"E	2°36'21.785"S
T2S6	105°2'32.843"E	2°36'25.313"S
T2S7	105°2'39.500"E	2°36'28.900"S
T2S8	105°2'38.792"E	2°36'27.000"S

Data Analysis

The data obtained were analyzed using a *matching system analysis*. This analysis was carried out using the LPT 1983 procedure for each supporting parameter of soil fertility observed. Based on its nutrient status, then calculations of fertilizer recommendations were carried out, including Urea, SP-36, and KCl. The data obtained is then written and submitted in a descriptive and tabulation manner as below (Table 2), especially the parameters pH, total-N, available-P, and available-K.

RESULTS AND DISCUSSION

Nutrient Status

The contents of total-N, available-P, K, and soil pH are shown in Table 3.

Table 2. Table of fertility assessment criteria (LPT, 1984)

Soil variables						
pH H_2O	<4.5 Very acid	4.5-5.5 Acid	5.5-6.5 Slightly acid	6.5-7.5 Neutral	7.6-8.5 Slightly alkaline	>8.5 Alkaline
	Very Low	Low	Medium	High	Very High	
Total-N	<0.10	0.10-0.20	0.21-0.50	0.51-0.75	>5.00	
Available-P	<10	10-15	16-25	26-35	>35	
Available-K	<0.1	0.1-0.2	0.3-0.5	0.6-1.0	>1.0	

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Table 3. Soil N, P, K contents and pH and their status

Sampling codes	Parameter			
	N (%)	P (ppm)	K (cmol kg^{-1})	pH
Sri Katon village				
T1S1	0.25 [M]	26.18 [H]	0.13 [L]	4.3 [VA]
T1S2	0.26 [M]	40.86 [VH]	0.38 [L]	4.59 [A]
T1S3	0.08 [VL]	35.26 [VH]	0.13 [L]	4.1 [VA]
T1S4	0.18 [M]	31.78 [H]	0.13 [L]	3.99 [VA]
T1S5	0.29 [M]	14.68 [L]	0.19 [L]	4.07 [VA]
Average	0.21 [M]	29.75 [H]	0.19 [L]	4.21 [VA]
Damar Wulan village				
T2S1	0.33 [M]	10.03 [VL]	12.07 [VL]	3.86 [VA]
T2S2	0.35 [M]	12.65 [VL]	12.07 [VL]	3.91 [VA]
T2S3	0.38 [M]	3.84 [VL]	15.09 [L]	3.90 [VA]
T2S4	0.40 [M]	6.36 [VL]	12.07 [VL]	3.72 [VA]
T2S5	0.26 [M]	3.34 [VL]	12.07 [VL]	3.55 [VA]
T2S6	0.34 [M]	2.88 [VL]	12.07 [VL]	3.15 [VA]
T2S7	0.35 [M]	8.57 [VL]	15.09 [L]	3.84 [VA]
T2S8	0.24 [M]	2.74 [VL]	12.07 [VL]	3.44 [VA]
Average	0.33 [M]	6.30 [VL]	12.83 [L]	3.67 [VA]

Notes: VA= very acid; A=acid; VL= very low; L=low; M = medium; H=height; VH= very high

In the overflow type C in Sri Katon Village, with a total-N content of 0.08% to 0.29%, with an average of 0.21%, which was moderate, the available-P value had a value of 14.68 ppm to 40.86 ppm, with an average of 29.75 ppm, which was a high criterion. Furthermore, available-K had a value of 0.13 cmol kg^{-1} to 0.38 cmol $kg^{-1,}$ with an average of 0.19 cmol kg^{-1} was low criteria. The pH value in Sri Katon Village had a value of 3.99 to 4.59, with an average of 4.21, which was very acidic.

In the overflow type C in Damar Wulan Village with a total N content of 0.24% to 0.40% with an average of 0.33% which is a moderate criterion, the available P value has a value of 2.74 ppm to 12.65 ppm with an average 6.30 ppm with very weak criteria. Furthermore, available K has a value of 12.07 cmol kg^{-1} to 15.09 cmol kg^{-1} with an average of 12.83 cmol kg^{-1} which is a low criterion. The pH value in Damar Wulan village was in the range of 3.15 to 3.91 with an average of 3.67 (very acid).

Sulfidic Depth

Field analysis for the depth of pyrite in the village of Sri Katon using the help of tools in the form of a drill and meter, and material in the form of *Hydrogen Peroxide* to see the depth of pyrite located at the drilling point, which is presented in Table 4.

Table 4. Depth of pyrite in the area study of the tidal lowland

Sampling sites	Pyrite Depth (cm)
C1,C3	100
C2	90
C4	110
C5	>120

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Based on the results of data analysis in the field, it was found that the lowest pyrite depth value was in sample C2, namely > 90 cm, then the point of drilling the soil with the deepest pyrite depth, namely in sample C5, from this sample no pyrite layers were found at a depth of > 120 cm, which means that the depth of pyrite in the sample is deeper than 120 cm from the soil surface. Sulfidic hazard is one of the main limiting factors that can inhibit the growth of disturbed plants in tidal lowlands (Imanudin *et al.*, 2016).

Water State

Depth of groundwater

Observation of the groundwater level was carried out directly at the observation site in Sri Katon Village on August 23, 2022, while the observation in Damar Wulan Village was carried out on November 30, 2022. The results of observing the depth of the groundwater table are presented in Table 5.

Table 5. Groundwater depth

Sampling codes	Groundwater level (cm)
Sri Katon village	
T1S1	-48
T1S2	-42
T1S3	-13
T1S4	-42
T1S5	-17
Average	-32
Damar Wulan village	
T2S1	-38
T2S2	-25
T2S3	-35
T2S4	-38
T2S5	-40
T2S6	-30
T2S7	-28
T2S8	-35
Average	-34

Groundwater observation data in Sri Katon Village are at a depth of 13-48 cm below the ground surface, and groundwater observation data in Damar Wulan Village are at a depth of 25-40 cm below the ground surface. Cultivation of plants that want land with dry conditions, the land should not be inundated, where the groundwater table must be lowered below the root zone, namely at a depth of 40-50 cm below the soil surface. Therefore, it is necessary to strive for water management at the beginning of the growth period, namely by managing maximum drainage. In this condition, the operation of the valve-type sluice gate is placed in front so that it can withstand high tides and release water at low tide.

The data on the depth of the groundwater table in the table cannot be used as a factor in determining when to cultivate rice. This is due to the high and low depths of the groundwater table, which continues to change according to conditions both at high and low sea levels. As a result, the research area could not be planted with rice all the time. The depth of the groundwater table can be a factor that must be considered in planning irrigation and drainage systems for crop cultivation productivity. In irrigation system planning, if the depth of the groundwater table approaches the soil surface limit, it will make the condition of the plants become excessive water, which can be the cause of plant damage. However, if the depth of the groundwater table is low, the plants will lack water.

Rainfall

The average monthly rainfall data for 2020 to 2022 were obtained from the Palembang Climatology Station, South Sumatra, which is contained in the

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histogram graph in Figure 4. Rainfall data for this research location has an average total annual rainfall from 2020 to 2022, which is 2965 mm year^{-1}. The rainfall data were obtained from the Palembang Climatology Station, South Sumatra.

Fertilization Recommendations

Based on the results of soil analysis that have been carried out in the laboratory, the calculation of recommended doses of Urea, KCl, and lime doses for the soil in paddy rice fields observed in this study was carried out. The calculation results of fertilizer are presented in Table 6.

From the calculation of fertilizer to produce 5 tons ha^{-1} rice grain, 90 kg ha^{-1} of N nutrient is needed, 19 kg ha $^{-1}$ of K nutrient, 50 kg ha^{-1} of P nutrient or equivalent to 300 kg SP36 ha^{-1} and from the results of calculating the dosage of lime to increase one point in soil pH, 2 tons of lime per hectare is required, which is stated by the Agency for Agricultural Research and Development (2015). At the location of Sri Katon Village, the addition of urea fertilizer to each sample was 69.57 kg ha^{-1} to 160.67 kg ha^{-1} with an average of 103.48 kg ha^{-1}. Furthermore, the addition of KCl fertilizer to each sample amounted to 121.08 kg ha^{-1} up to 160.35 kg ha^{-1} with an average of 150.612 kg ha^{-1}. addition of SP-36 fertilizer to each sample of 194.42 kg ha^{-1} up to 779.73 kg ha^{-1} with an average of 487.075 kg ha^{-1}. Three locations do not require the addition of SP36 fertilizer. However, it is recommended that SP36 fertilizer be given at a dose of 50 kg ha^{-1} to 100 kg ha^{-1}. The addition of TSP fertilizer to each sample amounted to 152.16 kg ha^{-1} up to 610.22 kg ha^{-1} with an average of 381.19 kg ha^{-1}.

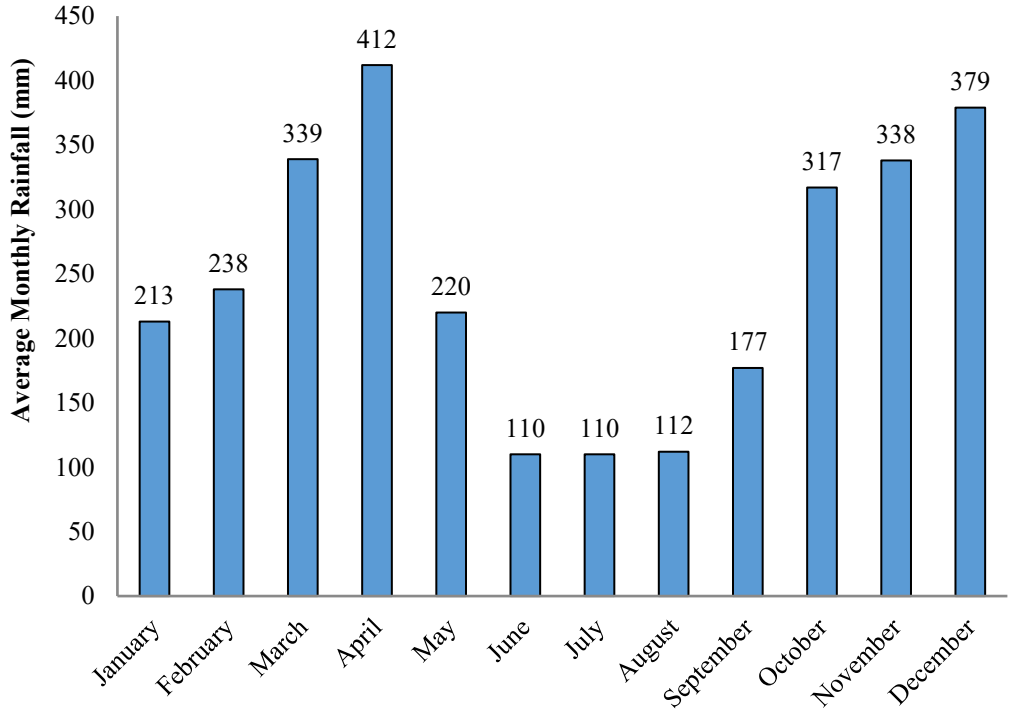

Figure 4. Monthly Rainfall Data (mm) for 2020 – 2022.

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Table 6. Specific recommended fertilizer doses of Urea, KCl, SP36, and TSP doses for research plots

Sampling codes	Fertilizer			
	Urea (kg ha $^{-1}$)	KCl (kg ha^{-1})	SP-36 (kg ha^{-1})	TSP (kg ha^{-1})
Sri Katon Village				
T1S1	86.96	160.35	194.42	152.16
T1S2	82.61	121.08	-	-
T1S3	160.87	160.35	-	-
T1S4	117.39	160.35	-	-
T1S5	69.57	150.93	779.73	610.22
Average	103.48	150.61	487.08	381.19
Damar Wulan Village				
T2S1	52.17	-	920.96	720.75
T2S2	43.48	-	787.62	616.40
T2S3	30.43	-	1236.01	967.31
T2S4	21.74	-	1107.75	866.94
T2S5	82.61	-	1261.46	987.23
T2S6	47.83	-	1284.87	1005.55
T2S7	43.48	-	995.27	778.91
T2S8	91.30	-	1292.00	1011.13
Average	51.63	-	1110.74	869.28

Note: - = does not require fertilizer addition

At the Damar Wulan Village location, the addition of urea fertilizer to each sample was 21.74 kg ha^{-1} up to 91.30 kg ha^{-1} with an average of 51.63 kg ha^{-1}. Furthermore, the addition of KCl fertilizer to each sample does not require the addition of fertilizer. However, it is recommended that KCl fertilizer be given at a dose of 25 kg ha^{-1} to 50 kg ha^{-1}. The addition of SP-36 fertilizer to each sample amounted to 787.62 kg ha^{-1} up to 920.96 kg ha^{-1} with an average of 1110.743 kg ha-1. Furthermore, the addition of TSP fertilizer to each sample amounted to 616.40 kg ha^{-1} up to 1011.13 kg ha^{-1} with an average of 869.2775 kg ha^{-1}.

The performance of rice growth in the area study is shown in Figure 5. The average rice production is about 5.50 t ha^{-1}.

Figure 5. The condition of rice cultivation in tidal lowland of C type in Delta Salek

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Correlation of Groundwater Depth and Nutrient Content

Tidal lowland land is land that has the potential for contamination with sulfidic hazards, so the regulation of groundwater depth is an important thing to do in agricultural cultivation in tidal land. The depth of the groundwater table at the location to be cultivated must be higher than the depth of the sulfidic layer. This is done so that pyrite cannot be oxidized. Pyrite can be oxidized if the depth of the groundwater table is lower than the sulfidic layer or in oxidized condition (Ritung *et al.,* 2011) efforts to control the height of the inundation, namely, to create channels that can quickly remove water and control the sulfidic hazard, namely by adjusting the height of the groundwater level must be reduced over the sulfidic layer. Sutandi *et al.* (2011) stated that pyrite oxidation causes a decrease in soil nutrient status (Armanto *et al*., 2023). Soil that has been oxidized by pyrite will cause some of the soil nutrients to be cleaved by acidic drainage water, decreased soil pH which also causes low available P, and accumulation of active metal content such as Fe and Al which can bind P so that P availability will decrease. Oxidation of pyrite produces some acids (H^-) in the drainage water, so that by the process of mass action, the bases are kicked out of the soil adsorption complex. As the bases in the soil exchange complex decrease, the base saturation also decreases. Furthermore, the values of pH, P, Ca, Mg, K, and CEC, pyritic soils that have been oxidized tend to be lower in value than pyritic soils that have not been oxidized.

In line with the research results of Zhang et al (2022), that groundwater depth directly affects soil nitrate-N and soil organic C, available P and K concentrations, and indirectly affects soil inorganic N concentrations. Therefore, groundwater depth should be considered as one of the environmental factors that most affect soil nutrient variations. This study provides new insights into soil nutrient variations under conditions of various groundwater depths. So that agricultural management in swampy areas is highly dependent on the ability of farmers to control the groundwater level.

CONCLUSIONS

The conclusions are:

1) Regarding the P element parameters, there were variations in diversity between Sri Katon Village, which had an average of 29.75 ppm with high criteria, and Damar Wulan, which had a P value of 6.30 ppm with a very low criterion level. However, there were no significant differences in the nutrient status between the two observations for the parameters N, K, and pH.
2) Recommended fertilizer in the T1S5 sample had the largest addition of SP-36 (779.73 kg ha^{-1}), primarily because some samples did not require additional P nutrients. The average amount of urea added to each sample in Sri Katon Village was the lowest, averaging 103.48 kg ha^{-1}. In contrast, the K did not require the addition of fertilizer in any observation sample in Damar Wulan Village. The lowest addition was urea, with an average of 51.63 kg ha^{-1} in each sample, and the largest addition was SP-36, with an average of 1110.743 kg ha^{-1}.
3) The relationship between the depth of the groundwater table and nutrient content found in the potential for contamination of sulfidic elements which can cause pyrite to oxidize if the depth of the groundwater table is lower than the sulfidic layer which can cause a decrease in nutrients such as P, K, C, and Mg.

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