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WATER RETENTION OPTION OF DRAINAGE SYSTEM FOR DRY SEASON CORN CULTIVATION AT TIDAL LOWLAND AREA

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ABSTRACT

Farming constraint at tidal lowland area is about water management related to the nature of excessive water during wet season and insufficient water during dry season. This field research objectives was to find out the corn crop culti-vation in August 2014 which entered dry season. The iinstallation of subsurface drainage that previously had functioned as water discharge was converted into water retention. The research results showed that corn had grown well during peak dry season period (October) in which water table was at –50 cm below soil surface, whereas water table depth was dropped to –70 cm below soil surface in land without subsurface drainage. This condition implied that installation of subsurface drainage at dry season had function as water retention, not as water discharge. Therefore, network function was inverted from water discharge into water retention. It had impact on the development of optimum water surface that flow in capillary mode to fulfill the crop's water requirement. Corn production obtained was 6.4 t ha^{-1}. This condition was very promising though still below the maximum national production. The aapplications of subsurface drainage was still not optimumum due to the supply of water from the main system was not the same because of the soil physical properties diversity and topography differences.

Keywords: corn; subsurface drainage; tidal lowlands; water retention

INTRODUCTION

Agricultural activities at tidal lowlands are progressively showing good result. It is indicated by the land productivity in which most of reclaimmed tidal lowlands at South Sumatra which had two times planting (planting index (PI) of 200). The key success was the development of water management infrastructures equipped with water control structure at tertiary level for most of the land. In order to increase land productivity into PI of 300, new innovation of water table control technology is needed. According to Imanudin *et al*., (2011), the objective of this innovation is to make farmers keep cultivating in a limited water condition. Therefore, it is necessary for the cultivation of maize crops to install the hydraulic appropriate structure which able to control water table. Corn is a dry land crop which is sensitive to wet condition. Water logging or shallow water table effected the production losses of 20-50%. (Kahlown *et al.,* 1998). However, for the maximum production, a medium maturity grain requires between 500 and 800 mm of water. It depends on climatic condition (FAO, 2015).

The water table control innovation was conducted by installing subsurface drainage and had been studied for the last two years (Bakri *et al*., 2014). The results of applied study on tidal lowlands showed that this system was only effective during transition period. Water flooding was excessive during wet season so that open channel system was still needed. This system was capable to lower water table depth during transition period which facilitate corn cultivation. In the dry condition the system was possible to transform into water retention. Water retention system in subsurface drainage provides water table condition that is not exceeding the critical depth value for corn crop (Imanudin *et al*., 2011).

Subsurface drainage installation was ideally constructed at depth of 0.6 m below soil surface (Lamm and Trooien, 2005). The recommended spacing between pipe channels for subsurface drainage on clay textural dominated soil was 6 m (Nelson and Smoot, 2012). For tidal lowland agriculture, it should use the concept of

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intensive shallow drainage which was able to maintain the water level in the soil under roots zone and prevent the oxidation (Imanudin and Armanto, 2012). The drain spacing between 8 m channel, and 20 cm depth was successfully tested in the peat land reclamation area (Imanudin and Susanto, 2015).

According to Ityel *et al.,* (2014), that the subsurface drainage and sub irrigation system can improve soil aeration. In this study, installation of underground pipes planted at a depth of 40 cm below the soil surface and the surface coated the perforated pipe filter of coconut husk fibers. This condition creates the addition of oxygen content. This system can also control the water table at a depth of 0.7-0.8 m below the ground surface. It has been tried in sandy loam soil texture and effective to increase the uptake of nitrogen and reduce the loss of nutrients due to leaching (Zhou *et al*., 2000). The effect of water level control method under subsurface drainage was highly significant to decrease nitrate and phosphate loss. For nitrate loss of N can be reduced up to 44% and for phosphate can be reduced up to 60% annually (Williams *et al.,* 2015).

Based on the above description, the application of this study on subsurface drainage system is important to be conducted. This paper presented field study results related to the operation of subsurface drainage shifting system from water discharge system into water retention system.

MATERIALS AND METHODS

This study was conducted at tidal lowlands area of B typology land in which water can not overflow into farm land so that high tide irrigation is not feasible to be conducted. The implementation of this field study was on the third planting period of July to October 2014. The corn seed was planted at experimental plot having area of 0.25 ha.

Water management network was consisted of tertiary and secondary channels (Figure 1). The existing open channel system was maintained by providing micro channels with inter-channel distance of 8 m. Subsurface pipe installation was buried at channel base with depth of 20 cm from micro channel base so that pipe depth was 50 cm relative to soil surface (Bakri *et al.,* 2014). The drainage pipe was made from perforated PVC pipe which was capped with coconut fiber on its surface (Imanudin and Bakri, 2014).

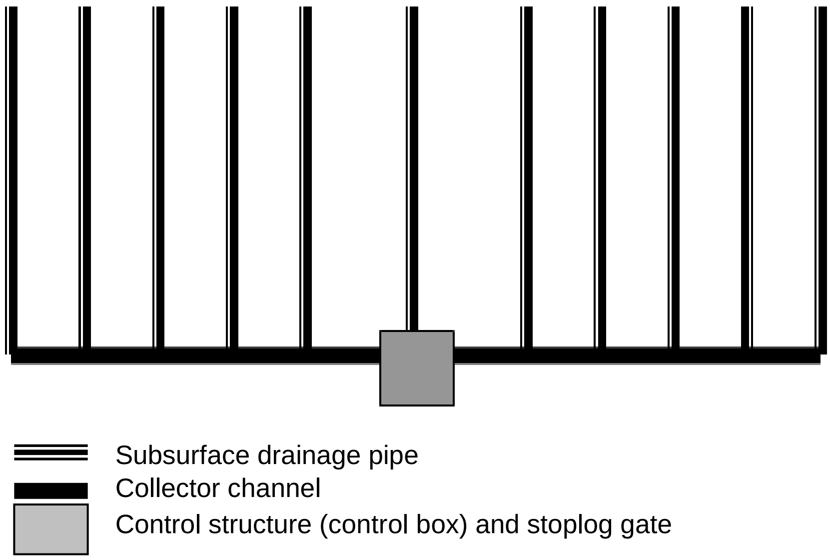

Figure 1. Diagram of micro water management system equipped with subsurface drainage pipe in field

For water table control purpose, all pipes were connected by using the fork system in which the end part was connected to collector pipe. The control structure (control box) was constructed in the middle of collector pipe equipped with stop log gate. The function of this stop log gate was to prevent water from flowing out into tertiary channel.

In addition, the data of rainfall and channel water surface depth was processed by using SEW-30 concept (*Surplus Excess Water – 30*). It used the figure of 30 cm below the soil surface because generally crops other than rice will grow optimum in the groundwater below 30 cm. (Kanwar *et al.,* 1988., Tan *et al.,* 1999; Tan *et al.,* 2002). This concept was used to show the condition of soil water excess (cm day^{-1}) during crop growing period with the following equation:

$$SEW = 30 = \sum_{j=1}^{m} \frac{30 - x_j}{24}$$

where x_j is water table surface at the end of respective hours and m (meter) is final total hours during plant growth.

RESULTS AND DISCUSSION

Physical Characteristics of Soil

Soil capability to distribute water is highly depend on its hydraulic conductivity value. The measurement of soil hydraulic conductivity was conducted directly in land plot by using auger hole method. The results of direct measurement in field showed that soil hydraulic conductivity in general had moderate values (Table 1). The magnitude value of soil hydraulic conductivity is highly affected by soil texture, organic matter content and field condition such as root distribution of plant (Callaghan *et al.,* 2014). Moderate values of soil hydraulic conductivity are suitable for application of subsurface drainage. This was due to the fact that vertical and horizontal water movements are capable to counter balance water retention capacity from subsurface pipe. On the other hand, if soil hydraulic conductivity is very slow, then the flow capacity is also slow below the retention or capacity of subsurface pipe drainage which resulting in flooded land condition.

Textural classes at upper layer (Table 2) in the study area were consisted of clay, loamy clay and loam clay. Soil with loam texture is a transition between sand and clay textures that has relatively good soil holding capacity and soil nutrients, less sticky and relatively soft as well as has good aeration (Saxton and Rawls, 2006). On the other hand, soil at the second layer soil (Table 3) is dominated by clay texture with magnitude greater than 50%. This soil layer has slow water flow capacity. Therefore the ability of the texture of clay is very low in the water flow, it is because the soil is dominated by micro pores (Alavijeh and Liaghat, 2009).

Table 1. Observation results of soil hydraulic conductivity

No.	Point	Hydraulic conductivity (cm hour^{-1})	Criteria
1	1	20.88	Moderate
2	2	16.7	Moderate
3	3	20.5	Moderate
4	4	19.6	Moderate
5	5	19.87	Moderate
6	6	17.25	Moderate

Climatic and Hydrological Condition

Climatic conditions according to the Oldeman classification is classified as agro-climatic zone C1. The average monthly temperature is 27.5^0 C, the lowest temperature is 26^0 C in January and the highest temperature is 28.7^0 C in October, and the average relative humidity is 80%. The annual rainfall in 2014 amounted to 2,553 mm with characteristics of tropical cli-mates where hot and humid conditions occur throughout the year. In 5-6 months in a row the rainfall was more than 200 mm per month, the number of rainy days were ranging between 15-22 days per month and 1-2 months of drought with rainfall of less than 100 mm per month.

Land with type B classification will only have potential tide irrigation in the rainy season. Groundwater table depth is 10-20 cm below the soil surface during the rainy season and the dry season is down to a depth of 100 cm. Hence it is important to control ground water table in the dry season so that the ground water level can be maintained at a depth of 40-50 cm below the soil surface.

Table 2. Soil textural classes of layer 1

Observation Points	Layer Depth (cm)	Textural Fraction (%)			Textural Classes
		Sand	Loam	Clay	
T1	0-17	32.4	44	23.6	Clayey loam
T2	0-15	28.4	40	31.6	Loamy clay
T3	0-13	18.4	58	23.6	Loam
T4	0-9	36.4	40	23.6	Loam
T5	0-12	40.4	38	21.6	Loam

Table 3. Soil textural classes of layer 2

Observation Points	Layer Depth (cm)	Textural Fraction (%)			Textural Classes
		Sand	Loam	Clay	
T1	17-60	16.4	34	49.6	Clay
T2	15-60	12.4	16	51.6	Clay
T3	13-60	12.4	36	51.6	Clay
T4	19.-60	12.4	36	51.6	Clay
T5	12.-60	14.4	34	51.6	Clay

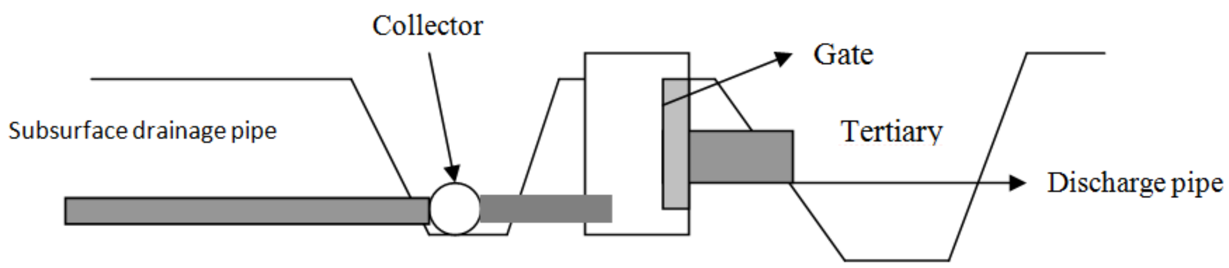

Figure 2. Centralized control system using control box

Characteristics of Water Management Network

Water management network at the study area of Mulyasari Village (P17-5S) could be classified into three classes as follows: (1) Macro Channel (Primary Channel and Navigation Channel), (2) Meso Channel (Secondary Channel of SPD and SDU) and (3) Micro Channel (Tertiary Channel, Quarterly Channel and Micro Channel). Each water management network was directly interconnected based on its level sequence, i.e. shallow meso channel result in improper function of micro channel which in turn create disturbance of farming practices.

The existence of macro channel as part of water management network can also be used as transportation means and trading, whereas meso channel without water gate structure can also function similar to macro channel. Micro channel was directly “contact with” farm land. Condition of each channel can be described as follows:

1. Tertiary Channel: this channel is located at every two paddy field plots (200 m) which connected to secondary channels consisting of Main Drainage Channel (SDU) and Village Irrigation Channel (SPD) in perpendicular position. The condition of tertiary channels nowadays is relatively clean because water weeds and mud sediment has been cleaned and transported into Farm Road. One Secondary Block (256 ha) is consisted of 17 Tertiary Channels.
2. Quarterly Channel: this channel is perpendicular to Tertiary Channel and

covers one paddy field plot (100 m). This channel is frequently planted with rice crop and other wetland plants. The condition of this channel is relatively clean.

3. Micro Channel: this channel is located at the center of farm land plot so that during land tillage operation for rice crop by using hand tractor which in turn make this channel level with paddy field soil surface. Prior to planting operation, this channel was rebuilt so it consisted of 7 units per half of hectare (14 units per hectare). Farmers usually develop this channel in greater numbers for corn cultivation with inter-channel distance of 6 to 8 m in order to discharge more water.
4. Subsurface drainage pipe is installed below micro channel with inter channel distance of to 8 m. Pipe was buried at depth of 20 cm from the base of micro channel. Monitoring box (control box) is installed to control water table depth such as shown in Figure 2.

Corn Cultivation

The third planting was started in June. The cultivated area was 5,000 m^2 located in tertiary channel (Tc) 5. Duration for corn cultivation was 3 months and the soil tillage was done by using hand tractor. Soil tillage consisted of plowing and harrowing operations which was conducted a week before planting and soil tillage duration was 7 days. The used variety was Pioneer (P27) with magnitude of 3 packs having weight of 5 kg per pack. Plant dressing was conducted when plant was 2 weeks old and it was done only one time. Fertilizers used in this corn cultivation were consisted of Urea, TSP and KCl respectively with doses of 250 kg ha^{-1}, 200 kg ha^{-1} and 200 kg ha^{-1}. Fertilizing would be done when the plant was 14 days and 40 days old, respectively. Fertilizing was done by spreading fertilizers in the vicinity of corn plant.

In addition to fertilizing and weeding, farmers also did crop's maintenance by regu-lating crop water requirement through operation of tertiary water gate. This activity was conducted by changing water gate position based on its function and water requirement, i.e. water gate was located at front position for water discharge operation (drainage) and water gate is located at rear position for water supply into farm land (irrigation).

Normally, pests which attack corn plant are caterpillar and rat. Pest control was conducted by using chemical pesticide with application dose of 1 l ha^{-1}. The frequency of pest control was two times when corn plant was 26 days and 60 days old, respectively.

Harvesting operation for corn was conducted when corn plant was 3 months old, i.e. on 29 September 2014. Corn harvesting used manual labor with wage of Rp 60,000 per day per labor. Corn was harvested by manual picking and followed by threshing operation using corn thresher machine. After the threshing operation, corns were put into sack and transported by motor vehicle for the next step drying operation. Drying operation period was 2 days in bright sun condition and 4 days for cloudy condition. Harvest yield of corn for land area of 0.5 ha was 3.2 tons and similar to 6.4 t ha^{-1} corn production. While the results of the production of corn grown in dry land intercropping systems with green beans produce an average of 4.5 t ha^{-1} (Sabaruddin *et al.,* 2011). It was also higher compared to the national maize production target of 5 t ha^{-1}. Therefore, by setting the proper water management in the wetland, the production would go well, and even higher than in dry land. However, it was still low compared to the results of Sutardjo *et al.,* (2011) research which reported a maximum production of hybrid corn was 7.7 t ha^{-1}. Elmi *et al.,* (2005) also found that the cultivation of corn in wetland with the control of water level through an underground irrigation system, where the water table maintained at depth of 0.6 m below soil surface was capable to produce yield between 8.4 to 8.6 t ha^{-1}. According to Antonelli *et al.* (2015), the sun flower showed that the plants are able to absorb water up to a depth of 2 m but this condition depends on the plant roots. In dry condition corn can grow normal when the depth of the roots could reach more even though the ground water table is at a depth 1.2 m below soil surface (Imanudin e*t al.,* 2010).

Water Status Evaluation as Impact of Water Retention Operation on Subsurface Drainage System

Field observation results of water table condition (Figure 3) showed that water table depth at location near the channel was the lowest with magnitude of -66 cm from soil surface and the highest water table depth was -7 cm from soil surface during dry season. Water table depth far from the channel had the lowest value of -82 cm from soil surface and the highest value of -4 cm from soil surface. This condition showed that water table condition became higher at a location near the channel during wet season and lower at a location far from the channel during dry season. Figure 3 showed clearly that there was an increase of water table depth during wet season which indicated the proper function of subsurface drain-age system as water retention. Water retention by closing water gate at control box structure result-ed in water infiltration into soil and there was no water loss into tertiary channel. Surface flow was collected in open channel and subsequently infiltrated into subsurface drainage pipe.

The water movement mechanisms in the process of water table filling during rainfall can be seen in Figure 4 (A). The rainfall water in this condition would infiltrate into soil and the excess water would flow into micro channel. The bottom part of micro channel was equipped with sub-surface drainage system so that the channel would not be flooded by the water which infiltrated into subsurface pipe. This condition may provide surface water reserve that would prevent the water table declined.

During dry period (Figure 4B), high tide water had fa unction solely to fill tertiary channel so that no lateral water movement from land into the tertiary channel. A control box was operated in closed condition so that the available water in land could not flowing out. This condition was able to maintain the stable water table surface at the depth needed by crops which in turns was capable to supply crop water requirement through capillary action.

Water status evaluation with SEW-30 concept for food crops in general is modified by using 10 cm addition resulting in SEW-40 cm. This condition is needed because corn can grow better if water table depth was in the range of 40 to 60 cm (Williamson and van Schilfgaarde, 1965). Analysis results showed that water table depth was relatively good (Figure 5) in fulfilling crop water requirement because total excess water was 612 cm. It showed that the role of subsurface drainage system was effective in decreasing water lost in which water was slowly decrease even during very limited rainfall con-dition. According to Nosetto *et al.* (2009), water table depth has significant effect on capillary water movement which affects water status in the root zone. The capillary water movement is highly affected by soil texture (Imanudin *et al.,* 2010). The ideal depth for sandy soils is located 140 cm below soil surface. The results study showed that corn production had decreased by magnitude of 0.05 kg per m^2 for every 10 cm increase of water table depth.

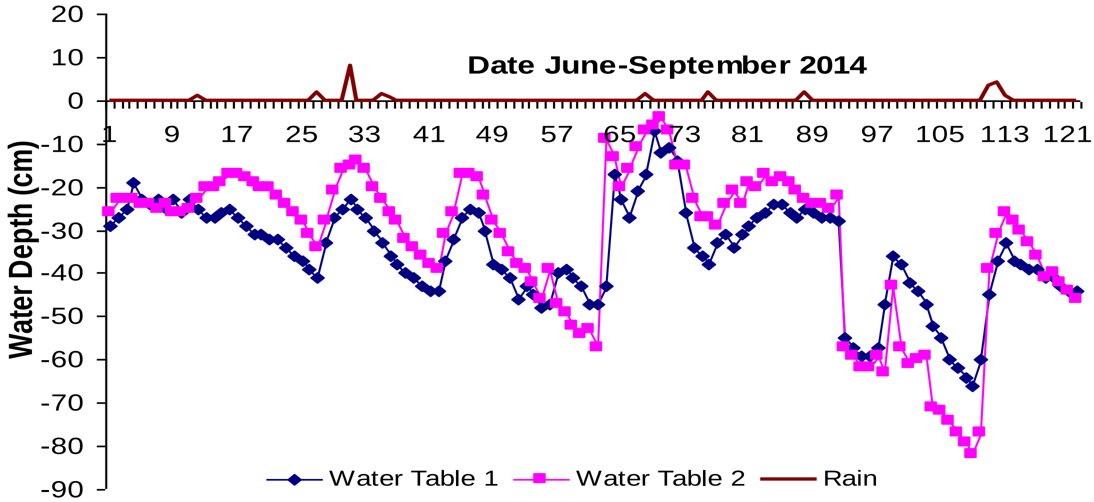

Figure 3. Water tabel dynamics in corn cultivation at dry season of June-September 2014

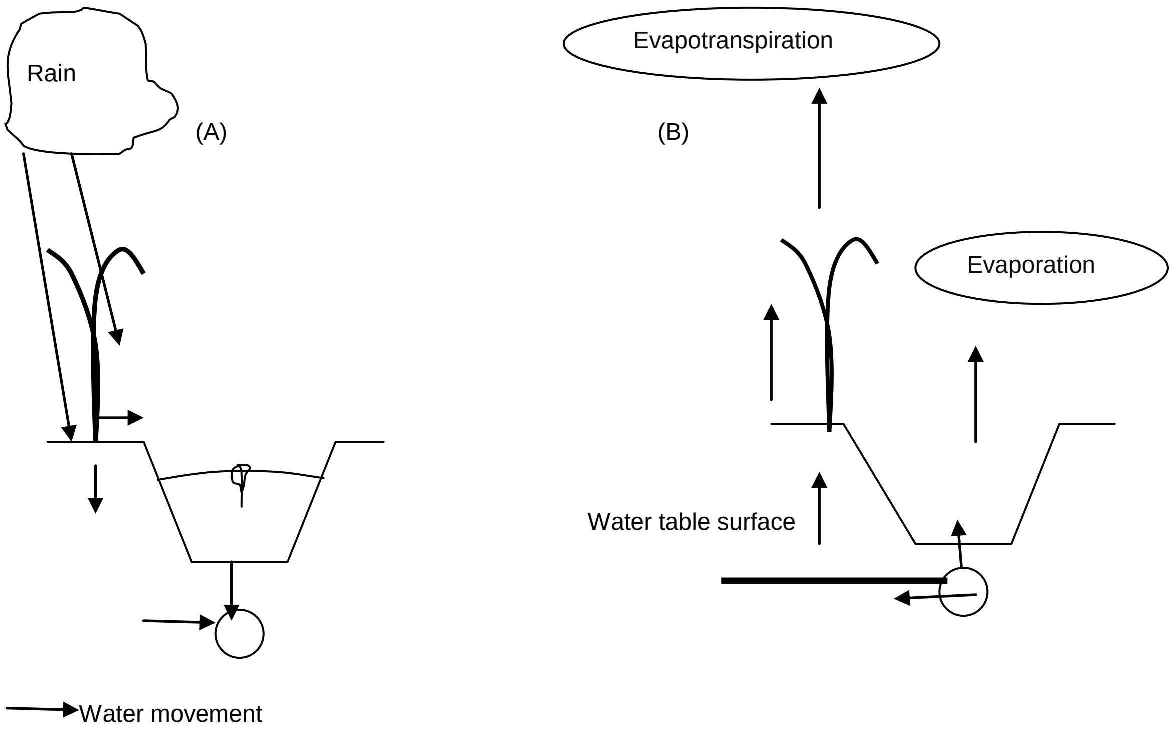

Figure 4. Water movement mechanisms on subsurface drainage system of water retention option: (A) Rainfall water retention and (B) Capillary water utilization (subirrigation)

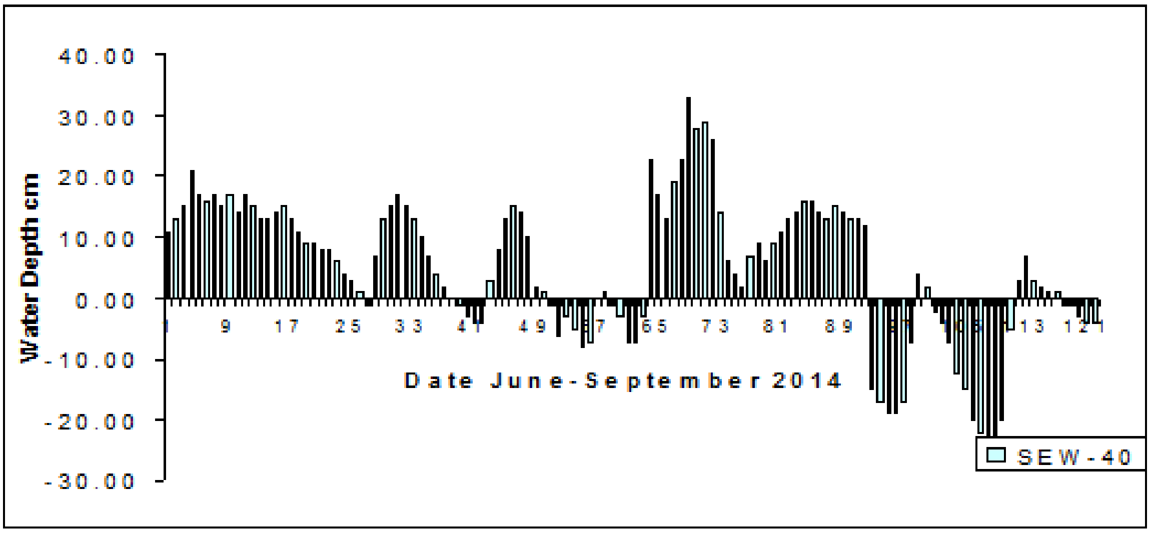

Figure 5. Water excess analysis at critical limit of 40 cm below soil surface

The best condition to fulfill crop water requirement through capillary water movement was at water table depth of –100 cm with water supply from rainfall or limited irrigation (Beltrão *et al*., 1996). According to Liu and Luo (2011), most of capillary water movement can fulfill crop water requirement at water table depth not greater than 110 cm. At dry condition where water table reach 150 cm, the contribution of water table was 65% of potential evapotrans-piration requirement. The effect of shallow water table has been tested on loam soil texture, showing that the effect of the water table was very significant to achieve the water requirement of plants that reached 60% in the event the need irrigated land (Karimov *et al.,* 2014). Added by Satchithananantham *et al.* (2014), in a fine sandy loam texture, up to 92% of the crop water demand was met by capillary rise from the shallow water table.

CONCLUSION AND SUGGESTION

As a conclusion, the key success for crop cultivation at tidal lowlands area is water table control. The control option for dry season is different than that of wet season. The option of water table control at dry condition (Third crop) is directed toward water retention so that the water gate is operated in maximum closing. This water retention can also decrease water lost through percolation and may increase water table depth so that subsurface drainage system has function as sub irrigation. The positive effect from the change in operation had impact on fulfilling the crop water requirement in dry season without provision of water pump. Farmers can conduct three times planting (Index Cropping System 300%) with potential cropping patern is rice-corn-corn.

Further study is needed for the land having different characteristics such as C land typology that has high soil hydraulic conductivity. The application of different spacing between channels at subsurface drainage system might be explored for different soil textures and this system will be applicable if tertiary channel is equipped with water gate.

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