VARIABILITY OF GROUND WATER TABLE AND SOME SOIL CHEMICAL CHARACTERISTIC ON TERTIARY BLOCK OF TIDAL LOWLAND AGRICULTURE SOUTH SUMATERA INDONESIA

Momon Sodik Imanudin*, Satria J Priatna, Elisa Wildayana, and M. Edi Armanto

Faculty of Agriculture, Sriwijaya University, Indonesia
Indralaya Campus Jl. Palembang-Prabumulih Km 32, Sumatera Selatan
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ABSTRACT

Agriculture and irrigation policies in the tidal wetlands are often too general, thus at the level of farm units they are often inaccurate in term of quality and quantity. The research purpose was to analyze the groundwater levels and to determine the effect of groundwater levels in relation to some soil chemical characters in tidal wetlands P17-5S Mulyasari village Delta Telang II Banyuasin. Indicators of potential land can be analyzed from parameters of variability of soil acidity, Al and Fe content, organic matter and phosphorus and nitrogen status of the soil. Managed limited area was the smallest unit of water management (tertiary plots). The decision was taken based on the dominant values of the hydro-physical and chemical characters. Input criteria design involved the nature of the soil, land use, and hydrology. The field study and analysis showed dominance in soil physical variability. Around 50% of hydraulic conductivity was classified rapid soil with soil acidity is relatively high, moderate nitrogen, low phosphorus, and moderate potassium. Based on these conditions, cropping pattern applied was rice-corn, rice-water melon, soil fertility can be improved through fertilization of N and P; increasing water gate in the tertiary plots, and the water management aimed to controlled drainage.

Keywords: Variability, ground water, chemical characters, tertiary plots, tidal wetlands

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INTRODUCTION

Swamp area in Indonesia ranges from 33.32 million ha of which 9.01 million ha have potential to be developed into agricultural land. From the 9.01 million ha, around 6.00 million ha are classified as tidal wetlands, and the rest belongs to back swamp areas, which spread across the east coast of Sumatra, Kalimantan and Papua. In South Sumatra tidal wetlands stretches along the East coast with an area estimated to be around 2.92 million ha.

Utilization of tidal wetlands in South Sumatra for agriculture has lasted approximately 25-30 years through transmigration program. So far there is no standard to determine the basis for policy making agriculture and irrigation. Therefore, existing programs often unnecessary and even damaging to the environment (Armanto, Susanto, & Wildayana, 2017; Armanto & Wildayana, 2016; Momon S. Imanudin & Armanto, 2012).

Tidal farmland conditions are quite diverse, especially on the characteristics of the soil and the influence of the tidal flood water at the soils. The conditions cause the need for good management system to be used for agricultural land, thus becoming productive

*Corresponding Author: Email : momon_unsri@yahoo.co.id
Tidal wetlands in the process of its formation is influenced by the tide, located in estuaries or along the beach. Reclamation of tidal wetlands also called swamp area development is a process of activities shown to improve the function and benefits of the swamp as a natural resource potential for the benefit and welfare of the general public (Armanto, 2014).

Swamp utilization for farmland requires good management to optimize the existing potential. Management of wetlands has several problems, one of which is water management. Swamps have distinctive characteristics, which impacts caused by human activities or natural changes in the environment can lead to changes in the initial conditions.

In the development of tidal land as well, soil acidity problems may affect the availability of essential nutrients and soil chemical properties, i.e. organic matters, N, Al and Fe. One effective way to manage acid sulfate soil, through appropriate water management (Armanto, Adzemi, Wildayana, & Imanudin, 2013; Armanto, Imanudin, Wildayana, Junedi, & Zuhdi, 2016; M.S. Imanudin & Bakri, 2014). Improvement of soil fertility will be valid when the water level control has been carried out in accordance with the purpose and soil functions (Imanudin and Armanto, 2012). On the other hand knowledge of farmers to manage and control groundwater levels are still low in addition to the condition of the network system that has not been optimum support swampy areas of the farm system (Momon Sodik Imanudin, Armanto, & Susanto, 2011). If the condition of water management is allowed no improvement then the soil quality will continue to decline and production followed at least until the past 10 years. But if there is improvement of water, pyrite remediation can be accelerated to 3-5 years (Bronswijk, Groenenberg, Ritsema, van Wijk, & Nugroho, 1995). The research aimed to analyze the groundwater levels and to determine the effect of groundwater levels in relation to some soil chemical characters in tidal wetlands P17-SS Mulyasari village Telang Delta II Banyuasin.

MATERIALS AND METHOD

The research has been conducted on reclaimed tidal lowland (P17-SS) Mulyasari village, Tanjung Lago Banyuasin, South Sumatra Province. The area characterize as B typology where the tide water can only irrigated the land during the rainy season. In the dry condition the tide water still possible to fill water in tertiary canal, so could maintenance ground water position in the farm. The field research was using semi-detailed survey. Determination of sample points and field observations conducted randomized controlled. The model is in the tertiary block with located at number 5 area of 16 ha. The tertiary block is divided into two locations: the first farmland of 8 ha and the second farmland of 8 ha. In every measurement of groundwater levels is done by drilling the ground to a depth of 120 cm with a diameter of 8 cm and soil sampling (Figure 1). Soil sampling was taken on August to see the effect of the ground water table drop in dry period. During oxidation process the solubility of iron and aluminum would increase.

Soil sampling for analysis of chemical properties performed at each location observation of water level. Laboratory analysis includes an analysis of soil chemical properties Consist pH level of soil acidity, organic matter content, total nitrogen (N), the levels of aluminum (Al) and iron (Fe).

Water level observation data presented

![Figure 1. Skematic the ground water table monitoring in the field](image)
in graphical form and connecting it with ground water level at least 30 cm. Limit of 30 cm showed the same figure for food crops. The diversity of ground water level will affect the status of soil fertility status characterized by pH, N, Al, organic matter (OM) and Fe. This parameter is the main indicator of soil chemical properties to view the eligibility status of land for agriculture in wetlands (Momon S. Imanudin & Armanto, 2012).

Management area is limited in the smallest unit of water management, which is at tertiary unit (Figure 2). The decision was taken based on the dominant values of the character of the hydro-physical and chemical soil. The design criterion is to include the types of land use in one growing season, the desired depth of ground water, and the distance between channels. Statistical analysis was performed to determine the dominance of the diversity of soil properties. Values are calculated from the results of the most dominant qualitative assessment of hydraulic conductivity class, soil acidity, nutrient content and the content of aluminum. The decision taken is the choice of land use, network operation and improvement of soil fertility.

RESULTS AND DISCUSSION

In this paper we focus on discussion of characteristics of climate and hydrology; soil acidity phenomena; organic matter content; total N; Al values; Fe content and relationship between ground water level with soil chemical characters.

Characteristics of Climate and Hydrology

Climatic characteristics of the study area (Mulyasari village P17-55) included in the category of tropical rain, the hot and humid conditions occur along the year. The monthly average temperature as around 17 °C and a relative humidity of 87%. The rainy season in 2014 (Figure 3), successively occur within 5-6 months (> 150 mm per month) and 2-3 months of dry (< 100 mm per month). Calculation montly evapotraspiration (ETo) using empirical method showed the value of ETo during rainy season is about 70-75
mm/month, and during the dry condition is around 110-130 mm/month. For the water balance, the average value of evapotranspiration is 120 mm/month was taken, the water deficit occurs in June through September. In these months the main problem is the crop water stress and irrigation effort required (water supply). The elnino phenomenon also considered (Figure 4) showed that the dry period during 2015 was longer than 2016 (normal climatic condition). It means that the deficit water in 2015 was more than 4 month, and need water supply required, and gate operation more operated as retaining water.

In B type, the conditions of area where the basic channel is lower than the average height of a rice field, the gravity irrigation cannot be done. Irrigation can happen when the tide is able to overflow the land. In the dry months tide water could not enter the land, so that in this condition could only make arrests tertiary water in the channel. With the availability of water in the groundwater tertiary canals in the plots can be maintained at a depth of 30-40 cm below the soil surface.

Ground water level observations done just that in August, the land area of business I and II. Status of ground water (Figure 5) shows the second business area is more fluctuating.
groundwater levels. Farmland II is mentioned as business land closer to the secondary drainage channels so that the water level is lower than business land I. The average water level is 44.5 cm LU 1 and LU 2 is -52.8 cm below the soil surface. When viewed plants against rice plant water level (30 cm) this figure is included critical, but more sensitive to corn figure in the initial growth at 50 cm, and when the plants are already high can be 150 cm below ground. Conditions in the field of corn plants have been aged 20 days so as to be in a safe condition.

**Soil Acidity Phenomena**

Parameter soil chemical properties are often a reference assessment of land potential in tidal include soil pH, organic matter content, N, Al and Fe, from the parameters of soil chemical properties will be explained as follows. Generally soils in tidal areas have fertility low, is due to have a high value of acidity (low pH). The low pH is due to the oxidation process pyrite layer. Besides this land has the characteristics of nutrient deficiency, the presence of ions or compounds that poison (Al, Fe, and SO4) and organic matter that has not been decomposed. Besides that, the state of the water system are less well become a limiting factor in management. However, an area of land in the delta Telang I large part of organic material is decomposed.

Qualitative assessment shows the distribution of soil acidity does not show the real diversity. The level of soil acidity classified from acid to very acid, good at business area I and II (Table 1). PH analysis conducted in the laboratory on soil conditions already experienced drying. The influence of soil acidity is very evident in the cultivation suitability of plantcultivation. Normal plants generally grow well at pH 5-7. High acidity (pH <4.0) impact on the increased solubility of Al, Fe, and Mn. The destruction of the mineral lattice structure, due to the high acidity result in the release of Al is more intensive. At the Al content from 0.5 to 2.0 ppm of cultivated plants are already experiencing barriers to growth, and at a level of 25 ppm of plant decreased results. Iron and Mn are generally poison the plants in the form of ferrous ions (Fe^{2+}) ions and manganese (Mn^{2+}) in anaerobic conditions.

The decrease in pH after perfect oxidized soil in the ground show that there are compounds that can be oxidized S produces H + ions and SO4 - resulting in soil pH drops, also the presence of organic acids. An important part besides other iron in the process of formation of pyrite. The formation of pyrite (FeS₂) are as follows:

\[
\text{Fe}_2\text{O}_3(s) + 4\text{SO}_4^{2-}(aq) + 8\text{CH}_2\text{O} + \frac{1}{2}\text{O}_2 \rightarrow 2\text{FeS}_2(s) + 8\text{HCO}_3^- + 4\text{H}_2\text{O}
\]

When pyrite oxidation is an incident that will increase soil acidity, because it produces sulfuric acid. The content of pyrite is

| Samples | L1 code | pH  | Criteria | L2 code | pH  | Criteria |
|---------|---------|-----|----------|---------|-----|----------|
| 1       | T1L1    | 4.21| very acid| T1L2    | 3.74| very acid|
| 2       | T2L1    | 4.28| very acid| T2L2    | 4.14| very acid|
| 3       | T3L1    | 4.35| very acid| T3L2    | 4.46| very acid|
| 4       | T4L1    | 4.50| acid     | T4L2    | 4.49| acid     |
| 5       | T5L1    | 4.63| acid     | T4L2    | 4.71| acid     |
| 6       | T6L1    | 4.91| acid     | T6L2    | 5.08| acid     |
| 7       | T7L1    | 4.38| very acid| T7L2    | 4.39| acid     |
| 8       | T8L1    | 4.34| very acid| T8L2    | 4.21| acid     |

Remarks: */ Evaluation criteria is based on standard of Soil Research Center (1983)
a measure of the potential acidity by reaction:

\[ \text{FeS}_2 + 15/4 \text{O}_2 + 7/2 \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_3 + 2\text{SO}_4^{2-} + 4\text{H}^+ \]

The higher content of pyrite in the soil, the more the resulting H⁺ ions that cause acidity. The higher the total potential acidity higher the pyrite or sulfide content in the soil. According to the terms of the land and soil fertility is economically unfavorable because the soil is saturated with Ca. Therefore, to raise the pH of the soil, is not to negate the potential acidity, but with a lower active acidity that is the concentration of H⁺ ions in the soil solution.

Water management is an important part in controlling soil acidity in tidal wetlands. Land within reduction condition having a pH above 5. Thus, the ground water level should be maintained at a depth of 30-60 cm above the attachment pyrite (Momon Sodik Imanudin, Armanto, Susanto, & Bernas, 2010). This is due to the depth of pyrite the study area is located at a depth of 70-90 cm. In the research potential acid sulphate soil with a layer of pyrite at a depth of 30 cm from the surface of the soil and the ground water level 20 cm below the layer of pyrite, it is suggested that the drying period is no more than 4 weeks.

### Organic Matter Content

Organic matter content was classified as very low to high with a range of values from 0.32 to 6.74 (Table 2). On farmland 1 layers 1 T3 with the highest value at a value of 6.74%, and the lowest value at T7 organic materials with a value of 2.9%. On the second layer of organic material highest value at T3 with a value of 4.7%, while the lowest organic material found on T7 with a value of 0.32. Qualitatively to the top layer, the organic matter content is high. The diversity of organic material is also influenced by soil water status. Frequently flooded land has a higher organic matter, this is due to the decomposition process in this area is hampered. The diversity of the ground water level is also affected by the micro topography.

From the above data it can be concluded for organic materials research sites good for corn. Organic materials play an important role in determining the ability of the soil to support plant growth. The role of soil organic matter is to increase soil fertility, improve soil structure, increase the ability of soil to hold water, increasing the pore soil and improve soil microbial growth media. Low levels of soil organic matter means that the soil’s ability to support low crop productivity and vice versa.

### Total N

Based on the results of soil analysis in the laboratory, the value of N-highest total on farmland 1 are at T6 with a value of 0.30% and lowest values contained in T1 with a value of 0.08%, while in the layer 2 the highest value contained T6 with a value of 0.45% and the lowest score on T1 and T2 with a 0:11 score. Total N value of land in the farmland 1 can be seen in Table 3.

### Table 2. Values of soil organic content in farmland I (%)

| Samples | L1 code | OM  | Criteria  | L2 code | OM  | Criteria |
|---------|---------|-----|-----------|---------|-----|----------|
| 1       | T1L1    | 3.03| moderate  | T1L2    | 3.43| high     |
| 2       | T2L1    | 3.62| high      | T2L2    | 2.35| moderate |
| 3       | T3L1    | 6.74| high      | T3L2    | 4.70| high     |
| 4       | T4L1    | 4.57| high      | T4L2    | 2.55| moderate |
| 5       | T5L1    | 4.50| high      | T5L2    | 1.48| low      |
| 6       | T6L1    | 4.43| high      | T6L2    | 3.09| moderate |
| 7       | T7L1    | 2.91| moderate  | T7L2    | 0.32| very low |
| 8       | T8L1    | 4.93| high      | T8L2    | 2.07| moderate |

Remarks: */ Evaluation criteria is based on standard of Soil Research Center (1983)
Al Values

Based on results of laboratory analysis of the farmland first acquired a different value of each point. Al reply highest value at layer 1 are at T7 has a value of 11.37 ppm and the lowest value contained in T6 with a value of 3.62 ppm, while the second layer of the highest value of Al contained in the value of 3.85 ppm T3 and T1, T2 Al undetectable values. Aluminum Al content of the highest value found in the soil with the ground water table depth is 68 cm below the soil surface. The condition was due to the influence of pyrite oxidation (Table 4).

The main constraint on agriculture is swampy area was due to the high concentration of alumunium in the soil. When the soil having average value of more than 5 me/100g which mean that at least about 3 to 5 ton/ha of lime is needed to neutralize this aluminum (Imanudin and Armanto, 2012). Tha lime application of 2,5 ton/ha was capable to make soil pH at 5,3 degree, under swanmy soil at Banyu Urif Banyuasin District of South Sumatera (Sagala, 2010).

The high concentration of Al in root zone will disturbe the absorbtion of Nutrient N, P, and K . Land and water management in swamp areas should also try to maintain or add organic materials. It churns the increased solubility of hydrogen ion and aluminum in the root zone. Management should also include a continuous pattern of monoculture cultivation of rice misalaya for too long. There should be cutting cycles, or cultivation of crops in the dry season (da Silva, 2014).

### Table 3. Total N values in farmland I (%)

| Samples | L1 code | Total N | Criteria | L2 code | Total N | Criteria |
|---------|---------|---------|----------|---------|---------|----------|
| 1       | T1L1    | 0.08    | low      | T1L2    | 0.11    | low      |
| 2       | T2L1    | 0.13    | low      | T2L2    | 0.11    | low      |
| 3       | T3L1    | 0.27    | moderate | T3L2    | 0.14    | low      |
| 4       | T4L1    | 0.31    | moderate | T4L2    | 0.25    | moderate |
| 5       | T5L1    | 0.31    | moderate | T4L2    | 0.19    | low      |
| 6       | T6L1    | 0.30    | moderate | T6L2    | 0.45    | moderate |
| 7       | T7L1    | 0.14    | low      | T7L2    | 0.17    | low      |
| 8       | T8L1    | 0.26    | moderate | T8L2    | 0.16    | low      |

Note: */ Evaluation criteria is based on standard of Soil Research Center (1983)

### Table 4. Values of Al content in farmland I (ppm)

| Samples | L1 code | Al value (ppm) | GWL depth (cm) | Status  |
|---------|---------|----------------|----------------|---------|
| 1       | T1L1    | 1.22           | -42            | moderate|
| 2       | T2L1    | 1.22           | -48            | moderate|
| 3       | T3L1    | 10.51          | -35            | high    |
| 4       | T4L1    | 5.42           | -32            | high    |
| 5       | T5L1    | 8.42           | -51            | high    |
| 6       | T6L1    | 2.62           | -47            | moderate|
| 7       | T7L1    | 11.37          | -68            | very high|
| 8       | T8L1    | 6.82           | -33            | high    |

Note: */ Evaluation criteria is based on standard of Soil Research Center (1983)

GWL (depth of ground water level, cm)
Inceraseng Al could effect to the phosphor absobrtion. The problem nutrient deficiency in swampy areas is dur to low availability of P. Research (Fageria, Knupp, & Moraes, 2013) showed that the best treatmen of P fertilizer is at 175 mg P kg$^{-1}$. It was had significant positive correlation with grain yield. Added by (Marpaung & Ratmini, 2014), the application of SP36 (fertilizer of P) in 100kg/ha was commonly use in the field, and farmer get rice production around 4-5 ton/ha.

### Fe Content

Indicators of land quality in swamp area can be seen from the iron content. Sources of iron derived from iron content is highest in the T1 contained in the layer 1, which is the lowest value of 1.95 ppm on farmland 1 cannot be detected while the second layer is highest value on the T3 and T5 and T6 Fe value cannot be detected. Excess iron in the land have a big impact on plants that make the plants become Fe iron toxicity and deficiency will also inhibit the growth of chlorophyll. Critical limits the concentration of Fe in the soil solution which cause iron poisoning is about 100 ppm at pH 3.7 and 300 ppm or higher at pH 5.0 (Table 5).

| Samples | L1 code | Fe value (ppm) | GWL depth (cm) | Status |
|---------|---------|----------------|----------------|--------|
| 1       | T1L1    | 1.95           | -42            | moderate |
| 2       | T2L1    | 0.19           | -48            | moderate |
| 3       | T3L1    | 0.12           | -35            | high   |
| 4       | T4L1    | 0.11           | -32            | high   |
| 5       | T5L1    | 0.49           | -51            | high   |
| 6       | T6L1    | 1.85           | -47            | moderate |
| 7       | T7L1    | 0.88           | -68            | very high |
| 8       | T8L1    | 0.10           | -33            | high   |

Note: */ Evaluation criteria is based on standard of Soil Research Center (1983) GWL (depth of ground water level, cm)

Soils condition, Fe is present as ferric hydroxides with low plant availability, However, in anaerobic soils condition and at low redox potential (Eh), Fe is moved to its soluble form Fe$^{2+}$ and can absorb excessively by crop. Iron toxicity occurs in swampy rice production due to excess ferrous iron (Fe$^{2+}$) formation in reduced soils (Wu et al., 2014). Some rice variety was tolerance till Iron pulse stresses (1,000 mg L$^{-1}$ = 17.9 mM Fe$^{2+}$). However field research found that the total dry grain will decrease 50% if iron concentration higher than 250µg g$^{-1}$ dry weight in the rice leaf (Genon, de Hepcee, Duffy, Delvaux, & Hennebert, 1994).

The concentration of Fe in the solution that causes the symptoms of poisoning Fe rice variety IR 64 lightweight (scoring 3) is 52 ppm Fe, symptoms of poisoning Fe was (scoring = 5) = 143 ppm Fe, and symptoms of intoxication Fe heavy (scoring ≥ 9) is ≥ 325 ppm Fe. At a concentration of 400 ppm Fe impede the growth of the rice plant, plant dry weight decreased from 2.69 g (control no symptoms of iron poisoning) to 0.39 g / clumps or decreased 85.5%.

Control of iron toxicity can be done by combining the use of tolerant variety, and somewhat tolerant plants growing environmental improvements such as improved drainage, balanced fertilization, of lime and organic fertilizer. This condition has
been proven that the water system in the study area has been good thus relatively very low iron content and even some point is not detected. (Momon S. Imanudin & Armanto, 2012) reported that the proper water management in tertiary block was capable to reduce the iron solubility from 78.68 ppm to 41.31 ppm at Delta Saleh and from 78.59 ppm to 39.24 ppm at Delta Telang I.

Relationship between ground water table with soil chemical characters

The results of laboratory analysis of water level relationship with pH, OM, N, Al and Fe are presented in Table 6. Based on the results table shows that the relationship advance groundwater against chemical properties of soil, farmland I and II has a pH that is acidic. In conditions of low ground water level, then the level of soil organic matter tends to be lower. The value of N at a high water level conditions will be susceptible to the leaching process thus decreasing the N content in the soil. In relation to the ground water level value of Fe and Al is based on laboratory analysis of Al and Fe lowest value in some point cannot be detected. This happens due to the leaching process in the field was done properly and the water quality of reachin good quality. Indicated that the contents of Al and Fe value is not detected in the laboratory analysis.

For that reason the main objective of the water management in swampy areas is leaching and flushing. To have proper operation for leaching and flushing, the canal should be maintenance in good condition (no sedimen) and completed by hydraulic structur.

According to (Kima, Chung, & Wang, 2014), the application irrigation water at 3 cm water depth was showed high rice growth performance in lowland area. In the area study Telang II rice production is 5-6 ton/ha in average. It was cultivated in wet season (November-February). The soil was in saturated condition and most of time periode the water depth was at10 cm above soil surface.

CONCLUSIONS

1. Factors affecting the ground water level are rainfall, tide water, physical soil properties, depths and distance to the channel, the channel cross-sectional area and the water level in the channel.

2. The presence of soil organic material will support the activities of soil microorganisms, so that the soil will be fertile and nutrients needed by the plants will be available. The research location has a pH of 3.74-5.26 classified as very acid to acid. By maintaining the ground water level at dept 30 cm below soil surface could make the soil under saturated zone, and reduction condition will create the pH 5 (suitable for crop).
3. The relationship between soil chemical properties and ground water level is strongly depend on the oxidation and reduction process in the root zone area, Time period in dry season (Augusts) will increase the solubility of aluminium, iron, increase, acidity and reduction availability of nutrient status.

4. Leaching and flusing is required to reduce the solubility of aluminium, iron and acidity in rooting zone. It should be done one week at the beginning of rainy season. To promote the leaching and flusing process in tertiary block, farmer should have a good design of micro canal system within complete hydraulic structure.

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