Relationship of Fe distribution with rice cultivation system in the Barito River Region

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Abstract. Swamp is very potential to be developed as an area of rice plants, but there are many obstacles such as pyrite layer (FeS2) and nutrient poor. In addition, Fe toxicity often occurs and gets worse when el nino or climatic changes occur, much of the swamp is dry and so does pyridine oxidation. Various adverse effects of Fe poisoning on rice have been widely reported, but the spatial distribution of Fe tidal land and its relationship with rice cultivation systems in the Barito River region has not been examined, especially on el nino conditions. Therefore, the purpose of this study is to determine the relationship between rice cultivation systems with Fe concentration distribution, especially in el nino conditions. This research was conducted in November 2015 to August 2017 using a survey method in the Barito River region, South Kalimantan. Overflow type maps and mud thickness maps are overlaid to create a soil sampling point. Data from field observations of rice cultivation systems in the zone were correlated with Fe concentrations. The results showed that the spatial concentration of Fe affected the rice cultivation system. Fe concentrations of most farmers plant rice without tillage and do not make upper boundaries of rice fields using local varieties. Whereas in locations where Fe concentrations are low the farming system is carried out by tillage and making boundaries between rice fields. In addition, there was also a shift in planting time during el nino conditions.

1. Introduction

The area downstream of the Barito River is a tidal area that is mostly planted with rice and is part of the Barito Kuala Regency. Barito Kuala Regency is a rice granary for the province of South Kalimantan. The harvest area of 66,995 hectares can be the biggest contributor to rice production reaching 263 thousand tons more than dry unhulled rice grain [1]. However, production is still below national production due to several factors, including frequent Fe2+ poisoning, especially in Type B. According to Audebert [2], iron poisoning can reduce yields by up to 50%. As a result, farmers experience losses and even crop failure, due to the Fe poisoning rice plants.

However, not all tidal rice fields in the Barito river area occur Fe poisoning, depending on the concentration of Fe, and the type of area, season, geographical conditions and water management. Distribution and concentration of iron (Fe) in Dadahup, Central Kalimantan, were 122-255 mg kg\(^{-1}\) in Typic Sulfaquent and 54-89 mg kg\(^{-1}\) in Histic Sulfaquent [3]. The values of redox potential, dissolved oxygen, and dissolved organic carbon content were evaluated to describe the Fe (III) / Fe (II) transformation in groundwater and were related to the distribution of iron in the water [4]. Much research on the distribution of Fe, such as that done in Nigeria, is limited to discussing Fe2+ in different
geomorphological zones in the Niger Delta region of Nigeria, which characterized the distribution and occurrence of Fe\(^{2+}\) in groundwater sources from the five geomorphological units that make up the Niger Delta [5]. Research on the distribution of Fe in the processing and spatial layers has never been carried out, especially in the Barito River area, especially in relation to the rice cultivation pattern in that area, even though this is very important for the success of rice cultivation. so that it can increase rice production and farmer welfare, therefore research on the distribution of Fe and its correlation with rice production is very important.

2. Materials and Methods
The research was carried out in tidal swamp areas along the Barito River, namely: from Tabunganen District (the rice plant area closest to the sea) to approximately 60 km upstream in the area in Barambai District. The geographic position of the study site lays at 2°90'00"- 3°30'00" S and 114°20'00" - 114°50'00" E, from 2015 to 2016.

2.1. Soil sampling
Characterization is done by making a profile, or minipit, or drilling. Taking soil samples based on the pre-determined unit mapping map. To see the morphology and vertical layer of the soil, a representative profile was made according to the percentage, while for the point to take the tiling layer, it was boring, 30 cm deep and then separated each layer based on soil diversity, Fe content was analyzed to the laboratory.

2.2. Parameters observed
The parameters observed including three components, namely: 1) Site characteristic includes the height, macro relief, drainage, and surface, or shape of the area; 2) Land use includes the main land use for rice cultivation, natural vegetation and water management; 3) Soil characteristics include effective depth, compaction, toxic compounds (pyrite), parent material, soil maturity (n value), groundwater level, overflow typology, organic matter, iron (Fe) and manganese. In addition, it also observed the thickness of the upper- and lower-layer horizons, soil color, texture, consistency, rice root conditions and horizon boundaries as well as several other soil morphologies.

2.3. Laboratory analysis and data analysis
Soil samples taken from the field were analyzed for physical and chemical properties. For the data from the analysis results in the laboratory, it is processed then compared between each unit of soil digging location, so that it is known how many types of sludge are present and contain high and heavy nutrients or their distribution, using histograms and graphs to describe the distribution of sludge in relation with nutrients or minerals and types of clay relating to the physical and chemical properties of the soil.

3. Results and Discussion
3.1. Fe distribution between layers and its relationship with rice cultivation patterns
The concentration of Fe in the processing layer (0-10 cm, 10-20 cm and 20-30 cm) of 44 sample points from the sea estuary to the upstream as far as 60 km is shown with a bar chart in (Figure 1 and 2), for ease of presentation. and discussion is divided into two groups, namely: 0–30 km and 30–60 km from the sea estuary. In Figures 1 and 2, it can be seen that in general the Fe concentration is higher in layer 1 than in layers 2 and 3. In the upstream part, the average available Fe concentration in layer 1 is 199.7 mg kg\(^{-1}\), in layer 2 is 114.1 mg kg\(^{-1}\), and layer 3 at 103.4 mg kg\(^{-1}\), while at the downstream part the pattern was almost the same as all Fe concentrations were much higher. downstream, the average Fe concentration for layer 1 was 449.1 mg kg\(^{-1}\), layer 2 was 391.9 mg kg\(^{-1}\), and layer 3 was 387.7 mg kg\(^{-1}\).
This pattern shows the accumulation of Fe in the downstream part of the upstream area because it is carried by water that returns at high tide and settles at low tide in the downstream area of the Barito river. In addition, Figures 1 and 2 also show that in several places, namely points 53 A and 53 B, the Fe concentration in layer 3 is higher than layer 2. In layer 1 at point 53 A, the concentration of Fe is 792 mg kg\(^{-1}\), then decreased in layer 2 of 440.7 mg kg\(^{-1}\), and increased again in layer 3 to 646.4 mg kg\(^{-1}\). At point 53 B, in layer 1 the concentration of Fe was 1221 mg kg\(^{-1}\), then decreased in layer 2 to 353.1 mg kg\(^{-1}\), and again increased to 437.9 mg kg\(^{-1}\). The difference in the pattern is thought to be due to the factor of the highest and lowest tides with strong currents.

Increasing water flow rate and water discharge can cause Fe to remain suspended [6], thus affecting the total suspension of sediment carried by water and affecting the sedimentation process [7]. Therefore, the concentration of Fe in samples 48A, 52B, 55A, 57A, and 59A which are in the downstream area near the sea estuary is very high (Figure 3) this affects the rice cultivation system carried out by farmers.

The decrease in Fe concentration with increasing depth is related to the chelation of Fe by organic matter through the humification process. Organic acids suppress Fe\(^{3+}\) activity by forming organo-metal complexes [8].
compounds [8]. The same thing was stated by [9] Revision Beach (1980) which states that the highest Fe$^{2+}$ concentration is at a depth of 2-15 cm, then decreases in the lower layer which contains little organic matter. The distribution pattern of Fe concentration in the soil profile tends to decrease with depth, this affects the pattern of rice cultivation, farmers planting rice in tidal land using large seeds so that the stems and roots can reach deeper layers (more than 10 cm), especially in type A, these large seeds are generally 2 months old, such as local varieties that can be planted in Layer 2 with high Fe concentration.

3.2. Fe distribution spatially and its relationship with rice cultivation patterns

Water is one of the agents that influence the distribution of Fe in tidal swamplands which carry mud particles mixed with Fe and other elements which eventually settle to form alluvial soils. Horizontally, the tide moves from the sea estuary towards the mainland upstream. The more upstream the difference between the maximum and maximum low tide is the smaller the value. This affects the distribution of Fe concentration at each location. The results of this study indicate that Fe concentration was higher in the downstream, near the sea estuary, in the middle and upstream Fe concentrations were at moderate to low levels (Figures 3, 4 and 5) in each layer.

In Layer 1 the distribution of Fe with the highest concentration is mostly in zone I with (downstream). It is strongly suspected that during the dry season there is pyrite (FeS$_2$) which produces Fe$^{3+}$, SO$_4$ and H$^+$ [10] in the upstream area which is carried by water at high tide which is then deposited in the downstream area, at low tide so that the Fe concentration becomes high. This is thought to be due to the difference between the high maximum and maximum tide which causes the water flow to move quickly carrying deposits containing Fe so that the total suspended sediment also increases in zone I, because higher currents also contain strong energy to move higher [6].

In layers 2 and 3, the concentration of Fe decreases at several sample points such as points 48 A and 55 A, in layers 2 and 3 it is quite high and even very high, it is assumed that the sedimentation process is different every year. there is the addition of sludge in the processing layer whose quality and amount vary, depending on the source of the mud and the amount of water [11]. The same thing also happened in the mangrove swamp area of Langkat, North Sumatra, where the thickness of the mud (sediment) varies every year with different organic C content.

In zone II, the concentration of Fe in layer 1 ranges from moderate (200-300 mg kg$^{-1}$) to low (0-100 mg kg$^{-1}$), whereas those in layers 2 and 3 are generally low, especially in layer 3 with concentrations <100 mg kg$^{-1}$ to 22.2 100 mg kg$^{-1}$. In zones III and IV the concentration of Fe ranged from moderate to low, from 278.7 mg kg$^{-1}$ to 77.6 mg kg$^{-1}$. Based on this spatial distribution, the safest rice cultivation from Fe poisoning is in zone II, III and zone IV because of the low Fe content in all layers. Whereas in zone I the Fe content is very high, especially in layer I. In zone I it is recommended to plant varieties resistant to Fe poisoning such as Inpara 1 or local varieties classified as resistant to high concentrations of Fe [12]. To avoid Fe poisoning, local rice farmers, with their local wisdom, usually plant rice on Type A tidal fields. The tide can enter at high tide and exit at low tide without the presence of a circumferential embankment to smooth the flow rate in and out. An increase in water flow rate and water discharge can cause Fe to remain suspended, so that it returns out of the land without settling much in the land and the concentration of Fe in the fields does not increase or even decrease, because it is leached too.

4. Conclusion

The spread of Fe vertically or between layers tends to reduce the concentration of Fe so that farmers adapt to rice cultivation using local seeds that are 2 months old so that they can be planted in layers of 20-30 cm. In addition, climate change must also be considered because it determines the right planting time to avoid crop failure, due to drought or flooding by increasing or delaying planting time. Whereas spatially it can be seen that the Fe with the highest concentration is in the downstream near the sea estuary so that farmers in the rice cultivation system, apart from using superior seeds that are resistant to Fe poisoning, also do not make the production, plots or embankments on land so that Fe can be washed at low tide.
Figure 3. Distribution of available Fe based on layer 1,2 and 3 (0-10 cm (a), 10-20 cm (b) and 20-30 cm (c)) in the regional rice fields of Barito River.
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