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Water Management for Rice in Tidal Lowland Reclamation Areas of South Sumatera, Indonesia

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ABSTRACT

Tidal lowland reclamation aims to extend food agricultural area. Land clearing was done at Delta Telang II, Kabupaten Banyuasin District, South Sumatra I period of 1981-1982. Most area of Delta Telang II had land typology of B/C and almost half of it already been changed into palm oil plantation. Therefore, the field study had been conducted to determine the potentials and constraints for development of paddy field. The research method was applied study and field experiment. Soil physical properties analyzed were texture, volume weight, and hydraulic conductivity. Rice used in this study was Inpara 3 variety. The research results showed that soil physical properties was appropriate for development of paddy field rice. Controlling of water level in tertiary level by farmers was a key succeeds to provide water for crops. Model of water gate is flap gate type and it is operated dominantly as drainage during rice growth period and only functioned as supply when crops entering generative phase. Average rice production was 7.5 t ha^{-1}. This condition was showed that using proper water management, balance fertilizer application, and adaptive rice variety resulted in successful rice crops cultivation at tidal lowland area and subsequently prevent land functional shifting.

Key words: Tidal lowland reclamation, water management, rice.

INTRODUCTION

Effort to increase food production, especially rice is continuously increasing because the staple food for most Indonesia population is rice. Rice production decrease had occurred in 2021. It was reported by National Statistical Center Council that rice harvest area had decreased with magnitude of 245.47 thousand ha or 2.30% compared to rice harvest area in 2020 with magnitude of 10.66 million ha (BPS, 2021). This condition becomes serious issue because irrigation land is yearly decreasing. For instance, land functional shifting with magnitude of 10-20 ha day^{-1} had occurred in West Java (Distan Jabar, 2019). Moreover, land functional shifting for period 15 years with magnitude of 570 hectares or equal to 30 ha yr^{-1} had occurred in Klaten District, Central Java (Nurelawati *et al*., 2018). Total land functional shifting per year in Indonesia was 150,000-200,000 ha (Pontas, 2018). Therefore, tidal lowland is the mainstay land to fulfill target of national rice production. Therefore, program of tidal lowland optimization has been issued by Agricultural Ministry and is more focused toward tidal lowland reclamation area (Kementan, 2019).

Tidal lowland reclamation area of Delta Telang II is located at Banyuasin District, South Sumatra, Indonesia. This land had reclaimed for food crops and horticultural crops in year of 1981-1982. Planting pattern is one time planting with rice-fallow pattern up to 2000 (Planting Index (PI) 100). Thus, most land had functional shifting into plantation crops (Megawaty, 2012). The government effort had succeeded in improving water management system from macro level up to

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micro level. Improvement of soil quality and water sufficiency guarantee farmers to conduct early crop plantation and an increase in yield (Imanudin *et al*., 2011). Lestari (2018) had added that land suitability analysis at district area is dominantly suitable for paddy field rice. Banyuasin District is physiographically dominated by tidal lowland and about 40.33% at Delta Telang II currently is utilized for rice crop.

The key succeed for tidal lowland utilization is how farmers can control water level according to crop water requirement in term of quantity, time and place (Imanudin et al., 2019). The depth of water table can change any time, especially is affected by rainfall, water condition in tertiary channel, river water condition and several physical soil characteristics such as texture, total pore space, volume weight (bulk density) and soil permeability (Bameri *et al*., 2021: Wu *et al*., 2021). High rainfall in long time can provide high water quantity for groundwater filling. The difference between groundwater filling and groundwater extraction cause variation of water table depth (Ngudiantoro *et al*., 2008). Watertable control with water gate operation and soil quality improvement are the main activities of land management for rice crop at swamp area (Maneepitak *et al*., 2019; Imanudin *et al*., 2021)

Water table surface is fluctuating throughout the year and the most appropriate planting pattern in farm plot is based on water table surface depth. The change of water status causes change in land use (Dumrongrojwatthana *et al*., 2020). Water diversity at each farmer's plot area is due to differences in soil humidity and water table surface depth (Bakri et al., 2015). Therefore, field observation is needed to determine water surface dynamics in tertiary plot and secondary channel in order to estimate soil water surface in relation to planting time and planting pattern policy (Imanudin *et al*, 2021). Water sufficiency in land area should be guaranteed. Option of operation policy in the field is highly determined by land hydro topography class, rainfall, and crop types. Land biophysical condition will determine water structure model that will be used (Hussain *et al*., 2021). The existence of water structure to control water level in tertiary channel is highly needed in order to increase planting index (Imanudin et al., 2020). In addition, water structure is also required to hold intrusion of brine water in case of long dry season as impact of climatic change (Stolpe *et al*., 2017). In addition, adaptation of water management network in the field at each rice growth phase is required to guarantee water sufficiency in root zone of crop. Moreover, intensive soil tillage can improve soil physical properties through increasing of porosity and decreasing of soil hydraulic conductivity. This condition will ease farmers to conduct several farming activities and subsequently has potential to increase farmer income (Goulart *et al*., 2020).

This paper will present field experience related to rice paddy field cultivation at tidal lowland area. It will discuss soil physical condition, water dynamics and crop growth. Succeed of rice production can be used as succeed indicator of integrate land and water management from three policies input consisting of water management network improvement, soil fertility and variety adaptation. By using these approaches, sustainability of rice cultivation at tidal lowland ca be maintained and land functional shifting from agricultural land into plantation land can be avoided.

METHODOLOGY

Location and Time

The study was conducted at reclaimed tidal lowland reclamation area in Banyu Urip Village Tanjung Lago Subdistrict, Delta Telang II, Banyuasin District, South Sumatra Province of

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Figure1. Administration map *Situation* of Delta Telang II, Banyuasin District

Indonesia. Field experiment was done within one tertiary plot in P17-6S (secondary block 6 located in south of primary channel 17) (Figure 1).

Soil analysis was done at Physical and Soil Conservation Laboratory, Soil Science Department, Agricultural Faculty, Sriwijaya University, Inderalaya. The study time was from January 2019 up to March 2019.

Equipment and Materials

Equipment used in this study were consisted of: 1) Inverse Auger Hole Unit, 2) Stopwatch, 3) Measuring tape, 4) Belgian drill, 5) Field knives, 6) Hoe, 7) Pieschall board, 8) wells pipe, 9) Ring Sample and 10) Camera. Materials used in this study were consisted of 1) Soil sample, 2) Plastics pouch, 3) Tag paper, 4) Rice seeds and 5) Writing utensils.

Methods

The research method was applied study and field experiment. The initial step began with soil survey to observe physical and chemical characteristics of soil. Soil physical characteristics were consisted of soil texture, soil hydraulic conductivity in the field and depth of water table surface. Soil chemical characteristics was conducted by observing acid sulphate layer depth through direct observation with peroxide solution. Field experiment for rice cultivation was conducted at the tertiary plot covering area of 16 ha as shown in Figure 2.

Observation at tertiary 7 plot was done by using wells pipe and observation at tertiary 5 channel was done by using pieschall board. Data of water level fluctuation in channel and in land is collected daily and was presented in graphical form. Analysis of excessive water was done by using SEW-20 concept approach (Imanudin et al., 2021). Rice of Impara 4 variety was planted by

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using direct seedling at dose of 50 kg ha^{-1}. Fertilization was done at three steps consisting of SP36 as base fertilizer at dose of 100 kg ha^{-1} second fertilizer consisting of Urea and SP36 at dose of 100 kg ha^{-1} respectively and the third fertilizer was Urea at dose of 100 kg ha^{-1}.

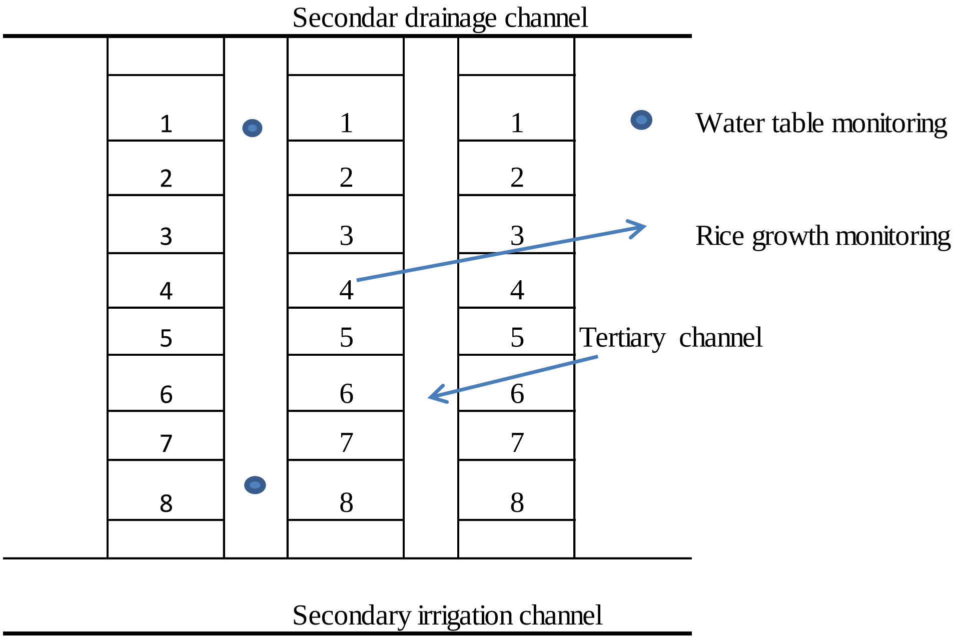

Figure 2: Work scheme in tertiary block.

The observed parameters were consisted of water table surface fluctuation, soil hydraulic conductivity by using auger hole method as well as soil sample to determine soil physical properties determination in laboratory covering water content analysis, texture, volume weight or bulk density and total pore space. Rainfall data is obtained from Meteorology, Climatology and Geophysic Council (BMKG) of Palembang Climatological Station as well as rice production data.

The recommended water management is by putting flap gate as drainage (located in front). This operation had done from soil tillage process, planting up to crop growth. Supply phase and combined drainage had done when crop is entering generative phase.

RESULTS AND DISCUSSION

Geographical Condition and Soil Characteristics

Delta Telang II as hydrological unit was separated by Telang River which is wedged by Musi River in east side, Banyuasin River in west side and Sebalik River and Gasing River in south side.

Crop cultivation effort was highly depend on rainfall and tidal water pattern in channels. This area is wet land dominated by swamps that has very high fluctuation of water flooding in which water flood the land with depth of +12 cm high during wet season, whereas the height of watertable was -113 cm during dry season.

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Planting season at Banyu Urip Village generally was Rice – Corn – Fallow. Rice was planted monoculturally at first planting season (MT I), starting with pre-planting phase (land tillage) in October, planting season in November and harvest season in March. Corn is planted at second planting season (MT II) from May up to September.

Soil texture in upper part (0-30 cm) was classified as loam and clayey loam (Table 1). These textural classes are very appropriate for rice crop cultivation (Nurmegawati, 2021). These textural classes show soil capability in providing water for crop is more easily available and clay fraction is increase in more depth location so that soil capability to store water is also increase.

Table 1. Analysis result of soil texture in laboratory

Sample code	Texture (%)			Texture
	sand	clay	loam	
T1	40.4	17.6	42	loam
T2	42.4	21.6	36	loam
T3	38.4	25.6	36	loam
T4	44.4	13.6	42	loam
T5	30.4	31.6	38	clay loam
T6	44.4	21.6	34	loam
T7	30.4	35.6	34	clay loam
T8	34.4	25.6	40	loam

Soil bulk density shows that soil density level is classified into mineral soil. This shown by the lowest bulk density with magnitude of 0.89 g cm^{-3} and the highest bulk density with magnitude of 1.22 g/cm^3.

Permeability is capability of soil to get through water and air within soil. It is soil property that show soil capability to release water. Soil having high permeability can increase rate of infiltration which in turn decrease rate of surface water flow. In soil science, permeability is qualitatively defined as decrease of gases, solutions, or crop root penetration. Moreover, permeability is also the measure of soil hydraulic conductivity.

Soil capability level to get through water is highly affected by soil water content. Therefore, soil hydraulic conductivity was differentiate into two classes, i.e. hydraulic conductivity in unsaturated condition and in saturated condition or frequently called as soil permeability. Because land at the study area is frequently in condition of saturated water, then permeability in this saturated condition shows steady flow pattern. Measurement of soil hydraulic conductivity is done by using Auger Hole Method and providing holes. Soil hydraulic conductivity which is conducted one time in February is presented in Table 2.

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Table 2. Hydraulic conductivity of soil in the field

Sample points	Depth	Permeability (cm/hr)	Criteria
1	0-20 cm	12.18	moderate
2	20-40 cm	9.74	moderate
3	40-60 cm	7.30	moderate
4	60-80 cm	4.87	moderate
5	80-100 cm	2.65	slow

Table 2 showed that soil permeability is classified as rather moderate and moderate. The values of soil hydraulic conductivity at observation sites are affected by several land condition, one of which is soil tillage. Hydraulic conductivity at saturated condition in paddy field soil should be relatively low in order to prevent water losses, but it should be relatively high to flush toxic elements (Imanudin *et al*., 2020). Permeability class at upper layer up to 80 cm depth is moderate and at depth of more than 80 cm is slow. This condition provides relatively good water movement at upper layer and soil capability to store water is increasing in accord to increasing soil depth. Therefore, soil physical condition of land is very appropriate for rice crop growth (Ozsahin *et al*., 2022).

Channel Network System of Water Management

Channel network system at reclaimed tidal lowland is consisted of macro channel covering of primary channel, meso channel consisting of secondary channel and micro channel consisting of tertiary channel, quarterly channel and micro channels. Sketch of channel network system is shown in Figure 3. Condition of channel network at tidal lowland area is very important to be considered for regulating irrigation water and drainage water that is closely related to growth and production of crop at tidal lowland area. One of succeed key in swamp development is water management control that capable to hold water as long as possible and drain the excess water as quick as possible.

Banyu Urip Village is located at Primary 17 Delta Telang II within block of secondary P17-6S. One secondary block has two secondary channels (1 Village Irrigation Channel (SPD) and 1 Main Drainage Channel (SDU). One secondary block has 17 tertiary channels and tertiary channel naming is started from secondary block estuary. Secondary block naming at Primary 17 Delta Telang II is calculated from Telang River. Model of water management system at secondary block P17-6S is *oneway flow system* in which water entering from SPD. Tertiary channels were not connected each other. For one way flow system, automatic water gates (flap-gate) were installed at tertiary channel estuary as water regulating at farming land area.

Banyu Urip Village is located at primary channel 17 in Delta Telang II. Primary channel 17 is the longest primary channel at Delta Telang II. Primary channel 17 has length of ± 15 km (Figure 3). It is primary channel that connect two rivers, i.e. Telang river and Banyuasin river. Primary channel 17 also frequently used as transportation lane, water requirement for household as well as as water channel during high tidal period and to drain water during low tide period from secondary channel into river.

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Figure 3. Condition of Primary 17 Channel at Telang II in 2019

Figure 4. Condition of Secondary P17-6S Channel in 2019

Secondary channel is a channel that perpendicular to primary channel (Figure 4). Banyu Urip Village at secondary P17-6S block has 2 secondary channels, i.e. SPD and SDU. These two secondary channels have different function. SPD has function as supplier of irrigation water and household need of farmers (bathing and washing), whereas SDU has function to drain water from farming land area. Currently SDU has double function in which it is frequently opened for water supply. Some farmers connected SDU with culvert.

Tertiary channel is a channel that perpendicular to secondary channel. Tertiary channel has function to carry water and to drain water from and into tertiary plots. Tertiary channel has length of about 850 m and distance between tertiary channels is 200 m (Figure 5). One plot of Secondary P17-6S has 17 tertiary channels and tertiary channel naming is started from tertiary channel which is closed to primary channel.

Figure 5. Condition of Tertiary Channel at TC 7 P17-6S in January 2019

Figure 6. Condition of Quarterly Channel at TC 7 P17-6S in January 2019

Operational and maintenance activities of water network at tertiary level are done by farmers. Farmers work in cooperation within one tertiary block before soil tillage period. Because the width, depth and length of tertiary channel is different than that of secondary channel, then farmers are unable to clean tertiary channel and it need heavy equipment aids. Tertiary channel condition at TC 7 P17-6S is shown in Figure 5.

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Quarterly channel is a channel that perpendicular to tertiary channel. This channel usually located at barrier amongst farming land plots. Quarterly channel is a channel that connected two tertiary channels. This channel has length of 200 m (Figure 6). Quarterly channel at Secondary P17-6S block is available at each barrier amongst farming land plots. Quarterly channel has function to aid water inflow into farming land plots and water outflow from farming land plots through micro channel.

Micro channel is a channel that located within farming land plots. This channel has function to regulate water within land to easy land flushing and can function as a way that helps famers to conduct crop fertilization (Figure 7). The width of micro channel at secondary P17-6S block is 20 cm or equal to width of hoe eye, but the channel depth is different depending on the crops to be cultivated. Micro channel depth is in the range of 10-15 cm for rice and in the range of 20-30 cm for corn. The distance between micro channels is in the range of 6-8m. Micro channel has function to ease flushing of toxic elements from farming land plots (Imanudin *et al*., 2021).

Figure 7. Condition of Micro Channel at TC 7 P17-6S in January 2019

Figure 8. Water gate at Tertiary Channel at TC 7 P17-6S in January (Drainage)

Operation of Tertiary Network

Reclamation area of Banyu Urip Village Telang II had no water gate at secondary network level. Therefore, operation of water management network is done only at tertiary level. Automatic water gates currently is constructed at tertiary channel (*flap-gate*) that has function to regulate the inflow and outflow of water based on differences in water level. If water is not required by land, *flap-gate* is placed in front pointing towards secondary channel. *Flap-gate* will close due to water level differences and water will move from inside and push flap gate during low tide period so that water will outflow into secondary channel (Figure 8).

Network system is pair comb model in which odd channel had its tertiary channel estuary located at SDU channel and even channel had its tertiary channel estuary located at SPD channel. For odd order such as tertiary 1, tertiary 3, tertiary 5 and tertiary 7, channel water gate is installed close to SDU channel, whereas for even order such as tertiary 2, tertiary 4, tertiary 6 and tertiary 8, channel water gate is installed close to SPD channel. Table 3 showed water gate operation that is more dominant as drainage. This is because land receive more rainfall water so that crop water requirement is obtained from rainfall water. High tidal water do not need to enter so that flap gate more functional to hold high tidal water. Water level balance should available in tertiary channel during seed ripening because rainfall is starting to decrease so that tertiary water gate is opened to allow high tidal water entering as supply. Water surface depth in channel should be at least 100 cm in order to prevent water losses at tertiary plot (Imanudin *et al*., 2019).

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Table 3. Water Gate Operation Schedule at Tertiary Level

Period	Growth phase	Gate Operation	Gate Function
December 2018-January 2019	Vegetative	Front	Drainage
January-February 2019	Generative	Front	Drainage
February-March 2019	Grain Ripening	Open	Drainage and supply

Condition of gate operation for B-type land that is more as drainage is in accord to study by Sulaeman *et al*. (2021) in which flap gate is operated as drainage during crop growth. Theoretically farmer need water supply for crop during generative phase which proven by higher crop production. Therefore, operation model conducted by farmers at Banyu Urip is already correct in which gate is opened by farmers when plant entering generative phase so that water supply is available by entering high tidal water (Figure 9). This operation is at least provide water surface balance in tertiary channel so that rainfall in land can be detained.

Figure 9. Watergate is opened to put high tidal water when crops is entering generative phase (March 2019)

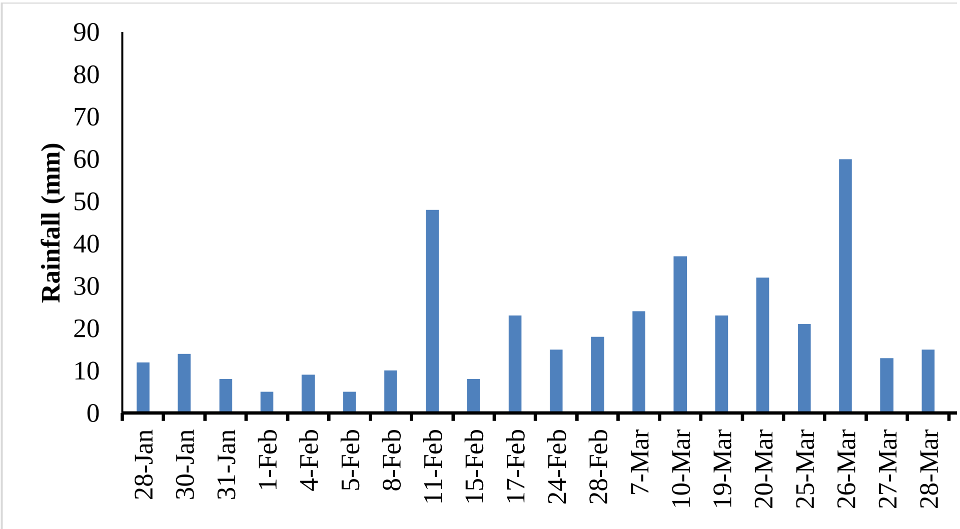

Figure 10. Rainfall Data of Tanjung Lago Subdistrict
(Source: Kenten Climatological Station, 2019)

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Evaluation of Soil Water table and Channel Water Level Dynamics

Condition of water table height and depth are one of factor that has important role in providing water for crops, especially at tidal lowland area. According to Susanto (1998), water table can fluctuates and will affect effective depth of crop roots. Rice crop requires water table condition close to soil surface with flooding depth of 4-5 cm and water application interval once in 2-3 days after flooding water is exhausted (Singh et al., 2018). Water table depth below 20 cm for more than three days will result in physiological interference of crops (Imanudin et al., 2021). Maneepitak et al. (2019) had stated that critical value of water table depth for rice cultivation at swamp area in Thailand was 15 cm below soil surface.

Factors that cause the occurrence of water table fluctuation are rainfall, evapotranspiration process, water table fluctuation in channel and soil permeability. Some of rainfall that reach soil surface will infiltrate into soil and some will flow in soil surface. Rainfall that enter into soil through infiltration process will increase water table depth. Some of this water moves below soil surface and subsequently flows into river and back to ocean (Ngudiantoro, 2009). Rainfall condition during rice growth at MT1 is relatively even (Figure 10).

First planting period (MT1) conducted at November 2018 up to March 2019. January is first planting period and rice at January 2019 has entering generative phase. January is wet month because rainfall intensity is starting high in this period. This can be observed from graph of daily rainfall of January 2019 up to March 2019. Rainfall intensity is high from January up to this graph. This condition may affect the fluctuation of water table in land. Water availability for rice crop can be fulfil based on this rainfall intensity.

Water table monitoring should also involve shallow water table. In this study, water table monitoring is done at tertiary plot (TC7) in which peischal board is installed in channel and wells pipe is installed on land. Observation is conducted daily. Because water table fluctuates according to space and time, correct water management regulation is needed so that water table can be controlled according to crop requirement at wet season and dry season. Water table control in tidal lowland reclamation is a key process that should be done correctly through controlling and detention of water (Susanto, 2000; Bueno et al., 2020).

Results of water table observation at wells installation point of TC7 P17-6S showed that January 2019 is rainfall season that cause increase of water table. This condition showed that season has significant effect on water table depth and water table will deeper from soil surface at dry season. On the other hand, water table will located near soil surface and can be above soil surface or flooding the land during wet season.

Water table dynamics at initial growth period was varies at depth of -5-10 cm below soil surface (Figure 11). This condition was relatively good because upper soil zone was still in wet condition and rainfall is still frequently occurring. Water table is increase and there is flooding period of 5-10 cm depth entering vegetative phase. Water requirement of crop is relatively higher at this condition and rainfall occurring is limited at middle phase and cause the drop of water table. Water table drop up to -10 cm limit provide opportunity for soil to improve its aeration system resulting in wet period and dry period.

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Rice crop need higher water quantity entering generative phase so that farmer open water gate to provide entering of high tidal water. Water table is increase due to rainfall and entering of high tidal water and land can be flooded at depth of 4-5 cm. Subsequently, water gate is functioned as drainage prior to harvest period so that water table drop at depth of -5-10 cm at the end of February-early March. This condition can improve capability of nutrients uptake by crop and aeration improvement. Study by Ishfaq et al. (2020) showed that rice irrigation model using wet and dry system is capable to save water and production increase in term of quality and quantity. This is proven that rice production at tidal lowland area that experience dry period (not flooded) had average production yield of 7.5 ton/ha and the highest yield of 9.0 ton/ha.

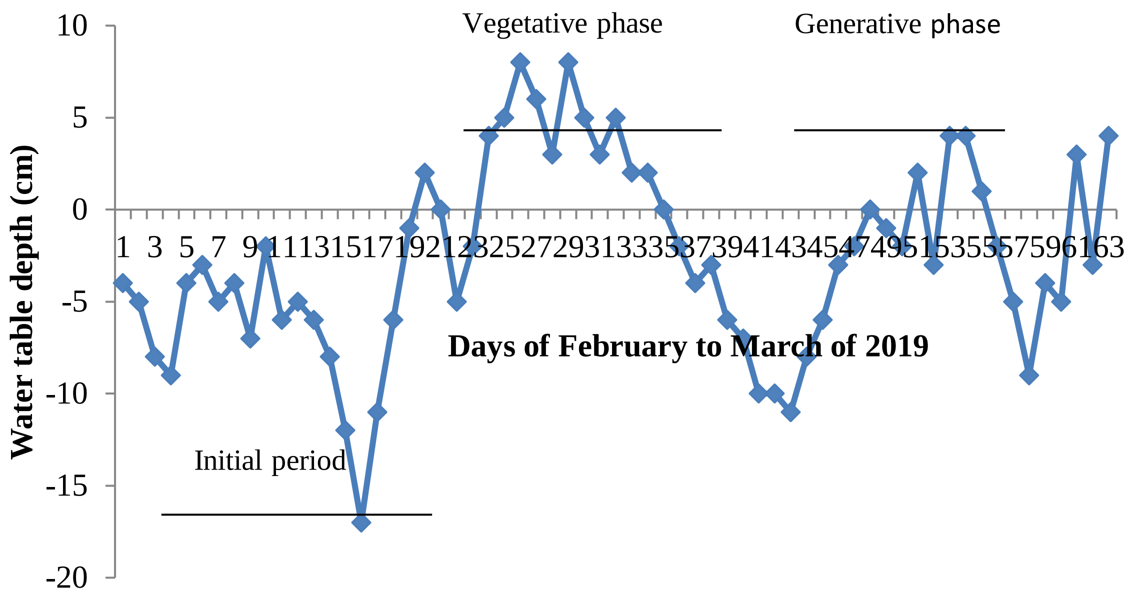

Figure 11. Water table fluctuation within period of January – March, 2019

Moreover, watertable fluctuation in tertiary channel is frequently used as indicator of water availability within crop root zone (Susanto, 2000). Measurement of tidal water movement is required to determine water surface elevation, either minimum or maximum. Equipment used to measure this water level is pieschal board. Pieschal board is installed in channel at maximum water level that is previously occurred. Observation was done daily at 8.00 am.

The highest water level in channel based on observation was occurred in early of February with magnitude of 100 cm above channel surface (Figure 12). This is due to high rainfall intensity in early of February. The lowest water level in channel was occurred in March with magnitude of 36 cm above channel surface. This is due to low rainfall intensity at early March. Water table depth was at 10-15 cm below soil surface when water level in channel was 90-100 cm. This condition is ideal for crop because rainfall is still occurring so that soil surface is at saturated water condition.

Water level in channel at January 2019 was low with magnitude of 54 cm above channel surface. However, water level in channel at early February was increase achievement of 80 cm up to 100 cm above channel surface as the highest

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water level in tertiary channel. The range of water level at middle of February 2019 up to early March was decrease, i.e. 90 cm to 36 cm above channel surface as the lowest water level because of low rainfall intensity. Water table surface is increase again up to 77 cm above channel surface at the end of March.

Water table surface is varies depending on time interval of water surface height detention in channel. Water surface dynamics in tertiary channel can be seen in Figure 12. The small influence from water surface fluctuation in channel on water table fluctuation and the occurrence of drastic drop of water table is due to drop of water surface in channel so that water management at the study area is by maintaining water surface height in channel. The rate of water losses is dependent on material types, i.e. the more porous the material, the faster the water losses. On the other hand, soil physical properties is also affect nutrients uptake by crop. Soil having high bulk density is in dense condition so that crop has difficulty to develop and absorb soil nutrients (Jin Jiang et al., 2018). Imanudin et al. (2017) had stated that function of water management network at tidal lowland is not only to maintain water table height, but also to improve physical and chemical land quality. Regular leaching follow by water flushing in channel during low tide period is important. This process is capable to decrease toxic elements such as Fe, Al, and SO_4.

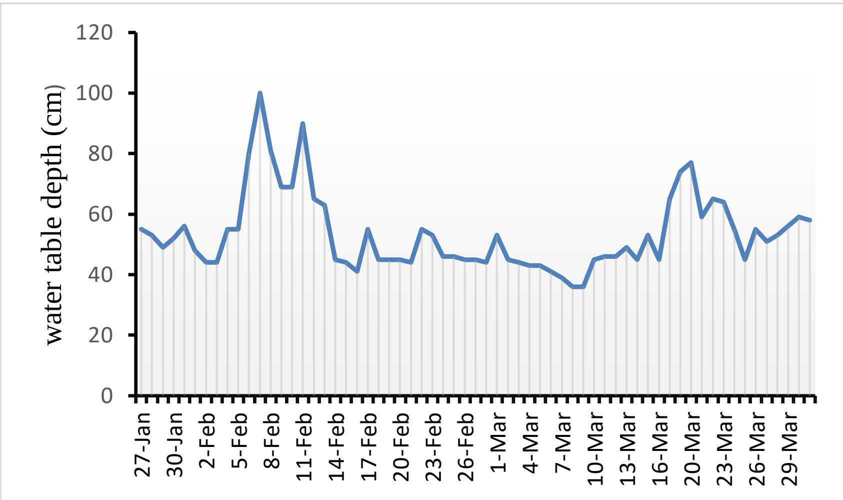

Figure 12. Water table fluctuation in tertiary channel

Production Yield of Rice Crop

The growth of rice plants in the generative phase showed good performance (Figure 13). water management options in tertiary gate with functioning as a supply (at SPD site) and drainage (at SDU site) can maintain water level in 50-100 cm in tertiary canal. This condition could reduce water loss in tertiary block. So that the crop water requirement could fulfilled by the rainfall.

Interview results with farmers showed that average harvest yield for rice crop at Banyu Urip Village was 7-9 ton/ha (Table 4). Harvest yields for each plot are as follows: Plot no.1 owned by Mr. Suprapto as the chief of farmer group at tertiary 7 was 8.7 ton; Plot no.2 owned by Mrs. Sumi was 8.3 ton; Plot no.3 owned by Mr. Arto was 7.4 ton; Plot no.4 owned by Mr. Sugiman was 7.9 ton. Plot no.5 owned by Mr. Roni was 8.4 ton; Plot no.6 owned by Mr. Erwin was 8.9 ton; Plot no.7 owned by Mr. Kasman was 9.1 ton and Plot no.8 owned by Mrs. Marwati was 8.5 ton.

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Figure 13. Rice growing performance in Tidal Lowland of Banyu Urif village of Banyuasin South Sumatra.

Table 4. Rice production per plot in the area study of tidal reclamation

Land plot number	Source person	Harvest yield (bag)	1 bag (kg)	Harvest yield ($t\ ha^{-1}$)
1	Suprapto	135	65	8.7
2	Sumi	128	65	8.3
3	Narto	115	65	7.4
4	Sugiman	122	65	7.9
5	Roni	130	65	8.4
6	Erwin	137	65	8.9
7	Kasman	141	65	9.1
8	Marwati	132	65	8.5

CONCLUSIONS

Conclusion from the study are as follows:

1. Analysis of physical soil appropriateness at the study area showed that land was very appropriate for rice crop cultivation. This was characterized by soil textural classes of loam and clay loam, soil volume weight in the range of 0.90 to 1.22 g cm^{-3}. This condition was supported by rather slow hydraulic conductivity in the range of 9.23- 4.97 cm hr^{-1}.
2. Proper water management with water gate operation as drainage during rice crop growth and as supply during generative phase had produced maximum yield with magnitude of 9.1 t ha^{-1}.
3. Crop cultivation sustainability is highly determined by refinement and improvement of water management network, improvement of soil fertility, washing and flushing of water in channels, adaptive crop selection and technology of water level control structure that is cheap and using local raw materials.

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