DEVELOPING STRATEGIC OPERATION OF WATER MANAGEMENT IN TIDAL LOWLAND AGRICULTURE AREAS OF SOUTH SUMATERA, INDONESIA [1)]

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ABSTRACT

The study objective was to develop mater management operational plan at tertiary blocks for rice and corn crops growth. Study area was reclaimed tidal swamp area located at Primer 10, Delta Saleh. This area was classified as C-typhology land (dry). The study method was survey, field measurements, computer simulation, and field action research. Study stages were consisted of survey and monitoring, water status evaluation, water management scenarios design, model simulation, and model adaptation. Computer model of DRAINMOD had been used to estimate the water table status and to design water table control operation at tertiary blocks. Simulation results showed that the model worked properly which was indicated by root mean square error of 1.45 cm, model efficiency of 0.97, and correlation coefficient of 0.84. Model adaptation for dry land condition (C-typhology) showed that the best scenario was land utilization pattern of rice-corn. This paper presented monthly water management operational plan for rice crop in first cropping season (MT1) during November-February period and for corn crop in second cropping season (MT2) during May-August period. Results of computer simulation and field study showed that the main objective of water management in this area was water retention in combination with land leaching.

Keywords: *Water table control, tidal swamp area, DRAINMOD*

I. INTRODUCTION

Most of reclaimed tidal swamp area in South Sumatra is located at the east coast. The land in this area is characterized by sulphate acid layers either in the potential or actual form. Field identification results showed that sulphate acid layers are affected by sea water fluctuation (tidal) and land hydrotophography classes. Reclaimed tidal swamp area of Delta Saleh is classified as potential sulphate acid land. Rice production level in this area was in average of 2.5-3.0 ton.ha^{-1} and cropping index was once per year (Imanudin *et al.*, 2004). This low production was related to water status heterogenity found at farm tertiary blocks. Water availability in swamp area is directly related not only to crop evapotranspiration requiremenet, but also to dynamic of soil fertility status (Imanudin and Susanto, 2007).

A computer model had been develepod to test the effectiveness of drainage system on micro levels. This model is called DRAINMOD (Skaggs, 1982; Skaggs, 1991). It was developed to evaluate water balance on shallow water table condition which made it very suitable to be used for tidal swamp areas (Susanto, 2002). This model was also well adapted to many land conditions according to characteristics of area agroclimate. It was tested successfully at several countries such as America (Ale *et al.*, 2008); Australia (Yang, 2006); Europe (Borin *et al.*, 2000), China (Zhonghua and Wan, 2006); and Indonesia (Susanto, 2001; Imanudin *et al*; 2009).

A study is needed to be done based on the above problems in order to evaluate the existing drainage system performance in controlling water table at tidal swamp areas by designing water management operational strategy at tertiary block levels. The use of computer model is need to be tested and developed because it can save time, labour, and cost. However, calibration process toward several parameters should be done in order to get a good result. The good result is represented by the similarity between model measurement results and field measurement results.

The research objective is to develop operational plan of water table control at tertiary block for rice and corn crops growth.

II. METHODOLOGY

A. Place and Time

Research and field study had been conducted at reclaimed tidal swamp areas. Location of demonstration plot was at Primer 10, Delta Saleh, Banyuasin Disrict (Figure 1). Research and field monitoring was done at two cropping seasons consisting of wet and dry seasons.

Observation period (water table monitoring) was done from November 2008 to November 2009. Field data since 2005 was used for model simulation.

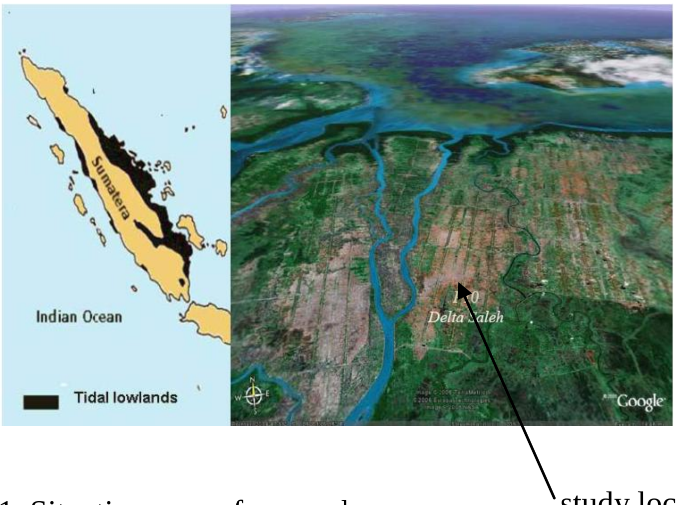

Figure 1. Situation map of research area

B. Equipments

The equipments used in this study are piezometer, wells (perforated plastic pipes), measuring boards, water pass, measuring tape, soil auger, discharge tube (*bailer*), stopwatch, digital camera, and agricultural equipments. Water status evaluation at tertiary blocks was done by computer simulation using software of DRAINMOD 5.1 (Skags, 1991).

Water table fluctuation measurements at land plots were done by using observation wells made from perforated plastic pipes having 3 m in length and 2.5 inches in diameter. These pipes were perforated at their sides and sink at depth of 2-2.5 m from soil surface. Upper part of pipes was closed and was only opened during the measurement period. In addition daily rainfall was recorded directly from rain gauges every 07.00 a.m.

C. Method

The research phases consisted of: 1) Survey and monitoring, 2) Evaluation of water status at tertiary blocks, 3) Scenario design and computer simulation, and 4) Adaptation of DRAINMOD model. Soil survey was conducted to determine soil physical characteristics such as texture, volume weight, total pore spaces, soil hydraulic conductivity, and depth of acid sulphate layers. Observation of soil physical characteristics was done at depth of 0-30 cm and 30-60 cm. Potential of high tide water at channels and water table fluctuation at tertiary blocks was observed daily within two cropping season period (wet and dry seasons).

Results of field data observation would be analyzed by comparing observation results with critical value of water table depth needed for rice and corn crops. The critical value used for rice was -20 cm and -60 cm for corn below soil surface.

In order to investigate water management scenarios at each sample areas that had been constructed (wet and dry areas), the field study would be conducted together with farmers. One of observation indicator is daily water table fluctuation monitoring and crop growth. Water management operational model consisted of water gate operational aspect and micro water management scheme improvement. Water table control in the field is shown in Figure 2.

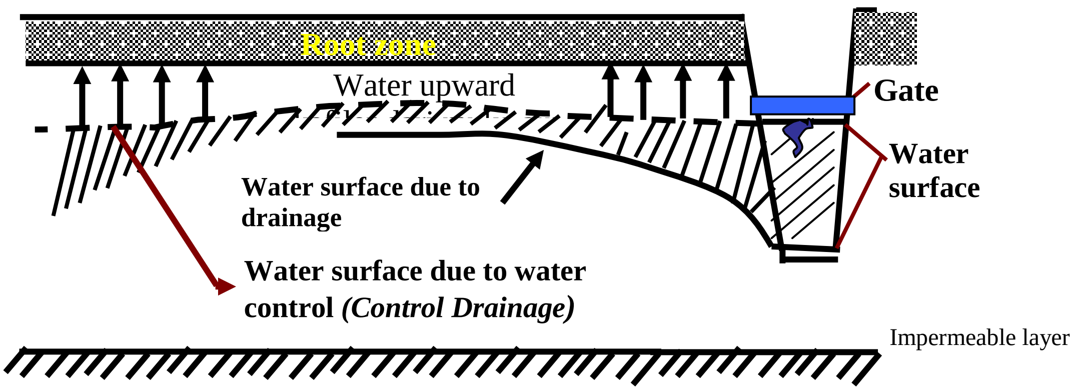

Figure 2. The water table profile as affected by water gate operation.

Crop water requirement is highly affected by crop growth stages. This dictates different water management plans at each stage (Table 2). For second crops such corn, the main focus in water management at farm level is drainage and water table control.

III. RESULTS AND DISCUSSIONS

A. Using DRAINMOD Model in Constructing Land Use Scenarios

Water management concept at C-typhology land was maximum utilization of rainfall water as irrigation water source. Rainfall water is utilized as irrigation water as well as for leaching and flushing operations. Management at this land was by using controlled drainage concept without over drain such as be worried by farmers (Imanudin *et al*., 2009). This is due to the fact that the study area had average acid sulphate layer of 60 cm below soil surface, whereas water table dropped up to 70-80 cm depth below soil surface (Figure 3). If the water table drops below this acid sulphate layer, then oxidation would take place which made low soil pH and increase of iron and aluminium precipitations. This condition is harmful for crops and crop production could decrease more than 50% (Minh, 1998).

Analysis of water table depth variation either from computer simulation of DRAINMOD results or field measurement results can be refered to Figure 3. Water table fluctuations in general showed the similar pattern. Water table during rainfall period was located above phyrite layer, whereas it was located below phyrite layer during dry season. Ther recommendation of land use pattern in the area study can be shown in Table 3.

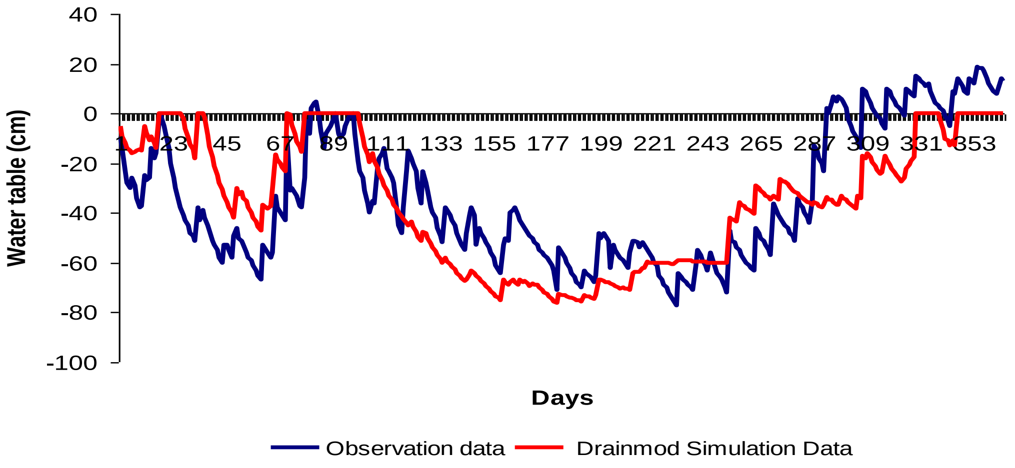

Figure 3. Water table dynamics pattern from computer simulation DRAINMOD and field measurements.

Table 3. Adaptation of DRAINMOD model in developing land utilization pattern guidance at C-typhology land (dry).

No	Months	Water status condition in land		Recommendation of land utilization
		Observation	DRAINMOD simulation	
1	January	Saturation	Saturation	Rice
2	February	Saturation	Saturation	Rice
3	March	Drop below soil surface, below zone of 30 cm	Drop below soil surface, below zone of 30 cm	Rice
4	April	Saturation	Saturation	Bare soil
5	May	Drop below soil surface, above zone of 30 cm	Drop below soil surface, above zone of 30 cm	Land preparation for corn
6	June	Drop below soil surface, below zone of 30 cm	Drop below soil surface, below zone of 30 cm	Corn cultivation
7	July	Drop below soil surface, below zone of 30 cm	Drop below soil surface, below zone of 30 cm	Corn cultivation
8	August	Drop below soil surface, below zone of 30 cm	Drop below soil surface, below zone of 30 cm	Bare soil
9	September	Drop below soil surface, above zone of 30 cm	Drop below soil surface, above zone of 30 cm	Land preparation for rice
10	October	Saturation	Saturation	Land preparation for rice in first cropping system
11	November	Flooding	Saturation	Rice cultivation in first cropping
12	December	Flooding	Saturation	Rice cultivation in first cropping

Note: Model Drainmod model is sensitive to water table above 10 cm, flooding land is considered as water saturated soil (excess water status)

Results of soil water status evaluation such as presented in Table 3 showed that in minimum water table control condition (conventional), the land was still experienced significant water table drawdown although during condition of wet period. This was shown during rice crop reproductive phase (February) in which land experienced water table drawdown below zone of 30 cm so that plants faced water stress and decrease in production.

Experience in tidal swamp areas management of Vietnam showed that water table control was very important, i.e. the negative effect would be produced if water table dropped in zone of 60-90 cm below soil surface that represented by increase of aluminium accumulation and soil pH compared to water table control in zone of 30 cm below soil surface (Minh *et al.*, 1998).

B. Model Adpatation in Developing of Water Control Operation for Rice at C-typhology Land (Dry Condition)

The recommended water management scenario was land cultivation using cropping pattern of rice-corn in which rice was planted on first cropping season in November-January/February and corn was planted in April to June/July. Problem for corn crop cultivation was that soil still in water saturated condition on February, March and April which required drainage outflow. On the other hand, the water table dropped below 30 cm in early May that created water stress for corn. This condition required water retention in channels and irrigation if possible.

DRAINMOD was capable to estimate water table fluctuations in order to develop water management plan for application in year of 2009 (Figure 4) only by using rainfall and soil physical characteristics data. Results of yearly water table observation showed deficit condition in which water table in land was frequently existed below zone of 30 cm even in wet season. This condition created water stress for rice crops. Computer simulation using DRAINMOD model recommended water gate operation at tertiary channel through water retention mode. The results indicated upward movement of water table located in zone of 30 cm and land was water saturated. This provides a good environment for better growth of rice.

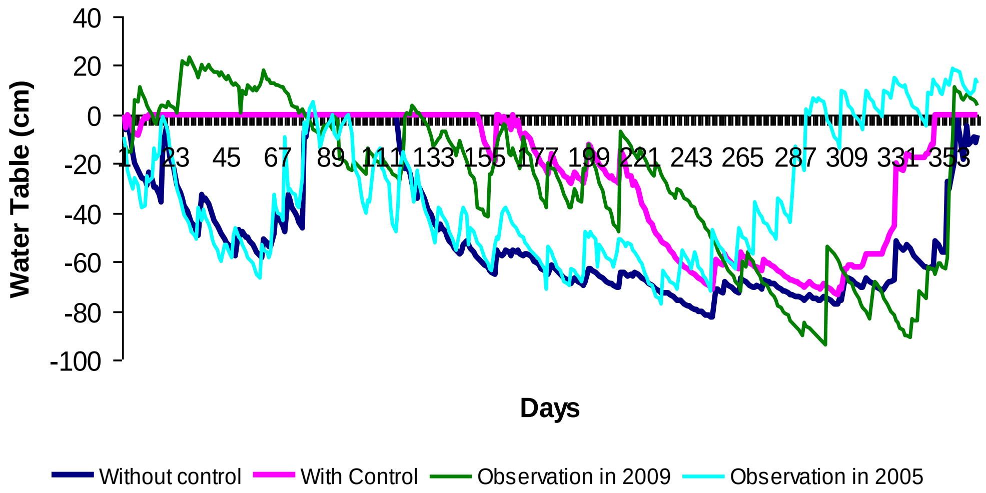

Figure 4. Daily water dynamics from water table control using computer simulation of DRAINMOD model.

In the Figure 4 clearly showed that there was water deficit in Delta Saleh area without water table control operation (data of 2005). The water table dropped far below acid sulphate layer and the land practically could not be cultivated for almost a year. Computer simulation results showed that water table dropped below root zone of 0 cm even in wet season without water retention measure in tertiary channel. Therefore, most farmers agree to retain the water during wet season, especially during rice crop cultivation.

Monthly water gates operation in tertiary level according to crop growth was shown in Table 5. Soil tillage operation was started since November for rice crop. The main objective of water management was water disposal at early period of soil tillage. This drainage process had been started since September or October. Its objective was to leach toxic elements and soil pH out of crop root zone. Water retention process was started since soil puddling up to seed sowing operation. The water disposal was conducted in seed sowing phase in which quarterly gates were opened so that water in land could be disposed through quarterly channels into tertiary channels.

Water gates were closed in tertiary channels during rice growth period from December to February. The closing operation was not fully closed but only about 40-50 cm. It is hoped that water can enter during high tide and water in tertiary block was not all disposed due to the retention action of gates at height of 40-50 cm during the low tide.

Table 5. Tertiary gate operation in the field for first cropping season of rice in December-February 2009 period.

Crop growth phases	Activity time	Gates operation	
		DRAINMOD simulation	Field adaptation
Land preparation	September-October	Open	Open
Soil tillage	October-November	Close/water retention	Close/water retention of 50 cm
Planting, direct seeds sowing (Tabela)	November	Close/water retention	Close/water retention of 50 cm
Vegetative growth	December-January	Close/water retention of 50 cm	Close/water retention of 50 cm
Reproductive growth	January-February	Close/water retention of 50 cm	Close/water retention of 50 cm
Maturity stage	February	Close/water retention of 50 cm	Close/water retention of 50 cm

The recommended cropping pattern based on field study and suggestion from farmers was rice-corn. The gates operation was mostly hold during rice crop cultivation that was started from October-December and January-February. The holding was done at 50 cm height. The water gate operation system is by holding water at 50 cm depth. This depth might provide water in tertiary channel be kept at 50 cm height, whereas water surface in tertiary channel upstream would be raised into 60 cm that made the entering of high tidal water to fill tertiary channel. The entering of high tidal water could also improved water quality and raised water surface in tertiary channel. This concept is known as combination of water retention and water supply.

C. Model Adpatation in Developing of Water Control Operation for Corn at C-typhology Land (Dry Condition)

Corn cultivation can be started if water table was dropped 30 cm below root zone. This can not be done directly after rice harvesting period because water table is still high that made soil layer within root zone was in saturated water condition. Therefore, the water gate was totally opened in March in order to flush accumulated acid elements during water retention at rice growth period. Computer simulation of DRAINMOD model had succed to develop monthly operational plan for water table control. The result of required water table for corn crops as an impact of water table control was shown in Figure 5.

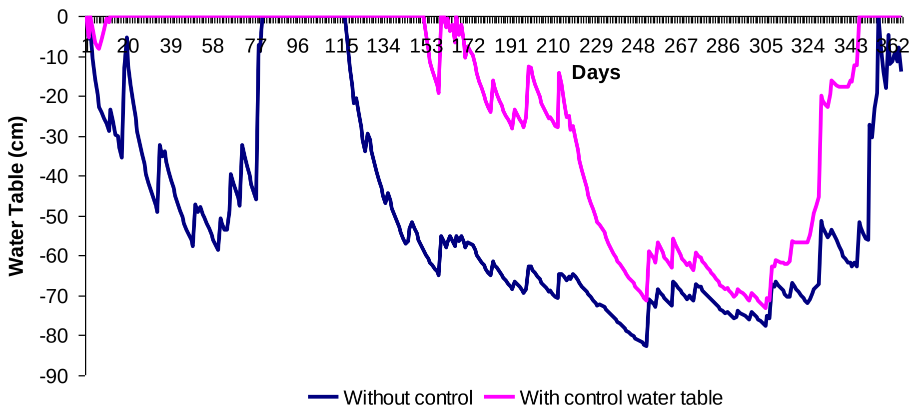

Figure 5. Results of DRAINMOD simulation in term of water gate effect on water table control for corn crop.

Figure 5 clearly showed that eventhough the water retention had occurred when crop was in generative phase (August), but water table was dropped near 60-70 cm below soil surface. This was due to no rainfall water and high tidal water could not be entered into tertiary channel. It was dangerous condition because crops would experience water stress (Kent and Andrew, 1990). Crops need water supply from outside source in this period.

Water table control operation for corn is shown in Table 6. Water gates were opened and tertiary channel should be equipped with smaller channels to lower water table during early corn planting. The water retention facilities and the entering of high tidal water were needed during generative phase of corn that was occurred in May-June. The efforts to control water table for corn had many constraints. Shallow condition of tertiary channel due to sedimentation made the water from quarterly channel and paddy field could not be discharged so that land was in water saturated condition on April. Farmers can do planting in the end of May. This made crop experienced water stress during generative phase because water table dropped below 60 cm in June-July. According to Zwart and Bastiaansen (2004), capillary water movement was not sufficient to fulfill crop evapotranspiration requirement if water table depth was dopped below 60 cm.

Table 6. Water management operational strategy for corn crop at C-typhology land (dry condition) at Delta Saleh

Crop growth	Months	Required water status condition	Water management objective	Water gate operation
Soil tillage	May	Field capacity, water table depth was -30-50 cm	Maximum drainage – land leaching	Maximum opening
Planting	May	Field capacity	Maximum drainage – land leaching	Maximum opening
Vegetative growth	June-July	Field capacity	Water retention	Closing/retention of 50 cm
Reproductive growth	June-July	Field capacity	Water retention	Closing/retention of 50 cm
Maturity-harvest phase	July	Field capacity	Water retention	Closing/retention of 50 cm

The effort to maintain field condition where water table depth was 40-50 cm below soil surface in dry season was very difficult. Recommended results of DRAINMOD simulation showed that to maintain field condition with water table close to 30 cm zone dictated water surface in tertiary channel should be in height of 40-50 cm. However, field fact showed that water in tertiary channel is always empty because high tidal water during dry season was not totally entering tertiary channel. The only way to maintain water table condition was that by closing the secondary drainage channel (DAM).

The strategy for corn crop cultivation was to accelerated cropping season so that corn was not experience water stress in reproductive phase. Soil tillage should be started in April and crops can be planted in May. However, rainfall intensity in April was still available and soil was in water-saturated condition that required channel discharge at tertiary blocks. The above conditions dictated that network improvement for corn cultivation was by acceleration of corn cultivation in April and by maintaining water table control so that water table was not quickly dropped at dry season.

IV. CONCLUSION AND RECOMMENDATION

A. Conclusion

1. Determination of water table dynamics at tertiary block could be conducted by using DRAINMOD program. Model adaptation in dry land condition (C-typhology) showed that the best scenario was land utilization pattern by using rice-bare soil. Monthly operational plan of water management for rice crop (first cropping season) was as follows: Water gates was opened (maximum drainage) at early phase of soil tillage (plowing); water control was needed by operating water gates as combination of supply and water retention in tertiary channel (kept at 50 cm) near the end of soil tillage. Water gates were opened (maximum drainage) in seeds sowing phase which was followed by operation of water gates as combination of supply and water retention until ripening

stage. Field test showed that this operational system was capable to maintain water table condition in zone of 20 cm above soil surface.

2. Recommended operation for corn crop was dominated by water table control system in tertiary channel (water retention) where all water gates operation at all corn crop growth phases was as water retention and as water supply before the entering of salt water (June-July). The maximum drainage was only be carried out after rice planting had finished and during land tillage for planting preparation.

B. Recommendation

Application of water management in field should be supported by complete water management infrastructures, especially the availability of water gates in tertiary channel. Water gates in tertiary channel are absolutely needed to hold water during crop growth period.Water management concept with water retention system on dry land condition (C-typhology) could create water quality problem in the long run. Therefore, water flushing in channel should be conducted. Water gates opening operation should be carried out in quick and proper manners to prevent over drain from land. In order to minimize environment degradation and to accelerate land remediation process, water management operation should always be conducted eventhough land was not be cultivated.

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