

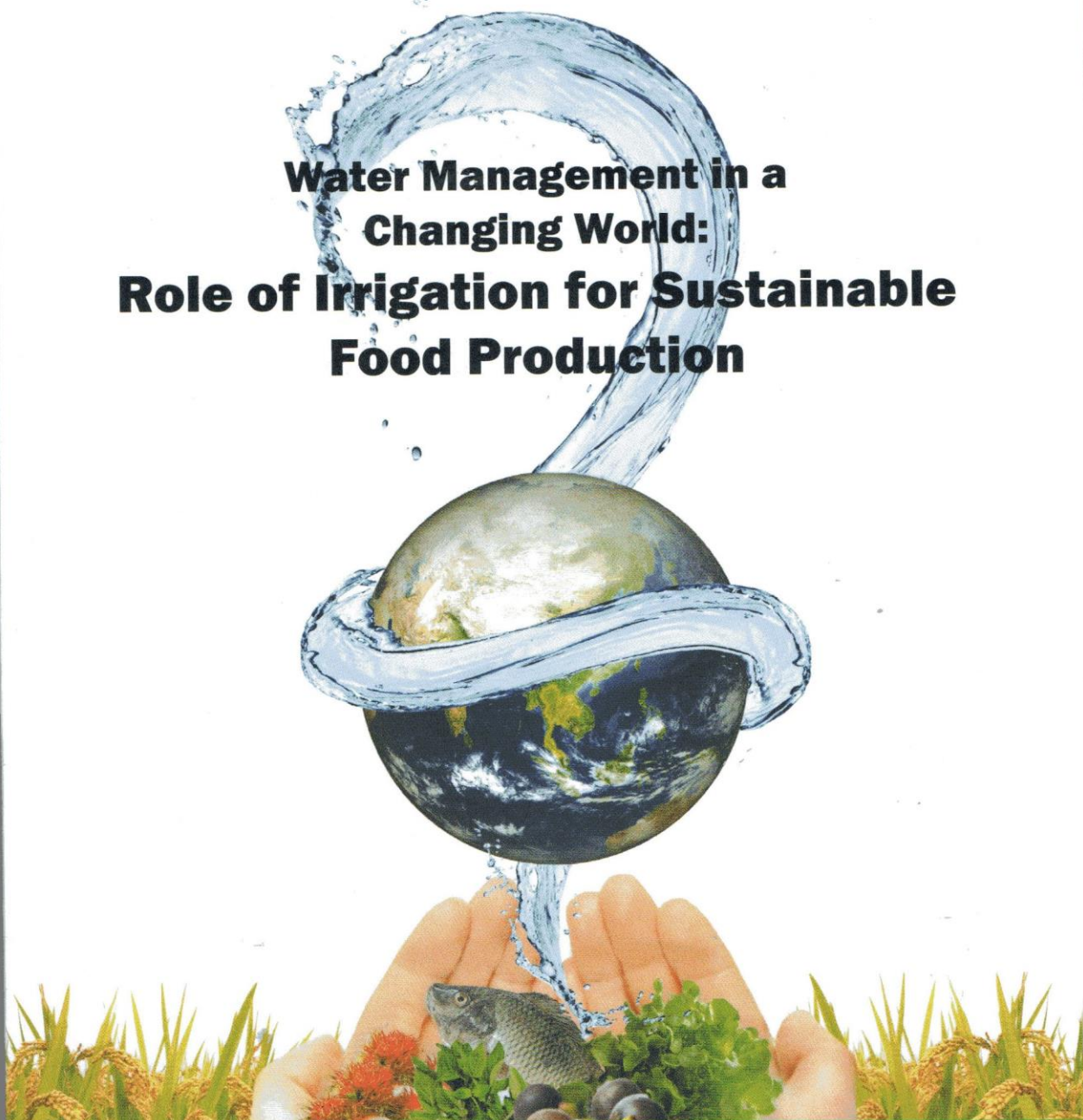


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El-Nino Effect on Water Management Objective in Tidal Lowland Reclamation Areas (*Adaptation Model for Corn*)

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Abstract: Phenomenon of climate change occurs almost every year and the real impact was felt in 2015 where South Sumatra suffered prolong drought due to the effects of El Nino. This condition made the majority of agricultural land was affected by drought and even fire. The study objective was to assess the effect of El Nino on the water management operating system as an effort to provide water for crops requirement. Crop adaptation model was implemented by using corn as a second crop and it was expected to maximize land use under dry condition and to protect land from fire hazards. The results showed that the network operation was the drainage system (opened gate) which implemented from June to August and water retention system (closed gate) was done from September to October. The water level has decreased from July to October. The peak water level was dropped to a depth of -190 cm below soil surface at the beginning of October. Water retention effort done by the farmers was too late because it should be done during less rainfall period in July. Water table depth was more than 190 cm so that corn experienced a water deficit and its production level was decreased to 6-6.5 tons/ha compared to its typical production level of 8 to 8.5 tons/ha. This means that the impact of the El - Nino events have lowered corn production by 25 %. This condition is still good by considering the fact that land can still be used and protected from fire hazards. Therefore, intensification of agriculture in wetlands had proved to be capable to prevent fire hazards.

Keywords: El-nino; tidal lowland; water management

1. INTRODUCTION

The El-Nino phenomenon recently has receive serious attention by Indonesia government, especially due to its impact on food crop production. El-Nino is the change of sea condition as a results of increasing temperature in Pacific ocean region close to equator. It can produce the deviation of atmospheric condition that has impact on climatic change [1]. The effect on climatic condition in Indonesia is in form of decreasing rainfall. This condition had been observed in 2015 where the volume of rainfall was decreased, especially during the dry months [2]. The need for additional water through irrigation in the dry season . Elnino have an impact on the decline in production of oil palm trees in wetlands, even on dry land area does not bear fruit the following year . For optimal growth of plants , the soil must be able to supply at least 5.5-6.5 mm / day [3]. This

means the water is needed for a minimum of 180 mm / month. While at the time of Elnino condition where rainfall is less than 180mm is for 4-5 months. During this required the addition of water.

The dry season condition in 2015 as an impact of El-Nino had shown extremely dry condition than that of 1997 [4]. The occurrence of dryness in Indonesia in 1997 had results in dryness of rice crop covering area of 517,614 ha and dried up condition with magnitude of 87,099 ha from total planting area of 11.13 million ha. Therefore, Indonesia should imported rice commodity in 1998 with magnitude of 7.1 million tons [5]. According to [6] reported that at dry planting season 2015 (April-July), area of rice crop which experienced dried up due to pest attack, flood and dryness was 19,724 ha or 0.44 percent from total planting area of 4,529,751 ha. The

government effort to anticipate dryness problems through development of embung technology and provision of water pumps was not produce maximum result. Therefore, the proper strategy is to maximize the utilization of swamp lowland and tidal lowland for food crop cultivation [7][2].

The key for successful agricultural cultivation at swamp lowland is how farmers are capable to control water table so that it always available near the root zone of crop. Rice crop may grows in optimum manner if maximum depth of water table is located at -20 cm from soil surface for not more than one week. However, rice yield may decrease if depth of water table is located at 10 to 20 cm for more than one week[8]. Rice cultivation during dry season in aerobe condition might decrease rice production by 30% than that of flooding soil condition [9]. Therefore, rice cultivation is not economical to be conducted during dry season at tidal lowland area. Rice cultivation is onlly conducted at initial period of dry season at A and B land typologies where water table is located at maximum depth of -20 cm [10]. On the other hand, maize (corn) crop may grows in optimum manner if maximum depth of water table is located at -100 cm to -150 cm. This condition had been adapted at tidal lowland area of South Sumatra [7][11]. Corn is one the crop which has could not tolerate or sensitive to water deficit. Stress water will come in the second week when the water availability only 0,4 to crop evapotranspiration [12]. Water table control effort in the field should take into account the micro climate condition and availability of channel network. The El-Nino effect which results in prolong dry season had forced farmers to change the water management objective. The current objective of water management in the field is drainage and retention. This paper objective is to discuss water management objectives as an effort to fulfill crop water requirement during prolong dry season as a results of El-Nino effect.

2. EXPERIMENTAL DETAILS

This study was conducted at tidal lowland area of Delta Telang II within selected secondary plots in Banyu Urip Villages. Land use at these villages is consisted of rice crop cultivation at period of November 2014 to March 2016 and corn cultivation at period of June 2014 to November 2016. Water table depth at secondary channel was observed for 24 hours in order to determine irrigation potential, whereas water table depth was observed by using well at dry season period to determine soil water status in land. Data processing was done by using computer model of DRAINMOD [13][14]. This model is used to predict water table status as an impact of water management through channel network operation. Data input for DRAINMOD model was daily rainfall from climatological station of Kenten. Rainfall data for wet season was taken from data of 2014, whereas rainfall data for dry season was taken from data of 2015. Soil data input for DRAINMOD model was soil hydraulic conductivity in the field. Water management scenario at wet season and dry season will be compared to field condition.

3. RESULTS AND DISCUSSION

A. Climatic and Hydrological Condition

The climate characteristics at Banyu Urip Village was categorized as tropical rain climate having hot and humid conditions for the whole year. Average monthly temperature was about 27°C and average relative humidity was 87%. Rainy season was consisted of 5-6 wet months period with rainfall magnitude of >150 mm.month⁻¹ and 2 – 3 dry months period with rainfall magnitude of < 150 mm.month⁻¹. However, climate shifting was occurred in 2015 which is characterized by longer dry season duration or dry months (see Figure 1). Rainfall due to El-Nino effect had showed dry condition with 4 dry months period. This was occurred during prolong dry season in 2015 and 1997. Most of South Sumatra area during these years had experienced fire, especially at lowland areas. On the other hand, normal climate condition in 2013 showed relatively high rainfall in which rainfall magnitude less than 100 mm was only occurred in July. If crop evapotranspiration is 4 mm/day, then crop water requirement can be supplied from rainfall with periode of 11 months and the rest was supplied through irrigation.

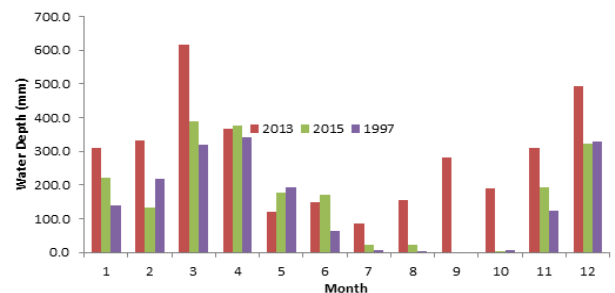


Figure 1. Rainfall condition as affected by El-Nino in 2015 and 1997 as well as normal condition in 2013.

Water table fluctuation in secondary channel can be seen in Figure 2. Based on observation of tidal pattern, this daily water table fluctuation was classified as diurnal tidal because high tidal water was only occurred once a day. High tidal water was started from 18.00 p.m to 22.00 p.m. or during night time. Therefore, the potential of high tidal water harvesting can only be done during this period. However, high tidal water can not enter the land so that an alternative effort is to hold high tidal water as much as possible within tertiary and secondary channels.

Water surface level in channel during low tidal period was -120 cm and during high tidal period was -70 cm. It means that filling up of water in channel was only about 50 cm. If secondary channel has length of 3 km and width of 10 m, then its storage capacity is $10 \times 0.5 \times 3,000\text{m} = 15,000 \text{ m}^3$ and it needs filling up duration of 5 to 6 hours. Water depletion in channel requires duration of 6 hours (duration of low tidal water was 6 hours).

In addition to surface water condition, the main limiting factor for tidal lowland development was availability of pyrite layer. Oxidation process will be occurred if water table level was below pyrite layer. This chemical reaction will produce acid substance which cause pH value drop below 3. Results of soil observation in the field showed that the depth of pyrite layer was about 110 – 120 cm below soil surface. Pyrite layer is located at relatively deep zone so that potential of pyrite layer

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oxidation that cause crop toxicity is relatively low if water table depth is always controlled by farmers. However, water table is dropped below pyrite layer and oxidation process can not be prevented during prolong dry season as a results of El-Nino effect.

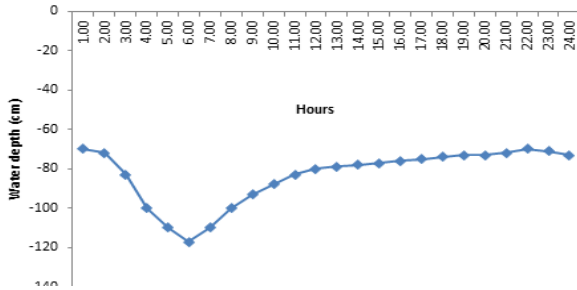


Figure 2. Pattern of high and low tidal water in secondary channel

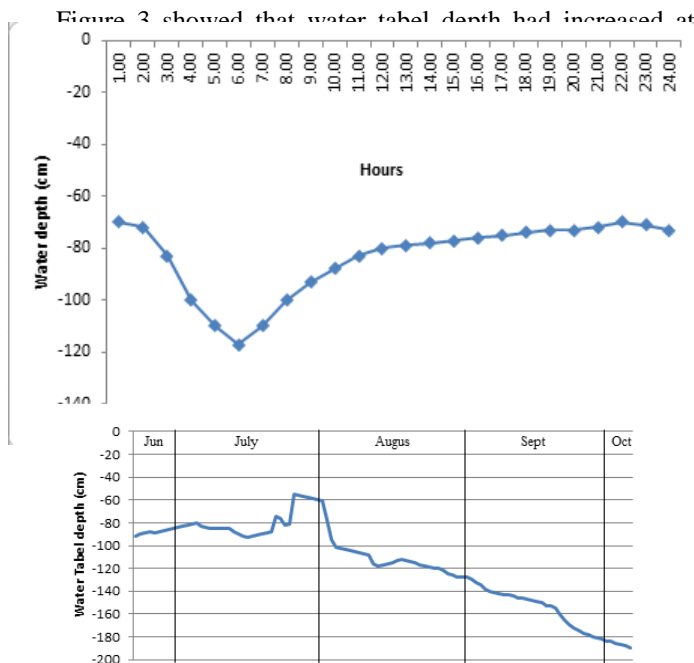


Figure 2. Water table fluctuation at dry condition as affected by El-Nino at Delta Telang II, Banyuasin in 2015.

If condition of water table depth was dropped more than 150 cm below soil surface, then requirement for crop evapotranspiration can no longer be supplied only from capillary movement of soil water [15]. Therefore, crop growth was not optimum without water supply from rainfall or irrigation water. This condition was occurred in 2015 in which water table depth was dropped up to 150 cm below soil surface since the third week of September, even water table depth was dropped close to 200 cm below soil surface in early October. This condition is vulnerable to dryness and pyrite oxidation occurrences. Oxidation process produce acid which through evaporation process will move into root zone of crop and produce toxicity effect on crop. The toxicity effect can extent to the subsequent planting season. Land leaching effort for subsequent planting season should be supported by sufficient amount of rainfall. This condition is certainly change the main objective of water management.

B. Network Performance Evaluation Using Computer Simulation of DRAINMOD

Table 1 showed that farmers had done land leaching at beginning of planting season of 2015. The objective of this activity is to flush out hazardous substances from the land (such as acids and metals) which had produced by pyrite oxidation from the previous dry season period. Tertiary water gate was closed to maintain land moisture, i.e. high tidal water is capable to enter tertiary channel, but water is retained in channel during low tidal water condition. Subsequently, drainage operation was done in land with an objective to lower water table depth in land. Due to sea water intrusion during dry season, tertiary water gate was operated in closed position to prevent saline water flowing into the land. Operation activity of this tertiary water gate was conducted to provide better environment for corn cultivation during dry season of 2015 (El-Nino). This operation was real activity in land and would be evaluated by using DRAINMOD model.

Table 2. Operation of tertiary channel gate at prolong dry season due to El-Nino in 2105

Date	Gate operation	Objective
22 June – 12 July	Opened	▪ Land leaching
13 July – 31 July	Closed	▪ Water holding within channel
1 August – 31 August	Opened	▪ Water drainage of land
1 September – 6 October	Close	▪ Water holding within channel ▪ Preventing saline water intrusion into land

Field operation result conducted by farmers showed that water table depth condition was not optimum for crop. Water table was drop up to critical level of > 150 cm in September-October. However, crop production was relatively good in which famers can harvest corn up to $6.8 \text{ ton} \cdot \text{ha}^{-1}$, i.e. this magnitude is relatively high. The water table drop at land plot with magnitude of more than -120 cm at 65 day after planting period had no significant effect on crop growth. Based on its characteristics, corn in this period requires less water which is indicated by water content of ear corn that is continously decrease up to its following development stages. Therefore, water table depth of -120 cm below soil surface would not impede crop development as long as capillary water is available to mantain soil moisture at pyrite layer, but not inundate pyrite layer in soil. Meanwhile, water table depth of more than 150 cm showed that corn was entering harvest period. The water table drawdown had effect only on the decrease of soil quality as a result of pyrite oxidation impact. Therefore, corn production should still be increased because corn production in previous year even had achieved magnitude of 8 ton/ha . The decrease in corn production not only due to water requirement that was not fulfilled at maximum level, but also due to nutrients absorption interference as a result of pyrite oxidation effect during period of September-October.

According to [16], rice cultivation at El-Nino climate condition had higher production level than that of Lanina or normal condition climate. This was occurred as long as crop water requirement was fulfilled. Rice cultivation with sufficient

irrigation water supply had higher yield at dry condition because crop had received sufficient solar radiation, less pests and diseases and crop nutrients were in more available condition. This condition can not occur in tidal lowland area because of pyrite oxidation effect.

DRAINMOD model was used to determine water table dynamics condition as an impact of climate anomaly due to El-Nino effect. Computer simulation can produce an estimation of daily water table fluctuation at tertiary plot. Simulation was conducted by using data input of rainfall in years of 1997 and 2015 which characterized by prolong dry season as an impact of El-Nino. Simulation results would be compared to water table condition observed in the field having similar land typology. Comparison was conducted with water table data during normal climate and dry climate conditions. Figure 4 and 5, showed water table dynamics which occurred in 1997 and 2015 using computer simulation model of DRAINMOD. Simulation was conducted at alluvial soil in tidal lowland and peat soil.

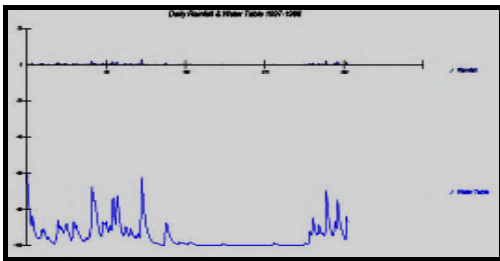


Figure 4. Water table condition in 1997 as affected by El-Nino using computer simulation model of DRAINMOD.

For example, simulation result by using rainfall data in 2005 showed that water table depth was more fluctuate in which water table depth was increased close to root zone during dry season period. The water table had decreased 100 cm below soil surface for one month or two month period only without operation of water gate. Figure of simulation results by using rainfall data of 1997 and 2005 with dry climate condition due to climate anomaly caused by El-Nino showed that duration of critical water table depth was more than 4 months. Water table depth was decreased up to constant value of 100 cm from May to November. Even water table depth was in critical zone (~ 100 cm) most of days within August-November period and this condition results in water deficit for crop evapotranspiration requirement in this area.

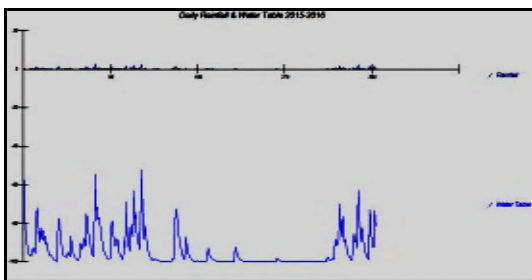


Figure 5. Water table condition in 2015 as affected by El-Nino using computer simulation model of DRAINMOD

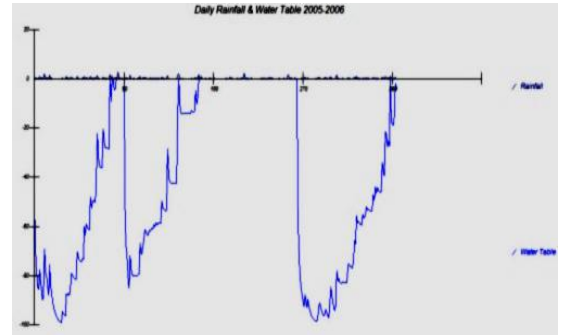


Figure 6. Water table condition during normal rainfall

Figure 7 showed water gate operation produced by using computer simulation of DRAINMOD. Water table was maintained at the depth of 50 cm below soil surface by using stop log gate operation from January to December. Operation system was constant in which water gate was constructed at position level of 50 cm so that water can flow out and flow in, but water level was maintained at height of 50 cm from channel base of tertiary channel. Water flow rate in vertical direction at tidal lowland area was relatively high so that water surface level in channel was similar to water table depth in tertiary plot. Water table depth during dry season through water gate operation could be increased from 100 cm below soil surface to 50 cm below soil surface. This condition showed that land use potential was only for second crops such as corn, soybean and watermelon. Rice crop during this period had low production because rainfall was limited around flowering phase so that water availability was insufficient for crop evapotranspiration requirement. Rice crop had experienced water stress if water table depth was less than 20 cm below soil surface for more than three days period [11]. However, water retention should be conducted by using intermittent pattern during January-February period in which water gate should be opened at least for three days. The objective of this water retention operation is to flush out toxic materials from root zone of crop. Water retention was done permanently only around the end of wet season in March.

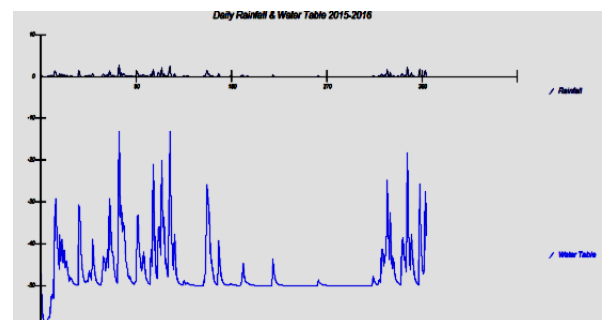


Figure 7. Water table under maintenance in 50 cm water depth at tertiary canal

C. Guidance for The Change of Water Network Operation as an Impact of El-Nino

Management of micro water network is water management at tertiary plot which consisted of operation at tertiary channel, quarterly channel and micro channel, respectively. Quarterly

channel is consisted of two channels that has function to flow in and to flow out water having dimension of 1 m in width, 0.7 m in depth and 100 m in length or having similar length to land length. For design purpose of one way flow system, stoplog gate was installed at upstream section of quarterly channel or precisely at water entrance section of tertiary channel and its end section is covered with soil.

The main objective of micro water management at tidal lowland area is not only to maintain water table depth at optimal condition in order to fulfill crop evapotranspiration requirement, but also to prevent pyrite oxidation effect on roots of crop. The depth of pyrite layer in land was in the range of 110 to 120 cm below soil surface which ease the farmers to manage water within tertiary plot so that water table depth was not dropped to minimum depth of about 100 cm or more than 110 cm below soil surface. Therefore, daily high tidal water was conditioned to reach quarterly channel, even water should enter land plots during the highest tidal water period. The objectives of this efforts are to leach the land and to maintain soil moisture in land before corn planting.

Results of computer simulation showed that water retention in channel at depth of 50 cm was capable to maintain water table at depth of 50 cm below soil surface. Field operation was conducted not only to retain rainfall water, but also to flow in high tidal water into channel during the highest tidal period (Figure 8). The highest tidal period was occurred at 18.00 pm to 22.00 pm or during night time. Therefore, water gate in tertiary channel should be operated in open position to harvest high tidal water during night time. Subsequently, stop log water gate in quarterly channel should be installed so that water can flow into channel during high tide and water can be retained during the end of high tide period. Stoplog gate can be substituted with sack filled with compacted soil. Figure 8 showed the controlled drainage system. Farmers had conducted this operation in September, but it should be better implemented since May. This stoplog gate is permanently closed to prevent seawater intrusion.



Figure 8. Water gate operation using controlled drainage system in September 2015.

Water in channel should be continuously controlled according to crop water requirement of corn so that daily observation of high tidal and low tidal periods should be routinely conducted to determine water gate operation at each channel. If crop requires more water, then water should be maintained at full level in channel by closing all water gates. On the other hand, if crop requires less water then water gate board of stoplog should be installed in quarterly channel according to the required water level. Water in channel would be decreased due to seepage loss after 2 weeks so that water addition should be done as described for the first water flow in.

Table 2 described the control operation of monthly water table depth at normal condition and dry condition as affected by El-Nino for food crops at B typology land in tidal lowland area.

Month	Normal Climate Condition (Drainmod Simulation)	Dry Climate Condition in 2015 (Farmer)	Dry Climate Condition (Drainmod Simulation)
January	Maximum drainage	Maximum drainage	Control drainage in combination with flushing every one week
February	Maximum drainage	Maximum drainage	Controlled drainage
March	Maximum drainage	Maximum drainage	Controlled drainage
April	Maximum drainage	Maximum drainage	Controlled drainage
May	Controlled drainage	Maximum drainage	Controlled drainage
June	Controlled drainage	Maximum drainage	Controlled drainage
July	Controlled drainage	Controlled drainage	Full retention
August	Controlled drainage	Controlled drainage	Full retention
September	Controlled drainage	Full retention	Full retention
October	Maximum drainage	Full retention	Controlled drainage
November	Maximum drainage	Maximum drainage	Controlled drainage
December	Maximum drainage	Maximum drainage	Maximum drainage

To overcome the lack of water supply in the dry season, due to limited irrigation water, the ground water potential could be developed for the micro scale [17]. This technology has been adapted to non-tidal lowland areas on the cultivation of chili crop. It was success for irrigation water supply, and shown good production [2]. Groundwater at a depth of 25-30 m with discharge of 30 liters / minute is sufficient to serve the cultivate horticulture crop in one ha areas.

IV. CONCLUSION AND RECOMMENDATION

A. Conclusion

- Distribution and magnitude of rainfall as an impact of El-Nino showed that dry month condition was 4-5 months longer than that of normal condition (2-3 months). Therefore, land had experienced water deficit. Water management conducted by farmers was relatively good through water retention effort in channel in September. However, farmers effort was not optimum as indicated by water table drawdown with magnitude of more than 150 cm below soil surface which caused pyrite oxidation.
- Corn production during El-Nino dry climate was 6.8 ton/ha or 15-20% lower than that of total maximum production

level. Corn growth was hampered due to the effect of pyrite oxidation and drawdown of capillary water.

- Water table control during El-Nino condition should started since January. Water control at wet season was controlled drainage, whereas around dry season to dry season was water retention at 40-50 cm level so that high tidal water can flow in and low tidal water can be retained. Total closing was done at September-October to retain water and to prevent intrusion of salt water.

B. Recommendation

Anticipation toward climatic change for agriculture in tidal lowland area is highly depended on availability and comprehensiveness of micro water management network. Farmers should be provided with guidance and technical assistance so that they can determine weather condition and water gate operation in the field. Further study is needed for water network operation at meso level (secondary channel).

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