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DRAINMOD MODEL ADAPTATION FOR DEVELOPING RECOMMENDATIONS TO MAINTAIN WATER TABLE IN THE TERTIARY BLOCK OF TIDAL LOWLAND RECLAMATIONS AREAS (A Case Study in Sugihan Kanan Under Corn Cultivation)

Momon Sodik Imanudin, [1,2)] Satria Jaya Priatna,[1] Bakri [1] and Abdul Madjid Rohim [2]

ABSTRACT

Tidal lowland at typology C is characterized by high topography and tidal overflow could not irrigate the land, thus the lands can only receive water from rain and water seepage through the tertiary channels. The main key to successful agricultural cultivation is to maintain the ground water level does not quickly descend and to elevate the water table in the dry season. Field study was conducted in Tidal reclamation area of Jalur 25 Sugihan Kanan, Bandar Jaya Village, Air Sugihan, OKI District South Sumatra. The DRAINMOD model computer was used to simulate water levels in dry and wet climates. The measured main parameters are hydraulic conductivity and drain spacing as well as daily rainfall data. The simulation results showed that the research area belongs to rainfed type and the main objective of water management is to retain water and to determine some efforts how to increase the ground water level through pump irrigation in the dry season. The application of pump irrigation was applied to the plant which entering the generative phase. The pump irrigation was provided to distribute water into the quarter channels and the worm (micro) channels. The effect of this application caused the groundwater level approached about 30 cm below soil surface, while groundwater level in areas without pump irrigation facility was in the range of 50-60 cm. Besides efforts to increase the water table, liming is still required in order to increase production. Lime application of 1 ton/ha had significant effect on increasing production. Corn production with this treatment was capable to produce 5 tons/ha, while non-treated land areas only produce 2-3 tons/ha.

Keywords : DRAINMOD, corn, pump irrigation, tidal lowland

Comment [A1]: Please read carefully the Guide for the author.
Almost format is not following the author guideline.

Comment [A2]: Full name
Ogan komering ilir District, South Sumatra Province

Comment [A3]: Dry and rain season?
Or dry and wet climate condition?

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1. INTRODUCTION

Extensive land clearing of tidal lowland areas for agricultural enterprise in South Sumatra was started since 1969. About 400,000 ha of tidal lowland had been reclaimed through transmigration progarm. Banyuasin area so far had showed successful effort in rice production at South Sumatra with magnitude higher than 40 percent of total rice production. However, this successful effort had not followed by other agricultural areas because planting index at these areas was less than 200 %. One of relatively less productive area is Sugihan Kanan with rice production level of less than 5 ton.ha^{-1} and most of its agricultural land had one planting index (Imanudin et al., 2017).

The key success for land management at tidal lowland areas is how to manage soil water level at elevation level required by crop's root zone (Imanudin et al., 2010). Othe important factor is availability of structures and infrastructure of water management network to facilitate land leaching process and water flooding in channels. Inadequate drainage facility frequently results in toxic elements accumulation and high soil acidity (Imanudin et al, 2010). In addition, not all swamp areas are capable to provide good water quality from secondary channel for supply. Many channels had carried acid water or saline water during dry season which should be prevented from entering tertiary channels. Water gates at tertiary channel are absolutely required for water retention process.

The construction of field operation planning requires daily water table data during period of rain and dry seasons either at dry or wet climate conditions. Daily water table data so far is frequently unavailable. Therefore, DRAINMOD computer model can provide aid in presenting dynamics condition of daily water table. This data can be used to construct weekly operational plan in the field for crop cultivation. This paper will present results of water table dynamics obtained from DRAINMOD modelling and operational planning that will be implemented during planting season. Field adaptation was conducted by corn planting at dry season. The recommended DRAINMOD model for water filling in channels will be implemented through passive approach (water retention) and active approach through water pumping from tertiary channel.

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Comment [A7]: Why only imanudin in introduction

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Comment [A10]: Why use DRAINMOD? And please add supported reference

The objectives of this field study are to construct operational model for water table control for corn planting at dry season through computer modelling of DRAINMOD model followed by field validation process through water gate operation and effort of water filling in channel through the use of water pump.

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In the objection you use corn, but you never mention before, please mention 1 or 2 sentences in introduction

2. METHODS

This research was implemented at tidal lowland area of tertiary plot-4 at Bandar Jaya Vilage, Jalur 25, Air Sugihan Subdistrict, Ogan Komering Ilir District. It was conducted from May to October 2017. The research site is classified as C typhology land in which it can not receive water through high tidal irrigation because high tidal water can not enter into this land. Water from seconday channel only capable to fill tertiary channel.

Materials used in this study are soil sample, corn seeds, fertilizers, pesticides, crop's protecting plastics and chemicals for soil analysis in the laboratory. Equipments used in this study are consisted of piezometer, wells (perforated PVC pipe), 12 inch PVC pipe, elbow, marking board, water pass, meteran, soil bor, excavation tube (bailer), stopwatch, GPS (*Global Positioning System*), flap water gate made of fibre, 10 inch PVC pipe, digital camera and agricultural equipments. For evaluation of water status at tertiary block and land drainage planning was conducted through computer simulation by using DRAINMOD 5.1 software(Skags, 1992).

Comment [A12]: Where the GPS data?

Input parameters for DRAINMOD are soil physical characteristics consisting of impermeable layer depth, soil hydraulic conductivity value and climate data consisting of temperature and daily rainfall. Water network information is consisted of the depth and distance amongst channels. Simulation was conducted to determine soil water table dynamics at dry climate condition (Elnina) and wet climate condition (Lanina).

Comment [A13]: Please recheck the definition. I suggest to delete

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Observation of water table monitoring was extended to period prior to dry season in May 2017. The corn seeds used in this study was Pioner P21 variety. In order to support land drainage system, farmers developed micro channel with depth of 30 cm and distance between channels in the range of 8 to 10 m. Two treatments were used in this study: first, crop without lime addition and water source only from water gate retention; second, crop with lime addition at dose of 1.5 $ton.ha^{-1}$ and water supply from irrigation by using pump. In order to provide water in tertiary channel for pumping operation, farmers had conducted temporary water retention (dam) by using canvas platics. Pumping opration was conducted at crop's generative phase. Irrigation used in this study was furrow irrigation in which water is delivered to fill collector channel and water from this channel subsequently was distributed to fill micro channel. Irrigation was applied once in a week.

Comment [A15]: Make more systematic or you can make some diagram

Computer simulation result from DRAINMOD model and adaptation of water surface control in the field will be used to construct operational planning for water surface control for corn cultivation. This information will bring benefit for farmers in implementing crop cultivation at land having similar typhology (C type) and they can prepare irrigation infrastructure means according to local resources.

Comment [A16]: Make more simple and easy to understand

Analysis method for soil water status is done by using SEW-30 concept. The calculation of SEW-30 is based on Sieben formula (Sieben, 1964 *in* Skaggs, 1991). This concept is used to determine condition of soil water excess (cm-day) during crop growth period. Concept of water excess 30 cm above the root zone has an objective to evaluate fluctuation height of soil water table during winter period within agricultural land area. Value of water excess 30 cm above the root zone can be calculated in order to predict soil water excess during crop growth period. The equation used for this calculation is as follows:

Comment [A17]: cm-day or cm/day

Comment [A18]: what you mean? To evaluated fluctuation of water table during winter? So did this model suitable for no in winter period. Indonesia doesn't have snow

$$SEW-30=\sum_{i=1}^{n}(30-x_i) \qquad [3]$$

where x_i is soil water table at i-th day, with i is the first day and n is number of days during crop growth. The DRAINMOD model actually calculate hourly value of SEW-30 cm instead of daily value so that calculation of SEW-30 value is more accurate and can be formulated by using the following equation:

Comment [A19]: what the mean?

$$SEW-30=\sum_{j=1}^{m}(30-x_j)/24 \qquad [4]$$

where x_j is soil water table at the end of respective hours and m is total hours during crop growth period. Water table position with critical limit of 30 cm is done with consideration value of 30 cm below soil surface is selected because most of food crops will experience physiological disturbance if soil water table is drop down from 30 cm point or increase upward from 30 cm point from soil surface. That is, if soil water is far from critical value of 30 cm or close to soil surface, then it will create excess water condition. This condition is apply for non-rice food crop. On the contarry, rice crop is withstand toward water flooding condition and will experience stress if soil water is below 30 cm depth zone or even below 20 cm depth zone

3. RESULTS AND DISCUSSION

3.1. Soil Physical Characteristics

Soil physical characteristics at the study area is classified as good. This is indicated by soil bulk density below 1 (Table 1) at depth of 30-60 cm (root zone) which showed that soil had relatively high total pore space resulting in relatively high water holding capacity. The decrease of soil bulk density is followed by the decrease of total pore space at deeper soil layers. Soil layer above 60 cm showed the increase of clay content so that soil bulk density can be classified into mineral soil. The main limiting factor is soil acidity level than can be classified as acid soil with pH of 4-5.

Comment [A20]: How you can determine the soil physics is good? What the reference?

Table 1. Soil physical characteristics and soil acidity kevel

Depth	Bulk Density (g/cm^{3})	Total Pore Space (%)	Water content (%)	pH
0-30 cm	0.67	77	65.95	4.8
30-60 cm	0.74	73	6715	4.6
> 60 cm	0.98	64	7293	4.2

Comment [A21]: Is it correct?

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Soil textural class is showed by ratio of clay, sand and loam fractions (Table 4.2). Although soil fraction composition had occurred, soil texture at the study area is qualitatively can be classified into loamy clay class. Clay fraction tend to increase with the increase of soil depth. Clay fraction with magnitude of 7.6 % at soil layer depth 0 - 30 cm had increased to 21.6 % at soil layer depth of 60 cm. The increase of clay fraction below soil surface had produce beneficial effect in which land is capable to store water at depth above 60cm so that soil water depth at this layer is not quickly deplete. In addition, soil water contribution at this layer through capillary movement is very important to supply crop water requirement.

Table 2. Distribution of sand, loam and clay fractions at several soil layers

Depth	Percentage (%)			Soil Texture
	Sand	Clay	Loam	
0-30 cm	29.4	7.6	63	Loamy clay
30-60 cm	26.4	14.6	59	Loamy clay
>60 cm	14.4	21.6	64	Loamy clay

Comment [A24]: Where is silt? Loam? What standard did you use?

3.2. Computer Simulation of DRAINMOD in estimating soil water table

DRAINMOD is drainage model that capable to estimate the depth of soil water table for swamp lowland and peat land areas. The main inputs for this model are consisted of rainfall, crop evapotranspiration, soil hydraulic conductivity and network characteristics data. Condition of water flow within soil is assumed to be constant (steady condition) in Drainmod model.

Comment [A25]: Crop transpiration? evapotranspiration

In case of reclaimed tidal lowland area at Sugihan Kanan, some model inputs were consisted of soil hydraulic conductivity of 0.34 m.day^{-1}, impermeable layer depth of 2 m, distance between tertiary channels at current condition in the field was 250 m, initial soil water depth is assumed 10 cm below soil surface and average channel depth of 1.5 m. The constructed scenario can be seen in Table 3. Simulation was conducted at two climatic conditions consisting of normal climate (normal rainfall) and dry rainfall due to Elnino. The simulation stages were consisted of simulation on the existing network condition without control effort followed by simulation on water gate operation.

Table 3. Scenario planning constructed at initial stage of DRAINMOD simulation

Microclimate scenario	Water management options	
	Conventional (without control)	Using control
Normal Rainfall Condition in Year of 2014	Soil water table indicator	Soil water table indicator
Dry Rainfall Condition (El Nino) in Year of 2015	Soil water table indicator	Soil water table indicator
Wet Rainfall Condition (Lanina)	Soil water table indicator	Soil water table indicator

in Year of 2016

Computer simulation results of DRAINMOD for normal climate condition was shown in Figure 1. Simulation results showed that variation of soil water table at condition of initial to final rainy season had safe value in term of land firing probability. However, simulation results also showed that over drain had been occurred on land. This is indicated by quick drawdown of soil water table elevation in case of no rainfall occurrence more than one week period. Results of soil water table fluctuation either at normal rainfall condition or dry rainfall condition (Elnino) showed similar trend in term of soil water table condition for January-May period. Land was still in safe condition from fire hazard during this period. Although soil water table drops into critical depth value (80 -100 cm), but rainfall was still occurred so that soil water elevation could increase again close to 30 cm depth. The vulnerable condition started to occur at days of 140 (entering of May) in which rainfall was decrease and soil water elevation was continuously drop exceeding the critical limit (- 80cm). Rainfall was normal in year of 2014, soil water elevation was continuously drop into the lowest point of – 115 cm in September and start to increase when entering October although it was still in critical depth limit. Safe condition was again occurred in November, whereas dry climate condition (Elnino) in 2015 showed that soil water elevation was drop up to depth of – 118 cm which was also occurred in September. However, condition of soil water elevation was still at critical depth value up to December due to very limited rainfall. This is due to the fact that soil had high porosity so that farmers are reluctant to open tertiary channel because rainfall water was assumed to have insufficient capability to supply soil water table and channels. Therefore, effort should be done to deliver water into quarterly channel through water pumping from tertiary channel. This requires stepping detention during high tidal water in tertiary channel.

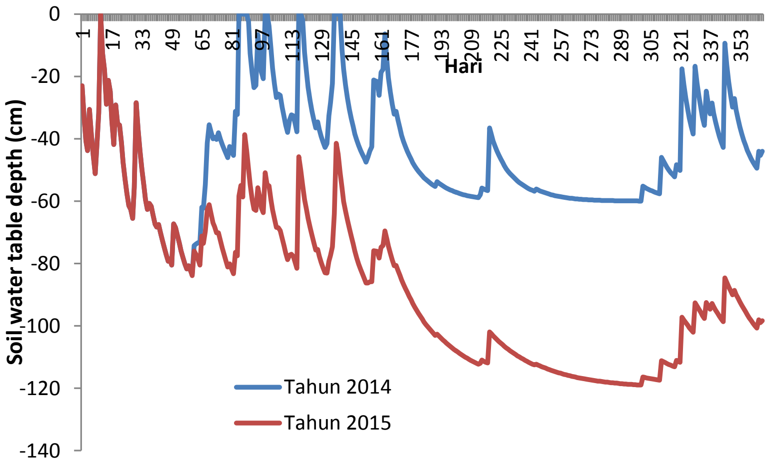

Figure 1. Soil water table fluctuation resulting from DRAINMOD simulation at condition of without control.

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Simulation results from Figure 1 showed that open drainage system with distance between channel of 250 m and channel dimensions as follows: upper width of 2.0 m and lower width 1.2 m as well as depth of 1.2 m was excessive in term of dimension size. This channel dimension is only suitable for channel system in mineral soil. Therefore, water losses was very quick indicated by water drawdown up to 40 cm in case of no rainfall occurrence for two weeks period.

Simulation using shallow drainage system was subsequently tried in order to determine the proper channel dimension at peat land with objective to prevent excessive water losses. The depth of tertiary channel was only 1 m with bottom width of 30 cm. Simulation result (Figure 2) showed that soil water table drawdown was not as fast as the existing channel dimension. Simulation result of shallow drainage showed that soil water table condition in year of 2015 (Elnino) was within safe zone up to June. The control measure can be done in June period.

Because drainage system had already been built and it was impossible to conduct filling activity, then the choice was to conduct water retention immediately by using controlled dam system. Therefore, computer simulation of DRAINMOD was implemented at initial stage. Simulation was also conducted to determine impact of water retention within tertiary channel (Figure 1). Water retention simulation would be done during the least rainfall occurence period in May. Simulation results showed that soil water table elevation can be increased up to depth of 30-40 cm below soil surface during May-June.

Soil water table elevation was located at 60 cm below soil surface during dry season of July-November. Land at this condition was relatively safe from fire hazard. This condition would be achieved if soil water table elevation in tertiary channel was not drop more than 40 cm from soil surface. Condition of this controlled drainage system was found in the field during October where soil water table was located at safe zone, i.e. 40-50 cm below soil surface. This condition at least also prevent phyrite oxidation, although pumping irrigation supply was needed to fulfill crop water requirement. Pump facilities are highly needed if farmers would cultivate corn during dry season at B and C land typhology areas. Pump was only operated for one month during seed filling phase and irrigation was applied once in a week.

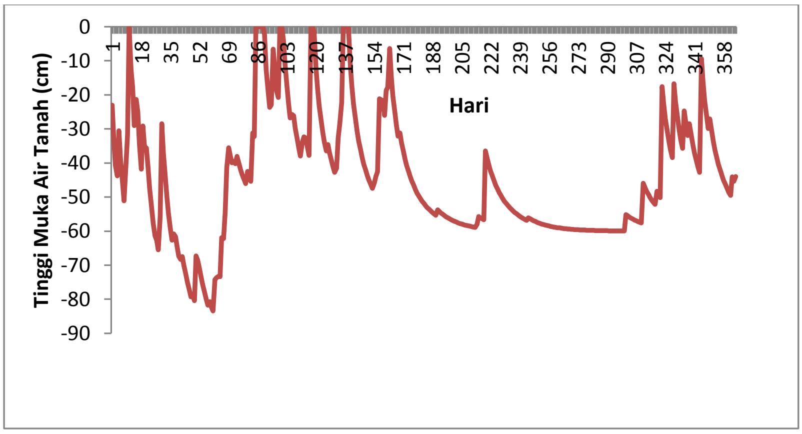

Figure 2. Computer simulation result at shallow drainage condition or 50 cm water retention.

Water retention measure was highly needed because land area at the study location had high water losses (Figure 3). Control structures are needed to support network opeation as water retention. The dam pattern equipped with overflow structure is the proper model to be applied in tertiary channel. Farmers currently used sand bags to withstand water losses. Effort to elevate soil water table elevation can be done by using water pumping from tertiary channel into quarterly channel which was subsequently delivered further into collector and micro (worm) channels.

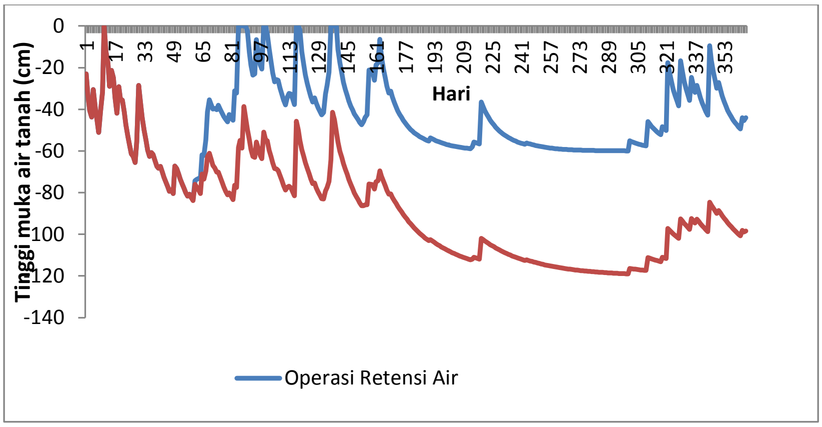

Figure 3. Soil water table dynamics affected by water retention sistem (detention system)

3.3. Field Adaptation of Water Dynamics at Dry Season Condition (July 2017)

Water table elevation was hourly observed in order to determine soil water table dynamics which is affected by fluctuation of water surface in channel. Results of this hourly observation can be seen in Figure 3. Average value of water table depth was in the range of 37 to 41 cm below soil surface. This magnitude was very ideal for the growth of corn crop. Hourly observation of soil water table showed that decrease of water surface in secondary channel was followed by decrease of water surface in tertiary channel, whereas the increase of water surface in secondary channel was followed by the increase of water surface in tertiary channel. This condition was not followed by the change of soil water table. The soil water table movement was relatively stable from maximum depth condition of – 50 cm into minimum depth condition of – 33 cm. The movement of soil water table was highly affected by rainfall. The insignificant different of water table depth at tertiary block was due to water availability in tertiary channel. Therefore, horizontal movement of water (seepage) was practically small and can be neglected as long as water along tertiary channel was available at height of 50-60 cm.

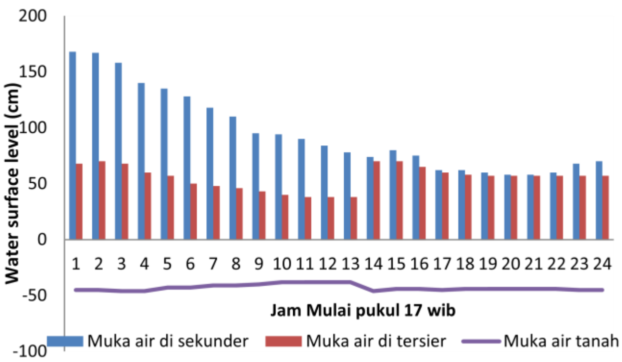

Figure 3. Condition of daily water surface level at tertiary channel and tertiary block in July.

Comment [A27]: the picture was difficult to understand

The relationship between water level elevation in tertiary channel and soil water table as a result of water retention impact (Tabel 2) showed that water level elevation in tertiary channel on May-July was located at 70 cm depth and water level elevation in secondary channel was located at 168 cm depth. This condition can produce soil water table elevation at 30 cm below soil surface.

Table 2. Relationship amongst water level at tertiary channel,

secondary channel and soil water table.

No	Locations	Water surface level (cm)
1	Tertiary channel	70 cm
2	Secondary channel	168 cm
3	Soil water table	-30 cm

3.4. The network operation and corn growth (PS2)

The network operational guideline in tertiary channel could be summarized in Table 3. Operation was conducted each month according to crop growth phases.

Table 3. Operation of tertiary network by using goose neck water gate

Month	Estimation of crop’s growth	Water management	Operation of goose neck water gate

	phases	objective	Inner Section	Outer Section
May-June	Land preparation and planting	Controlled drainage	Goose neck is turned 45^o	Closed with valve materials
July-August	Vegetative	Controlled drainage	Goose neck is turned 45^o	Closed with valve materials
September-October	Generative	Supply, soil water filling	Goose neck is turned 45^o (additional supply from water pump)	Pipe is opened

Crop evapotranspiration requirement at dry season entering September could not be fulfilled if solely rely on capillary water movement from soil water table depth of 50 cm. Capillary water only capable to supply 45 % of crop evapotranspiration requirement at this condition so that other water supply was needed. Farmers used water pump to fill soil water table (Figure 4).

Significant increase of soil water table was observed on corn cultivation which was supplied through pump irrigation. Water can be elevated with magnitude of 20 cm. Soil water table on land without pump irrigation was located at depth of 40-50 cm below soil surface, whereas soil water table on land supplied with pump irrigation was located at about 30 cm (Figure 5). If soil water table was located at depth of 30 cm below soil surface, then crop evapotranspiration requirement can be fully supplied from capillary water movement

Figure 4. Pump irrigation on corn cultivation to elevate soil water table level.

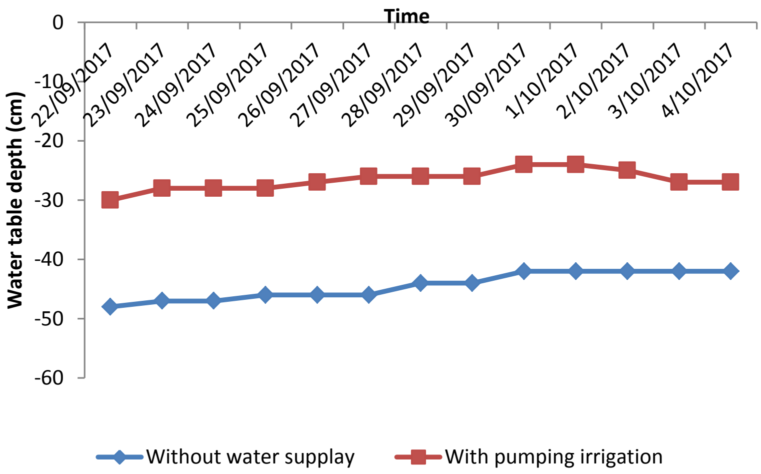

Figure 5. Condition of soil water table at the middle of September 2017 affected by pump irrigation.

Corn production achieved by using maximum technological inputs consisting of improvement of irrigation system and soil quality showed good yield with magnitude of about 3 ton.ha^{-1} although this production level was still lower than corn production achieved by farmers at Telang II area with magnitude of 7-8 ton.ha^{-1} (Imanudin and Bakri, 2014). The yield of corn would be optimum under water table at 50-60 cm below soil surface. Since the water table drop in more than 100 cm, the performance of corn growth decrease.

4. CONCLUSION AND RECOMMENDATION

- Hydrotopographical characteristics at the study area was classified into C class in which land area is not receive overflow from high tidal water. However, water availability in channel is capable to control soil water table.

Comment [A28]: lot of typo, some word still use Indonesia, picture is not clear/ difficult to understand. Lack of reference.
Explanation the result need improvement.
Need more clear the target

- Komputer model DRAINMOD computer model can be used to estimate fluctuation of soil water table at several climatic conditions. Simulation results can be utilized to construct monthly water management plan.
- The main objective for water management at tertiary level was water retention due to soil physical condition which is characterized by high porosity and high hydraulic conductivity. Therefore, operational model was controlled drainage.
- Water retention in tertiary channel at depth of 70 cm was capable to maintain soil water table elevation at 30 cm below soil surface. Soil water table elevation should not be drop below 50 cm in order to prevent phyrite oxidation.
- Liming measure at dose of 1-2 ton.ha was still required at initial stage of reclamation because of high acidity and high aluminium solubility.

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Comment [A29]: Lack of update the reference, at least from 2009-2019, please follow the role of guide lines

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Kepada: Momon sodik Imanudin

Rab, 21 Okt 2020 jam 09.09

Yth. Bapak Momn Sodik Imanuddin

Dengan hormat,

Bersama ini kami ingin bertanya perihal perbaikan naskah. Naskah hasil telaah reviewer telah kami kirimkan pada tanggal 5 Oktober 2020. Kami menunggu naskah perbaikan dari Bapak.

Demikian disampaikan, atas perhaian dan kerjasamanya diucapkan terimakasih.

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Dewan Editor

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Jum, 19 Feb 2021 jam 15.04
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Dengan hormat,

Terimakasih telah memperbaiki artikel. Naskah akan kami kirimkan kepada reviewer untuk ditelaah ulan.

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Dewan Editor

PERBAIKAN MAKALAH TAHAP I

19 FEBRUARI 2021

DRAINMOD MODEL ADAPTATION FOR DEVELOPING RECOMMENDATIONS WATER MANAGEMENT IN THE TERTIARY BLOCK OF TIDAL LOWLAND AGRICULTURE

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ABSTRACT

The main key to successful agricultural cultivation is to maintain the ground water level to fulfill crop water requirement, particularly in the dry season. Field study was conducted in Tidal reclamation area of section 25 at Sugihan Kanan, Bandar Jaya Village, Air Sugihan, Ogan Komering Ilir District of South Sumatra. The DRAINMOD computer model was used to simulate water levels in dry and wet climatic condition. The measured main parameters are soil hydraulic conductivity and drain spacing as well as daily rainfall data. The simulation results showed that the research area belongs to rainfed type and the main objective of water management is to retain water and to determine some efforts how to increase the ground water level through pump irrigation in the dry season. The application of pump irrigation was applied to the plant which entering the generative phase. The pump irrigation was provided to distribute water into the quarter channels and the worm (micro) channels. The effect of this application caused the groundwater level approached about 30 cm below soil surface, while groundwater level in areas without pump irrigation facility was in the range of 50-60 cm. Besides efforts to increase the water table, liming is still required in order to increase production. Lime application of 1 ton/ha had significant effect on increasing production. Corn production with this treatment was capable to produce 5 tons/ha, while non-treated land areas only produce 2-3 tons/ha.

Keywords : DRAINMOD, corn, water management; pump irrigation, tidal lowland

ABSTRAK (IN INDONESIAN)

Kunci utama keberhasilan pertanian di rawa pasang surut adalah begaimana petani mampu mengendalikan muka air agar sesuai dengan pertumbuhan tanaman, terutama di musim kemarau. Kajian lapngan sudah dilaksanakan di lahan reklamasi Jalur 25 Sugihan Kanan, Desa Bandar Jaya. Air Sugihan Kanan Kabupaten Ogan Komering Ilir Sumatera Selatan.Komputer model DRAINMOD digunakan untuksimulasi muka air pada kondisi iklim basah dan kering. Parameter utama yang diukur adalah keterhantaran hidroulik, jarak antar saluran dan curah hujan harian. Hasil simulasi menunjukan area studi tergolongsawah tadah hujan, sehingga tujuan utama pengelolaan air adalah retensi air hujan dan perlu upaya menikan muka air tanah di saat musim kemarau misalnya melalui system irigasi pompa. Aplikasi irigasi ponpa dilakukan pada tanaman jagung memasuki fase generative. Melalui system pompa air di alirkan dari saluran tersier ke saluran kuarte dan saluran cacing. Dari usaha ini air tanah naik mencapai kedalaman 30 cm dari permukaan tanah, Sementara pada petakan yang tidak di berika irigasi pompa air tanah hanya berada di kedalaman 50-60 cm. Selain usaha menaikan muka air tanah, aplikasi pengapuran masih diperlukan. Aplikasi

rendah dosis 1 ton/ha nyata meningkatkan produksi. Tanaman jagung dengan perlakuan kapur mampu menghasilkan produksi 5 ton/ha, sementara tanpa perlakuan kapur dan tanpa upaya penaikan muka air tanah hanya menghasilkan 2 ton/ha.

Kata kunci: DRAINMOD; jagung; pengelolaan air; irigasi pompa; rawa pasang surut

INTRODUCTION

Extensive land clearing of tidal lowland areas for agricultural enterprise in South Sumatra was started since 1969. About 400,000 ha of tidal lowland had been reclaimed through transmigration progarm. Banyuasin area so far had showed successful effort in rice production at South Sumatra with magnitude higher than 40 percent of total rice production (Disperta, 2017). However, this successful effort had not followed by other agricultural areas because planting index at these areas was less than 200 %. One of relatively less productive area is Sugihan Kanan with rice production level of less than 3 $ton.ha^{-1}$ and most of its agricultural land had one planting index (Imanudin et al., 2016). The soil is classified as acid sulphate soil which has high acidity and Alumunium content (Fahmi et al., 2014). Aluminum toxicity was produced an alteration of biochemical and physiological reaction of plants and then to their crop productivity. Decreasing in root growth is one of an initial and most evident symptoms of Al-toxicity. The nutrient availability was decrease also due to bond reaction Al-P (Koesrini, et al., 2014). On the otherhand Increasing levels of aluminum and iron in the soil solution also cause a decrease in the quality of water in the canals, soil pH and water pH dropping to a range of 2.3-3. Then the water channeled should be fluch out and replaced by fresh water from the rain or tide water (Sukitprapanon, et al., 2019).

The key success for land management at tidal lowland areas is how to manage soil water level at elevation level required by crop’s root zone (Imanudin et al., 2010; Bakri et al., 2015). According to Fahmi et al., (2014) water status availability in root zone is main factor hat determine the successful agriculture in acid sulphate soil. Rain water was very important water resources mainly in acid sulphate soil. It was due to pyrite oxidation process during dry period, then make ground water high toxic element and very acid. Fresh water from tide is not possible for land irrigation. Thus, to fulfill water crop requirement mainly achieved by rain water (Imanudin et al., 2019). Therefore water retention in channels is important to do with the block technique (Nurzakiah et al., 2016). Water in the canal is managed at a depth of 60-90 cm, to create groundwater in the root zone at a depth of 10-30 cm (Herawati et al., 2020). Diharapkan dengan sistem drainase terkendali air di saluran tetap tersedia untuk menjaga agar air tanah berada dalam zona akar dan selalu diatas lapisan pirit (Sasirat, et al., 2019).

Othe important factor is availability of structures and infrastructure of water management network to facilitate land leaching process and water flooding in channels. Inadequate drainage facility frequently results in toxic elements accumulation and high soil acidity (Bakri et al., 2015). In addition, not all tidal lowland areas are capable to provide good water quality from secondary channel for supply (Hartoyo et al., 2010; Megawaty et al., 2012). Many channels had carried acid water or saline water during dry season which should be prevented from entering tertiary channels (Hairmansis et al., 2017; Tafarini, and Yazid., 2018). Water gates at tertiary channel are absolutely required to be installed for control drainage and water retention process (Lasmana et al., 2017; Imanudin et al., 2019).

The construction of field operation planning requires daily water table data during period of rain and dry seasons either at dry or wet climate conditions (Imanudi et al., 2010; Negm et al., 2016).. Daily water table data so far is frequently unavailable, difficult to mesure, and costly . Therefore, DRAINMOD computer model can provide aid in presenting dynamics condition of daily water table (Madramootoo et al., 1999; Wahba et al., 2018; Askar et al., 2020). This data can be used to construct weekly water management operational plan in the field for crop cultivation (Imanudin, et al., 2011). According to Skaggs et al., (2012) statistical analysis shows acceptable results where the simulation model with daily water level prediction results calibrated with field data shows Nash-Sutcliffe (EF) modeling efficiency values are 0.68 and 0.72, the daily drainage rate (EF = 0.73) and 0.49), and monthly drainage volume (EF = 0.87 and 0.77).The simulated result was high correlation between predicted and measured (Wan et al., 2009; Malakshahi, et al., 2020). Proper drainage planning by DRAIMOD simulation model was also depend on the quality of data input . Physical and Hydrological parameters such as rainfall, and soil hydraulic conductivity was very essential data input. (Negm et al., 2014; Askar et al., 2020). Model was also successfully work for developing of land drainage design (Sojka et al, 2019). The model is able to provide input on the proper use and operate of drainage network infrastructure (Askar et al., 2020). Model could provide better predictions of groundwater table depths under shallower drainage systems. And produce management tool to minimize environmental issues in agriculture field (Davoodi et al., 2019). The DRAINMOD model is excellent drainage modelling for estimating the depth of the groundwater table (Davoodi et al., 20019). The estimated groundwater level from simulation and modeling results shows the value of r^2 = 0.93 (Ashkan et al., 2020). An adaptation model for the trofical area has been carried out in tidal lowland reclamatioan areas in Banyuasi South Sumatra. The simulation result found r^2 0,83. Hydrological parameters is limited factor to have a good statistical analysis (Imanudin, et al., 2011).

This paper will present results of water table dynamics obtained from DRAINMOD modelling and operational planning that will be implemented during planting season. Field adaptation was conducted by corn planting at dry season. The recommended of DRAINMOD model for water supply in tertiary channels will be implemented by rainfall harvesting method (passive approach) and active approach through water pumping from tertiary channel during very dry condition. The objectives of this field study are to construct the operational model for water table control for agriculture purpose.

MATERIALS AND METHODS

This research was implemented at tidal lowland area of tertiary plot-4 at Bandar Jaya Vilage, Jalur 25, Air Sugihan Subdistrict, Ogan Komering Ilir District (Figure 1). It was conducted from May to October 2017. The research site is classified as C typhology land in which it can not receive water through high tidal irrigation because high tidal water can not enter into this land. Water from seconday channel only capable to fill tertiary channel.

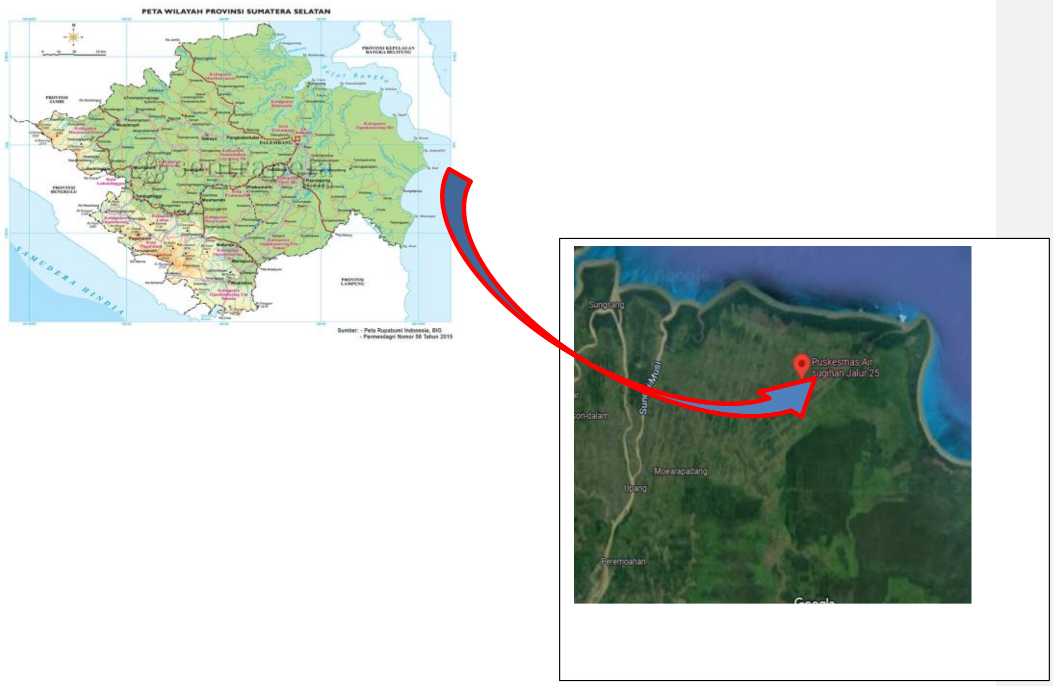


Figure 1. Maps of the area study in tidal lowland recamations of sugihan OKI

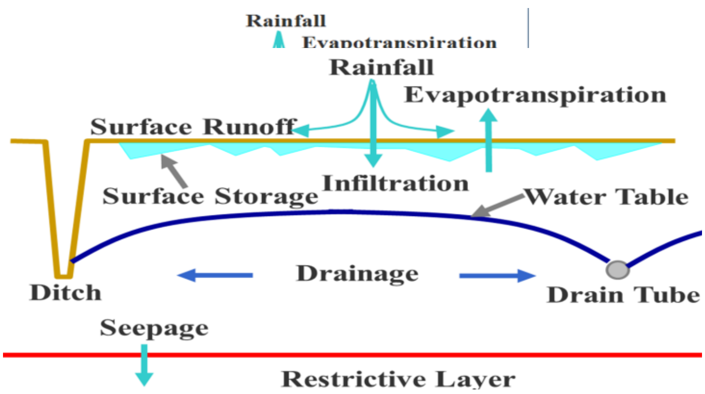
Materials used in this study are soil sample, corn seeds, fertilizers, pesticides, crop's protecting plastics and chemicals for soil analysis in the laboratory. Equipments used in this study are consisted of piezometer, wells (perforated PVC pipe), 12 inch PVC pipe, elbow, marking board, water pass, meteran, soil bor, excavation tube (bailer), stopwatch), flap water gate made of fibre, 10 inch PVC pipe, digital camera and agricultural equipments. For evaluation of water status at tertiary block and land drainage planning was conducted through computer simulation by using DRAINMOD 5.1 software (Skaggs et al., 2012).

The coseptual model to develop DRAINMOD is based on the water balance analysis within vertical soil column unit per surface area. The calculation is starting from impermeable layer up to soil surface which is located between drainage channels (Skaggs, 1978). Calculation of water balance within soil profile for time period of dt is mathematically can be expressed as follows :

$$\Delta Va = F - D - Ds \quad [1]$$

$$P = F + RO + \Delta S \quad [2]$$

where ΔVa is the change of soil air volume (cm), F is infiltration (cm), ET is evapotranspiration (cm), D is lateral flow (negative sign indicates drainage flow and positive sign indicates subsurface irrigation conditions) in cm, *Ds* is side seepage flow (positive sign indicates upward capillary flow) in cm, P is precipitation (rainfall) in cm, RO is surface flow (cm), and ΔS is the change of surface water storage. As illustration, drainage profile system in DRA



Skaggs (

Rainfall inputs in DRAINMOD model is hourly rainfall as well as maximum and minimum temperatures which is read from weather data and water balance that is conducted every hour.

Input parameters for DRAINMOD are soil physical characteristics consisting of impermeable layer depth, soil hydraulic conductivity value and climate data consisting of temperature and daily rainfall. Water network information is consisted of the depth and distance amongst channels. Simulation was conducted to determine soil water table dynamics at dry and wet climate condition .

Observation of water table monitoring was extended to period prior to dry season in May 2017. The corn seeds used in this study was Pioner P21 variety. In order to support land drainage system, farmers developed micro channel with depth of 30 cm and distance between channels in the range of 8 to 10 m.

There are two treatments were used in this study:

- first, crop without lime addition and water source only from water gate retention; supply water only form the water capillarity movement
- second, crop with lime addition at dose of 1.5 $ton.ha^{-1}$ and water supply from irrigation by using pump. In order to provide water in tertiary channel for pumping operation, farmers had conducted temporary water retention (dam) by using canvas platics. Pumping opration was conducted at crop's generative phase. Irrigation used in this study was furrow irrigation in which water is delivered to fill collector channel and water from this channel subsequently was distributed to fill micro channel. Irrigation was applied once in a week.

The computer model DRAINOD was used for predicting daily water table as effect of deference climatic condition. Data input of DRAINMOD simulation model were hydraulic conductivity, soil water retention, and land drainage system (drain spacing, depth and width of channel), and crop physiological data. Scenario for model operational was constructed based on different climatic conditions.

Analysis method for soil water status under root zone was calculated using SEW-30 concept. The calculation of SEW-30 is based on Sieben formula (Skaggs et al, 2012). This concept is used to determine condition of soil water excess (cm/day) during crop growth period. Concept of water excess 30 cm above the root zone has an objective to evaluate fluctuation height of soil water table during wet period (rainy season) within tidal lowland agriculture area (Imanudin et al., 2018). Value of water excess 30 cm above the root zone can be calculated in order to predict soil water excess during crop growth period. The equation used for this calculation is as follows:

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

where x_i is soil water table at (days to), with i is the first day and n is number of days during crop growth. The DRAINMOD model actually calculate hourly value of SEW-30 cm instead of daily value so that calculation of SEW-30 value is more accurate and can be formulated by using the following equation:

$$SEW-30=\sum_{j=1}^{m}(30-x_j)/24 \qquad [2]$$

where x_j is soil water table at the end of respective hours and m is total hours during crop growth period. Water table position with critical limit of 30 cm is done with consideration value of 30 cm below soil surface is selected because most of food crops will experience physiological disturbance if soil water table is drop down from 30 cm point or increase upward from 30 cm point from soil surface. That is, if soil water is far from critical value of 30 cm or close to soil surface, then it will create excess water condition (Negm et al., 2014). This condition is apply for non-rice food crop. On the contarry, rice crop is withstand toward water flooding condition and will experience stress if soil water is below 30 cm depth zone or even below 20 cm depth zone (Imanudin et al., 2011; Imanudin et al., 2019).

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RESULTS AND DISCUSSION

Soil Physical Characteristics

Soil physical characteristics at the study area is shown on Table 1. Soil has high porosity and low bulk density in top layer. This is indicated that soil had relatively high total pore space resulting in relatively high water holding capacity. The decrease of soil bulk density is followed by the decrease of total pore space at deeper soil layers. Refer to the water movement means that on the rotting zone area the water movement was easy to drain and submerges by gravity forces.

Soil layer above 60 cm showed the increase of clay content so that soil bulk density can be classified into mineral soil. The main limiting factor is soil acidity level than can be classified as acid soil with pH of 4-5. It is also reported also by Koesrini et al., (2014) when pH <5 the Aluminum toxicity is increase in soil. It is the main stress factor for plant growth on tidal lowland agriculture

Table 1. Soil physical characteristics and soil acidity kevel

Depth	Bulk Density (g/cm^{3})	Total Pore Space (%)	pH
0-30 cm	0.98	46	4.8
30-60 cm	1,15	48	4.6
> 60 cm	1,25	55	4.2

Soil textural class is showed by ratio of clay, sand and loam fractions (Table 4.2). Although soil fraction composition had occurred, soil texture at the study area is qualitatively can be classified into silt loam class at 0-60 cm, and clay texture in the layer of 60 cm below soil surface. Clay fraction is tend to increase with the increase of soil depth.

Table 2. Distribution of sand, loam and clay fractions at several soil layers

Depth	Percentage (%)			Soil Texture
	Sand	Clay	Silt	
0-30 cm	29.4	7.6	63	Silt loam
30-60 cm	26.4	14.6	59	Silt loam
>60 cm	14.4	64	21.6	Clay

Clay fraction with magnitude of 7.6 % at soil layer depth 0 - 30 cm had increased to 21.6 % at soil layer depth of 60 cm. The increase of clay fraction below soil surface had produce beneficial effect in which land is capable to store water at depth above 60cm so that soil water depth at this layer is not quickly deplete. In addition, soil water contribution at this layer through capillary movement is very important to supply crop water requirement. According to Zipper et al., (2015) the contribution of ground water through capillary rise is strongly depend on soil texture. Increasing clay fraction on the soil more provide water by capillary rise than soil having sandy soil. Added by Gao et al (2017), that at groundwater depth in 1 m below soil surface he capillary upward was supplied about 41% of the crop evapotranspiration. In this case mean that the supply water was required to fulfil crop water requirement when the water table start drop at 70 cm.

Computer Simulation of DRAINMOD in estimating soil water table

DRAINMOD is drainage model that capable to estimate the depth of soil water table for swamp lowland and peat land areas. The main inputs for this model are consisted of rainfall, crop evapotranspiration, soil hydraulic conductivity and drainage network characteristics data. Condition of water flow within soil is assumed to be constant (steady condition) in Drainmod model (Skaggs et al, 2012).

In case of reclaimed tidal lowland area at Sugihan Kanan, some model inputs were consisted of soil hydraulic conductivity of 0.34 $m.day^{-1}$, impermeable layer depth of 2 m, distance between tertiary channels at current condition in the field was 250 m, initial soil water depth is assumed 10 cm below soil surface and average channel depth of 1.5 m. The constructed scenario can be seen in Table 3. Simulation was conducted at two climatic conditions consisting of normal climate (normal rainfall) and dry rainfall due to Elnino. The simulation stages were consisted of simulation on the existing network condition without control effort followed by simulation on water gate operation.

Table 3. Scenario planning constructed at initial stage of DRAINMOD simulation

Microclimate scenario	Water management options	
	Conventional (without control)	Using control
Normal Rainfall Condition in Year of 2014	Soil water table indicator	Soil water table indicator
Dry Rainfall Condition (El Nino) in Year of 2015	Soil water table indicator	Soil water table indicator
Wet Rainfall Condition (Lanina) in Year of 2016	Soil water table indicator	Soil water table indicator

Computer simulation results of DRAINMOD for wet and dry climate condition was shown in Figure 3. Simulation results showed that variation of soil water table at condition of initial to final rainy season had safe value in term of land firing probability. However, simulation results also showed that over drain had been occurred on land. This is indicated by quick drawdown of soil water table elevation in case of no rainfall occurrence more than one week period. Results of soil water table fluctuation either at normal rainfall condition or dry rainfall condition (Elnino) showed similar trend in term of soil water table condition for January-May period.

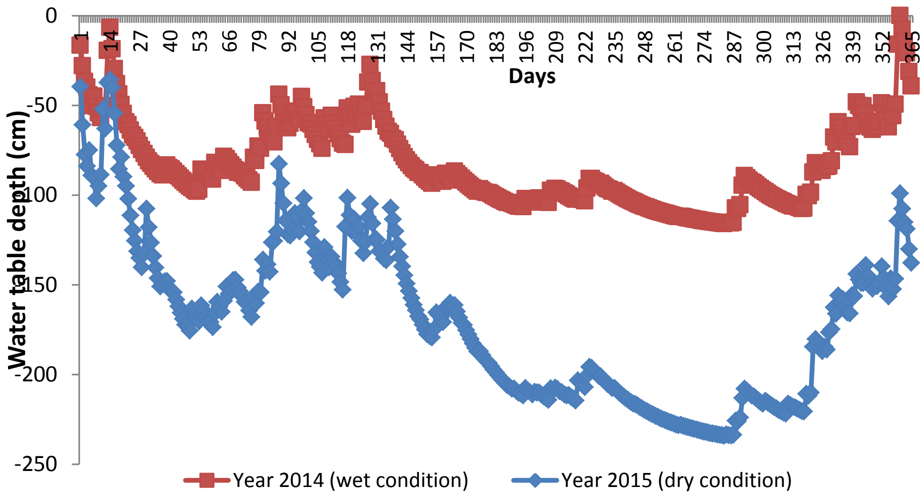

Figure 3. Soil water table fluctuation resulting from DRAINMODsimulation model under control and of without control.

Land was still in safe condition from fire hazard during this period. Although soil water table drops into critical depth value (80 -100 cm), but rainfall was still occurred so that soil water elevation could increase again close to 30 cm depth. The vulnerable condition started to occur at days of 140 (entering of May) in which rainfall was decrease and soil water elevation was continuously drop exceeding the critical limit (- 80cm). In this periode the pirit oxidation also could haven and will create the decreasing pH and in the root zone.

On the other hand the soil has a pirit layer around 60-70 cm below soil surface. When the ground water table level drops to 100 cm, oxidation layer will occur. This process would produce the high soil acidity and increase solubility of iron and aluminum content which may have harmful for crop. Reported by Koesrini et al., (2014) that application of lime with 2.0 Mg ha-1 is still required for increasing pH in the soil. Added by Fahmi et al., (2014) the lime application was efficient in combination by good land preparation through intensive soil leaching and intermittent water logging. It was also reported by Ar-Riza, et al., (2015) that main problem is difficult to get fresh water for leaching and flushing process. Those for managing acid sulphate soil are still required lime application to increase pH. According to Aksani et al., (2018) increase productivy of tidal lowland rice cultivation was achieved by 10 Mg ha-1 rice straw compost, and NPK fertilizers that should be applied are 315 kg urea ha-1, 135 kg SP-36 ha-1 and 90 kg KCl ha-1, Mean that water availablty is not anly a single factor for increase land productivity. .

Rainfall was in normal condition in year of 2014, soil water elevation was continuously drop into the lowest point of – 115 cm in September and start to increase when entering October although it was still in critical depth limit. Safe condition was again occurred in November, whereas dry climate condition (Elnino) in 2015 showed that soil water elevation was drop up to depth of – 118 cm which was also occurred in September. However, condition of soil water elevation was still at critical depth value up to December due to very limited rainfall. This is due to the fact that soil had high porosity so that farmers are reluctant to open tertiary channel because rainfall water was assumed to have insufficient capability to supply soil water table and channels. Therefore, effort should be done to deliver water into quarterly channel through water pumping from tertiary channel. This requires stepping detention during high tidal water in tertiary channel.

Simulation results from Figure 1 showed that open drainage system with distance between channel of 250 m and channel dimensions as follows: upper width of 2.0 m and lower width 1.2 m as well as depth of 1.2 m was excessive in term of dimension size. This channel dimension is high capacity to drain water. Therefore, water losses was very quick indicated by water drawdown up to 40 cm in case of no rainfall occurrence for two weeks period.

Simulation using shallow drainage system was subsequently tried in order to determine the proper channel dimension at peat land with objective to prevent excessive water losses. The depth of tertiary channel was only 1 m with bottom width of 30 cm.

Simulation result (Figure 2) showed that soil water table drawdown was not as fast as the existing channel dimension. Simulation result of shallow drainage showed that soil water table condition in year of 2015 (Elnino) was within safe zone up to June. The control measure can be done in June period.

Because drainage system had already been built and it was impossible to conduct filling activity, then the choice was to conduct water retention immediately by using controlled dam system. Therefore, computer simulation of DRAINMOD was implemented at initial stage. Simulation was also conducted to determine impact of water retention within tertiary channel (Figure 4). Water retention simulation would be done during the least rainfall occurence period in May. Simulation results showed that soil water table elevation can be increased up to depth of 30-40 cm below soil surface during May-June. Soil water table elevation was located at 60 cm below soil surface during dry season of July-November. Land at this condition was relatively safe from fire hazard. This condition would be achieved if soil water table elevation in tertiary channel was not drop more than 40 cm from soil surface.

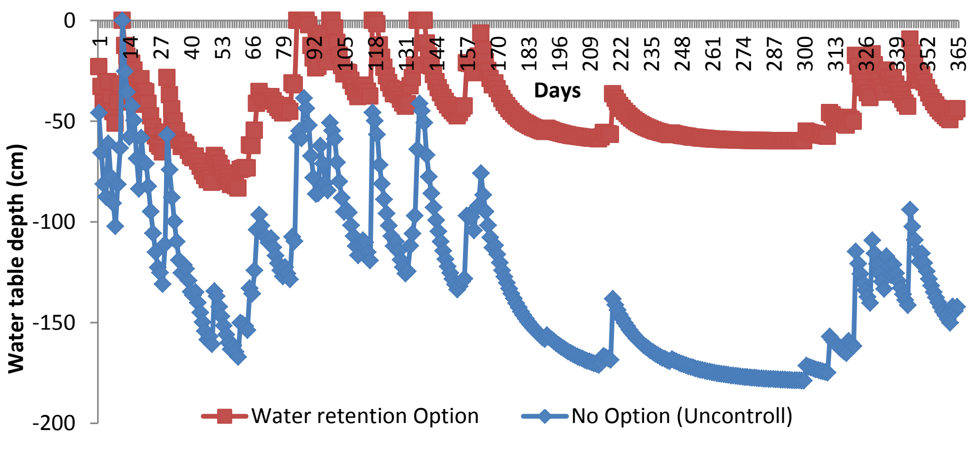

Figure 4. Computer simulation result at shallow drainage condition or 50 cm water retention

Condition of this controlled drainage system was found in the field during October where soil water table was located at safe zone, i.e. 40-50 cm below soil surface. This condition at least also prevent phyrite oxidation, although pumping irrigation supply was needed to fulfill crop water requirement. Pump facilities are highly needed if farmers would cultivate corn during dry season at B and C land typhology areas. Pump was only operated for one month during seed filling phase (generative period) and irrigation was applied once in a week.

Water retention structure was highly needed because land area at the study location had high water losses. Control structures are needed to support network operation as water retention (rainfall harvesting). The dam pattern equipped with overflow structure is the proper model to be applied in tertiary channel (Figure 5). Farmers currently used sand bags to withstand water losses. Effort to elevate soil water table elevation can be done by using water pumping from tertiary channel into quarterly channel which was subsequently delivered further into collector and micro (worm) channels.

Control drainage is the best option for water management in the area study. Farmer keep the water in tertiary canal minimum at 50 cm above the bottom level of the canal. By maintaining water level in the tertiary 50-60 cm than the ground water table purposed above the piritic layer during the dry season..

Figure 5. Hydraulic structure in tertiary canal for water retention and control drainage in tidal lowland type C.

4.3. Field Adaptation of Water Dynamics at Dry Season Condition (July 2017)

Water table elevation was hourly observed in order to determine soil water table dynamics which is affected by fluctuation of water surface in channel. Results of this hourly observation can be seen in Figure 6. Average value of water table depth was in the range of 37 to 41 cm below soil surface. This magnitude was very ideal for the growth of corn crop. Hourly observation of soil water table showed that decrease of water surface in secondary channel was followed by decrease of water surface in tertiary channel, whereas the increase of water surface in secondary channel was followed by the increase of water surface in tertiary channel. This condition was not followed by the change of soil water table. The soil water table movement was relatively stable from maximum depth condition of – 50 cm into minimum depth condition of – 33 cm. The movement of soil water table was highly affected by rainfall. The insignificant different of water table depth at tertiary block was due to water availability in tertiary channel. Therefore, horizontal movement of water (seepage) was practically small and can be neglected as long as water along tertiary channel was available at height of 50-60 cm.

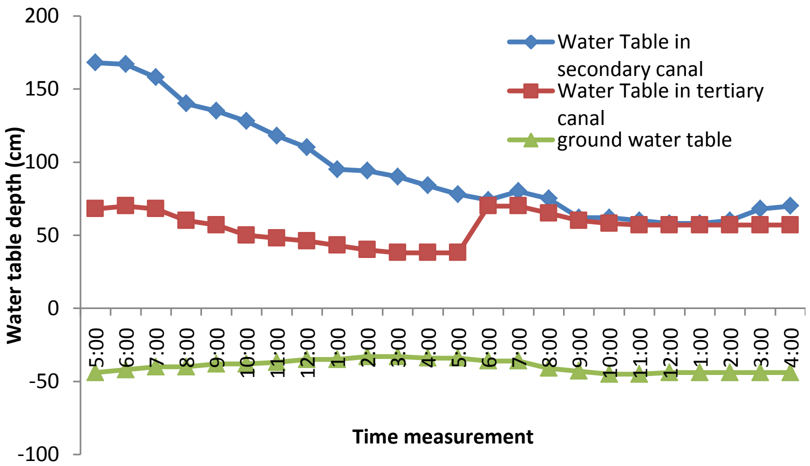

Figure 6. Condition of daily water surface level at tertiary channel and tertiary block in July.

The relationship between water level elevation in tertiary channel and soil water table as a result of water retention impact (Tabel 4) showed that water level elevation in tertiary channel on May-July was located at 70 cm depth and water level elevation in secondary channel was located at 168 cm depth. This condition can produce soil water table elevation at 30 cm below soil surface.

Table 4. Relationship amongst water level at tertiary channel, secondary channel and soil water table.

No	Locations	Water surface level (cm)
1	Tertiary channel	70 cm
2	Secondary channel	168 cm
3	Soil water table	-30 cm

The network operation and corn growth (PS2)

The network operational guideline in tertiary channel could be summarized in Table 5. Operation was conducted each month according to crop growth phases.

Table 5. Model Operation of tertiary network by using goose neck water gate

Month	Estimation of crop's growth phases	Water management objective	Operation of goose neck water gate	
			Inner Section	Outer Section
May-June	Land preparation and planting	Controlled drainage	Goose neck is turned 45^o	Closed with valve materials
July-August	Vegetative	Controlled drainage	Goose neck is turned 45^o	Closed with valve materials
September-October	Generative	Supply, soil water filling	Goose neck is turned 45^o (additional supply from	Pipe is opened

water pump)

Crop evapotranspiration requirement at dry season entering September could not be fulfilled if solely rely on capillary water movement from soil water table depth of 50 cm. Capillary water only capable to supply 45 % of crop evapotranspiration requirement at this condition so that other water supply was needed. Farmers used water pump to fill soil water table (Figure 7).

Significant increase of soil water table was observed on corn cultivation which was supplied through pump irrigation. Water can be elevated with magnitude of 20 cm. Soil water table on land without pump irrigation was located at depth of 40-50 cm below soil surface, whereas soil water table on land supplied with pump irrigation was located at about 30 cm (Figure 8). If soil water table was located at depth of 30 cm below soil surface, then crop evapotranspiration requirement can be fully supplied from capillary water movement. Reported by Fan Yang et al., (2011) the capillary rise could not support the crop water requirement when the ground water table below 2,5m. and when the ground water table maintenance at 50 cm, than the irrigation is not required.

Figure 7. Pump irrigation on corn cultivation to elevate soil water table level.

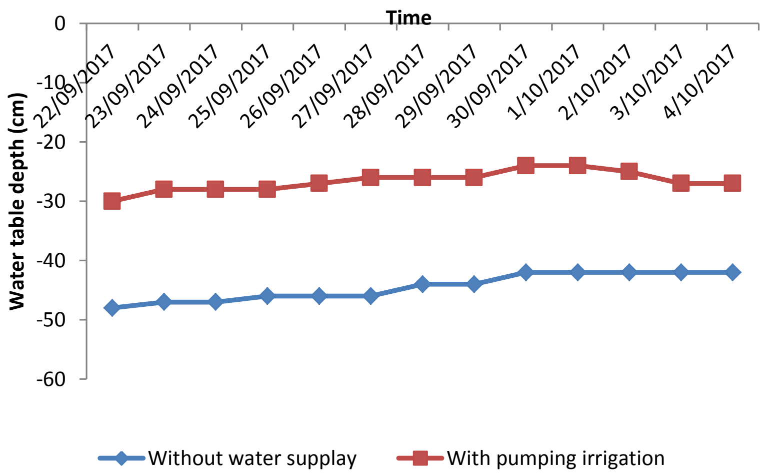

Figure 8. Condition of soil water table at the middle of September 2017 affected by pump irrigation.

Corn production achieved by using maximum technological inputs consisting of improvement of irrigation system and soil quality showed good yield with magnitude of about 3 ton.ha^{-1} although this production level was still lower than corn production achieved by farmers at Telang II area with magnitude of 7-8 ton.ha^{-1} (Imanudin and Bakri, 2014). The yield of corn would be optimum under water table at 50-60 cm below soil surface (Bakri et al., 2015). Since the water table drop in more than 100 cm, the performance of corn growth decrease. Reported by Liu, and Luo (2011) in Australia that the significant contribution of ground water table is ranging between 40-150 cm. It was contributed more than 65% of the potential evapotranspiration. However under 40-50 cm the water requirement of crop was fulfil by water capillary rise.

CONCLUSIONS

- Hydrotopographical characteristics at the study area was classified into C class in which land area is not receive overflow from high tidal water. However, water availability in channel is capable to control soil water table.

- Komputer model DRAINMOD computer model can be used to estimate fluctuation of soil water table at several climatic conditions. Simulation results can be utilized to construct monthly water management plan.
- The main objective for water management at tertiary level was water retention due to soil physical condition which is characterized by high porosity and high hydraulic conductivity. Therefore, operational model was to retain water during the rainy season (rainfall harvesting) and controlled drainage during second crop (corn).
- Water retention in tertiary channel at depth of 70 cm was capable to maintain soil water table elevation at 30 cm below soil surface. Soil water table elevation should not be drop below 50 cm in order to prevent phyrite oxidation.
- Liming application at dose of 1-2 ton.ha was still required at initial stage of reclamation because of high acidity and high aluminium solubility.

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Based on the reviewing process, hereby I suggest the Editor of Journal of Tropical Soils to:
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1. Jelaskan Drainmod model itu bagaimana persamaannya.
2. Penulisan reference di Introduction
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1. **Impact to soil science and technology**
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DRAINMOD MODEL ADAPTATION FOR DEVELOPING RECOMMENDATIONS WATER MANAGEMENT IN THE TERTIARY BLOCK OF TIDAL LOWLAND AGRICULTURE

ABSTRACT

The main key to successful agricultural cultivation is to maintain the ground water level to fulfill crop water requirement, particularly in the dry season. Field study was conducted in Tidal reclamation area of section 25 at Sugihan Kanan, Bandar Jaya Village, Air Sugihan, Ogan Komering Ilir District of South Sumatra. The DRAINMOD computer model was used to simulate water levels in dry and wet climatic condition. The measured main parameters are soil hydraulic conductivity and drain spacing as well as daily rainfall data. The simulation results showed that the research area belongs to rainfed type and the main objective of water management is to retain water and to determine some efforts how to increase the ground water level through pump irrigation in the dry season. The application of pump irrigation was applied to the plant which entering the generative phase. The pump irrigation was provided to distribute water into the quarter channels and the worm (micro) channels. The effect of this application caused the groundwater level approached about 30 cm below soil surface, while groundwater level in areas without pump irrigation facility was in the range of 50-60 cm. Besides efforts to increase the water table, liming is still required in order to increase production. Lime application of 1 ton/ha had significant effect on increasing production. Corn production with this treatment was capable to produce 5 tons/ha, while non-treated land areas only produce 2-3 tons/ha.

Keywords : DRAINMOD, corn, water management; pump irrigation, tidal lowland

ABSTRAK (IN INDONESIAN)

Kunci utama keberhasilan pertanian di rawa pasang surut adalah begaimana petani mampu mengendalikan muka air agar sesuai dengan pertumbuhan tanaman, terutama di musim kemarau. Kajian lapngan sudah dilaksanakan di lahan reklamasi Jalur 25 Sugihan Kanan, Desa Bandar Jaya. Air Sugihan Kanan Kabupaten Ogan Komering Ilir S adalah keterhantaran hidroulik, jarak antar saluran dan curah hujan harian. Hasil simulasi menunjukkan area studi tergolongsawah tadah hujan, sehingga tujuan utama pengelolaan air adalah retensi air hujan dan perlu upaya menikan muka air tanah di saat musim kemarau misalnya melalui system irigasi pompa. Aplikasi irigasi ponpa dilakukan pada tanaman jagung memasuki fase generative. Melalui system pompa air di alirkan dari saluran tersier ke saluran kuarte dan saluran cacing. Dari usaha ini air tanah naik mencapai kedalaman 30 cm dari permukaan tanah, Sementara pada petakan yang tidak di berika irigasi pompa air tanah hanya berada di kedalaman 50-60 cm. Selain usaha menaikan muka air tanah, aplikasi pengapuran masih diperlukan. Aplikasi rendah dosis 1 ton/ha nyata meningkatkan produksi. Tanaman jagung dengan perlakuan kapur mampu menghasilkan produksi 5 ton/ha, sementara tanpa perlakuan kapur dan tanpa upaya penaikan muka air tanah hanya menghasilkan 2 ton/ha.

Kata kunci: DRAINMOD; jagung; pengelolaan air; irigasi pompa; rawa pasang surut

INTRODUCTION

Extensive land clearing of tidal lowland areas for agricultural enterprise in South Sumatra was started since 1969. About 400,000 ha of tidal lowland had been reclaimed through transmigration progarm. Banyuasin area so far had showed successful effort in rice production at South Sumatra with magnitude higher than 40 percent of total rice production (Disperta, 2017). However, this successful effort had not followed by other agricultural areas because planting index at these areas was less than 200 %. One of relatively less productive area is Sugihan Kanan with rice production level of less than 3 ton.ha^{-1} and most of its agricultural land had one planting index (Imanudin et al., 2016). The soil is classified as acid sulphate soil which has high acidity and Alumunium content (Fahmi et al., 2014). Aluminum toxicity was produced an alteration of biochemical and physiological reaction of plants and then to their crop productivity. Decreasing in root growth is one of an initial and most evident symptoms of Al-toxicity. The nutrient availability was decrease also due to bond reaction Al-P (Koesrini, et al., 2014)

The key success for land management at tidal lowland areas is how to manage soil water level at elevation level required by crop's root zone (Imanudin et al., 2010; Bakri et al., 2015). Added by Fahmi et al., (2014). Water status availability in root zone is main factor hat determine the successful agriculture in acid sulphate soil. Rain water was very important water resources mainly in acid sulphate soil. It was due to pyrite oxidation process during dry period, then make ground water high toxic element and very acid. Fresh water from tide is not possible for land irrigation. Thus, to fulfill water crop requirement mainly achieved by rain water (Imanudin et al; 2016).

Othe important factor is availability of structures and infrastructure of water management network to facilitate land leaching process and water flooding in channels. Inadequate drainage facility frequently results in toxic elements accumulation and high soil acidity (Bakri et al., 2015). In addition, not all tidal lowland areas are capable to provide good water quality from secondary channel for supply (Hartoyo et al., 2010; Megawaty et al., 2012). Many channels had carried acid water or saline water during dry season which should be prevented from entering tertiary channels (Hairmansis et al., 2017; Tafarini, and Yazid., 2018). Water gates at tertiary channel are absolutely required to be installed for control drainage and water retention process (Lasmana et al., 2017; Imanudin et al., 2019).

The construction of field operation planning requires daily water table data during period of rain and dry seasons either at dry or wet climate conditions. Daily water table data so far is frequently unavailable, difficult to mesure, and costly . Therefore, DRAINMOD computer model can provide aid in presenting dynamics condition of daily water table (Madramootoo et al., 1999; Wahba et al., 2018). This data can be used to construct weekly water management operational plan in the field for crop cultivation (Imanudin, et al., 2011) Added by Skaggs et al., (2012) statistical analysis shows acceptable results where the simulation model with daily water level prediction results calibrated with field data shows Nash-Sutcliffe (EF) modeling efficiency values are 0.68 and 0.72, the daily drainage rate (EF = 0.73) and 0.49), and monthly drainage volume (EF = 0.87 and 0.77).The simulated result was high correlation between predicted and measured (Wan et al., 2009). Proper drainage planning by DRAIMOD simulation model was also depend on the quality of data input. Physical and Hydrological parameters such as rainfall, and soil hydraulic conductivity was very essential data input. (Negm et al., 2014). Model was also successfully work for developing of land drainage design (Sojka et al, 2019). The model is able to provide input on the proper use and operate of drainage network infrastructure. Model could provide better predictions of groundwater table depths under shallower drainage systems. And produce management tool to minimize environmental issues in agriculture field (Davoodi et al., 2019).

This paper will present results of water table dynamics obtained from DRAINMOD modelling and operational planning that will be implemented during planting season. Field adaptation was approach through water ... purpose. this field study are to construct the operational model for water table control for agriculture purpose.

MATERIALS AND METHODS

This research was implemented at tidal lowland area of tertiary plot-4 at Bandar Jaya Vilage, Jalur 25, Air Sugihan Subdistrict, Ogan Komering Ilir District. It was conducted from May to October 2017. The research site is classified as C typhology land in which it can not receive water through high tidal irrigation because high tidal water can not enter into this land. Water from seconday channel only capable to fill tertiary channel.

Materials used in this study are soil sample, corn seeds, fertilizers, pesticides, crop's protecting plastics and chemicals for soil analysis in the laboratory. Equipments used in this study are consisted of piezometer, wells (perforated PVC pipe), 12 inch PVC pipe, elbow, marking board, water pass, meteran, soil bor, excavation tube (bailer), stopwatch), flap water gate made of fibre, 10 inch PVC pipe, digital camera and agricultural equipments. For evaluation of water status at tertiary block and land drainage planning was conducted through computer simulation by using DRAINMOD 5.1 software (Skaggs et al., 2012).

Input parameters for DRAINMOD are soil physical characteristics consisting of impermeable layer depth, soil hydraulic conductivity value and climate data consisting of temperature and daily rainfall. Water network information is consisted of the depth and distance amongst channels. Simulation was conducted to determine soil water table dynamics at dry and wet climate condition .

Observation of water table monitoring was extended to period prior to dry season in May 2017. The corn seeds used in this study was Pioner P21 variety. In order to support land drainage system, farmers developed micro channel with depth of 30 cm and distance between channels in the range of 8 to 10 m.

There are two treatments were used in this study:

- first, crop without lime addition and water source only from water gate retention; supply water only form the water capillarity movement
- second, crop with lime addition at dose of 1.5 $ton.ha^{-1}$ and water supply from irrigation by using pump. In order to provide water in tertiary channel for pumping operation, farmers had conducted

temporary water retention (dam) by using canvas platics. Pumping opration was conducted at crop's generative phase. Irrigation used in this study was furrow irrigation in which water is delivered to fill collector channel and water from this channel subsequently was distributed to fill micro channel. Irrigation was applied once in a week.

The computer model DRAINOD was used for predicting daily water table as effect of deference climatic condition. Data input of DRAINMOD simulation model were hydraulic conductivity, soil water retention, and land drainage system (drain spacing, depth and width of channel), and crop physiological data. Scenario for model operational was constructed based on different climatic conditions.

Analysis method for soil water status under root zone was calculated using SEW-30 concept. The calculation of SEW-30 is based on Sieben formula (Skaggs et al, 2012). This concept is used to determine condition of soil water excess (cm/day) during crop growth period. Concept of water excess 30 cm above the root zone has an objective to evaluate fluctuation height of soil water table during wet period (rainy season) within tidal lowland agriculture area (Imanudin et al., 2018). Value of water excess 30 cm above the root zone can be calculated in order to predict soil water excess during crop growth period. The equation used for this calculation is as follows:

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

where x_i is soil water table at (days to), with i is the first day and n is number of days during crop growth. The DRAINMOD model actually calculate hourly value of SEW-30 cm instead of daily value so that calculation of SEW-30 value is more accurate and can be formulated by using the following equation:

$$SEW-30=\sum_{j=1}^{m}(30-x_j)/24 \qquad [2]$$

where x_j is soil water table at the end of respective hours and m is total hours during crop growth period. Water table position with critical limit of 30 cm is done with consideration value of 30 cm below soil surface is selected because most of food crops will experience physiological disturbance if

30 cm depth zone or even below 20 cm depth zone (Imanudin et al., 2011; Imanudin et al., 2019).

RESULTS AND DISCUSSION

Soil Physical Characteristics

Soil physical characteristics at the study area is shown on Table 1. Soil has high porosity and low bulk density in top layer. This is indicated that soil had relatively high total pore space resulting in relatively high water holding capacity. The decrease of soil bulk density is followed by the decrease of total pore space at deeper soil layers. Refer to the water movement means that on the rotting zone area the water movement was easy to drain and submerges by gravity forces.

Soil layer above 60 cm showed the increase of clay content so that soil bulk density can be classified into mineral soil. The main limiting factor is soil acidity level than can be classified as acid soil with pH of 4-5. It is also reported also by Koesrini et al., (2014) when pH <5 the Aluminum toxicity is increase in soil. It is the main stress factor for plant growth on tidal lowland agriculture

Table 1. Soil physical characteristics and soil acidity kevel

Depth	Bulk Density (g/cm$^{3)}$	Total Pore Space (%)	pH
0-30 cm	0.67	77	4.8
30-60 cm	0.74	73	4.6
> 60 cm	0.98	64	4.2

Soil textural class is showed by ratio of clay, sand and loam fractions (Table 4.2). Although soil fraction composition had occurred, soil texture at the study area is qualitatively can be classified into loamy clay class. Clay fraction tend to increase with the increase of soil depth.

Depth	Sand	Clay	Silt	Soil Texture
0-30 cm	29.4	7.6	63	Loamy clay
30-60 cm	26.4	14.6	59	Loamy clay
>60 cm	14.4	21.6	64	Loamy clay

Clay fraction with magnitude of 7.6 % at soil layer depth 0 - 30 cm had increased to 21.6 % at soil layer depth of 60 cm. The increase of clay fraction below soil surface had produce beneficial effect in which land is capable to store water at depth above 60cm so that soil water depth at this layer is not quickly deplete. In addition, soil water contribution at this layer through capillary movement is very important to supply crop water requirement. According to Zipper et al., (2015) the contribution of ground water through capillary rise is strongly depend on soil texture. Increasing clay fraction on the soil more provide water by capillary rise than soil having sandy soil. Added by Gao et al (2017), that at groundwater depth in 1 m below soil surface he capillary upward was supplied about 41% of the crop evapotranspiration. In this case mean that the supply water was required to fulfil crop water requirement when the water table start drop at 70 cm.

Computer Simulation of DRAINMOD in estimating soil water table

DRAINMOD is drainage model that capable to estimate the depth of soil water table for swamp lowland and peat land areas. The main inputs for this model are consisted of rainfall, crop evapotranspiration, soil hydraulic conductivity and drainage network characteristics data. Condition of water flow within soil is assumed to be constant (steady condition) in Drainmod model (Skaggs et al, 2012).

In case of reclaimed tidal lowland area at Sugihan Kanan, some model inputs were consisted of soil hydraulic conductivity of 0.34 m.day^{-1}, impermeable layer depth of 2 m, distance between tertiary channels at current condition in the field was 250 m, initial soil water depth is assumed 10 cm below soil surface and average channel depth of 1.5 m. The constructed scenario can be seen in Table 3.

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Drainmod Model Adaptation for Developing Recommendations Water Management in the Tertiary Block of Tidal Lowland Agriculture

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ABSTRACT

The primary key to successful agricultural cultivation is maintaining the groundwater level to fulfill crop water requirements, particularly during the dry season. Field study was conducted in Tidal reclamation area of section 25 at Sugihan Kanan, Bandar Jaya Village, Air Sugihan, Ogan Komering Ilir District of South Sumatra. The DRAINMOD computer model was used to simulate water levels in dry and wet climatic conditions. The principal measured parameters are soil hydraulic conductivity and drain spacing, as well as daily rainfall data. The simulation results showed that the research area belongs to the rainfed type, and the main objective of water management is to retain water and determine some efforts to increase the groundwater level through pump irrigation in the dry season. The application of pump irrigation was applied to the plant entering the generative phase. The pump irrigation was provided to distribute water into the quarter and worm (micro) channels. The effect of this application caused the groundwater level to approach about 30 cm below the soil surface, while groundwater level in areas without pump irrigation facility was in the range of 50-60 cm. Besides efforts to increase the water table, liming is still required in order to increase production. Lime application of 1 Mg ha^{-1} had a significant effect on increasing production. Corn production with this treatment could produce 5 Mg ha^{-1}, while non-treated land areas only produce 2-3 Mg ha^{-1}.

Keywords: Corn, DRAINMOD, pump irrigation, tidal lowland, water management

INTRODUCTION

Extensive land clearing of tidal lowland areas for agricultural enterprise in South Sumatra was started in 1969. About 400,000 ha of tidal lowland had been reclaimed through the transmigration program. Banyuasin area has shown successful effort in rice production at South Sumatra with a magnitude higher than 40 percent of total rice production (Desperate 2017). However, this successful effort had not followed by other agricultural areas because the planting index at these areas was less than 200%. One relatively less productive area is Sugihan Kanan, with a rice production level of fewer than 3 Mg.ha^{-1}, and most of its agricultural land had one planting index (Imanudin *et al.* 2016). The soil is classified as acid sulfate soil, with high acidity and Alumunium content (Fahmi *et al.* 2014). Aluminum toxicity has produced an alteration of biochemical and physiological reactions of plants and then to their crop productivity. Decreasing root growth is one of the initial and most evident symptoms of Al-toxicity. The nutrient availability was also decreasing due to bond reaction Al-P (Koesrini *et al.* 2014). On the other hand, Increasing levels of aluminum and iron in the soil solution also cause a decrease in the quality of water in the canals, soil pH and water pH dropping to a range of 2.3-3. Then the water channeled should be fluch out and replaced by freshwater from the rain or tidewater (Sukitprapanon *et al.* 2019).

The key success for land management at tidal lowland areas is how to manage soil water level at elevation level required by crop's root zone (Imanudin *et al.* 2010; Bakri *et al.* 2015). According to Fahmi *et al.* (2014), water status availability in the root zone is the main factor determining the thriving agriculture in acid sulfate soil. Rainwater was an essential water resource, mainly in acid sulfate soil. The pyrite oxidation process during a dry period made groundwater a highly toxic element and very acidic. Freshwater from the tide is not possible for land irrigation. Thus, to fulfill water crop requirement mainly achieved by rainwater (Imanudin *et al.* 2019). Therefore water retention in channels is vital to the block technique (Nurzakiah *et al.* 2016 [Belum ada pada Refference]). Water in the canal is managed at a 60-90 cm depth to create groundwater at 10-30 cm (Herawati *et al.* 2020 [Belum ada pada Refference]). Diharapkan dengan sistem drainase terkendali air di saluran tetap tersedia untuk menjaga agar air tanah berada dalam zona akar dan selalu diatas lapisan pirit (Sasirat *et al.* 2019) [Belum ada pada Refference].

Another critical factor is the availability of structures and infrastructure of water management networks to facilitate the land leaching process and water flooding in channels. Inadequate drainage facility frequently results in toxic elements accumulation and high soil acidity (Bakri *et al.* 2015). In addition, not all tidal lowland areas can provide good water quality from a secondary channel for supply (Hartoyo *et al.* 2010; Megawaty *et al.* 2012). Many channels had carried acid water or saline water during the dry season, which should be prevented from entering tertiary channels (Hairmansis *et al.* 2017; Tafarini and Yazid 2018). Watergates at the tertiary channel must be installed to control the drainage and water retention process (Lasmana *et al.* 2017; Imanudin *et al.* 2019).

The construction of field operation planning requires daily water table data during rain and dry seasons, either at dry or wet climate conditions (Imanudin *et al.* 2010; Negm *et al.* 2016). Daily water table data so far is frequently unavailable, difficult to measure, and costly. Therefore, the DRAINMOD computer model can aid in presenting the dynamics condition of the daily water table (Madramootoo *et al.* 1999 [Belum ada pada Refference]; Wahba *et al.* 2018; Askar *et al.* 2020 [Belum ada pada Refference]). This data can be used to construct weekly water management operational plans in the field for crop cultivation (Imanudin *et al.* 2011). According to Skaggs *et al.* (2012), statistical analysis shows acceptable results where the simulation model with daily water level prediction results calibrated with field data shows Nash-Sutcliffe (EF) modeling efficiency values are 0.68 and 0.72, the daily drainage rate (EF = 0.73) and 0.49), and monthly drainage volume (EF = 0.87 and 0.77). The simulated result was a high correlation between predicted and measured (Wan *et al.* 2009; Malakshahi *et al.* 2020). Proper drainage planning by the DRAIMOD simulation model also depended on the quality of data input. Physical and Hydrological parameters such as rainfall and soil hydraulic conductivity were essential data input. (Negm *et al.* 2014; Askar *et al.* 2020 [Belum ada pada Refference]). The model was also successful for developing land drainage design (Sojka *et al.* 2019). The model can provide input on the proper use and operation of drainage network infrastructure (Askar *et al.* 2020 [Belum ada pada Refference]). The model could provide better predictions of groundwater table depths under shallower drainage systems. Moreover, produce management tools to minimize environmental issues in the agriculture field (Davoodi *et al.* 2019). The DRAINMOD model is excellent drainage modeling for estimating the depth of the groundwater table (Davoodi *et al.* 20019). The estimated groundwater level from simulation and modeling results shows the value of r^2 = 0.93 (Ashkan *et al.* 2020). An adaptation model for the tropical area has been carried out in tidal lowland reclamation areas in Banyuasi, South Sumatra. The simulation result found r^2 0.83. Hydrological parameters are essential factors that will have a better statistical analysis (Imanudin *et al.* 2011).

This paper will present the results of water table dynamics obtained from DRAINMOD modeling and operational planning implemented during planting season. Field adaptation was conducted by corn planting at dry season. The recommended DRAINMOD model for water supply in tertiary channels will be implemented by rainfall harvesting method (passive approach) and active approach through water pumping from the tertiary channel during the dried condition. The objectives of this field study are to construct the operational model for a water table control for agriculture purposes.

MATERIALS AND METHODS

This research was implemented at the tidal lowland area of tertiary plot-4 at Bandar Jaya Village, Jalur 25, Air Sugihan Subdistrict, Ogan Komering Ilir District (Figure 1). It was conducted from May to October 2017. The research site is classified as C typhology land in which it can not receive water through high tidal irrigation because high tidal water can not enter into this land. Water from secondary channel only capable of filling tertiary channel.

Materials used in this study are soil samples, corn seeds, fertilizers, pesticides, crops protecting plastics, and chemicals for soil analysis in the laboratory. Equipment used in this study are consisted of a piezometer, wells (perforated PVC pipe), 12 inch PVC pipe, elbow, marking board, water pass, meter, soil bor, excavation tube (bailer),

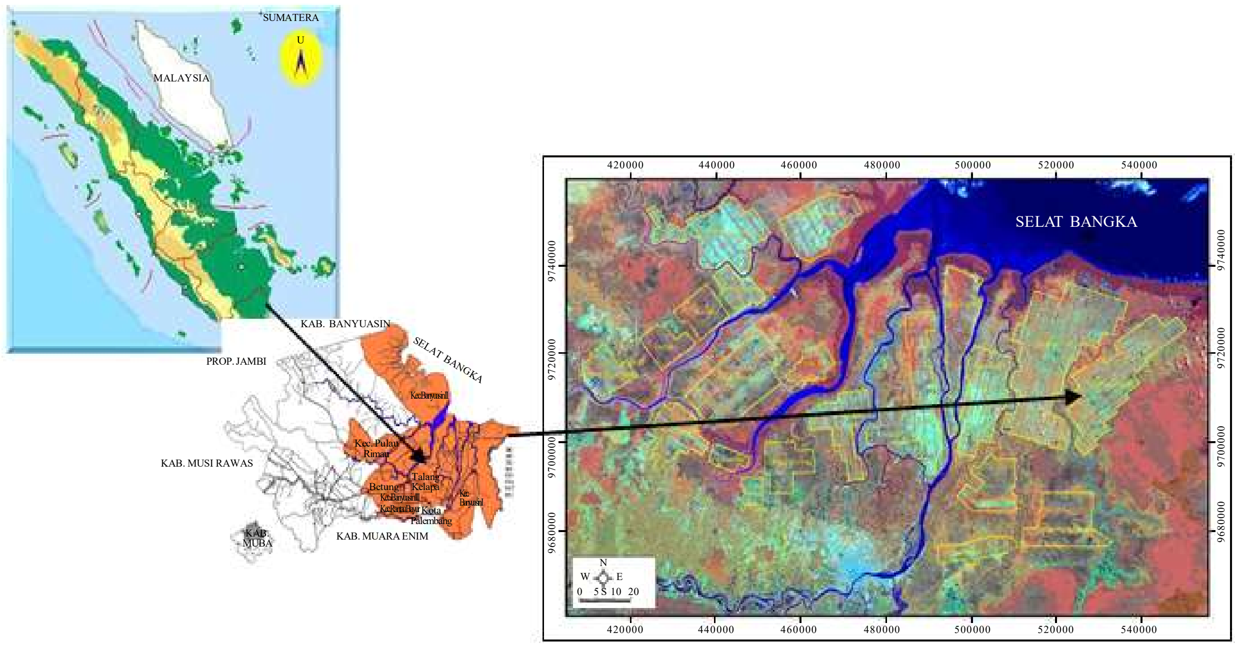

Figure 1. Maps of the area study in tidal lowland recamations of sugihan.

stopwatch), flap watergate made of fiber, 10 inch PVC pipe, digital camera, and agricultural equipment. For evaluation of water status at tertiary block and land, drainage planning was conducted through computer simulation using DRAINMOD 5.1 software (Skaggs *et al.* 2012).

The conceptual model to develop DRAINMOD is based on the water balance analysis within vertical soil column unit per surface area. The calculation starts from the impermeable layer up to the soil surface between drainage channels (Skaggs 1978). Calculation of water balance within soil profile for a time period of dt is mathematical can be expressed as follows :

$$\Delta Va = F - D - Ds \qquad [1]$$

$$P = F + RO + \Delta S \qquad [2]$$

Where ΔVa xi is the change of soil air volume (cm), F is infiltration (cm), ET is evapotranspiration (cm), D is lateral flow (negative sign indicates drainage flow and a positive sign indicates subsurface irrigation conditions) in cm, *Ds* is side seepage flow (positive sign indicates capillary flow upward) in cm, P is precipitation (rainfall) in cm, RO is surface flow (cm), and ΔS xj is the change of surface water storage. As an illustration, the drainage profile system in DRAINMOD can be seen in Figure 2.

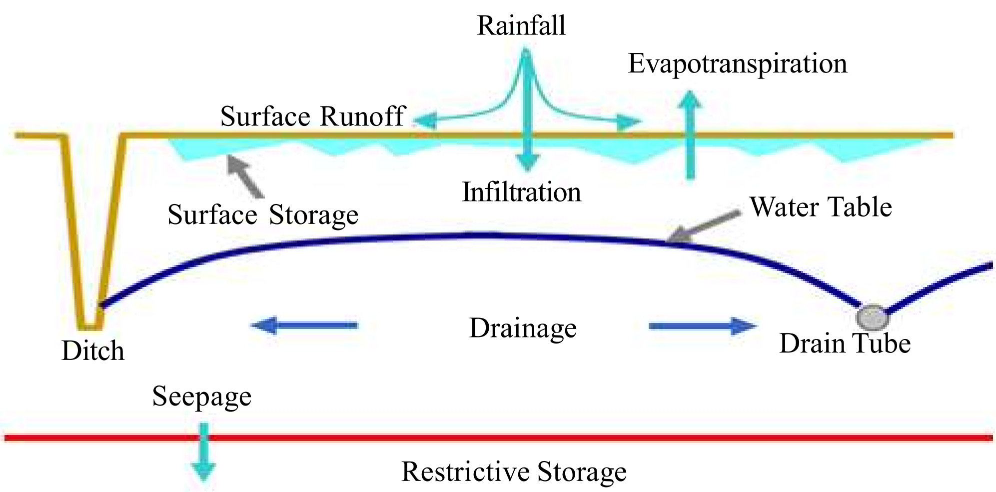

Figure 2. Schematic view of water table control system in open channel and subsurface. (Skaggs 1978).

Rainfall inputs in the DRAINMOD model are hourly rainfall, and maximum and minimum temperatures, which are read from weather data and water balance conducted every hour.

Input parameters for DRAINMOD are soil physical characteristics consisting of impermeable layer depth, soil hydraulic conductivity value, and climate data consisting of temperature and daily rainfall. Water network information has consisted of the depth and distance amongst channels. A simulation was conducted to determine soil water table dynamics at dry and wet climate conditions.

Observation of water table monitoring was extended to a period prior to dry season in May 2017. The corn seeds used in this study were Pioneer P21 varieties. To support the land drainage system, farmers developed a microchannel up to 30 cm with a distance between channels of 8 to 10 m.

There are two treatments were used in this study:

firstly, crop without lime addition and water source only from watergate retention; supply water only from the water capillarity movement;

Secondly, a pump added crops with 1.5 $Mg.ha^{-1}$ lime and water supply from irrigation. In order to provide water in the tertiary channel for pumping operation, farmers had conducted temporary water retention (dam) by using canvas plastics. The pumping operation was conducted at the crop's generative phase. Irrigation used in this study was furrow irrigation in which water is delivered to fill collector channel, and water from this channel subsequently was distributed to fill microchannel. Irrigation was applied once a week.

The computer model DRAINMOD was used for predicting the daily water table as the effect of deference climatic conditions. Data input of the DRAINMOD simulation model were hydraulic conductivity, soil water retention, land drainage system (drain spacing, depth, and width of channel), and crop physiological data. The scenario for the model operation was constructed based on different climatic conditions.

The analysis method for soil water status under the root zone was calculated using the SEW-30 concept. The calculation of SEW-30 is based on the Sieben formula (Skaggs *et al.* 2012). This concept is used to determine the condition of soil water excess (cm day^{-1}) during the crop growth period. The concept of water excess 30 cm above the root zone has an objective to evaluate fluctuation height of soil water table during a wet period (rainy season) within tidal lowland agriculture area (Imanudin *et al.* 2018). The value of water excess 30 cm above the root zone can predict soil water excess during crop growth. The equation used for this calculation is as follows:

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

x_i is the soil water table at (days too), with i is the first day and n is the number of days during crop growth. The DRAINMOD model calculates the hourly value of SEW-30 cm instead of the daily value so that the calculation of SEW-30 value is more accurate and can be formulated by using the following equation:

$$SEW-30=\sum_{j=1}^{m}(30-x_j)/24 \qquad [2]$$

x_j is the soil water table at the end of respective hours, and m is the total hours during the crop growth. Water table position with a critical limit of 30 cm is done with consideration value of 30 cm below the soil surface is selected because most of the food crops will experience physiological disturbance if the soil water table is drop down from 30 cm point or increase upward from 30 cm point from the soil surface. If soil water is far from the critical value of 30 cm or closes to the soil surface, it will create excess water conditions (Negm *et al.* 2014). This condition is applied for non-rice food crops. On the contrary, rice crop is withstanding water flooding condition and will experience stress if soil water is below 30 cm depth zone or even below 20 cm depth zone (Imanudin *et al.* 2011; Imanudin *et al.* 2019).

RESULTS AND DISCUSSION

Soil Physical Characteristics

Soil physical characteristics in the study area are shown in Table 1. Soil has high porosity and low bulk density in the top layer. Meaning that soil had relatively high total pore space resulting in relatively high water holding capacity. The decrease of soil bulk density is followed by the decrease of total pore space at deeper soil layers. The water movement means that on the rotting zone area, the water movement was easy to drain and submerge by gravity forces.

The soil layer above 60 cm showed the increase of clay content so that soil bulk density can be classified into mineral soil. The main limiting factor is soil acidity level than can be classified as acid soil with a 4-5. It is also reported by Koesrini *et al.* (2014) when pH <5, the Aluminum toxicity is an

Table 1. Soil physical characteristics and soil acidity level.

Depth	Bulk Density (g cm^{-3})	Total Pore Space (%)	pH
0-30 cm	0.98	46	4.8
30-60 cm	1.15	48	4.6
> 60 cm	1.25	55	4.2

increase in soil. It is the main stress factor for plant growth in tidal lowland agriculture.

Soil textural class is shown by the ratio of clay, sand, and loam fractions (Table 2). Although soil fraction composition had occurred, soil texture at the study area is qualitative can be classified into silt loam class at 0-60 cm and clay texture in the layer of 60 cm below the soil surface. Clay fraction tends to increase with the increase of soil depth.

Clay fraction with the magnitude of 7.6 % at soil layer depth 0 - 30 cm had increased to 21.6 % at a depth of 60 cm. The increase of clay fraction below soil surface had produced a beneficial effect in which land can store water at depth above 60cm so that soil water depth at this layer is not quickly depleting. In addition, soil water contribution at this layer through capillary movement is significant to supply crop water requirements. According to Zipper *et al.* (2015), the contribution of groundwater through capillary rise is strongly dependent on soil texture, and increasing clay fraction on the soil more provides water by capillary rise than soil having sandy soil. Added by Gao *et al.* (2017), at groundwater depth 1 m below the soil surface, the capillary upward was supplied about 41% of the crop evapotranspiration, which means that the water supply was required to fulfill crop water requirements when the water table started to drop at 70 cm.

Computer Simulation of DRAINMOD in estimating soil water table

DRAINMOD is a drainage model capable of estimating the depth of soil water table for swamp lowland and peatland areas. The main inputs for this model are consist of rainfall, crop evapotranspiration, soil hydraulic conductivity, and drainage network characteristics data. The water flow condition within the soil is assumed to be constant (steady condition) in the Drainmod model (Skaggs *et al.* 2012).

In the case of reclaimed tidal lowland area at Sugihan Kanan, some model inputs have consisted of soil hydraulic conductivity of 0.34 m.day^{-1}, impermeable layer depth of 2 m, the distance

Table 2. Distribution of sand, loam and clay fractions at several soil layers.

Depth	Percentage (%)			Soil Texture
	Sand	Clay	Silt	
0-30 cm	29.4	7.6	63	Silt Loam
30-60 cm	26.4	14.6	59	Silt Loam
>60 cm	14.4	64	21.6	Clay

Table 3. Scenario planning constructed at the initial stage of DRAINMOD simulation.

Microclimate scenario	Water management options	
	Conventional (without control)	Using control
Normal Rainfall Condition in the Year of 2014	Soil water table indicator	Soil water table indicator
Dry Rainfall Condition (El Nino) in the Year 2015	Soil water table indicator	Soil water table indicator
Wet Rainfall Condition (Lanina) in the Year 2016	Soil water table indicator	Soil water table indicator

between tertiary channels at a current condition in the field was 250 m, initial soil water depth is assumed 10 cm below the soil surface and average channel depth of 1.5 m. The constructed scenario can be seen in Table 3. The simulation was conducted at two climatic conditions: typical climate (average rainfall) and dry rainfall due to Elnino. The simulation stages have consisted of simulation on the existing network condition without control effort followed by simulation on watergate operation.

Computer simulation results of DRAINMOD for wet and dry climate conditions are shown in Figure 3. Simulation results showed that the soil water table variation at the condition of the initial to the final rainy season had a safe value in land firing probability. However, simulation results also showed that over drain had been occurred on land, and they were indicated by a quick drawdown of soil water table elevation in case of no rainfall occurrence for more than one week period. The soil water table fluctuation results either at normal or dry rainfall conditions (Elnino) showed a similar trend in terms of soil water table conditions for the January-May period.

The land was still in safe condition from fire hazards during this period. Although the soil water table drops into critical depth value (80 -100 cm), rainfall still occurred so that soil water elevation could increase again close to 30 cm depth. The vulnerable condition started to occur at days of 140 (entering of May) in which rainfall was decreased, and soil water elevation was continuously drop exceeding the critical limit (- 80cm). In this period, pyrite oxidation could also haven and create a decreasing pH in the root zone.

On the other hand, the soil has a pyrite layer around 60-70 cm below the soil surface. When the groundwater table level drops to 100 cm, an oxidation layer will occur. This process would produce high soil acidity and increase the solubility of iron and aluminum content, which may be harmful to crops-reported by Koesrini *et al.* (2014) that applying lime with 2.0 Mg ha^{-1} is still required for increasing pH in the soil. Added by Fahmi *et al*. (2014), the lime application was efficient in combination with good land preparation through intensive soil leaching and intermittent waterlogging. It was also reported by Ar-Riza *et al*. (2015) that the main problem is challenging to get fresh water for the leaching and flushing process. Those for managing acid sulfate soil are still required lime application to increase pH. According to Aksani *et al*. (2018), increased productivity of tidal lowland rice cultivation was achieved by 10 Mg ha^{-1} rice straw compost, and NPK fertilizers that should be applied are 315 kg urea ha^{-1}, 135 kg SP-36 ha^{-1}, and 90 kg KCl ha^{-1}, Mean that water availability is not only a single factor for increase land productivity.

Rainfall was average in 2014; soil water elevation continuously dropped to the lowest point of – 115 cm in September and started to increase when entering October, although it was still within

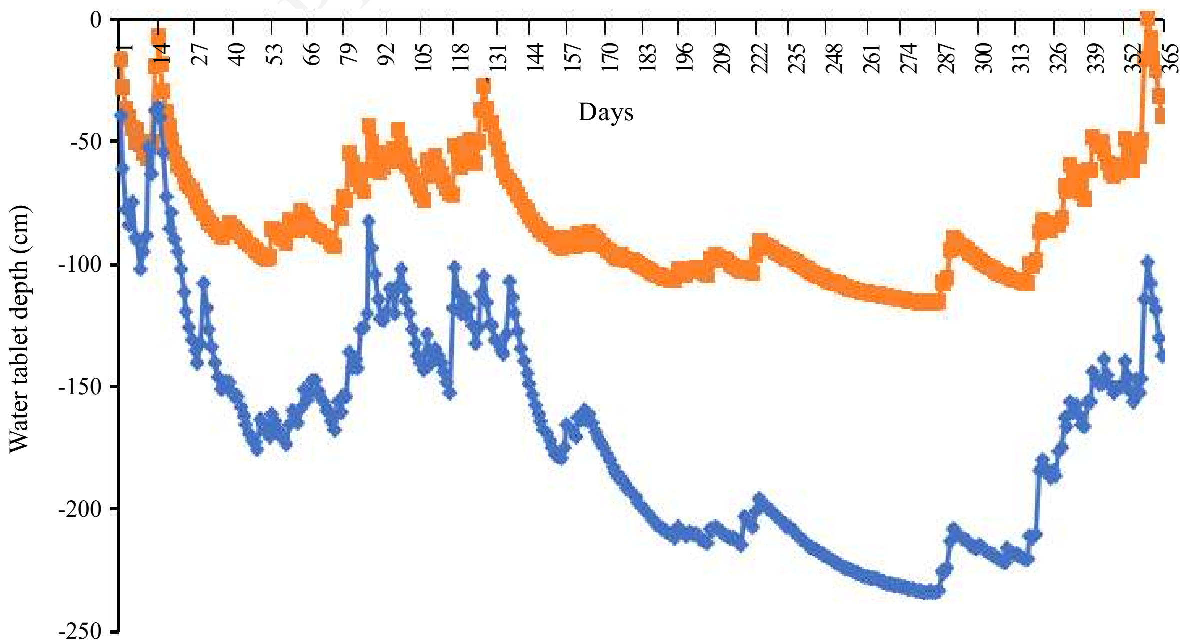

Figure 3. Soil water table fluctuation resulting from DRAINMODsimulation model under control and of without control. ▬■▬ : Year 2014 (wet condition), ▬◆▬ : Year 2015 (dry condition).

the critical depth limit. The safe condition again occurred in November, whereas the dry climate condition (Elnino) in 2015 showed that soil water elevation dropped to a depth of – 118 cm, which occurred in September. However, soil water elevation was still at a critical depth value up to December due to minimal rainfall. Since soil had high porosity, farmers were reluctant to open tertiary channels because rainfall water was assumed to be insufficient to supply the soil water table and channels. Therefore, water pumping from the tertiary channel should be made to deliver water into quarterly channels, which requires stepping detention during high tidal water in the tertiary channel.

Simulation results from Figure 1 showed an open drainage system with the distance between channels of 250 m and channel dimensions as follows: upper width of 2.0 m and lower width 1.2 m, as well as the depth of 1.2 m, was excessive in terms of dimension size. This channel dimension is a high capacity to drain water. Therefore, water losses were rapid, indicated by a water drawdown of up to 40 cm in case of no rainfall for two weeks.

Simulation using a shallow drainage system was subsequently tried to determine the proper channel dimension at peatland to prevent excessive water losses. The depth of the tertiary channel was only 1 m with a bottom width of 30 cm. Simulation result (Figure 2) showed that soil water table drawdown was not as fast as the existing channel dimension. Simulation results of shallow drainage showed that soil water table condition in 2015 (Elnino) was within a safe zone up to June. The control measure can be done in the June period.

Because the drainage system had already been built and it was impossible to conduct filling activity, the choice was to conduct water retention immediately using a controlled dam system. Therefore, a computer simulation of DRAINMOD was implemented at the initial stage. The simulation was also conducted to determine the impact of water retention within the tertiary channel (Figure 4). Water retention simulation would be done during the least rainfall occurrence period in May. Simulation results showed that soil water table elevation could be increased up to a depth of 30-40 cm below the soil surface during May-June. Soil water table elevation was located at 60 cm below the soil surface during the dry season of July-November. Land at this condition was relatively safe from fire hazards. This condition would be achieved if soil water table elevation in the tertiary channel was not dropped more than 40 cm from the soil surface.

The condition of this controlled drainage system was found in the field during October, where the soil water table was located at a safe zone, i.e., 40-50 cm below the soil surface. This condition also prevents pyrite oxidation, although pumping irrigation supply was needed to fulfill crop water requirements. Pump facilities are highly needed if farmers cultivate corn at B and C land typology areas during the dry

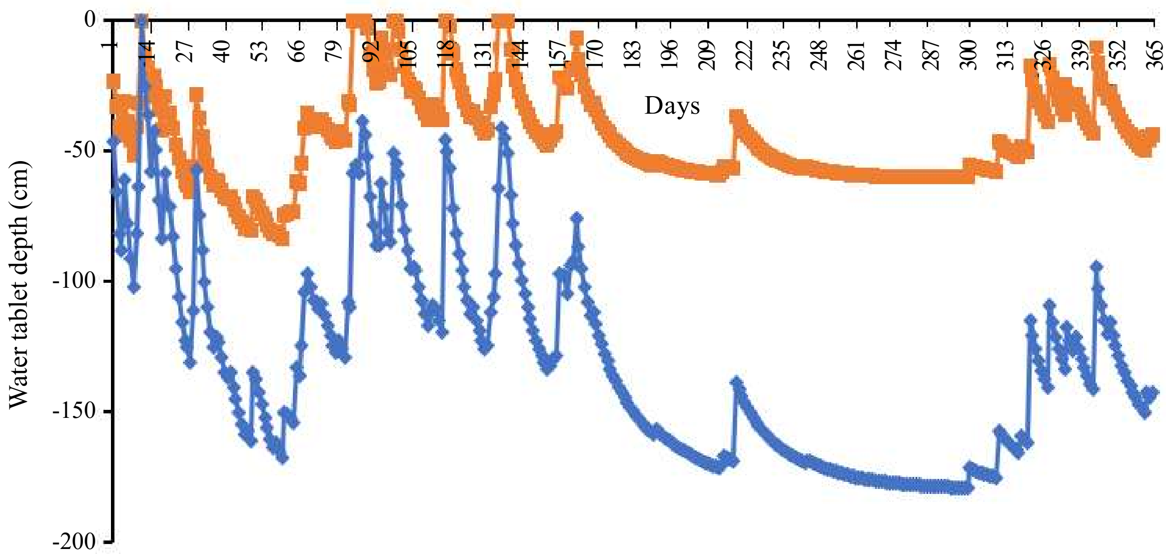

Figure 4. Computer simulation result at shallow drainage condition or 50 cm water retention. ▬■▬ : Water retention option, ▬◆▬ : No option (Uncontroll).

Figure 5. Hydraulic structure in tertiary canal for water retention and control drainage in tidal lowland type C.

season. The pump was only operated for one month during the seed filling phase (generative period), and irrigation was applied once a week.

A water retention structure was highly needed because the land area at the study location had high water losses. Control structures are needed to support network operation as water retention (rainfall harvesting). The dam pattern equipped with an overflow structure is the proper model for the tertiary channel (Figure 5). Farmers currently use sandbags to withstand water losses. The effort to elevate soil water table elevation can be made by water pumping from the tertiary channel into the quarterly channel, which was subsequently delivered further into the collector and micro (worm) channels.

Control drainage is the best option for water management in the area study. The farmer keeps the water in the tertiary canal minimum at 50 cm above the bottom level of the canal. By maintaining the water level in the tertiary 50-60 cm than the groundwater table purposed above the pyritic layer during the dry season.

Field Adaptation of Water Dynamics at Dry Season Condition (July 2017)

Water table elevation was hourly observed to determine soil water table dynamics, which is affected by the fluctuation of water surface in the channel. Results of this hourly observation can be seen in Figure 6. The average value of water table depth was 37 to 41 cm below the soil surface, and this magnitude was ideal for the growth of the corn crop. Hourly observation of the soil water table showed a decrease of water surface followed by a

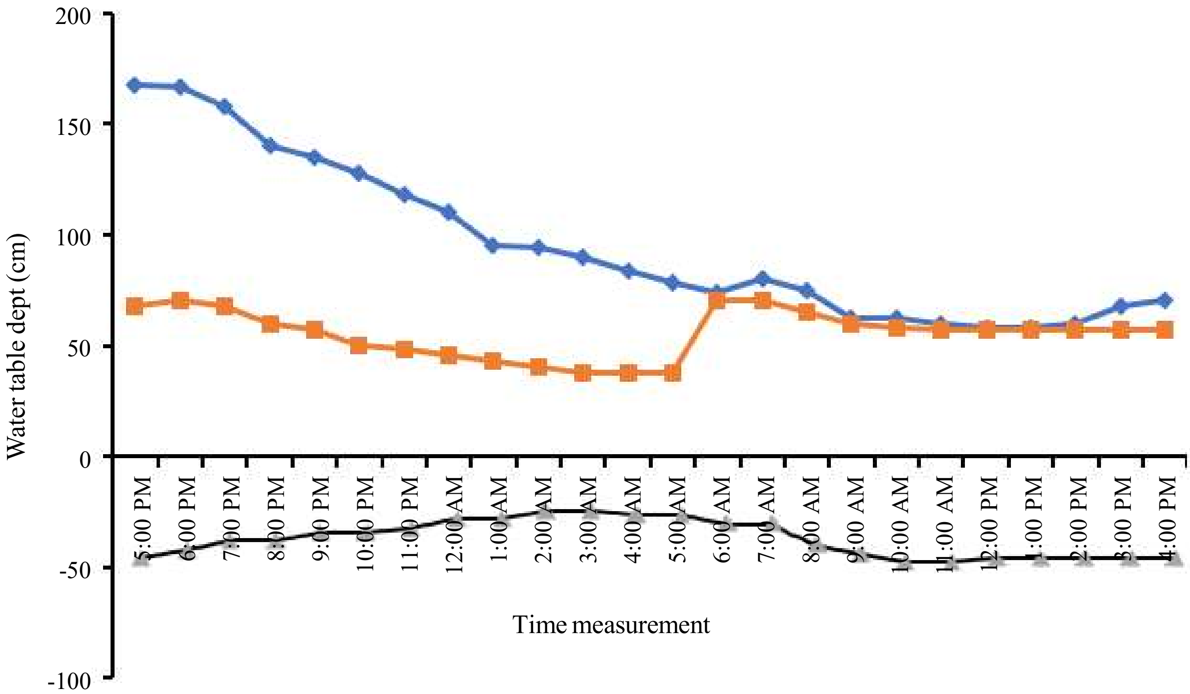

Figure 6. Condition of daily water surface level at the tertiary channel and tertiary block in July. —◆—: Water table in secondary canal, —■—: water table in tertiary, —▲—: ground water table.

Table 4. The relationship amongst water level at the tertiary channel, secondary channel, and soil water table.

No	Locations	Water surface level (cm)
1	Tertiary channel	70 cm
2	Secondary channel	168 cm
3	Soil water table	-30 cm

decrease in the secondary channel in the tertiary channel. In contrast, the increase of water surface in the secondary channel was followed by the increase in the tertiary channel. The change of soil water table did not follow this condition. The soil water table movement was relatively stable from a maximum depth condition of – 50 cm into a minimum depth condition of – 33 cm. The movement of the soil water table was highly affected by rainfall. The insignificant difference in water table depth at the tertiary block was due to water availability in the tertiary channel. Therefore, the horizontal movement of water (see page) was practically slight and can be neglected as long as water along the tertiary channel was available at the height of 50-60 cm.

The relationship between water level elevation in the tertiary channel and soil water table as a result of water retention impact (Tabel 4) showed that water level elevation in a tertiary channel on May-July was located at 70 cm depth and water level elevation in the secondary channel was located at 168 cm depth. This condition can produce soil water table elevation at 30 cm below the soil surface.

The network operation and corn growth (PS2)

The network operational guidelines in the tertiary channel can be summarized in Table 5. The operation was conducted each month according to crop growth phases.

Crop evapotranspiration requirement at dry season entering September could not be fulfilled if solely rely on capillary water movement from soil water table depth of 50 cm. Capillary water could only supply 45% of crop evapotranspiration requirements at this condition, so another water supply was needed. Farmers used a water pump to fill the soil water table (Figure 7).

A significant increase of soil water table was observed on corn cultivation which was supplied through pump irrigation. Water can be elevated with a magnitude of 20 cm. The soil water table on land without pump irrigation was located 40-50 cm below the soil surface, whereas the soil water table on land supplied with pump irrigation was located at about 30 cm (Figure 8). If the soil water table was located at a depth of 30 cm below the soil surface, then crop evapotranspiration requirement can be fully supplied from capillary water movement. Fan Yang *et al*. (2011 [belum ada pada reference]) reported that the capillary rise could not support the crop water requirement when the groundwater table was below 2.5m. Moreover, when the groundwater table maintenance is at 50 cm, irrigation is not required.

Corn production achieved using maximum technological inputs consisting of improvement of irrigation system, and soil quality showed good yield with a magnitude of about 3 $Mg.ha^{-1}$. However, this

Table 5. Model Operation of the tertiary network by using gooseneck watergate.

Month	Estimation of crop's growth phases	Water management objective	Operation of gooseneck watergate	
			Inner Section	Outer Section
May-June	Land preparation and planting	Controlled drainage	The gooseneck is turned 45°	Closed with valve materials
July-August	Vegetative	Controlled drainage	The gooseneck is turned 45°	Closed with valve materials
September-October	Generative	Supply, soil water filling	The gooseneck is turned 45° (additional supply from water pump)	Pipe is opened

Figure 7. Pump irrigation on corn cultivation to elevate soil water table level.

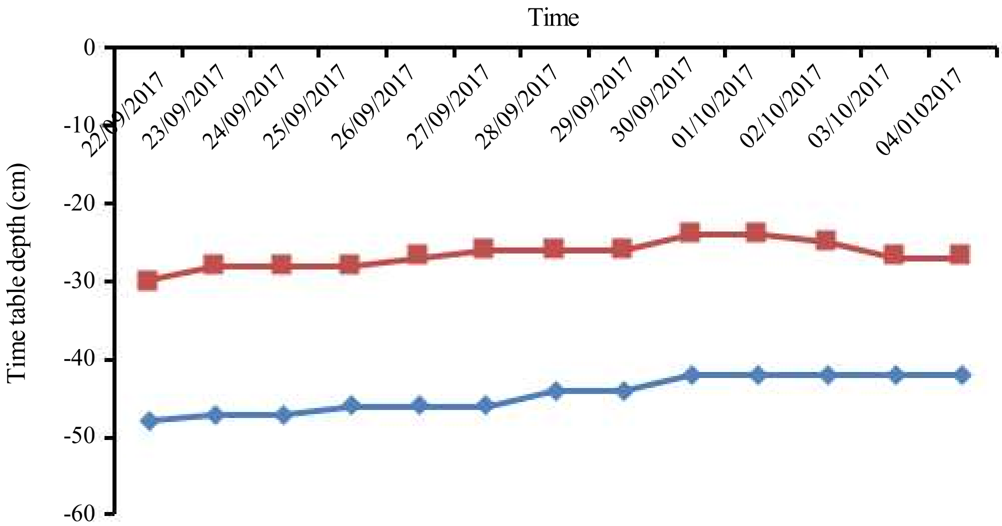

Figure 8. The condition of the soil water table in the middle of September 2017 was affected by pump irrigation.

production level was still lower than corn production achieved by farmers at the Telang II area with a 7-8 Mg.ha^{-1} (Imanudin and Bakri 2014). The yield of corn would be an optimum underwater table at 50-60 cm below the soil surface (Bakri and Bernas 2015). Since the water table dropped by more than 100 cm, the performance of corn growth decreased as reported by Liu and Luo (2011) in Australia that the significant contribution of the groundwater table ranges between 40-150 cm. It was contributed more than 65% of the potential evapotranspiration. However, capillary water rise fulfilled the crop's water requirement under 40-50 cm.

CONCLUSIONS

Hydrotopographical characteristics at the study area were classified into C class in which land area does not receive the overflow from high tidal water. However, water availability in the channel is capable of controlling the soil water table.

Komputer model DRAINMOD computer model can be used to estimate fluctuation of the soil water table at several climatic conditions. Simulation results can be utilized to construct a monthly water management plan.

The main objective for water management at the tertiary level was water retention due to physical soil conditions characterized by high porosity and high hydraulic conductivity. Therefore, the operational model was to retain water during the rainy season (rainfall harvesting) and control drainage during the second crop (corn).

Water retention in the tertiary channel at a depth of 70 cm could maintain soil water table elevation at 30 cm below the soil surface. Soil water table elevation should not be a drop below 50 cm in order to prevent pyrite oxidation.

At the initial reclamation stage, limiting application at a dose of 1-2 Mg ha^{-1} was still required because of high acidity and high aluminum solubility.

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Drainmod Model Adaptation for Developing Recommendations Water Management in the Tertiary Block of Tidal Lowland Agriculture

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ABSTRACT

The primary key to successful agricultural cultivation is maintaining the groundwater level to fulfill crop water requirements, particularly during the dry season. Field study was conducted in Tidal reclamation area of section 25 at Sugihan Kanan, Bandar Jaya Village, Air Sugihan, Ogan Komering Ilir District of South Sumatra. The DRAINMOD computer model was used to simulate water levels in dry and wet climatic conditions. The principal measured parameters are soil hydraulic conductivity and drain spacing, as well as daily rainfall data. The simulation results showed that the research area belongs to the rainfed type, and the main objective of water management is to retain water and determine some efforts to increase the groundwater level through pump irrigation in the dry season. The application of pump irrigation was applied to the plant entering the generative phase. The pump irrigation was provided to distribute water into the quarter and worm (micro) channels. The effect of this application caused the groundwater level to approach about 30 cm below the soil surface, while groundwater level in areas without pump irrigation facility was in the range of 50-60 cm. Besides efforts to increase the water table, liming is still required in order to increase production. Lime application of 1 Mg ha^{-1} had a significant effect on increasing production. Corn production with this treatment could produce 5 Mg ha^{-1}, while non-treated land areas only produce 2-3 Mg ha^{-1}.

Keywords: Corn, DRAINMOD, pump irrigation, tidal lowland, water management

INTRODUCTION

Extensive land clearing of tidal lowland areas for agricultural enterprise in South Sumatra was started in 1969. About 400,000 ha of tidal lowland had been reclaimed through the transmigration program. Banyuasin area has shown successful effort in rice production at South Sumatra with a magnitude higher than 40 percent of total rice production (Desperate 2017). However, this successful effort had not followed by other agricultural areas because the planting index at these areas was less than 200%. One relatively less productive area is Sugihan Kanan, with a rice production level of fewer than 3 Mg.ha^{-1}, and most of its agricultural land had one planting index (Imanudin *et al.* 2016). The soil is classified as acid sulfate soil, with high acidity and Alumunium content (Fahmi *et al*. 2014). Aluminum toxicity has produced an alteration of biochemical and physiological reactions of plants and then to their crop productivity. Decreasing root growth is one of the initial and most evident symptoms of Al-toxicity. The nutrient availability was also decreasing due to bond reaction Al-P (Koesrini *et al.* 2014). On the other hand, Increasing levels of aluminum and iron in the soil solution also cause a decrease in the quality of water in the canals, soil pH and water pH dropping to a range of 2.3-3. Then the water channeled should be fluch out and replaced by freshwater from the rain or tidewater (Sukitprapanon *et al.* 2019).

The key success for land management at tidal lowland areas is how to manage soil water level at elevation level required by crop's root zone (Imanudin *et al*. 2010; Bakri *et al.* 2015). According to Fahmi *et al*. (2014), water status availability in the root zone is the main factor determining the thriving agriculture in acid sulfate soil. Rainwater was an essential water resource, mainly in acid sulfate soil. The pyrite oxidation process during a dry period made groundwater a highly toxic element and very acidic. Freshwater from the tide is not possible for land irrigation. Thus, to fulfill water crop requirement mainly achieved by rainwater (Imanudin *et al.* 2019). Therefore water retention in channels is vital to the block technique (Nurzakiah *et al.* 2016). Water in the canal is managed at a 60-90 cm depth to create groundwater at 10-30 cm (Herawati *et al.* 2020). With the controlled drainage system water in the canal is still available to keep groundwater table in the root zone and always above the pyrite layer. So that pyrite oxidation can be avoided in the soil profil (Sasirat *et al.* 2019).

Another critical factor is the availability of structures and infrastructure of water management networks to facilitate the land leaching process and water flooding in channels. Inadequate drainage facility frequently results in toxic elements accumulation and high soil acidity (Bakri *et al.* 2015). In addition, not all tidal lowland areas can provide good water quality from a secondary channel for supply (Hartoyo *et al.* 2010; Megawaty *et al.* 2012). Many channels had carried acid water or saline water during the dry season, which should be prevented from entering tertiary channels (Hairmansis *et al.* 2017; Tafarini and Yazid 2018). Watergates at the tertiary channel must be installed to control the drainage and water retention process (Lasmana *et al.* 2017; Imanudin *et al.* 2019).

The construction of field operation planning requires daily water table data during rain and dry seasons, either at dry or wet climate conditions (Imanudin *et al.* 2010; Negm *et al.* 2016). Daily water table data so far is frequently unavailable, difficult to measure, and costly. Therefore, the DRAINMOD computer model can aid in presenting the dynamics condition of the daily water table (Masoud *et al.* 2021; Wahba *et al.* 2018; Ashkan *et al.* 2020). This data can be used to construct weekly water management operational plans in the field for crop cultivation (Imanudin *et al.* 2011). According to Skaggs *et al.* (2012), statistical analysis shows acceptable results where the simulation model with daily water level prediction results calibrated with field data shows Nash-Sutcliffe (EF) modeling efficiency values are 0.68 and 0.72, the daily drainage rate (EF = 0.73) and 0.49), and monthly drainage volume (EF = 0.87 and 0.77). The simulated result was a high correlation between predicted and measured (Wan *et al.* 2009; Ashkan *et al.* 2020). Proper drainage planning by the DRAIMOD simulation model also depended on the quality of data input. Physical and Hydrological parameters such as rainfall and soil hydraulic conductivity were essential data input. (Negm *et al.* 2014; Ashkan *et al.* 2020). The model was also successful for developing land drainage design (Sojka *et al.* 2019). The model can provide input on the proper use and operation of drainage network infrastructure (Ashkan *et al.* 2020). The model could provide better predictions of groundwater table depths under shallower drainage systems. Moreover, produce management tools to minimize environmental issues in the agriculture field (Davoodi *et al.* 2019). The DRAINMOD model is excellent drainage modeling for estimating the depth of the groundwater table (Davoodi *et al.* 20019). The estimated groundwater level from simulation and modeling results shows the value of r^2 = 0.93 (Ashkan *et al.* 2020). An adaptation model for the tropical area has been carried out in tidal lowland reclamation areas in Banyuasi, South Sumatra. The simulation result found r^2 0.83. Hydrological parameters are essential factors that will have a better statistical analysis (Imanudin *et al.* 2011).

This paper will present the results of water table dynamics obtained from DRAINMOD modeling and operational planning implemented during planting season. Field adaptation was conducted by corn planting at dry season. The recommended DRAINMOD model for water supply in tertiary channels will be implemented by rainfall harvesting method (passive approach) and active approach through water pumping from the tertiary channel during the dried condition. The objectives of this field study are to construct the operational model for a water table control for agriculture purposes.

MATERIALS AND METHODS

This research was implemented at the tidal lowland area of tertiary plot-4 at Bandar Jaya Village, Jalur 25, Air Sugihan Subdistrict, Ogan Komering Ilir District (Figure 1). It was conducted from May to October 2017. The research site is classified as C typhology land in which it can not receive water through high tidal irrigation because high tidal water can not enter into this land. Water from secondary channel only capable of filling tertiary channel.

Materials used in this study are soil samples, corn seeds, fertilizers, pesticides, crops protecting plastics, and chemicals for soil analysis in the laboratory. Equipment used in this study are consisted of a piezometer, wells (perforated PVC pipe), 12 inch PVC pipe, elbow, marking board, water pass, meter, soil bor, excavation tube (bailer),

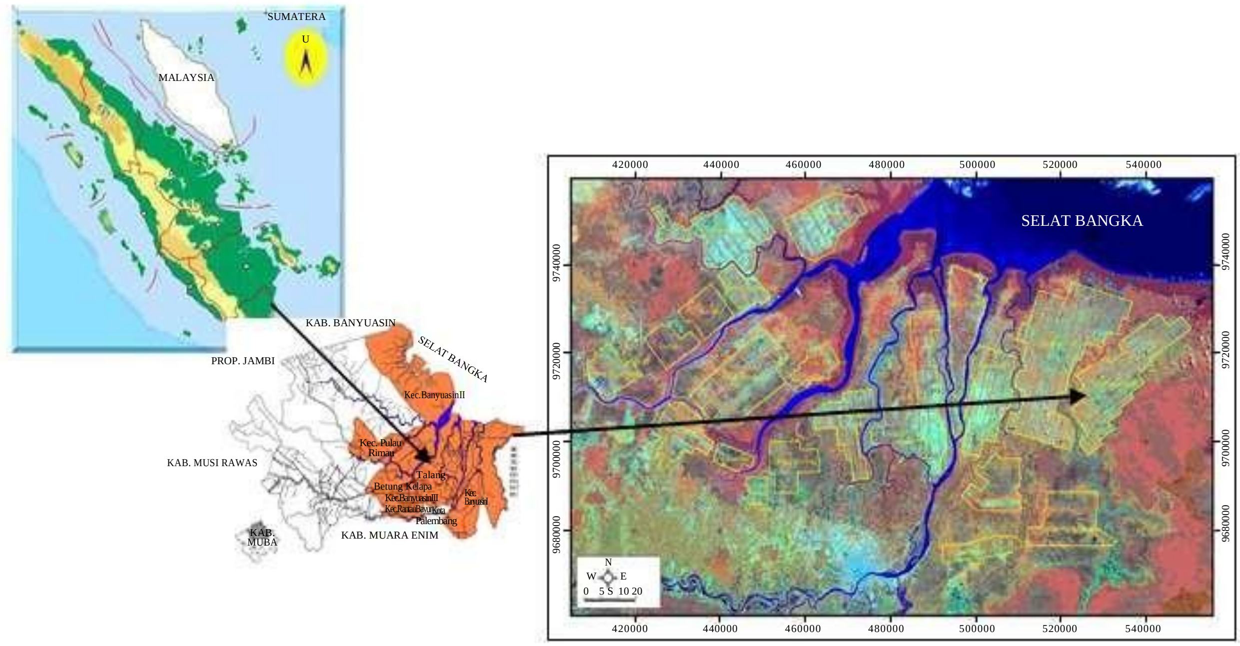

Figure 1. Maps of the area study in tidal lowland recamations of sugihan.

stopwatch), flap watergate made of fiber, 10 inch PVC pipe, digital camera, and agricultural equipment. For evaluation of water status at tertiary block and land, drainage planning was conducted through computer simulation using DRAINMOD 5.1 software (Skaggs *et al.* 2012).

The conceptual model to develop DRAINMOD is based on the water balance analysis within vertical soil column unit per surface area. The calculation starts from the impermeable layer up to the soil surface between drainage channels (Skaggs 1978). Calculation of water balance within soil profile for a time period of dt is mathematical can be expressed as follows :

$$\Delta Va = F - D - Ds \qquad [1]$$

$$P = F + RO + \Delta S \qquad [2]$$

Where ΔVa xi is the change of soil air volume (cm), F is infiltration (cm), ET is evapotranspiration (cm), D is lateral flow (negative sign indicates drainage flow and a positive sign indicates subsurface irrigation conditions) in cm, *Ds* is side seepage flow (positive sign indicates capillary flow upward) in cm, P is precipitation (rainfall) in cm, RO is surface flow (cm), and ΔS xj is the change of surface water storage. As an illustration, the drainage profile system in DRAINMOD can be seen in Figure 2.

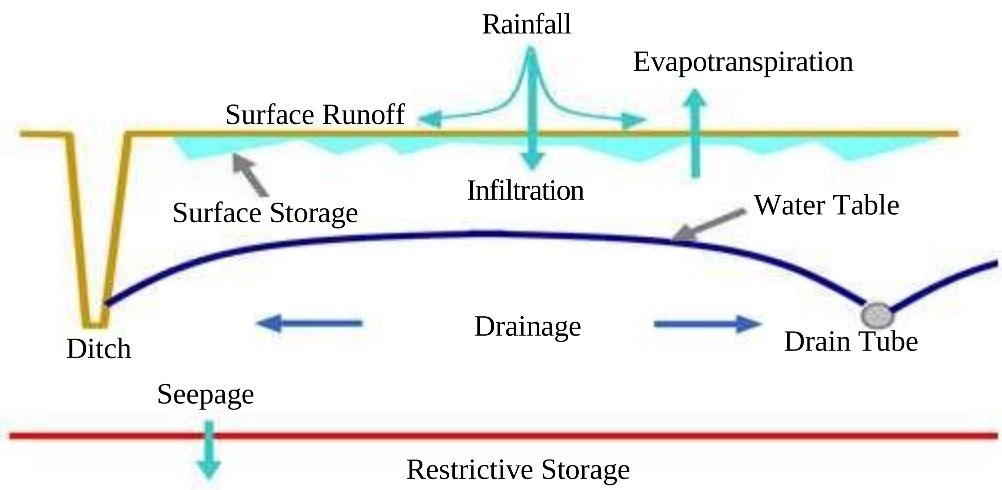

Figure 2. Schematic view of water table control system in open channel and subsurface. (Skaggs 1978).

Rainfall inputs in the DRAINMOD model are hourly rainfall, and maximum and minimum temperatures, which are read from weather data and water balance conducted every hour.

Input parameters for DRAINMOD are soil physical characteristics consisting of impermeable layer depth, soil hydraulic conductivity value, and climate data consisting of temperature and daily rainfall. Water network information has consisted of the depth and distance amongst channels. A simulation was conducted to determine soil water table dynamics at dry and wet climate conditions.

Observation of water table monitoring was extended to a period prior to dry season in May 2017. The corn seeds used in this study were Pioneer P21 varieties. To support the land drainage system, farmers developed a microchannel up to 30 cm with a distance between channels of 8 to 10 m.

There are two treatments were used in this study:

firstly, crop without lime addition and water source only from watergate retention; supply water only from the water capillarity movement;

Secondly, a pump added crops with 1.5 $Mg.ha^{-1}$ lime and water supply from irrigation. In order to provide water in the tertiary channel for pumping operation, farmers had conducted temporary water retention (dam) by using canvas plastics. The pumping operation was conducted at the crop's generative phase. Irrigation used in this study was furrow irrigation in which water is delivered to fill collector channel, and water from this channel subsequently was distributed to fill microchannel. Irrigation was applied once a week.

The computer model DRAINMOD was used for predicting the daily water table as the effect of deference climatic conditions. Data input of the DRAINMOD simulation model were hydraulic conductivity, soil water retention, land drainage system (drain spacing, depth, and width of channel), and crop physiological data. The scenario for the model operation was constructed based on different climatic conditions.

The analysis method for soil water status under the root zone was calculated using the SEW-30 concept. The calculation of SEW-30 is based on the Sieben formula (Skaggs *et al.* 2012). This concept is used to determine the condition of soil water excess (cm day^{-1}) during the crop growth period. The concept of water excess 30 cm above the root zone has an objective to evaluate fluctuation height of soil water table during a wet period (rainy season) within tidal lowland agriculture area (Imanudin *et al.* 2018). The value of water excess 30 cm above the root zone can predict soil water excess during crop growth. The equation used for this calculation is as follows:

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

x_i is the soil water table at (days too), with i is the first day and n is the number of days during crop growth. The DRAINMOD model calculates the hourly value of SEW-30 cm instead of the daily value so that the calculation of SEW-30 value is more accurate and can be formulated by using the following equation:

$$SEW-30=\sum_{j=1}^{m}(30-x_j)/24 \qquad [2]$$

x_j is the soil water table at the end of respective hours, and m is the total hours during the crop growth. Water table position with a critical limit of 30 cm is done with consideration value of 30 cm below the soil surface is selected because most of the food crops will experience physiological disturbance if the soil water table is drop down from 30 cm point or increase upward from 30 cm point from the soil surface. If soil water is far from the critical value of 30 cm or closes to the soil surface, it will create excess water conditions (Negm *et al.* 2014). This condition is applied for non-rice food crops. On the contrary, rice crop is withstanding water flooding condition and will experience stress if soil water is below 30 cm depth zone or even below 20 cm depth zone (Imanudin *et al.* 2011; Imanudin *et al.* 2019).

RESULTS AND DISCUSSION

Soil Physical Characteristics

Soil physical characteristics in the study area are shown in Table 1. Soil has high porosity and low bulk density in the top layer. Meaning that soil had relatively high total pore space resulting in relatively high water holding capacity. The decrease of soil bulk density is followed by the decrease of total pore space at deeper soil layers. The water movement means that on the rotting zone area, the water movement was easy to drain and submerge by gravity forces.

The soil layer above 60 cm showed the increase of clay content so that soil bulk density can be classified into mineral soil. The main limiting factor is soil acidity level than can be classified as acid soil with a 4-5. It is also reported by Koesrini *et al.* (2014) when pH <5, the Aluminum toxicity is an

Table 1. Soil physical characteristics and soil acidity level.

Depth	Bulk Density (g cm^{-3})	Total Pore Space (%)	pH
0-30 cm	0.98	46	4.8
30-60 cm	1.15	48	4.6
> 60 cm	1.25	55	4.2

increase in soil. It is the main stress factor for plant growth in tidal lowland agriculture.

Soil textural class is shown by the ratio of clay, sand, and loam fractions (Table 2). Although soil fraction composition had occurred, soil texture at the study area is qualitative can be classified into silt loam class at 0-60 cm and clay texture in the layer of 60 cm below the soil surface. Clay fraction tends to increase with the increase of soil depth.

Clay fraction with the magnitude of 7.6 % at soil layer depth 0 - 30 cm had increased to 21.6 % at a depth of 60 cm. The increase of clay fraction below soil surface had produced a beneficial effect in which land can store water at depth above 60cm so that soil water depth at this layer is not quickly depleting. In addition, soil water contribution at this layer through capillary movement is significant to supply crop water requirements. According to Zipper *et al.* (2015), the contribution of groundwater through capillary rise is strongly dependent on soil texture, and increasing clay fraction on the soil more provides water by capillary rise than soil having sandy soil. Added by Gao *et al*. (2017), at groundwater depth 1 m below the soil surface, the capillary upward was supplied about 41% of the crop evapotranspiration, which means that the water supply was required to fulfill crop water requirements when the water table started to drop at 70 cm.

Computer Simulation of DRAINMOD in estimating soil water table

DRAINMOD is a drainage model capable of estimating the depth of soil water table for swamp lowland and peatland areas. The main inputs for this model are consist of rainfall, crop evapotranspiration, soil hydraulic conductivity, and drainage network characteristics data. The water flow condition within the soil is assumed to be constant (steady condition) in the Drainmod model (Skaggs *et al.* 2012).

In the case of reclaimed tidal lowland area at Sugihan Kanan, some model inputs have consisted of soil hydraulic conductivity of 0.34 m.day^{-1}, impermeable layer depth of 2 m, the distance

Table 2. Distribution of sand, loam and clay fractions at several soil layers.

Depth	Percentage (%)			Soil Texture
	Sand	Clay	Silt	
0-30 cm	29.4	7.6	63	Silt Loam
30-60 cm	26.4	14.6	59	Silt Loam
>60 cm	14.4	64	21.6	Clay

Table 3. Scenario planning constructed at the initial stage of DRAINMOD simulation.

Microclimate scenario	Water management options	
	Conventional (without control)	Using control
Normal Rainfall Condition in the Year of 2014	Soil water table indicator	Soil water table indicator
Dry Rainfall Condition (El Nino) in the Year 2015	Soil water table indicator	Soil water table indicator
Wet Rainfall Condition (Lanina) in the Year 2016	Soil water table indicator	Soil water table indicator

between tertiary channels at a current condition in the field was 250 m, initial soil water depth is assumed 10 cm below the soil surface and average channel depth of 1.5 m. The constructed scenario can be seen in Table 3. The simulation was conducted at two climatic conditions: typical climate (average rainfall) and dry rainfall due to Elnino. The simulation stages have consisted of simulation on the existing network condition without control effort followed by simulation on Watergate operation.

Computer simulation results of DRAINMOD for wet and dry climate conditions are shown in Figure 3. Simulation results showed that the soil water table variation at the condition of the initial to the final rainy season had a safe value in land firing probability. However, simulation results also showed that over drain had been occurred on land, and they were indicated by a quick drawdown of soil water table elevation in case of no rainfall occurrence for more than one week period. The soil water table fluctuation results either at normal or dry rainfall conditions (Elnino) showed a similar trend in terms of soil water table conditions for the January-May period.

The land was still in safe condition from fire hazards during this period. Although the soil water table drops into critical depth value (80 -100 cm), rainfall still occurred so that soil water elevation could increase again close to 30 cm depth. The vulnerable condition started to occur at days of 140 (entering of May) in which rainfall was decreased, and soil water elevation was continuously drop exceeding the critical limit (- 80cm). In this period, pyrite oxidation could also haven and create a decreasing pH in the root zone.

On the other hand, the soil has a pyrite layer around 60-70 cm below the soil surface. When the groundwater table level drops to 100 cm, an oxidation layer will occur. This process would produce high soil acidity and increase the solubility of iron and aluminum content, which may be harmful to crops- reported by Koesrini *et al.* (2014) that applying lime with 2.0 Mg ha^{-1} is still required for increasing pH in the soil. Added by Fahmi *et al*. (2014), the lime application was efficient in combination with good land preparation through intensive soil leaching and intermittent waterlogging. It was also reported by Ar-Riza *et al*. (2015) that the main problem is challenging to get fresh water for the leaching and flushing process. Those for managing acid sulfate soil are still required lime application to increase pH. According to Aksani *et al.* (2018), increased productivity of tidal lowland rice cultivation was achieved by 10 Mg ha^{-1} rice straw compost, and NPK fertilizers that should be applied are 315 kg urea ha^{-1}, 135 kg SP-36 ha^{-1}, and 90 kg KCl ha^{-1}, Mean that water availability is not only a single factor for increase land productivity.

Rainfall was average in 2014; soil water elevation continuously dropped to the lowest point of – 115 cm in September and started to increase when entering October, although it was still within

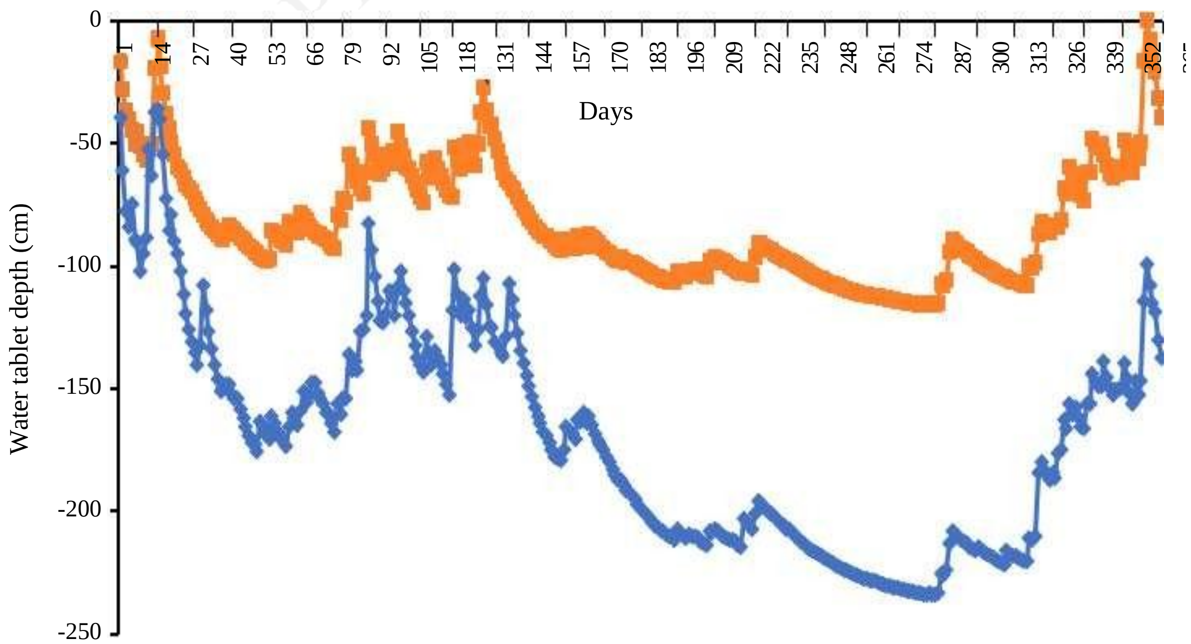

Figure 3. Soil water table fluctuation resulting from DRAINMODsimulation model under control and of without control. —■—: Year 2014 (wet condition), —◆—: Year 2015 (dry condition).

the critical depth limit. The safe condition again occurred in November, whereas the dry climate condition (Elnino) in 2015 showed that soil water elevation dropped to a depth of – 118 cm, which occurred in September. However, soil water elevation was still at a critical depth value up to December due to minimal rainfall. Since soil had high porosity, farmers were reluctant to open tertiary channels because rainfall water was assumed to be insufficient to supply the soil water table and channels. Therefore, water pumping from the tertiary channel should be made to deliver water into quarterly channels, which requires stepping detention during high tidal water in the tertiary channel.

Simulation results from Figure 1 showed an open drainage system with the distance between channels of 250 m and channel dimensions as follows: upper width of 2.0 m and lower width 1.2 m, as well as the depth of 1.2 m, was excessive in terms of dimension size. This channel dimension is a high capacity to drain water. Therefore, water losses were rapid, indicated by a water drawdown of up to 40 cm in case of no rainfall for two weeks.

Simulation using a shallow drainage system was subsequently tried to determine the proper channel dimension at peatland to prevent excessive water losses. The depth of the tertiary channel was only 1 m with a bottom width of 30 cm. Simulation result (Figure 2) showed that soil water table drawdown was not as fast as the existing channel dimension. Simulation results of shallow drainage showed that soil water table condition in 2015 (Elnino) was within a safe zone up to June. The control measure can be done in the June period.

Because the drainage system had already been built and it was impossible to conduct filling activity, the choice was to conduct water retention immediately using a controlled dam system. Therefore, a computer simulation of DRAINMOD was implemented at the initial stage. The simulation was also conducted to determine the impact of water retention within the tertiary channel (Figure 4). Water retention simulation would be done during the least rainfall occurrence period in May. Simulation results showed that soil water table elevation could be increased up to a depth of 30-40 cm below the soil surface during May-June. Soil water table elevation was located at 60 cm below the soil surface during the dry season of July-November. Land at this condition was relatively safe from fire hazards. This condition would be achieved if soil water table elevation in the tertiary channel was not dropped more than 40 cm from the soil surface.

The condition of this controlled drainage system was found in the field during October, where the soil water table was located at a safe zone, i.e., 40-50 cm below the soil surface. This condition also prevents pyrite oxidation, although pumping irrigation supply was needed to fulfill crop water requirements. Pump facilities are highly needed if farmers cultivate corn at B and C land typology areas during the dry

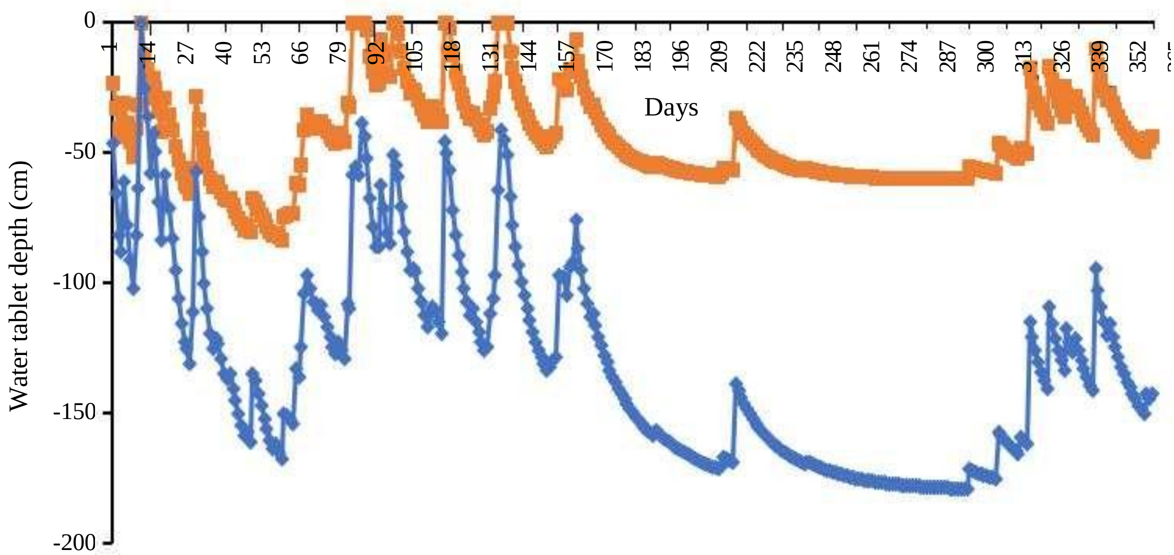

Figure 4. Computer simulation result at shallow drainage condition or 50 cm water retention. —■— : Water retention option, —◆— : No option (Uncontroll).

Figure 5. Hydraulic structure in tertiary canal for water retention and control drainage in tidal lowland type C.

season. The pump was only operated for one month during the seed filling phase (generative period), and irrigation was applied once a week.

A water retention structure was highly needed because the land area at the study location had high water losses. Control structures are needed to support network operation as water retention (rainfall harvesting). The dam pattern equipped with an overflow structure is the proper model for the tertiary channel (Figure 5). Farmers currently use sandbags to withstand water losses. The effort to elevate soil water table elevation can be made by water pumping from the tertiary channel into the quarterly channel, which was subsequently delivered further into the collector and micro (worm) channels.

Control drainage is the best option for water management in the area study. The farmer keeps the water in the tertiary canal minimum at 50 cm above the bottom level of the canal. By maintaining the water level in the tertiary 50-60 cm than the groundwater table purposed above the pyritic layer during the dry season.

Field Adaptation of Water Dynamics at Dry Season Condition (July 2017)

Water table elevation was hourly observed to determine soil water table dynamics, which is affected by the fluctuation of water surface in the channel. Results of this hourly observation can be seen in Figure 6. The average value of water table depth was 37 to 41 cm below the soil surface, and this magnitude was ideal for the growth of the corn crop. Hourly observation of the soil water table showed a decrease of water surface followed by a

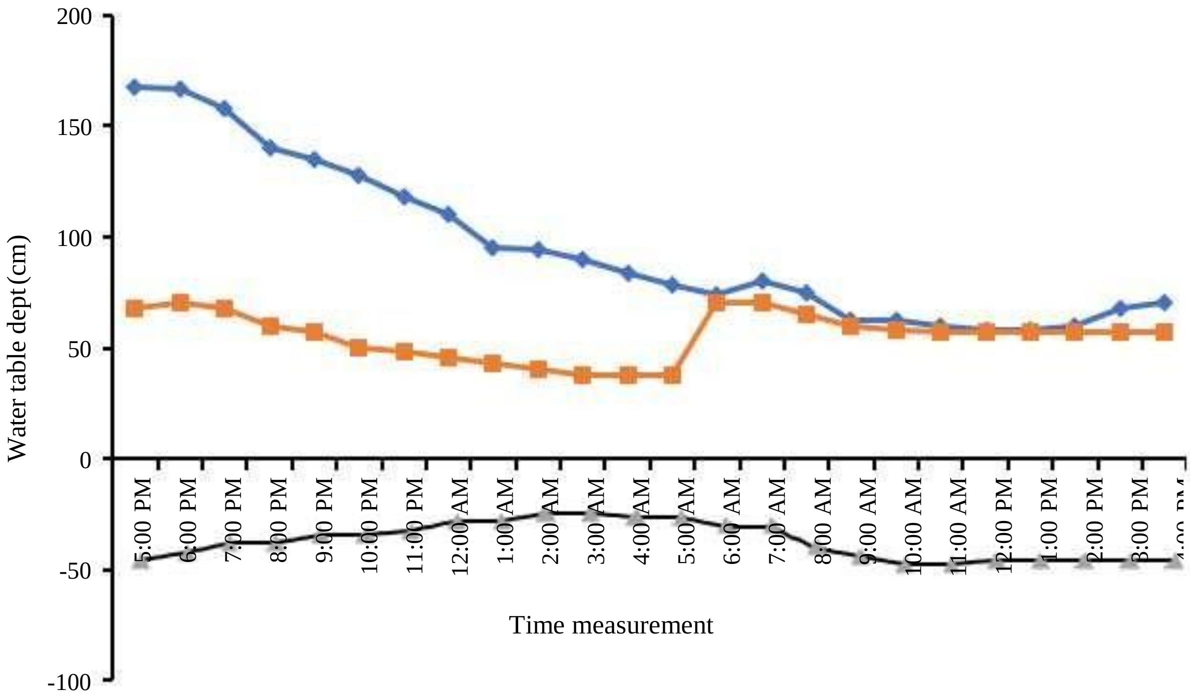

Figure 6. Condition of daily water surface level at the tertiary channel and tertiary block in July. —◆—: Water table in secondary canal, —■—: water table in tertiary, —▲—: ground water table.

Table 4. The relationship amongst water level at the tertiary channel, secondary channel, and soil water table.

No	Locations	Water surface level (cm)
1	Tertiary channel	70 cm
2	Secondary channel	168 cm
3	Soil water table	-30 cm

decrease in the secondary channel in the tertiary channel. In contrast, the increase of water surface in the secondary channel was followed by the increase in the tertiary channel. The change of soil water table did not follow this condition. The soil water table movement was relatively stable from a maximum depth condition of – 50 cm into a minimum depth condition of – 33 cm. The movement of the soil water table was highly affected by rainfall. The insignificant difference in water table depth at the tertiary block was due to water availability in the tertiary channel. Therefore, the horizontal movement of water (see page) was practically slight and can be neglected as long as water along the tertiary channel was available at the height of 50-60 cm.

The relationship between water level elevation in the tertiary channel and soil water table as a result of water retention impact (Tabel 4) showed that water level elevation in a tertiary channel on May-July was located at 70 cm depth and water level elevation in the secondary channel was located at 168 cm depth. This condition can produce soil water table elevation at 30 cm below the soil surface.

The network operation and corn growth (PS2)

The network operational guidelines in the tertiary channel can be summarized in Table 5. The operation was conducted each month according to crop growth phases.

Crop evapotranspiration requirement at dry season entering September could not be fulfilled if solely rely on capillary water movement from soil water table depth of 50 cm. Capillary water could only supply 45% of crop evapotranspiration requirements at this condition, so another water supply was needed. Farmers used a water pump to fill the soil water table (Figure 7).

A significant increase of soil water table was observed on corn cultivation which was supplied through pump irrigation. Water can be elevated with a magnitude of 20 cm. The soil water table on land without pump irrigation was located 40-50 cm below the soil surface, whereas the soil water table on land supplied with pump irrigation was located at about 30 cm (Figure 8). If the soil water table was located at a depth of 30 cm below the soil surface, then crop evapotranspiration requirement can be fully supplied from capillary water movement. Fan Yang *et al*. (2011) reported that the capillary rise could not support the crop water requirement when the groundwater table was below 2.5m. Moreover, when the groundwater table maintenance is at 50 cm, irrigation is not required.

Corn production achieved using maximum technological inputs consisting of improvement of irrigation system, and soil quality showed good yield with a magnitude of about 3 $Mg.ha^{-1}$. However, this

Table 5. Model Operation of the tertiary network by using gooseneck watergate.

Month	Estimation of crop's growth phases	Water management objective	Operation of gooseneck watergate	
			Inner Section	Outer Section
May-June	Land preparation and planting	Controlled drainage	The gooseneck is turned 45^o	Closed with valve materials
July-August	Vegetative	Controlled drainage	The gooseneck is turned 45^o	Closed with valve materials
September-October	Generative	Supply, soil water filling	The gooseneck is turned 45^o (additional supply from water pump)	Pipe is opened

Figure 7. Pump irrigation on corn cultivation to elevate soil water table level.

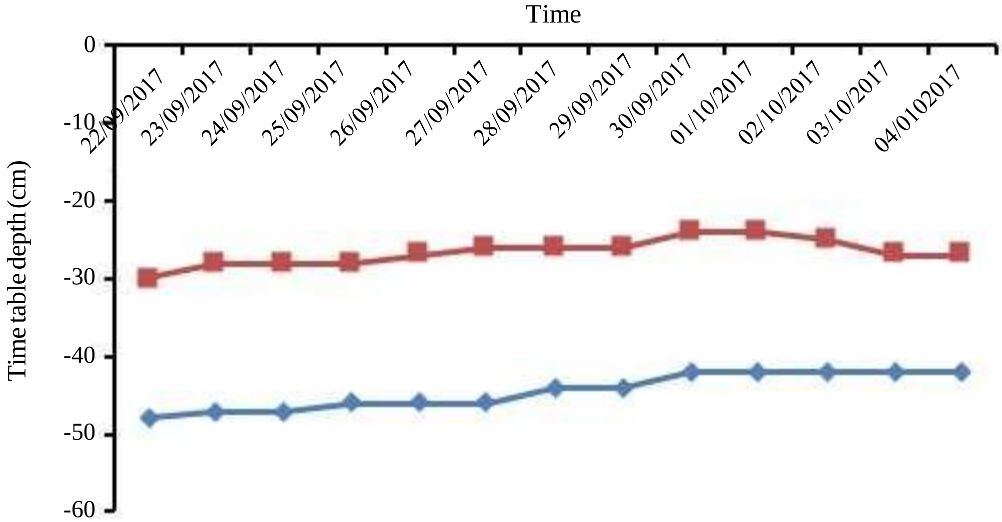

Figure 8. The condition of the soil water table in the middle of September 2017 was affected by pump irrigation.

production level was still lower than corn production achieved by farmers at the Telang II area with a 7-8 Mg.ha^{-1} (Imanudin and Bakri 2014). The yield of corn would be an optimum underwater table at 50-60 cm below the soil surface (Bakri and Bernas 2015). Since the water table dropped by more than 100 cm, the performance of corn growth decreased as reported by Liu and Luo (2011) in Australia that the significant contribution of the groundwater table ranges between 40-150 cm. It was contributed more than 65% of the potential evapotranspiration. However, capillary water rise fulfilled the crop's water requirement under 40-50 cm.

CONCLUSIONS

Hydrotopographical characteristics at the study area were classified into C class in which land area does not receive the overflow from high tidal water. However, water availability in the channel is capable of controlling the soil water table.

Komputer model DRAINMOD computer model can be used to estimate fluctuation of the soil water table at several climatic conditions. Simulation results can be utilized to construct a monthly water management plan.

The main objective for water management at the tertiary level was water retention due to physical soil conditions characterized by high porosity and high hydraulic conductivity. Therefore, the operational model was to retain water during the rainy season (rainfall harvesting) and control drainage during the second crop (corn).

Water retention in the tertiary channel at a depth of 70 cm could maintain soil water table elevation at 30 cm below the soil surface. Soil water table elevation should not be a drop below 50 cm in order to prevent pyrite oxidation.

At the initial reclamation stage, limiting application at a dose of 1-2 Mg ha^{-1} was still required because of high acidity and high aluminum solubility.

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