Study on Soil Sulfur, Organic-C and Nitrogen, Nutrient Content of Rice and Fertilization Recommendation in the Downstream Serayu Sub Watershed Area in Kesugihan District, Cilacap Regency

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Abstract. This study aims to: (i) determine the distribution of Sulfur, Organic-C and Nitrogen nutrients in the rice fields, (ii) know the relationship between Sulfur, Organic-C and Nitrogen soil with rice fields; and, (iii) find out recommendations for giving organic fertilizers for rice crop in the downstream Serayu sub-watershed Kesugihan District, Cilacap. This research was conducted in December-July 2020 with a survey method at a semi-detailed level of accuracy with a scale of 1:50,000. Determination of the sample point based on the Homogeneous Land Unit (HLU) map, which is made by overlaying the map, namely the Administration Map, Land Use Map, Slope Map and Soil Type Map in Kesugihan District. The results showed that the average soil pH was neutral, the electrical conductivity was very low, the average redox potential was in the moderately reduced class, the Organic-C content was very low (0.02–0.18%), available sulfur content is low (21–46 ppm). Distribution of total nitrogen nutrients in the soil had a tendency increasing with increasing soil depth, nutrient uptake from soil nitrogen is low in plants so that the yield of lowland rice plant had depend to soil N. The N uptake by rice plants affected by total soil nitrogen by 1.75%, yield per rice plants affected by 3.44% by nitrogen uptake, and total soil-N affected 3.25% of rice crop yields. Fertilization recommendation to increase sulfur nutrients in Kesugihan with ZA fertilizer is 63.68 kg ZA/ha; whilst, to increase soil Organic-C in Kesugihan District with manure of 7–8 tons/ha.

Keywords: Organic-C · Nitrogen · Fertilizer Recommendation · Rice

1 Introduction

Sulfur and Organic-C nutrients have an important role in the productivity of rice plants. [1] stated that sulfur plays an important role in plant metabolism related to several parameters of plant nutritional quality. Whilst, the Organic-C besides playing an important role in productivity, Organic-C plays a role in the sustainability of plant life because it can

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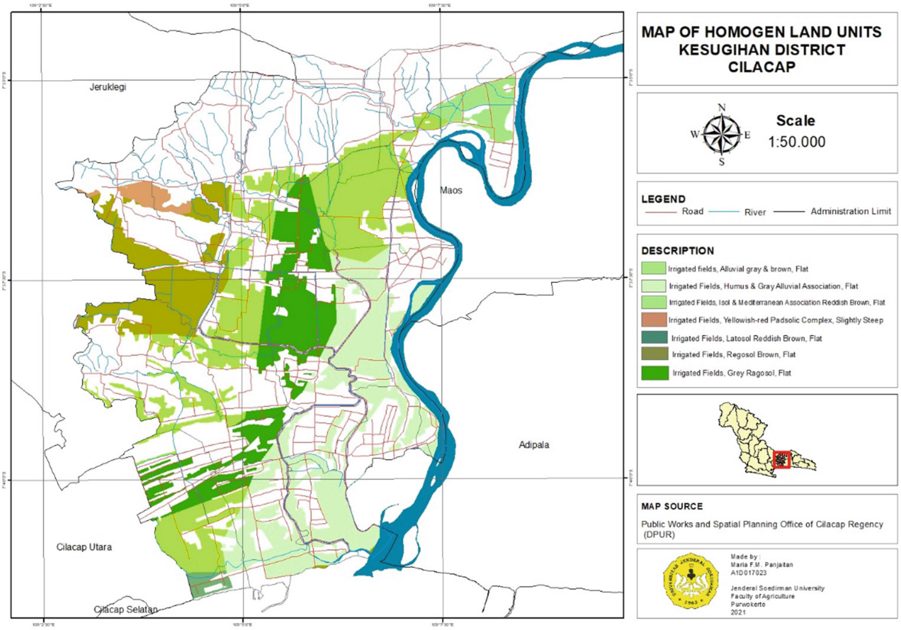

Fig. 1. Map of Homogeneous Land Units in Kesugihan District, Cilacap (Source: Maria F.M. Panjaitan, 2021).

increase soil fertility and use nutrients efficiently [2]. Organic-C plays an important function in increasing soil's CEC, so that play further function for plant in soil's cation exchange though its cation availability.

[3] stated that the carbohydrate content of milled rice is 78.9%, whilst of 6.8% protein, 0.7% fat and 0.6% others. Nitrogen (N) is an element that quickly shows its effect on the development of lowland rice, the main role of this element is to stimulate vegetative growth (stems and leaves), increase the number of tillers, and the number of grains/clumps [4].

In general, the efficiency of nitrogen uptake in irrigated rice fields can only reach 45% and the remaining (55%) cannot be utilized by plants [5], thus the N absorbed by plants is low. Then as stated by [4], rice plants have the capacity to absorb N in limited quantities, though the most of the N that is not absorbed by rice is lost due to volatilization, irrigation water washing, and leaching. To overwhelming, N fertilization from organic fertilizers is needed and is expected to increase the organic matter content in the soil, N-total, and increase nitrogen uptake by rice. The problem in nutrient application for flooded rice as the PK fertilizer has always overcome due to "kartu tani" (the fertilizer subsidy); but the N is still in low efficiency and this facing with same expectation too for C and S due to low compost application and lack of S as fertilizer (Fig. 1 and Fig. 2).

Kesugihan District is one of the rice-producing centers in Cilacap Regency. According to The Central Bureau of Statistics Cilacap Regency data in 2020 figures, it was

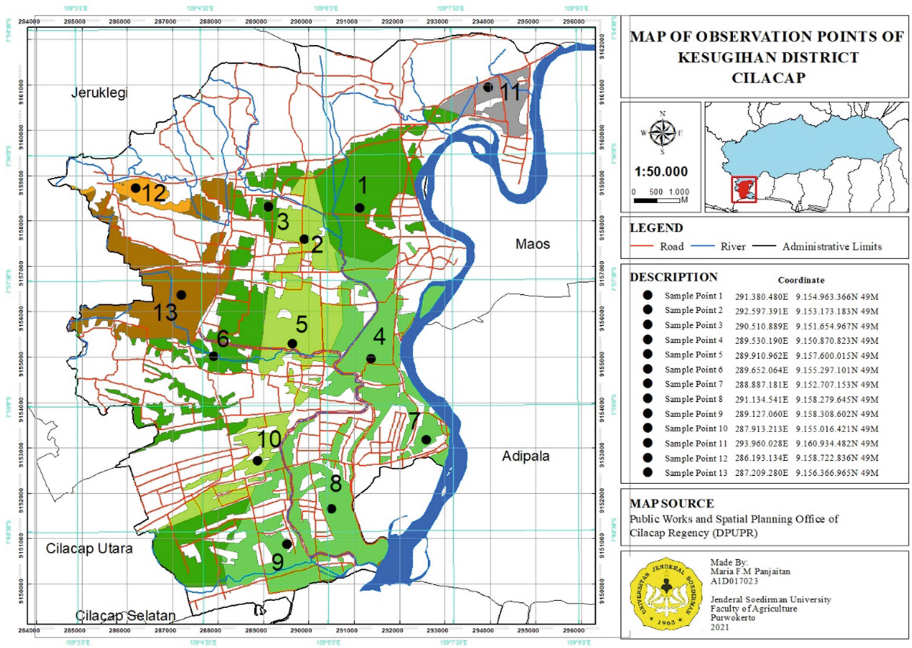

Fig. 2. Map of Observation Points in Kesugihan District, Cilacap Cilacap (Source: Maria F.M. Panjaitan, 2021[26]).

recorded that the area of rice fields in Kesugihan District was 3,763.45 ha, rice production in 2019 was 50,607 tons which decreased by 1,425 tons or 2.725% compared to 2018 [6]. In general, the study area, rice is harvesting 2–3 times a year.

Most of the rice fields in Kesugihan District are watering in the primary irrigation area sourced from the Serayu River flow. Given the position of Kesugihan District as a center for rice production, it is very important to increase the productivity of paddy fields. Therefore, research on nutrient surveys for C, S and N soils is very important.

This study aims to determine Serayu sub-watershed, downstream of Kesugihan Sub-district, Cilacap in: 1) the distribution of Organic-C, S and N nutrients in the soil, 2) the relationship of Organic-C, S and N soil with the yield of lowland rice, and 3) recommendations for the provision of organic fertilizers and N for planting.

2 Materials and Methods

This research was carried out from December to July 202. Soil sampling was carried out on the land of Kesugihan District, Cilacap Regency. Soil sample analysis was carried out at the Laboratory of Soil and Land Resources, Faculty of Agriculture, Jenderal Sudirman University, Karangwangkal, North Purwokerto.

Location of the research area is irrigated rice fields in Kesugihan District, Cilacap Regency. Cilacap Regency is located in the southern part of Central Java Province. Geographically, Cilacap Regency is located between 1080 4′ 30″ – 1090 22′ 30″ East

Longitude and 70 30′ 20” – 7 45′ 20″ South Latitude which is directly opposite the Indian Ocean with an area of 225,361 km2 which is divided into 24 sub-districts, 269 villages and 15 urban villages [6].

Materials used: soil samples from rice plantations, administrative maps, slope maps, soil type maps, and land use maps in Kesugihan District. Chemicals for soil chemical analysis include: KCl 1 M, sodium acetate, acetic acid, aquadest, BaCl2, Tween 80, HCl, phosphoric acid, K2Cr2O7 1 N and H2SO4. The tools used in this study were ArcGIS 10.4 GIS software, GPS, field knife, soil drill, plastic samples, paper bags, mortar, 0.5 mm and 2 mm soil filters. Tools for analysis in the laboratory including oven, spectrophotometer, erlenmeyer, dropper, beaker glass, test tube, measuring cup, filter paper, ziplock plastic, funnel, analytical balance, pH meter, ORP-meter, Electro Conductivity (EC) meter, bottle film and micropipette.

Sampling Design

Research was carried out using field survey methods and purposive sampling. Land units were analyzed using a physiographic analytical approach by grouping the survey area into homogeneous land units based on the villages area, slope, soil type, and land use. Overlaying maps of slope, soil type, and land use using the GIS ArcGIS 10.4 application carried out delineation of homogeneous land unit (HLU) boundaries. Sampling location points based on HLU were taken with a proportional distribution. Soil samples were taken from two depth composites, namely: 0–25 cm, 25–50 cm. Sampling was carried out at the sampling point in the form of five points in a zigzag manner, the distance between the points was 2–3 m using a soil drill and stored in the soil sample plastic. Then the soil sample was homogenized, dried, and ground using a mortar, which was later taken for analysis at the Soil Laboratory Faculty of Agriculture, Jenderal Soedirman University.

The map used for the implementation of the research in the field is the HLU Map, and the Observation Point Location Map with a scale of 1: 50,000. The HLU map was obtained from the results of overlaying the Administrative Map, Land Use Map, Slope Map, and Soil Type Map. Then seven (7) homogeneous land units were obtained and to be used as observation locations. From seven HLU then 13 points sampling were set to take soil and plan samples that for observes data from farmers. Variables observed included soil H2O pH, soil KCl pH, soil electrical conductivity, redox potential, soil organic C, soil available S, soil available N. Other variables: rice yields and climate data.

3 Results and Discussion

3.1 Chemical Properties at the Research Site the pH Value of H2O and the pH Value of KCl

The soil pH (H2O) obtained ranged from 7.03 - 7.85; means that the pH value of H2O obtained is neutral to slightly alkaline. According to [7], inundation in mineral soils results in an increase in the pH value of acidic soils and in alkaline soils, the pH value of the soil decreases or increases to near neutral. The pH of the KCl obtained ranged from 4.68–6.94 (acid to neutral). The pH of KCl is lower than the pH of H2O. According to [8],

Table 1. Correlation between research variables of soil samples at a depth of 0–25 cm

Variable	pH H_2O	pH KCl	EC	Potential Redox	Organic-C	S-Available	Yield Plant
pH H_2O		0.479	-0.072	-0.437	-0.477	-0.145	-0.558*
pH KCl			0.405	0.196	0.199	0.367 -0.016	0.739
EC				0.739**	0.514	0.510	0.414
Potential Redox					0.745**	0.482	0.632*
Organic-C						0.441	0.236
S-Available							0.557
Total-N (soil)							-0.460
Results							

Note: * The correlation is significant at the 0.05 level
** The correlation is significant at the 0.01 level.

determination of soil pH using 1 N KCl extracted has a lower pH than soil pH extracted with H2O; the concentration of H ions extracted using H2O is the concentration of H + that are only in the soil solution.

3.1.1 Electrical Conductivity (EC)

The electrical conductivity (EC) of the research area is less than 4,000 µS/cm, meaning it has a very low value. According to [9], rice plants are one of the plants that are sensitive to soil salinity; Soil EC of 2,000 µS/cm is considered optimal, but if 4,000–6,000 µS/cm is classified as marginal soil (low Electrical Conductivity).

3.1.2 Redox Potential

The redox potential of the research site ranges from 113–140 mV (moderately reduced). Inundation of rice fields can increase rice production. Flooding in lowland rice cultivation accelerates the decomposition of straw and softens the soil before planting [10].

3.2 Correlation Between Variables

The results of correlation analysis between variables showed that EC and soil redox potential were in moderate correlation with crop yields. Redox potential and EC are somewhat strongly correlated; as well as organic C and redox potential. Correlation between variables was determined in each homogeneous land unit and different soil depths, namely at a depth of 0–25 cm, 25–50 cm.

Based on Table 1, it can be said that pH H2O and pH KCl are negatively correlated with crop yields. This shows that the increase in soil pH is following by a decrease in crop yields and soil pH has a less close correlation with crop yields. [11] said that soil pH is very influential in plant growth, one of which is the availability of nutrients, if

Table 2. Correlation between sample research variables at a depth of 25–50 cm

Variables	pH H_2O	pH KCl	DHL	Potential Redox	Organic-C	S-Available	Yield Plant
pH H_2O		-0.076	0.359	-0.062	-0.077	0.168	-0.095
pH KCl			-0.223	-0.127	-0.361	-0.055	-0.022
DHL				0.496	*	-0.060	0.336
Potential Redox					0.550	0.243	0.534
Organic-C						0.301	0.539
S-Available							0.250
Yield Plant							

Description: * The correlation is significant at the 0.05 level.

the soil pH is not optimal it can potentially cause poisoning for plants. [12] stated that there is a relationship between redox potential and organic Organic-C in paddy fields. Redox potential of paddy soil in the research area has a correlation with Organic-C of r = 0.745.

Based on Table 2, it can be said that the correlation between pH H2O and pH KCl has a negative correlation. This means that an increase in the pH of H2O will be followed by a decrease in the pH of KCl. The correlation value between pH H2O, pH KCl with electrical conductivity, redox potential and organic C has a negative value. This means that there is an increase in the pH of H2O followed by a decrease in electrical conductivity, redox potential and organic C. This shows that pH has no effect on electrical conductivity, redox potential and organic C.

Cyio (2008) stated that a decrease in redox potential causes the soil to be reductive, releasing OH- thereby increasing soil pH. That is a negative correlation between soil KCl pH and available S. According to Wigena *et al.,* (2001), at a high pH there is a decrease in the positive charge on soil colloids and the deposition of Al ions so that a lot of $SO4^{2-}$ are released from soil colloid adsorption, then leached or lost by erosion. This condition results in S not being available to plants. [13] stated that, the higher the sulfur content in the soil is directly proportional to the decrease in soil pH and the decrease in pH from alkaline to slightly alkaline which will increase the availability of nutrients N, P, K and S, so that too to plant growth.

3.3 Nutrient Status of Sulfur and Organic-C Soil

3.3.1 Sulfur Nutrient Status

The nutrient status of sulfur is 21–46 ppm. The distribution of S-available values of soil is low and several other samples have moderate value. The low S in the study area was caused by the lack of fertilizer containing S nutrients such as ZA fertilizer. According to [14], inundation of paddy fields reduces the availability of S nutrients for plants, so that they are responsive to fertilization containing S.

Based on the graph of the quadratic function (Fig. 3) that the relationship between crop yields and available-S found the relationship y = -0.0131x^2 + 0.9819x -12.54 with R^2 = 0.4219. This shows that available-S has a low effect on rice yields, which is 42.19%. Sulfur application can have a positive effect, but relatively low, as it affect rice yields as shown in the study. The relationship between crop yields and low available-S has due to the lack of optimal sulfur fertilization in rice cultivation at the study site. This is in accordance with the statement of [15], that inappropriate sulfur fertilization affects the S status in soils.

3.3.2 Organic-C

Organic-C in location showed value 0.08–0.21% (low); indicates that the soil in the study area has poor soil chemical quality. Cultivation of paddy fields do not use straw as a source of organic C. They tend to sell to hay mills and burn the hay on-site, so organic matter cannot be returned or stored in the soil. According to [16], the burning of crop residues that can interfere with soil processing, causes organic matter to not be returned or not stored in the soil.

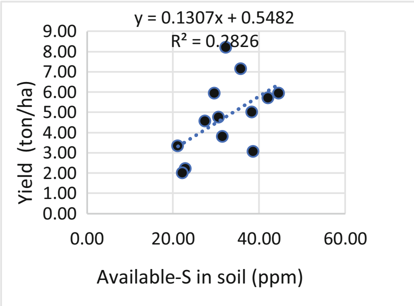

Fig. 3. Relationship between crop yields and S-available soil.

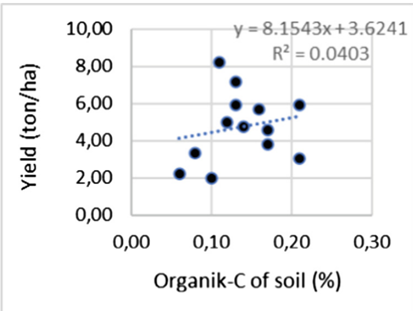

Fig. 4. Relationship between crop yields and soil organic C.

The relationship between crop yields and soil organic C was obtained $Y = -423.41x^2 + 126.32x - 3.8034$ with $R^2 = 0.2955$. This shows that Organic-C has a weak effect (Fig. 4) on plant yields, namely 29.55%. This is due to the lack of fertilizing organic matter such as manure and less effective soil management. According to [17] lack of organic matter fertilization will affect soil quality and reduce the supply of N, P, K and S nutrients so that it can inhibit plant growth. In addition, ineffective soil management will lead to loss of soil organic carbon content, then is leading to soil structural degradation and though to reduce crop yields. The addition of soil organic matter or soil organic carbon is one of the efforts to improve soil properties [18].Based on Table 1, it can be said that pH H_2O and pH KCl are negatively correlated with crop yields. This shows that the increase in soil pH is following by a decrease in crop yields and soil pH has a less close correlation with crop yields. [11] said that soil pH is very influential in plant growth, one of which is the availability of nutrients, if the soil pH is not optimal it can potentially cause poisoning for plants. [12] stated that there is a relationship between redox potential and organic Organic-C in paddy fields. Redox potential of paddy soil in the research area has a correlation with Organic-C of $r = 0.745$.

3.4 Fertilization Recommendations

Improvements that can be made to obtain high rice production with good quality are balanced fertilization (factory fertilizer and compost). Balanced fertilization until it reaches the status of adequacy but does not pollute the environment. This means that soil that has optimum levels of nutrients does not need to be fertilized, except for the replacement of nutrients transported by harvest. Sources of nutrients can be in the form of single fertilizers, compound fertilizers or a combination of both [19].

Based on Table 3, which is presented to determine the calculation of efforts to increase the status of available-S in soil or the addition of SO4 or sulfur with ZA fertilizer to increase sulfur nutrients at the study site have a range 41.94 - 88.38 kg ZA/ha or with 10.06 - 21.21 kg S/ha. ZA fertilizer is an inorganic fertilizer containing nitrogen and sulfur.

Nitrogen is the main nutrient in plant growth as a constituent of protein, while sulfur is a constituent of 21 amino acids that make up protein [20].

ZA fertilizer is an inorganic fertilizer containing compounds S (24%) in sulfate and N (21%) in the form of ammonium [21]. According to [22], ZA fertilizer or called Ammonium Sulfate is one of the inorganic pesticides designed to provide additional nitrogen and sulfur nutrients for plants. In addition, she said that ZA fertilizer is one type of organic herbicide that can kill weeds compared to other types of fertilizers [22].

Based on Table 4, fertilization recommendations to increase the Organic-C content with manure in the average of 8 tons/ha or with 0.03 kg Organic-C/ha. Manure with a weight of 0.03 kg/ha was applied by mixing it at the time of tillage.

Table 3. Recommendations for sulfur fertilization at the research site

Observation Point	S-Available (ppm)		Increase in S-available (ppm)	Nutrient Needs S	
	Value	Level	Level	(Kg S/ha)	(Kg ZA/ha)
1	30.64	Low	Average	14.56	60.67
2	29.71	Low	Average	14.12	58.83
3	35.84	Low	Average	17.03	70.96
4	31.58	Low	Average	15.01	62.52
5	27.45	Low	Average	13.04	54.35
6	38.64	Low	Average	18.36	76.52
7	38.37	Low	Average	18.23	75.98
8	42.11	Low	High	20.01	83.38
9	44.63	Low	High	21.21	88.38
10	32.38	Low	Average	15.39	64.11
11	21.18	Low	Average	10.06	41.94
12	22.92	Low	Average	10.89	45.38
13	22.66	Low	Average	10.77	44.87
			Average	15.28	63.68

According to [23], the benefits of organic fertilizer application is to improve soil structure, increase soil absorption of water, increase the ability to bind and store groundwater, and as a source of slow-release nutrients for plants. Provision of organic fertilizers can stimulate overall plant growth, namely on branches, stems, and leaves and plays an important role in the formation of green leaves. For this reason, fertilization aims to replace lost nutrients and can increase the supply of nutrients needed by plants to increase plant production and quality [24].

3.5 N-Paddy Plant Tissue

A stem diagram of the nitrogen content of rice plant tissue presented in Fig. 5 as follows. Figure 5 shows that the highest nitrogen content of rice plant tissue is at sample point 7, which is 5.31% and the lowest nitrogen content is at point 2, which is 0.27%. Nitrogen content in plant tissues affected by the uptake of nitrate and ammonium ions by plants. Slow movement of nitrogen especially in the form of NH4- generally occur in soil solution. This is like the statement of [24] which states that correlation soil N Correlation – Yield of rice is maybe not significant. He said that reduction of nitrate, which then absorbed into (amino acids) is slow, because to reduce nitrate to ammonia basically consists of two stages, namely the reduction of nitrate to nitrite by enzymes nitrate reductase and the second step is the reduction of nitrite to ammonia by the enzyme nitrite reductase. Next, ammonia is converted into amino acids and transported to the stem.

Table 4. Recommendations for organic-C fertilization at research sites

Observation Point	Soil Organic-C		Increase in Organic-C (%)	Recommended Fertilization	
	Value	1	C	-Organic Value (tons/ha)	Compost fertilizer (Tons/ha)
1	0.12	Very Low	Low	0.03	8
2	0.15	Very Low	Low	0.03	7
3	0.19	Very Low	Low	0.03	8
4	0.15	Very Low	Low	0.03	7
5	0.13	Very Low	Low	0.03	7
6	0.15	Very Low	Low	0, 03	7
7	0.16	Very Low	Low	0.03	8
8	0.16	Very Low	Low	0.03	7
9	0.14	Very Low	Low	0.03	8
10	0.16	Very Low	Low	0.03	8
11	0.17	Very Low	Low	0.03	8
12	0.13	Very Low	Low	0.03	8
13	0.12	Very Low	Low	0.03	8
Average				0.03	8

3.6 Correlation Between Total Soil Nitrogen and Plant Nitrogen Uptake and Rice Yield

The correlation between total soil nitrogen and plant nitrogen uptake and rice yields presented in Table 5. Based on Table 5, it can be concluded that the correlation value between total soil nitrogen and rice yield in soil depth 0–25 cm is $R^2 = 0.000121$ and is in the class interval 0.00–0.199, meaning that the relationship between variables is very weak but positive. Therefore, it can be concluded that there is a very weak relationship between total soil nitrogen and rice yields in the Prosperity District.

Nitrogen soil regression with lowland rice yields at a depth of 0–25 cm (Fig. 6). According to [25], a 1% increase in soil nitrogen content can increase rice production by 18,911 tons/ha.

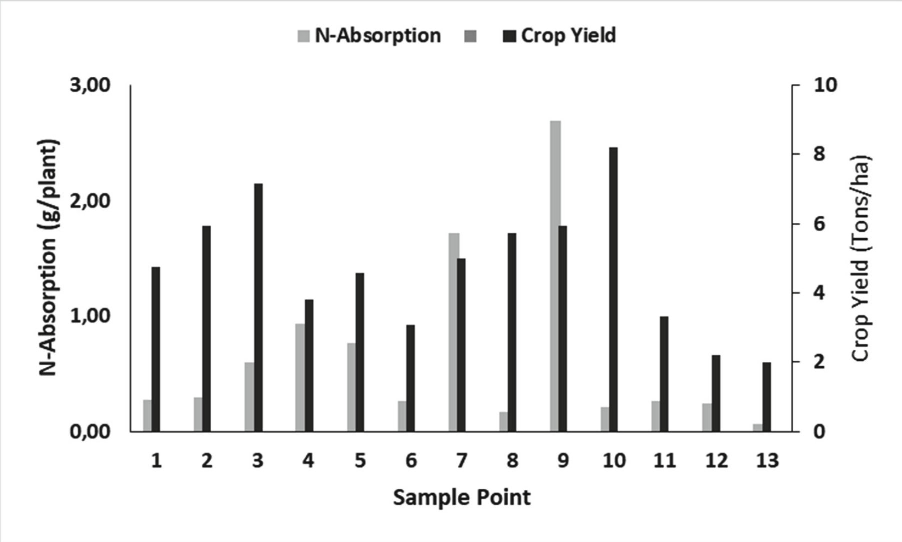

Fig. 5. Level of N-tissue (%) and crop yield (t/ha).

Table 5. N total, N absorption, and plant yield of the plants

	N-Total	N-absorption of	Plant Yield
N-Total		-0.181	0.0001
N-absorption of			0.185
Plant Yield			

The recommended dose of nitrogen fertilization in the downstream Serayu sub-watershed area, Kesugihan District, Cilacap Regency, is around 78–400 kg urea/ha. At field sample points 1 and 2, farmers need to add urea fertilizer of 77.78 kg/ha. The application of urea fertilizer in the range of 122–167 kg/ha needs to be added at sample points 8, 10, and 12. Urea dose at 211–266 kg/ha are necessarily add to field no 3, 4, 5, 6, 9, & 13. Whilst dose at 400 kg/ha need to give at field no 7 and 11.

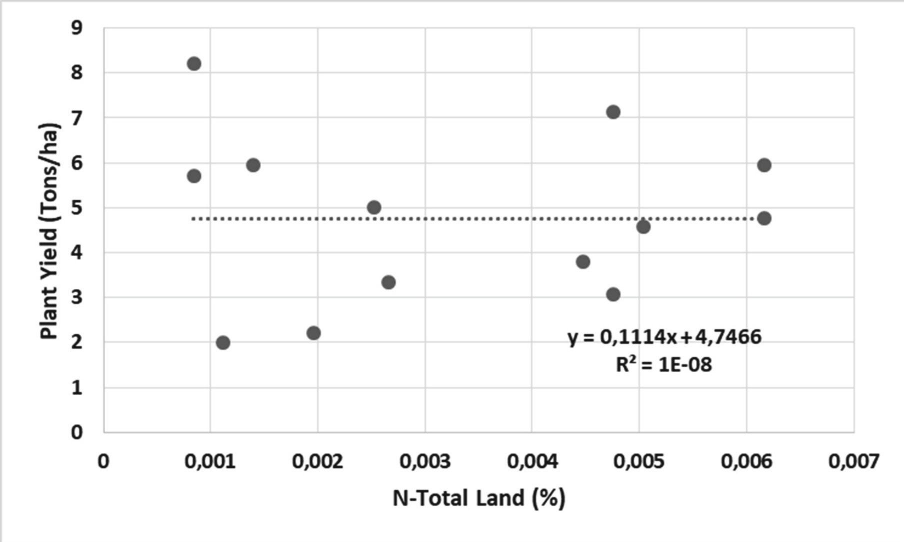

Fig. 6. The relationship of N-total soil with rice yields.

4 Conclusions

The nutrient status of the soil sulfur in the rice fields in the study area ranged from 21–46 ppm (low to moderate values). Soil Organic-C status is very low with a range of 0.02%-0.18%. The correlation between S-available soil and rice yields is positive. The correlation between Organic-C soil and the yield of lowland rice is positive. Fertilization recommendations to increase sulfur nutrients with ZA fertilizer range from 41.94 to 88.38 kg ZA/ha. Fertilization recommendations to increase soil Organic-C with manure have a range of 7–8 tons/ha. The N-total content of paddy fields in Kesugihan District ranged from very low to high, namely 0.08–0.62%. The relationship between the N-Total and N-absorption variables with the yield of lowland rice shows a positive value and has a very weak correlation. The recommended dose of nitrogen fertilization is 78–400 kg urea/ha. Figures and tables should be placed either at the top or bottom of the page and close to the text referring to them if possible.

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