

Characteristic of Soil and Water in Tidal Lands with Water Management *Garpu* System in Barambai and Cerbon Districts, South Kalimantan

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ABSTRACT

Barambai and Cerbon Districts, Barito Kuala Regency, which are tidal lands areas that have implemented a macro-level water management system called the *garpu* system. This *garpu* system was built in 1969 and has two secondary canals that flow from the Barito River to the end of the pond where the acid element water is stored. This research was conducted to determine the differences in soil characteristics (pH and dissolved Fe) and water quality (pH, EC, and SAR) in the area around the right pond canal and left pond canal of the *garpu* system and the criteria itself. This research used a survey method, specifically purposive sampling of soil and water samples based on one-kilometer distance. Soil and water samples were analyzed in the Soil Department Laboratory, at Lambung Mangkurat University. The results showed that the soil pH and concentration of dissolved-Fe did not show a significant difference between the area of right and left pond canals. The pH was 3.78 and 4.10, and the dissolved-Fe was 1453.7 and 709.4 ppm. The water quality (pH and EC) in the right and left canal areas did not show significant differences, whereas the SAR showed significant differences. The pH of the water in the right pond canal and the left pond canal were 3.99 and 3.68, the EC was 243 and 289 $\mu\text{S cm}^{-1}$, and the SAR was 0.34 and 0.47. The acidity of the water did not qualify as the standard criteria for irrigation water quality.

Keywords: characteristics of soil and water, *Garpu* system, tidal lands

INTRODUCTION

Tidal land is influenced by the daily rise and fall of sea levels (Rusdiansyah *et al.* 2019). Based on the distance of the influence of the tide from the river mouth, tidal land is divided into 4 types of overflows, namely types A, B, C, and D and one of the types of soil that develops in this land is acid sulfate soil (Jumberi and Alihamisyah, 2008). The area of tidal land in Indonesia is around 20.13 million ha, most of which is located on the islands of Kalimantan, Sumatra, Papua and Sulawesi (Suwanda and Noor, 2014). The tidal lands in South Kalimantan that have been reclaimed are spread across Barito Kuala Regency, Banjar Regency, and Tapin Regency, with an area of around 200,051 ha (Alihamisyah 2001).

The large area of land shows that tidal land has great potential to be used as agricultural land. This is supported by the abundance of available water so that it can be used as a source of irrigational water. However, there are several obstacles faced in the development of tidal land on this acid sulfate soil, both from the soil aspect, such as low soil pH, high solubility levels of Al, Fe, and Mn elements, and low availability of K and P nutrients and water aspects, such as waterlogging and physical conditions of the land (Napisah and Annisa, 2019). Based on the existing constraints, several stages of proper soil and water management are needed, one of the most important of which is the regulation of macro and micro water systems. Water management aims to maintain the availability and quality of water in the land, increase soil pH, keep soil pH from dropping due to oxidized pyrite layers, avoid potential flooding, and wash acid elements around plant roots (Suryadi *et al.* 2010).

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Tidal land in Barito Kuala Regency is spread across several districts, including Barambai and Cerbon District. In these districts, tidal land is utilized in agricultural and plantation activities. During agricultural activities, the water used comes from rainwater and Barito River water. This river water then flows through a water management system called the *garpu* system with ponds at both ends of the secondary river canal.

The *garpu* system was built in 1969 with the aim that water from the land plots would flow into the pond to wash away toxic elements. Over time, the soil and water conditions in this area will certainly change. Therefore, research is needed to determine the differences in soil characteristics and water quality in the two secondary-canals in the *garpu* system area and what the criteria are.

MATERIAL AND METHODS

Time and Location of Research

This research was conducted in the *garpu* system of Barambai and Cerbon Sub-districts, Barito Kuala Regency, South Kalimantan Province. Then continued with the analysis of soil and water samples at the Soil Department Laboratory, Lambung Mangkurat University, Banjarbaru. The research was carried out from August to November 2023.

Research Methods

This study was conducted using a survey method, namely taking soil and water samples by purposive sampling based on 1 km in the Barambai *garpu* system area. Soil samples were taken at a depth of 0-20 cm with 1 km between points so that 36 sampling points were obtained. Water samples were taken from each irrigation channel according to the soil sampling point so that 36 water sampling points were obtained (Fig. 1).

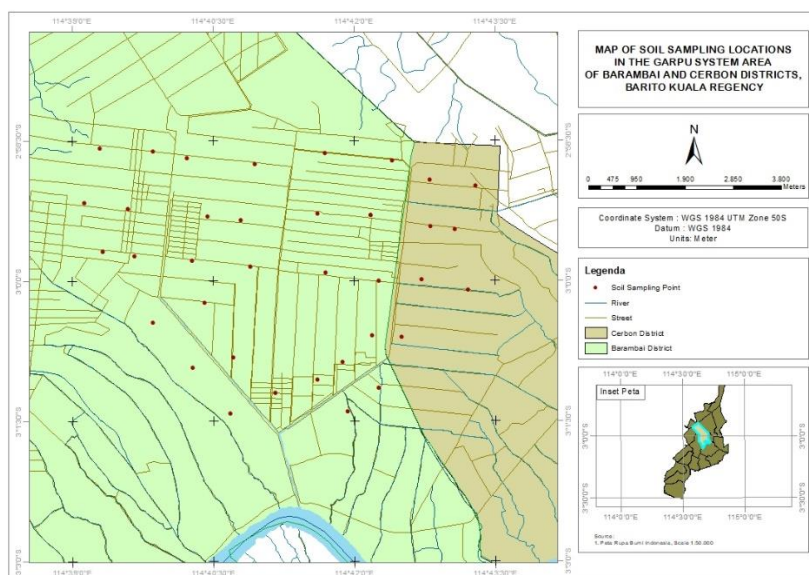


Figure 1. Map of study site

Research Implementation

The preparation carried out is to take care of the permit for the sampling location and prepare the tools and materials used in the field. Then, take soil

and water samples according to the location points on the map that have been made previously. The soil and water samples that have been taken are then analyzed in the laboratory according to the specified parameters. It is soil characteristic

parameters (pH and dissolved Fe) and water quality (pH, EC (Electrical Conductivity), and SAR (Sodium Adsorption Ratio)).

RESULTS AND DISCUSSION

Soil pH

The pH value of the soil in the area around the right pond and the left pond canals of the *garpu* water system of Barambai and Cerbon Districts did not show a significant difference with a very acidic pH criterion (Fig. 2). Based on the research conducted in August (dry season), it is known that the soil pH was quite varied ranging from 2.34 - 4.89 and the depth of pyrite was found at various soil depths, namely 0-50 cm and 50-100 cm. These results indicate that the acid sulfate soils found in the research location consist of actual and potential acid sulfate soils.

Soil acidity in acid sulfate soils is caused by the presence of a pyrite layer (FeS_2). If the pyrite layer is oxidized in aerobic conditions, the pH value will also be lower (Fahmi and Nursyamsi, 2021). Based on the Soil Chemical Assessment Criteria Tanah (Balai Penelitian Tanah 2008), the pH value in both channels is classified as very acidic. The pH value in the area around the right pond channel is more acidic because this area was dominated by actual acid-sulfate soil.

Farmers in both areas stated that lime application was carried out before planting (for paddy rice) and for orange, rubber and oil palm crops it was carried out periodically due to high soil acidity. A very large amount of lime is needed to eliminate all the effects of pyrite oxidation so that soil pH increases. Based on Mariana's research (2011), eliminating total potential acidity in acid sulfate soil requires 21.84-36.72 $\text{CaCO}_3 \text{ t ha}^{-1}$ lime, so lime application is needed periodically. Lime application is a method that can be used to increase

soil pH due to the oxidation of sulfidic materials in acid-sulfate soils (Hidayat and Fahmi, 2020). The selection of rice varieties that are suitable for planting on tidal land with acid pH is very necessary. Based on Hidayanto and Fiana (2021), the rice variety Inpara 1 has higher production (5.75 t ha^{-1}) compared to Inpara 2, Inpara 3, Inpara 4, Inpara 5 and local rice.

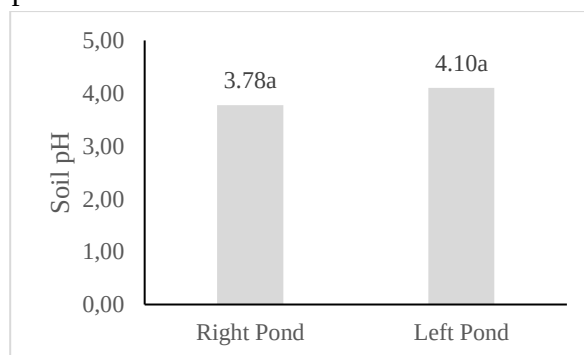


Figure 2. Average values of soil pH in the area around the right pond canal and left pond canal of the *garpu* water system of Barambai and Cerbon District. The same letters on the bar chart indicate no significant differences in the unpaired t-test ($\alpha = 5\%$).

Dissolved Iron

The oxidation process that occurs in acid sulfate soils due to the decrease in water level during the dry season causes the iron (Fe) content to dissolve in the form of Fe^{2+} quite high (Karimian *et al.*, 2017). The results showed that the average dissolved-Fe concentration in the area around the right pond canal was 1453.7 ppm and the left pond canal was 709.4 ppm. Although there was a considerable difference in dissolved-Fe concentrations, based on the dissolved-Fe t-test in the soil in the area around the right and the left pond canals of the *garpu* water system did not show a significant difference (Fig. 3). In the area around the right pond canal, the dissolved-Fe value was higher, this can be caused by the dominance of the actual acid sulfate soil compared to the area around

the left pond canal. Dissolved iron concentrations in both canals were classified as very high.

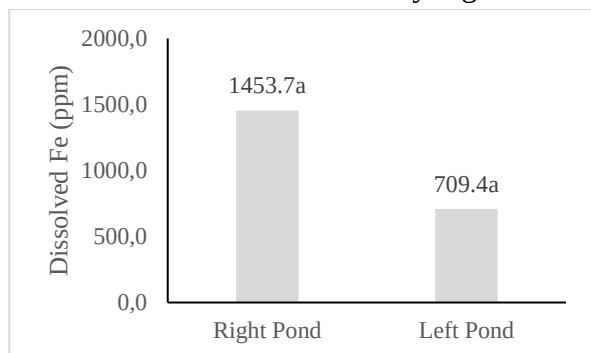


Figure 3. Average values of dissolved Fe in the area around the right pond canal and left pond canal of the *garpu* water system of Barambai and Cerbon District. The explanation for the supper script is the as that in Figure 2.

Dissolved Fe concentrations that are too high can be toxic to plants (Shamshuddin *et al.* 2014). Poisoning Fe in plants is characterized by discoloration of the leaves to reddish brown or brownish yellow, after which the plants wither and die (Susilawati and Nursyamsi, 2023). In 2021, Barambai District rice production was 37,157 t GKG with a total land area of 10,434 ha, which means that the average rice production was only 3.56 t ha⁻¹ (Rumah Data Barito Kuala 2021). This low rice production is related to the presence of dissolved Fe concentration in the soil as evidenced from the results of this study. Increased rice production is needed through planting rice varieties that are tolerant to dissolved Fe concentrations in the soil. Inpara 1, Inpara 2, Inpara 3, Inpara 4, Inpara 5, Inpara 6, Inpara 8 and Inpara 9 are rice varieties that are tolerant to Fe toxicity. Based on the research of Jumakir and Endrizal (2017) showed that Inpara 1, Inpara 3, Inpara 6 and Inpara 8 rice varieties produced 6.56-6.94 t ha⁻¹ rice production on acid sulfate soil in Senyerang Village, Senyerang District, West Tanjung Jabung Regency, Jambi Province.

Water pH

The acidity (pH) of the water in the area around the right pond canal and the left pond canal of the *garpu* water system based on the t-test did not show a significant difference (Fig. 4). The average pH value in the area around the right pond canal was 3.99 and the left pond canal was 3.68. Based on *Peraturan Pemerintah Nomor 22 Tahun 2021* concerning the Implementation of Environmental Protection and Management, the pH quality standard criteria for river water for irrigation is 6.00-9.00. Therefore, the average pH value in the *garpu* system was considered did not qualify the criteria for water quality standards for irrigation that have been set. At the beginning of the opening of the *garpu* system in the Barambai and Cerbon Districts, the water quality near the mouth of the main river was around 6.00. The increase in the pH of the water near the mouth of the secondary canal was caused by mixing with the main river water. Along the secondary canal to the pond, the pH of the water decreases further to below 3.00 due to the drainage of acid sulfate water from the tertiary canal (Klepper *et al.* 1987). Irrigation water quality is influenced by the source of water used, including rainwater.

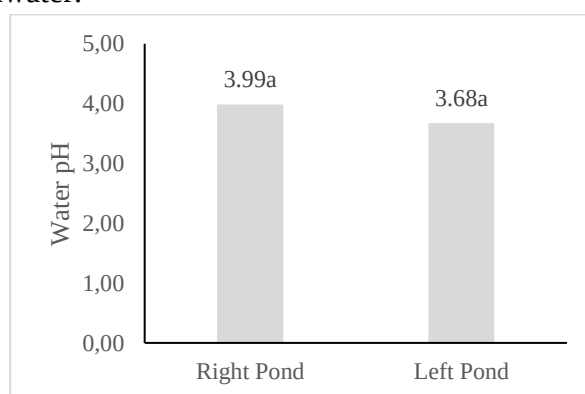


Figure 4. Average values of water pH in the area around the right pond canal and left pond canal of the *garpu* water system of Barambai and Cerbon District. The explanation for the supper script is the as that in Figure 2.

EC

Electrical conductivity (EC) is a number that shows the ability of ions in water to conduct electricity. The greater the ability of water to conduct electricity, the more salt content in the water due to seawater intrusion (Khumaeroh et al. 2023). The EC values in the area around the right pond canal and the left pond canal in the *garpu* system based on the t-test did not show significant differences (Fig. 5). The average value of EC in the area around the right pond canal was $243 \mu\text{S cm}^{-1}$ and the left pond canal was $289 \mu\text{S cm}^{-1}$. Based on water quality criteria according to FAO (1976), the EC values in both canals are classified as good because they are less than $750 \mu\text{S cm}^{-1}$. This low EC value indicates that there is no seawater intrusion, so the salt content is relatively low. This research was conducted during the dry season when the big tide (full moon) occurs and the influence of salt or brackish water has not entered so that the EC value in both areas is relatively the same and less than $750 \mu\text{S cm}^{-1}$. The quality of irrigation water needs to be maintained because if the EC is high, the salinity will also be high (Hadi et al. 2024). This high salinity will have an impact on plants, such as stunted plant growth, dry leaf tips, decreased water absorption by roots, root damage, and decreased production yields (Susila and Poerwanto, 2013; Atta et al., 2023).

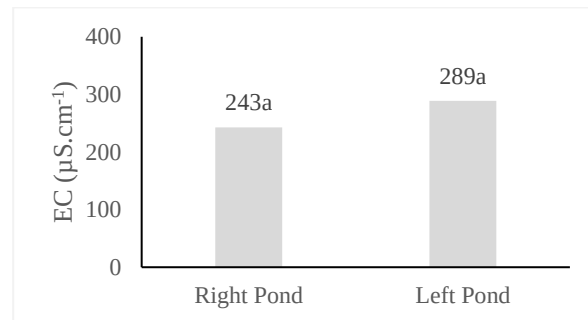


Figure 5. Average values of water EC in the area around the right pond canal and left pond canal of the *garpu* water system of Barambai and Cerbon District. The explanation for the supper script is the as that in Figure 2.

SAR

Irrigation water quality, besides being influenced by EC, is also influenced by SAR (Sodium Adsorption Ratio) values (Alavi et al. 2016). SAR is an irrigation quality parameter used in soil management due to the influence of sodium. SAR is a measure of the amount of Na ions relative to Ca and Mg ions in water. SAR values are very important in influencing agricultural production in clay and loam-textured soils through their effect in reducing soil permeability (Bell and Kron, 2021). Tidal soils are those that developed from fine-textured marine and alluvial deposits. The lower the SAR value, the better the quality of irrigation water (Farruq, 2018).

The SAR value of water in the area around the right pond canal and the left pond canal of the *garpu* water system based on the t-test showed a significant difference (Fig. 6). The average SAR value in the area around the right pond canal is 0.47 and the left pond canal is 0.34. Based on water quality criteria according to FAO (1976), the SAR value in both canals was classified as very good, because the value was <3 . Although it was in the same criteria, the average SAR value on the right canal was higher. This was because the Na^+

concentration was higher than Mg^{2+} and Ca^{2+} in the right pond canal, while the left pond canal was the opposite. An increase in Na concentration, when compared to Ca and Mg, can harm plants, such as stunted growth, and decreased quality and yield (Aboyeji and Ogunkoya, 2017; Ondrasek and Rengel, 2020).

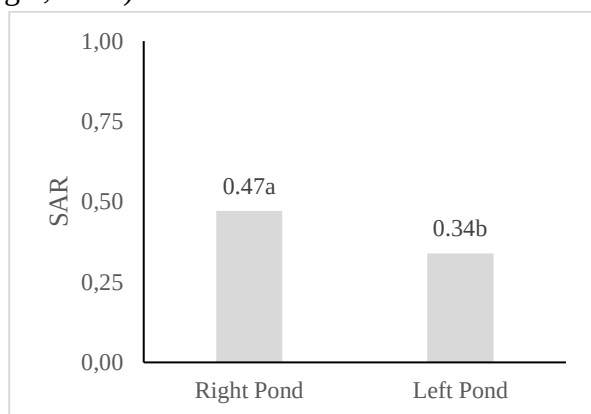


Figure 6. Average values of water SAR in the area around the right pond canal and left pond canal of the *garpu* water system of Barambai and Cerbon District. The different letters on the bar chart indicate significant differences in the unpaired t-test ($\alpha = 5\%$).

CONCLUSIONS

1. The pH value of the soil was classified in the very acidic category with the average pH value in the area around the right pond canal was 3.78 and the left pond canal was 4.10. The soil dissolved-Fe value was classified as very high with the average dissolved-Fe value in the area around the right pond canal was 1453.7 ppm and the left pond canal was 709.4 ppm.
2. The water pH value in the area around the right pond canal was 3.99 and the left pond channel was 3.68. The value of EC was classified as good with the average EC in the area around the right pond canal was $243 \mu S cm^{-1}$ and the left pond canal was $289 \mu S cm^{-1}$. The SAR value was classified as very good with the

average SAR in the area around the right pond canal was 0.47 and the left pond canal was 0.34.

3. The EC and SAR values of water in the area around the right and left pond canals qualify the irrigation water quality criteria, except for the pH value of the water.

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