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Water Table Fluctuation in Tidal Lowland for Developing Agricultural Water Management Strategies

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ABSTRACT

Water Table Fluctuation in Tidal Lowland for Developing Agricultural Water Management Strategies (MS Imanuddin, E Armanto, RH Susanto and SM Bernas): The research objective is to evaluate the water status in the tertiary block of tidal lowland for developing water management strategies and cropping pattern for food crop agriculture. The research was conducted in tidal lowland reclamation areas of Delta Saleh South Sumatera. The methodology used in this research was survey and monitoring. The result showed that the study area has a potential of acid sulphate soil which is indicated by phyrite layer at 60 cm below the soil surface. Variation of water table was very high in the range of 0-2 cm at rainy season and it was drop up to 90 to 100 cm below soil surface at dry season. This conditions result in the soil oxidation and the pH drop up to 2.5-3.5 (very acid). Analysis of water surplus and deficit during one year period was calculated by surplus excess water under 30 cm (SEW-30) and showed that the area study was experienced water deficit. Analysis of groundwater effect on soil moisture content showed that the critical water level was in 60 cm below soil surface. The soil moisture content at this point in the root zone was dropped into the wilting point level. It means that the water availability for crop water requirement is inadequate. For sustainable agriculture in the area study, the water table should be maintained in 50-60 cm below soil surface. Therefore, the recommendation of water management strategies in the study area is water retention in combination with control drainage system.

Keywords: Acid sulphate soil, surplus excess water, tidal lowland, water status

INTRODUCTION

Tidal lowland development at South Sumatra has been conducted by government since 1969 through transmigration program, but the Bugis farmers had previously developed this area since 1930s. Tidal lowland areas in South Sumatra are located along eastern coast of Sumatra and approximately covered 2.92 million ha (Euroconsult 1995). Total area of tidal lowland in South Sumatra that had been reclaimed was 373,000 ha. About 40% rice production at South Sumatra is currently produced from lowland areas and about 60% of this rice production was supplied from reclaimed tidal lowland areas (Dinas TPH Provinsi Sumatera Selatan 2006).

According to Saragih *et al. (*1996), water management is one of important factor for land management at tidal lowland area. This management is not only to reduce or to add surface water availability, but also to reduce soil acidity, to minimize land acidity due to pyrites layer oxidation, to minimize salinity hazards and flooding risks, as well as to reduce toxic chemical compounds as a result of pyrite layer oxidation. In order to establish the above conditions, water management operation is geared toward aspects of water table retention that is always located above pyrites layer and land leaching through a controlled drainage systems (Johnstona *et al.* 2005).

Tidal lowland development needs a proper planning, management, and utilization of land as well

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as proper technology application, especially water management aspect (Imanudin *et al*. 2009). The availability of acid sulphate layer is naturally occurred (Hussona *et al*. 2000). This soil has a good potential for agricultural development through proper management. Proper planning of water management is certainly need data of daily soil water status, thus yearly monitoring of that data is essential. Water table dynamics below the crop root zone has highly significant influence on soil water content (Johnstona *et al.* 2005) The crop will easily absorbed water if soil water status is at field capacity or above permanent wilting point. This condition will be established if water table surface is not drop more than 60 cm below the crop root system (Imanudin *et al.* 2009). Therefore, a field study to monitor water status at tertiary blocks is needed in order to develop water management and land utilization planning.

According to Suryadi and Schultz (2001), the option of water management is basically determined by soil conditions and hydrotophography factor. Water management option is used as a base consideration that subsequently transformed into operational procedures of the existing water structures. This means that after the first development stage where the channels are still in open system form which used to facilitate the soil ripening process and to drain excess water out of field, the next stage is to improve water management system by providing water regulating structures at the existing channels network.

The study objective is to investigate the water table dynamics of tertiary blocks in order to determine its influence on soil water content in the crop rooting system. This data is important to develop water management strategy and cropping pattern potential of tidal lowland area in South Sumatra Indonesia.

MATERIALS AND METHODS

Study Area

Study and field investigation was conducted in tidal lowland reclamation area. The demonstration plots are located at Primer 10, Delta Saleh, Banyuasin District (Figure 1). Study and field monitoring was conducted in two growing seasons consisting of wet and dry seasons. Observation period (water table monitoring) in the field was carried out from January to December 2005, whereas crop growth monitoring and field verification was conducted from November 2008 to August 2009.

Data Measurment

The water table fluctuation measurement in tertiary blocks was conducted by using observation wells made from PVC pipes having 3 m length and 2.5 inches in diameter. Theses pipes were bored on their sides and anchored within the depth of 2-2.5 m from soil surface. The upper part of pipe holes is covered and only disclosed during measurements. In addition, daily rainfall was observed by direct measurement from rainfall tipping buckets for every 07.00 *a.m.* time.

Calculation Methods

The study steps are as follows: (1) Survey, (2) Monitoring, and (3) Field observation to investigate the crop growth. Soil survey was carried out to determine the physical characteristics of soil such as texture, bulk density, total pores volume, soil hydraulics conductivity, and acid sulphate layer depth.

The deficit and excess of water were aprroached using water excess concept above 30 cm below soil surface (Surplus Excess Water/SEW-30). According to Skaggs (1991), excess water at 30 cm depth will produce physiological disorder for most crops. It means that if soil water is above 30 cm, then there will be an excess water for upland crop (Hussona *et al.* 2000). This study used SEW 30 and corn as crop indicator as well as SEW 20 and rice as crop indicator (Imanudin and Raharjo 2004). Excess water value above 30 cm can be calculated by the following relationship:

$$SEW - 30 = \sum_{i=1}^{n} (30 - x_i) \qquad [1]$$

where x_i is water table depth at day i, i is the first day and n is number of days during the crop growth.

Calculation analysis of soil water on the change of soil water content is conducted by using soil water balance approach at crop root zone (Ghasemi *et al.* 2003).

The rate of change in soil moisture content at the root zone can be described with a simple water balance equation as follow:

$$\frac{\Delta MC}{\Delta t} = I + S - ET \qquad [2]$$

where $\frac{\Delta MC}{\Delta t}$ is the rate of change in soil moisture content (cm d^{-1}), *I* is the rate of net infiltrated water through the upper boundary of the root zone (cm d^{-1}), *S* it the rate of net upward flow from the lower

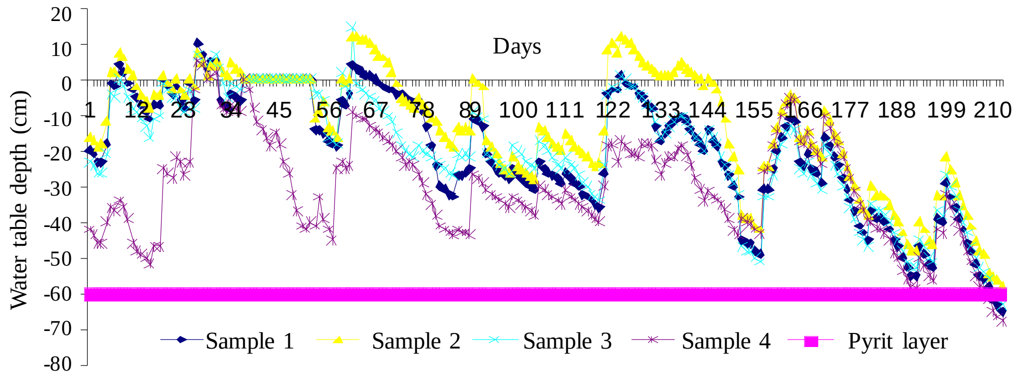

Figure 1. Daily fluctuation of water table in tertiary block (November 2008-July 2009). The areas having C typology relative to pyrite layer depth in 60 below soil surface (dash-line).

boundary (cm d^{-1}), and *ET* is the rate of crop evapotranspiration (cm d^{-1}).

With the presence of shallow field water table:

$$S=CR-D \quad [3]$$

where CR is the rate of capillary rise from the phreatic layer (cm d^{-1}) and D is the net downward flow from the root zone (cm d^{-1}).

RESULTS AND DISCUSSION

General Overview of Land Physical Condition

Delta Saleh reclamation area is classified into agroclimate type C1 based on Oldeman classification with monthly average temperature of 32^0C and yearly average rainfall of 2,500-2,800 mm. Rainy season is occured from October to April, whereas dry season is occured from May to September. Rainfall is relatively low and ineffective to fulfill the crop water requirement at dry season. This fresh water deficit problem is increase with the inflow of seawater or salt water during high tide.

Based on high tide water that overflow into the land, Delta Saleh lowland area in general is classified into C type overflow which means that it is not flooded during high tide or low tide. The land is not overflow by tide water, but the tide water still affected the water table in regular fashion. The available water is mostly from rainfall water because tide water can not enter the land which results in rain-fed characteristics of the land.

Water Table Dynamics on Tertiary Blocks

Results of daily water table analysis showed (Figure 1) that water table depth is sharply drawdown more than 1.2 m below soil surface at dry season. This condition made crop cultivation is impossible even for the second crops. Crops will experience water stress as well as may experience toxicity. If the water table drawdown is below 1.0 m, then the pyrite layer oxidation will occur. The crop planting management is a key factor to prevent this condition.

For current case of reclaimed land topography of C type at Delta Saleh, water table fluctuation is in the range of 5-20 cm (saturation to flooding conditions) at the wet season and gradually drop at the near of dry season in May. Water table start dropping since May, but soil is in humid condition (saturation) which results in insignificant effect of pyrite layer oxidation. During dry season from June to September, pyrite layer oxidation is unavoidable because water table level is at 0.77 MSL. The soil surface is at 2.0 MSL or soil water is 1.3 m below the soil surface. Phyrite layer at study area is 0.6-0.7 m from soil surface (Figure 1). It is obvious that pyrite layer on June-August will be oxidized. The oxidation occurred when the water level drop to 60 cm. This pyrite layer oxidation results in increase of aluminum and iron precipitations which produce a low soil quality (Ivarson *et al.* 1982)

Excess water analysis at 30 cm of root zone during one year (SEW-30) showed that land with C typology experienced water deficit (Figure 2) about more than 6 months. Positive value of excess water is starting from October to January. This condition creates the opportunity for rice planting. However, SEW value is dropped again near the end of January which made the decrease of rice production because generative growth period experience water deficiency. In general Figure 2 showed that land experience

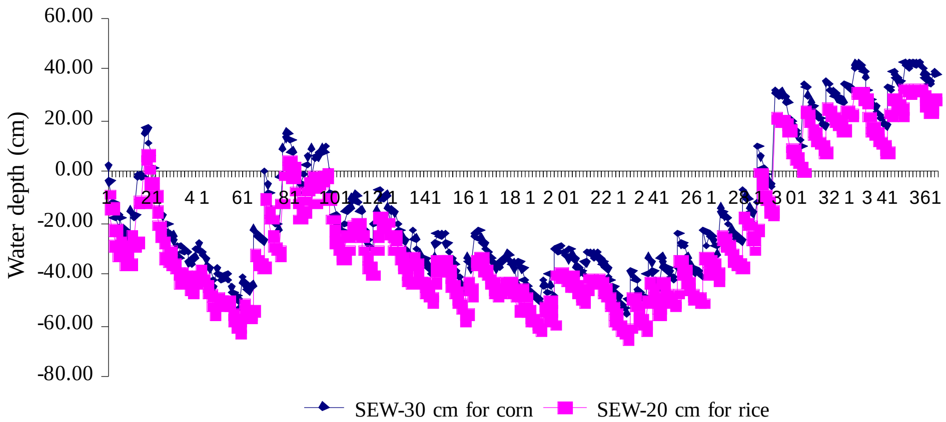

Figure 2. Calculation results of excess water under 20 cm and 30 cm zones below the soil surface.

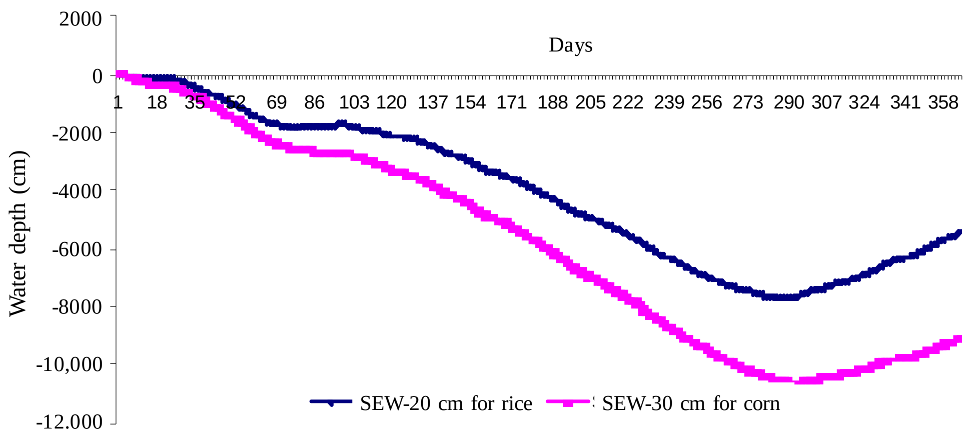

Figure 3. Water deficit cumulative relative to critical threshold of 20 cm and 30 cm below soil surface.

longer period of water deficit (soil water is retained longer below the critical zone).Observation showed that soil water condition has positive value only for three months. This is the main constraint for crop planting at tidal lowland area of C typology which mean that land experience water deficit and most of water table depth is located below 30 cm depth. This figure is a critical threshold for most food crops; even rice crop has tolerance at 20 cm depth no more than 3 days. Cumulative calculation by summing up total positive and negative values during one year is shown in Figure 3. Yearly cumulative value that showed soil water deficit at 30 cm critical threshold was 5.434 cm. It is clear that water at this condition is insufficient to leach the land. The land will experience toxicity from iron and aluminum due to pyrite oxidation result that can be disposed into channels through land leaching process without water management effort.

It is obvious from water availability analysis at the crop root zone that the land experience water deficit. Extended drawdown of soil water results in higher water volume that is needed for recharge process. Soil water condition above 30 cm zone is fulfilled at October. High hydraulics conductivity of soil due to high porosity made water difficult to be retained within long period, water is difficult to overflow, and lack of water for land leaching process.

Very significant effect of phyrite layer oxidation is shown by soil pH test in the field at dry season with magnitude of 2.5-3 (very acid), followed by water pH at secondary and tertiary channels. Soil acidity will increase near neutral pH starting at wet season due to increase of soil water content. The effect of phyrite oxidation is still apparent up to starting period of wet season due to limited water for leaching process. Precipitation effect of toxic compounds (Al,

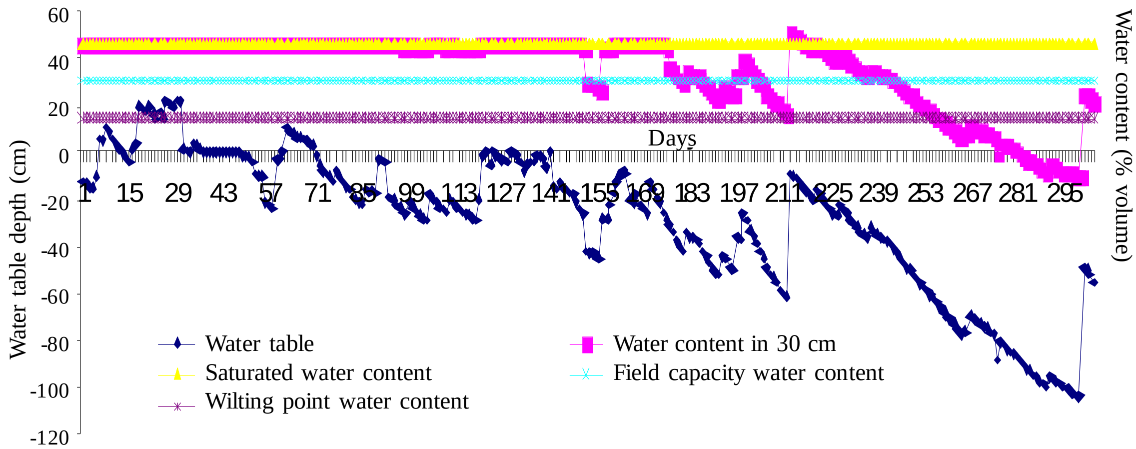

Figure 4. Soil water dynamics due to soil water change under root zone in November 2008 to August 2009. Critical point of water table found in 60 cm below soil surface.

Fe, Mn) is still apparent especially on availability and absorption of nutrients (Minh *et al*. 1998). This showed that the land is insufficiently leached and toxic elements are still found at crop rooting zone which made poor initial growth of rice due to iron toxicity. This effect can be solved by addition of agricultural limes (Ale *et al.* 2008).

Water Table Contribution Analysis for Soil Water Content Status and Rooting Zone

Fast water table drawdown if not followed by water supply will produce a decrease of soil water at root zone of crop. If this is occurred in longer period, then soil moisture within root zone area can exceed the permanent wilting point and plants will experience water stress. Illustration of soil water dynamics changes due to soil water change within root zone of crop can be seen in Figure 4.

Figure 4 is clearly showed that water table at depth 10-20 cm below soil surface was on saturated soil condition. Change of water status occurred if water table depth is dropped to 30-40 cm level. Soil moisture at this condition is approach field capacity level. Variation of soil water depth at 20-30 cm showed that the land was in moist condition which was more suitable for rice crop in this period. This occurred in rainy season (November-March). Exactly before dry season where the water level was on 40-50 cm below soil surface, it would be suitable for second crops or corn. Finally Corn can only be planted by providing a better micro water control to discharge excess water of rainfall within March-April period.

Field investigation showed that farmers were frequently delay planting period than providing drainage system to overcome flooding problem. They plant the crops in the end of June which is a late planting period because flowering period occurred in August. The peak of dry season is occurred in August where the water table may drop to 80-90cm below soil surface. Analysis of soil water contribution to soil moisture showed that the critical value was 60 cm. If the water table at 60 cm level more than three days, then root zone was in the permanent wilting point condition which result in water stress for crops. According to Zwart and Bastiaansen (2004), capillary water movement was not sufficient to fulfill crop evapotranspiration requirement if water table depth was dropped below 60 cm. Therefore irrigation was ideally given at water table condition before reaching to the wilting point (70% of available water is used up). Therefore, the water table for corn planting had to be kept at 40-50 cm level below soil surface.

CONCLUSIONS

Results of field investigation showed that land was highly dependent on water supply from rainfall because high tide irrigation can not reach into the land. This condition made water availability on land is highly affected by rainfall which made the water management objective is carried out water retention and maximizes the utilization of rainfall water.

Water table contribution analysis toward soil moisture content at root zone of crops showed that critical value of water table is achieved at 60 cm level. Soil water content at root zone was at permanent wilting point during this condition. Therefore, second crop cultivation efforts should be started at the latest on May.

Water management at this land should avoid total drainage concept with many deep open channels that results in land drying and pyrite layer oxidation. The most proper approach is through controlled drainage system using application of intensive shallow drainage to leach soil acidity. Leaching and flushing are important part in network operation at this area which is done at least twice a week.

Results of field investigation and water status evaluation in land can be used to design the probable cropping pattern consisting of: rice-fallow; rice-corn; corn-corn; and conservation rice. However, the most probable cropping pattern that can be done currently is rice with planting date in November and harvest time in January/February. Soil tillage can be done starting from October and one month for land preparation is considered sufficient for land leaching.

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