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Controlled Drainage Option for Rice Water Management in Tidal Lowland Reclamation Areas of South Sumatra, Indonesia

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ABSTRACT

The problem of rice cultivation at C type tidal lowland (it does not receive high tidal water inundation) is water shortage. The research objective was to develop an open water level control model to support rainwater storage in order to provide the water requirement for rice crops. The research method was a field experiment. Land with an area of 16 ha (one tertiary block) was planted with rice variety Inpari 32 at first planting season (MT 1) for the period October-February 2019/2020. Rainwater harvesting was done by maintaining the open water level in the canal at minimum depth of 50 cm (controlled drainage) resulting in saturated soil conditions and enable rainwater storage, which can be used to fulfil the rice water requirement. The water control gate operation was done by applying a controlled drainage system (opened gate). Annual rainfall of > 2500 mm at normal conditions is sufficient for rice cultivation, but if the annual rainfall is less than 2500 mm such as in 2019, then water supply is needed by using pump irrigation at the initial planting period and generative phase period. A water pump is operated if there is no rainfall during more than 10 days. Rice production is very good with average yield of 7.5 ton/ha such as at first planting in 2020.

Keywords: Rice, Tidal lowland, Control drainage, Water management

INTRODUCTION

Reclamation of tidal lowland in South Sumatra is started since 1969 with the main objective to extent agricultural land area in order to fulfil rice requirement because irrigation land area in Java Island is continuously decreasing due to land use change. Tidal lowland is very potential and strategic to be developed as agricultural land and can be a source for new production growth (commodities) because it has several advantages such as: i). Available at relatively extensive area and stand in relatively extensive overlay scale units; ii) having flat or even topography; iii) access into development area can be reached through land route and waterway which ease distribution line. Therefore, government gave main priority to these conditions of tidal lowland. One of the developed areas are Central Kalimantan 43,503 ha (Ekon, 2021); South Kalimantan 10,000 ha (Pantau Gambut, 2021); and South Sumatra of about 235,000 ha (Sariagri, 2020).

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Utilization of tidal lowland is primarily for food crops, especially rice. Land and water management have close relation with characteristics of land hydrotopography class, which indicate position of soil surface (land) height, high tidal water height and attenuation of high tidal water level within canal system between river and the land in question. Land hydrotopography condition can used as indication for the probability of inundation that capable to flood the land as well as inundated water can be drained (Herawati et al., 2020). Land that receives high tide water during the wet season and dry season is categorized as A type. This land has sufficient water all the time. Land that only receives high tide water during the wet season is categorized as B type, and land that does not receive high tidal effect in which high tidal water only flow into canal is categorized as C type (Suryadi, 1996). In this land the rain water was very important to support agriculture activity. The technology rainfall harvesting is very useful to be applied. Make the tertiary canal as a long storage is more effective to retain water and make root zone is full of water during the rainy season (Imanudin et al., 2018).

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Although tidal lowland is potential and strategic to be developed as agricultural land, this land has several problems in term of soil fertility such as low soil pH and low nutrients, high content of Fe and Al, flooding due to poor drainage as well as H2S and Mn content that can reach toxic level. Thus, the land requires ameliorant materials to improve physical and chemical properties (Masulili, 2015; Saragih., et al., 2019).

Oxidation of acid sulphate soil due to drainage will produce Fe metal that can reach toxic level and very high acidity. Therefore, technological innovation effort related to water management improvement at farmers level is needed (Imanudin et al., 2018; Broadmeadow et al., 2023). Water management has significant effect on soil fertility status as well as water supply effort at root zone in term of quantity and quality according to crop growth (Bakri et al., 2020). Good water management at tidal lowland with hydrotopography A type (low) at South Sumatra had succed to produce average rice yield of 6.5 ton/ha. However, rice production at high area (C type) in average is 3-4 ton.ha-1 and mostly only time planting per year (Koesrini et al., 2020). Water status at lowland rice agricilture can improve as found in irrigated rice field by using rain harvest model (Jaramillo et al., 2020; Sujariyaa et al., 2020). Drainage application should conduct at wet land for rice cultivation because excessive flooding has deterioration effect for crop growth and negative effect toward environment. Drainage effort can provide air space in crop roots and can improve nutrients uptake (Liu et al., 2021). Reported by Tuyishime et al. (2020) had stated that proper drainage effort on rice cultivation can increase yield in the range of 70% to 30% and nutrients uptake increase to 60-90%.

Therefore, farmers understanding is required that not only water supply, but also drainage effort is equally important to increase productivity of tidal lowland. This is especially true for low area such as at Delta Telang I that has relatively extensive area to receive high tide water inundation for irrigation. In the near future, it hoped that to support South Sumatra as National Food Barn, no other choice except to increase planting index at least 200% at all areas. The increase of planting index will prevent the extension of land functional change from food agricultural land into plantation land, especially oil palm. However, rice production at second season is still low so that the new innovation is required. The proposed technology should base on local resources and easily applied by community members. Imanudin et al. (2021) had added that micro environment modification is required in which a tertiary block such as at C type land (rainfed rice) can be conditioned into wet condition such as at A-type land (lower area). Rainfall harvesting technology is a rational choice to be apllied in the field. This technology had applied in Sudan (Delphine 2019); India (Hungdim et al., 2019) and Ethiopia (Aleminew et al., 2020).

Water management is one of determining factors for the success of agricultural development in tidal lowland in term of effort optimalization and preservation land resources (Schultz, 2017). This water management is not only to decrease or to increase surface water availability, but also to decrease soil acidity, prevent soil acidity due to oxidation of phyrite layer, prevent salinity hazards, flood hazards, flushing toxic elements that accumulated in root zone of crop (Yadav et al., 2019; Abdullah et al., 2021). Strategy of water surface control is addressed towards aspect of groundwater retention so that it is always located above pyrite layer and land flushing through a controlled drainage system (Xu et al., 2017; Imanudin et al., 2020; Vinto et al., 2023). The expected groundwater table condition is highly depended on crop types, soil types and local hydrological condition. Moreover, water should available in proper quantity, proper time and proper quality (Goulart et al., 2020; Koesrin, 2020) In addition, the choice of control operation method using controlled drainage model will decrease network operation cost because pump irrigation requires high cost. This paper will discuss controlled drainage option at tidal lowland of C type (dry) with an objective to drain excessive water up to average limit of high tidal water and to retain rainwater during rice growth period. The research objective is to develop a model of water table control for rice crop at wet season condition (First Planting Season or MT 1) at tidal lowland reclaimed area having C type (where high tidal water is incapable to flood the land).

METHODOLOGY

Field research was conducted on tidal lowland with

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C type inundation at Delta Telang I Primary 8 (P8-2S), Telang Jaya Village, Muara Telang Subdistrict, Banyuasin District, South Sumatra Province, Indonesia (Figure 1). Reclamation area of Delta Telang I is opened by the government through transmigration program in 1980/1981. Analysis of soil physical property characteristics is done in Soil Chemical and Fertility Laboratory, Faculty of Agriculture, Sriwijaya University. The research time is done within first planting season period (MT1) from October 2020 up to January 2021. Pilot plot area is 16 ha (one tertiary block).

Field Experiment

The method used in this research was a survey method with direct field experiment. The research area is one tertiary block of 16 ha. Indicator crop in adaptation toward controlled drainage is rice crop. Rice variety used in this research is Inpari 32. Controlled drainage model successfully developed at Delta Air Sugihan, South Sumatra (Imanudin et al., 2019a).

The water structure was designed is using a controlled drainage model (Figure 2). Water regulation model is by using paralon pipe having goose-neck structure (L). Paralon pipe having diameter 0, 30 m (12 inch) is installed side by side (2 pipes) at 50 cm height from canal base. This PVC pipe height is based on average high tidal water level in which high tidal water can still enter canal. The gate operation was simple as the goose-neck pipe could be removed without additional equipment. The canal should be full so that goose-neck pipe can be installed and rain water can be detained when farmers need water. When water in canal is full, there is no water losses in the land and root zone become saturate so that the land can be flooded when it rains. On the other hand, when rice crop require no more water, i.e. approaching harvest phase, goose-neck pipe can be uninstalled an d water in canal decrease up to minimum limit (50 cm) of controlled drainage. Soil water can be lowered up to 20-30 cm limit if rice crop approaching harvest phase.

The Rainfed rice system depanded on rainfall availavility. Retention option is the best way for water management in the farm level. It can provide water when the water supply from rainfall is reduced (Elnina effect). Then the agriculture in tidal lowland can continue unaffected by climate change (Kuntiyawichai et al., 2017).

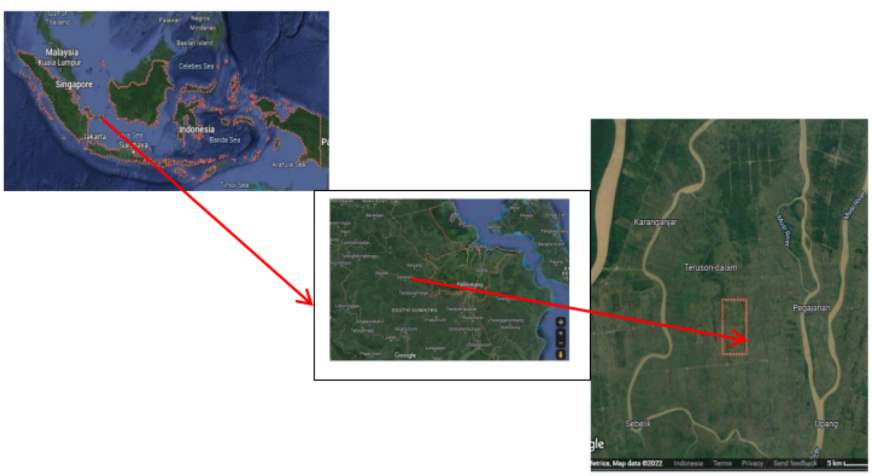

Figure 1. The study location map at Telang I Primary 8 Banyuasin Indonesia

Water retention effort by enabling tertiary canal as long storage is expected can maintain water table at position of root zone. Thus, land requires no water supply at wet season through pumping system that requires high cost. Water management for rice crop does not always have to be flooded because saturate condition during crop growth can decrease production up to 10-12%; so that oxygenation period for several

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days should be provided through lowering water table (El-Ghannam et al., 2020). Water retention in canal can also maintain water table level still near root zone, increasing effective rainfall and increasing water storage so that rice growth becomes better performance and increase in production (Chuan Chang et al., 2007).

Option design for water management objective that can be constructed at C type land is as follows (Table 1). The main objective of water management is controlled drainage and rain water retention. Control drainage not only to provide water during growing period but also to meintening the water lever for harvesting stage (Bueno et al., 2020). Drainage period is done to facilitate pore spaces filled with oxygen which in turn improve root respiration. Drainage is done up to limit 70% of saturated water level is exhausted. This condition is capable to increase rice yield if routinely conducted (Yuan et al., 2020).

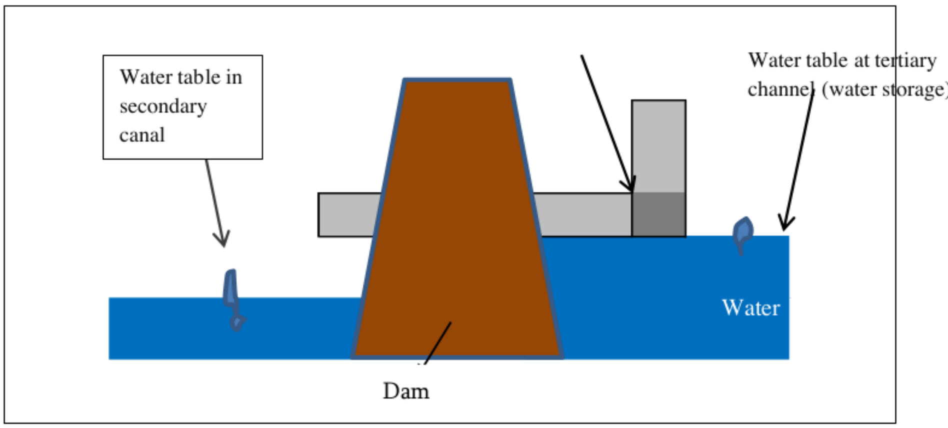

Figure 2. Hydraulics of water structure at tertiary canal has function as water retention (rainwater storage).

Tabel 1. Strategic design for water management operation at tertiary block for two different planting periods

Crop growth phase	Water Management Objective	
	First planting season of rice MT I	Second planting season of rice MT II
Initial growing period	Controlled drainage Cover pipe is opened	Controlled drainage Cover pipe is opened
Vegetative growth	Water retention, cover pipe is closed (rain water retention)	Water retention, cover pipe is closed (rain water retention)
Generative growth	Water retention, cover pipe is closed (rain water retention)	• Water retention, cover pipe is closed (rain water retention) • Pumping irrigation if no rain for 10 days
Generative phase	Controlled drainage Cover pipe is opened	Controlled drainage Cover pipe is opened

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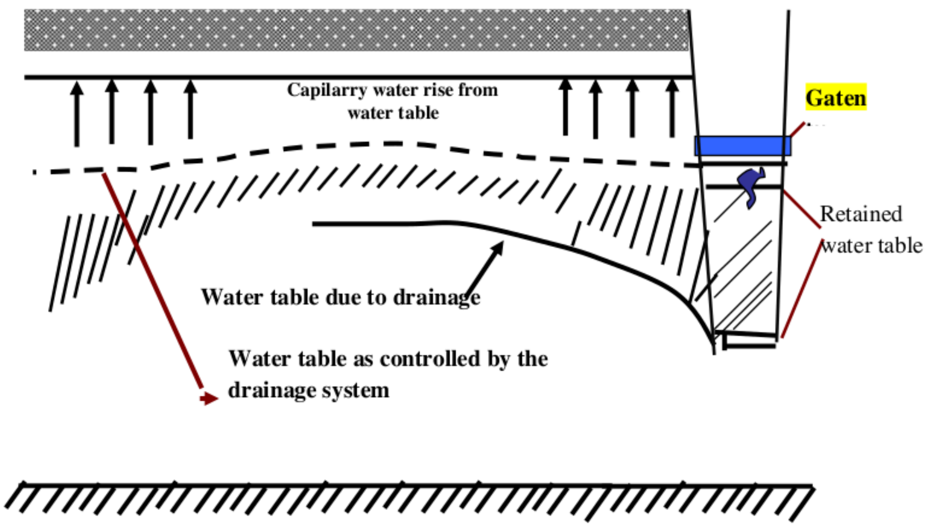
Operational management schematic at field level can be seen in Figure 3. Through water retention in tertiary canal, then water table at plot can be maintained at root zone. When it rains, water will fill in canal and increase of water table at tertiary block. At condition of rainfall more than 2,500 mm/yr., then water supply through pump irrigation at planting season period of rice is no longer needed. Water requirement is fulfil merely from rainfall so that maintaining water level in tertiary canal at minimum height of 50 cm is already sufficient to maintain water balance (Imanudin et al., 2020).



Imanudin *et al*. (2019).

Figure 3. Water table adjustment based on crop requirements using tertiary-level control gate

Hydrological Monitoring and Data Analysis

The observed parameters in this research are observation of water management network, measurement canal water level during first planting season (MT1 and MT2) for period of November 2020-January 2021 by using pleischal board, data processing by using SEW-20 values (Surplus Excess Water) to analyze water excess at root zone depth of 20 cm (Imanudin et al., 2021). Observation points of hydrological parameters within a tertiary block are shown in Figure 4.

Analysis of water excess and water shortage is calculated by using Surplus Excess Water (SEW-20) method with equation as follows:

$$SEW-20=\sum_{i=1}^{n}(20-x_i) \quad \text{.....................} (1)$$

where xi is depth of soil water at day i, i is the first day and n is total days during growth period. SEWx terminology is certain depth that defined as the starting water excess, which is usually used at depth below 20 cm. If the value of water table depth in land is above -20 cm then water is available and in excess for crop so that land is at surplus condition. On the other hand, if water table depth is less than 20 cm, then water shortage is occur and the land is in deficit condition. Optimum limit value of water table is 15 cm below soil surface (Phuoc et al., 2015). This is in accord to the study by Ardian et al. (2018), which showed optimum water table value for rice crop is in the range of -10 cm to -20 cm. Water supply through water pump is also noted as farmer efforts to fulfil water requirement in rice cultivation at tidal lowland of C type land.

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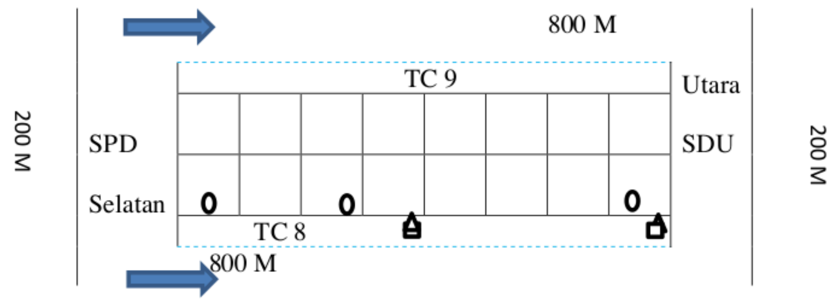

Remarks: Δ = *Well pipe,* □ = *Piscal board and* O = *Sampling point*
TS1 = located at land close to SPD with planting pattern of rice-rice-second crops
TS2 = located at center of land with planting pattern of rice-rice-rice
TS3 = located at land close to SDU with planting pattern of rice-rice
➡ water flow direction

Figure 4. Measurement points of hydrological parameters at sampling plot

RESULTS

General description of water management system and farm enterprise. Water management system is divided into two parts, i.e macro water management consisting of primary and and secondary canals as well as micro water management consisting of tertiary, quarterly and micro canals. Water management network applied at research location is based on one direction concept in which high tidal water from river flow into primary canal and then into village secondary canal (SPD) and subsequently into tertiary canal and finally into the land (Figure 5).

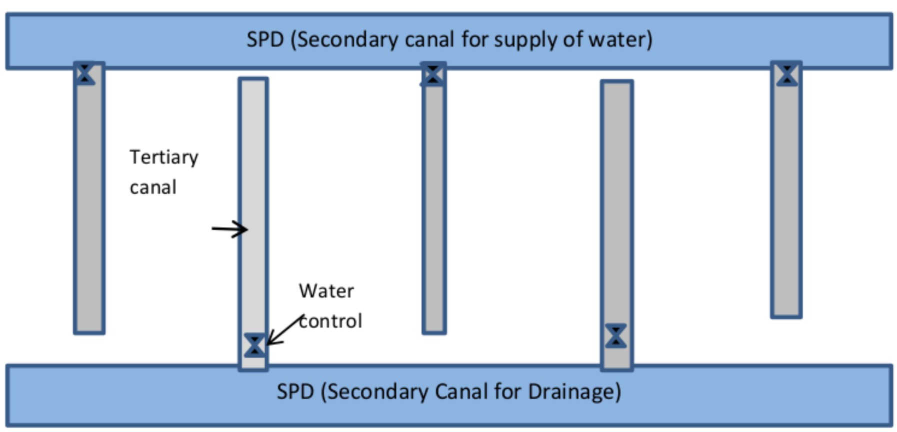

Figure 5. Pair comb canal system at tertiary network of C type at Telang I Primary

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High tidal water and low tidal water at research location only have effect on water level in canal (do not enter the land). Thus, irrigation should done by using pumping system particulary during dry season. However, the availability of water in tertiary canal can decrease drawdown rate of water table in paddy field. Farmer usually plant corn in April – May and harvest it in August – September and subsequently they plant rice.

First planting of rice (First Season) usually done in October and planting is done by direct seedling (Tabela). Planting usually done simultaneously in order to prevent pest and disease attack as well water availability during growth period. Rice planting process done through soil tillage using agricultural mechanization equipments. Farmers at Telang Jaya had used tractor or Jonder, i.e four wheel machine as well as hand tractor for land preparation job. Farmers usually pay rent cost with magnitude Rp. 800,000/ha for land preparation. Farmers at Telang Jaya Village usually use labeled seeds such as Impari 32 variety having advantages such high production up to 8 ton/ha, resistant to pests such as planthopper and blast that frequently attack rice crop. One hectare paddy field requires about 70 kg/ha of seeds.

Fertilization for rice crop at Telang Jaya Village usually with doses of urea 200 kg, 150 kg SP-36 and Phonska 150 kg. Fertilization done two times, i.e. first fertilization when rice crop age is 20 Days After Planting with doses of 100 kg urea and 100 kg SP-36, whereas the second fertilization is done when rice crop age is 60 Day After Planting with doses of 100 kg urea, 50 kg SP-36 and 150 kg Phonska. Plant maintenance done by weeding when pest is already exist. Weeding usually done by using herbicides and repeal. Water application done prior to fertilization and paddy field is in dry condition. Water application usually done by taking water available in tertiary canal by using water pump. Water pumping is not required during wet season.

Agricultural pattern at Telang Jaya Village actually capable to conduct planting index 300 (PI 300) because farmers had conducted Rice-Rice-Corn planting, but the yield at Planting Season 3 or MT3 is less satisfactory. This is due to lack of rainfall resulting in disturbance of crop growth. The use of water pump actually can solve the problem faced by farmers. However, the cost that should provided by farmers is also high because crop watering require long time of about ± 10 hours for one ha paddy field. Water application in paddy field conducted during growth period up to grain filling. Farmer siphon water from canal once a week. In addition to problem of water, farmer also complain about pest problem that attack rice crop, especially pests of planthopper and spear that are difficult to exterminated. Rice production for first planting season is in the range of 7-8 ton/ha and it was in the range of 4-5 ton/ha for the second planting season.

Rainfall condition and open water level dynamics

Water availability in land is highly affected by rainfall. Figure 6 shows monthly rainfall in 2019 and 2020. Rainfall is drier and dry season is longer in 2019. Land experience water deficit from July up to November in dry year (2019). Therefore, farmer still require additional water supply for second planting of rice in 2019. Some farmers use water pump if there is no rain more than 10 days. On the other hand, water shortage period only occurred for three months from August to September at normal condition (2020). Through water conservation effort (rainwater retention), water supply through pumping is no longer needed in this Water dynamics in a tertiary block is affected by water level in canal and rainfall condition (Kuntiyawichai et al., 2017; Imanudin et al., 2021).

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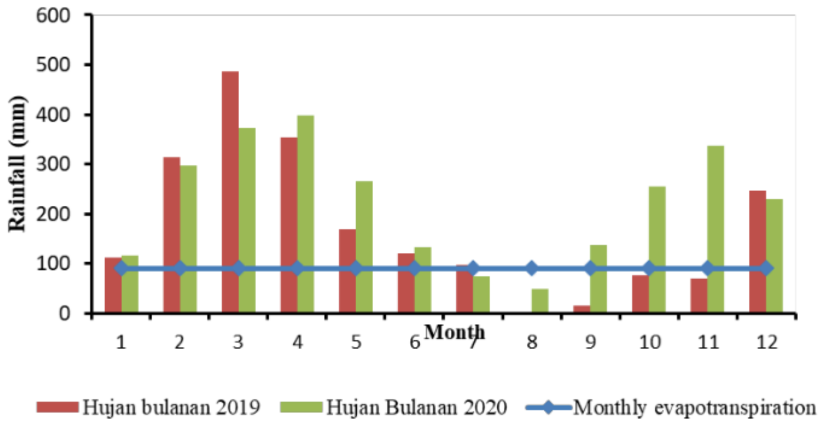

Figure 6. Monthly rainfall distribution in years of 2019 and 2020.

High tidal water unable to irrigate the land through gravitation for the case of C type land. High tidal water only enter to tertiary canal and if water in tertiary canal is full then percolation and lateral flow will low or considered non-existent so that land can function to store rainwater (Imanudin et al., 2021). Field observation in 8 Maret 2020 showed that water depth in tertiary canal is full (90 cm) and water table in land is relatively shallow at depth of 35-40 cm (Figure 7). Mean that the water table should maintenance in dept of 40cm during the dry season to avoid over drainage.

Water dynamics in tertiary canal at dry season condition (August) showed that there is 40 cm differences between maximum and minimum water level of high tidal. This means that land has potential to receive drainage treatment. Land capability to drain water (drainability) is relatively high in which water at 40 cm level occurred from 09.00 up to 23.00 wib (Figure 7). Water is unavailable in canal for about 16 hours so that water table drawdown (drain) will be very fast if no effort to fill water in tertiary canal.

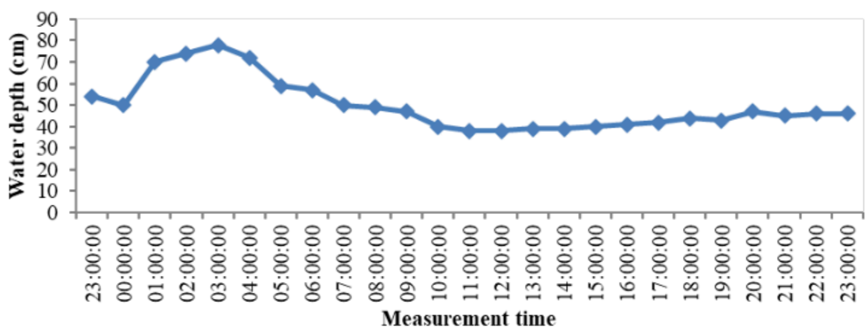

Figure 7. Hourly open water level measurement in tertiary canal (9-10 August 2020)

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Farmer did not conduct water control gate operation because there is no crops anymore on the land (Figure 8). Water table experience sharp drawdown up to depth of 100cm. Table 4.2 showed average drawdown of water table at depth of 88.1cm in north side and 74.7 cm in next to the land. On the other hand, phyrite layer had already located at depth of 90cm. This condition requires immediate water retention in tertiary canal so that water table is rise again and not located below pyrite layer. Condition in 2020 is relatively wet so that entering September-October water table is rise because rainfall is frequently occurring.

Figure 8. Land condition in August 2020 at Telang Jaya Primary 8

Soil characteristics description

Soil sampling conducted at depth of 0-30 cm. Subsequently samples analyzed in laboratory in order to determine soil texture class. Analysis results shown in Table 2. in which soil is dominated by loam texture. Loam texture is physically one of good texture class in storing and providing water and soil nutrients.

Tabel 2. Results of soil texture class determination in laboratory at 29 September 2020 at depth of 0-30 cm

Sample point	Texture fraction			Texture class**
	% Sand*	% Silt*	% Clay*	
TS 1	40.4	38	21.6	Loam
TS 2	38.4	42	19.6	Loam
TS 3	42.4	40	17.6	Loam
TS 4	42.4	40	17.6	Loam
TS 5	50.4	34	15.6	Loam
TS 6	38.4	40	21.6	Loam
TS 7	38.4	42	19.6	Loam
TS 8	32.4	30	23.6	Loam

Remarks: TS = sample point

Source: *Analisys from Soil Chemical and Fertility Laboratory, Faculty of Agriculture, Sriwijaya University (2020)

** Texture class is based on USDA

In addition, the most important observation in the field is phyrite layer depth. Phyrite is soil mineral (FeS2) that frequently found in swamp land-especially tidal lowland. Phyrite behind the peat layer or mineral soil flooded by water is safe for crops. However, if phyrite exposed and touch the air (O2), then it becomes very dangerous due to oxidation. This process results in very acid soil. Soil pH value can drop to < 3.5. At this pH condition, roots of crops such as rice, coconut and citrus are incapable to survive (Lakita et al., 2018). Pyrite become dangerous at this situation and subsequently pyrite oxidized to form jarosit mineral (at very acid pH) and goetit (at pH above 4). Therefore, pyrite layer depth is also important indicator in water management at tidal lowland area. Water table should maintenace in above the pyrite layer, In the field the water-table is maintained between 45 to 50 cm from the soil surface, hence, the depth of field drains should not exceed 65 cm (Imanudin et al., 2019).

Pyrite layer depth at the study area is still relatively depth in the range of 80-100 cm (Table 3). Therefore, the land is classified into potential acid sulphate because sulphidic layer is located at depth of > 50cm. Water table depth is in the range of 50-60 cm, during dry season which that located above pyrite layer so that soil have not experience phyrite layer oxidation. Soil capability indicator to drain water can be determined

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from permeability class. Permeability value affected by soil texture and increase in clay content will reduce permeability value. Soil permeability at upper layer is higher than that of lower layer. Upper layer has permeability in the range of slow up to relatively fast (0.20 – 9.46 cm.hr-1), whereas lower layer has permeability in the range of relatively slow up to moderate (1.10 -3.62 cm.hr-1).

The observed soil chemical characteristics are consisted of soil pH, N,P,K content, heavy metals content such as Al-dd, H-dd. Soil chemical characteristics can determine soil fertility level (Table 4). Results of soil chemical analysis showed that soil pH is acid but is not dangerous (>4) which indicate that pyrite is not oxidized yet. Organic matter content is relatively high (>5%). However, nitrogen and phosphorous content of soil is very low. Thus, the land should receive application of Urea and SP36 fertilizers. According to Sarangi et al., (2022) when the soil having pyrite oxidation, the soil increase toxicity of water-soluble Fe, Al, and Mn. It was affected owing to a high soil P fixation capacity. A deficiency of micronutrients, such as Zn and Cu. Thus the water management by control drainage is the best option to avoid water table meet the pyrite layer.

Table 3. Results of field pyrite checking in 13 September 2020

Sample points	Pyrite depth (cm)	Bulk density g/cm3	Total pores space (%)
TS 1	90	0.95	64
TS 2	98	0.79	70
TS 3	82	0.58	78
TS 4	80	0.67	75
TS 5	83	0.75	72
TS 6	97	0.69	74
TS 7	86	0.90	66
TS 8	100	0.85	68

Remarks: TS = Sample points

Soil pH value has profound effect in determining elements availability that can be absorbed by crops. Results of soil chemical analysis (Table 4) showed that soil pH is acid in the value range of 4.63 to 4.96. This soil pH value is still in tolerance limit for the life of microorganisms and vegetation.

Exchangeable aluminium value (Al-dd) is relatively high in the range of 2-4 me/100g. This Al-dd content is highly affected by phyrite layer depth. The study by Sutandi et al. (2011) indicated that lower phyrite depth has effect on soil pH decrease and Al-dd increase as well as tend to decrease values of K, Ca, Mg, Cu and Zn. Oxidation of sulphidic soil for two years is significantly decrease pH, N-total, C-organic, KTK, Ca, Mg and K. Application of soil organic matter capable to improve soil condition that experience phyrite oxidation (Rendana et al., 2018).

Table 4. Laboratory analysis results of soil chemical property

No	Sample	pH H_2O*	C-Organic (%)*	N-total (%)*	P-available (ppm)*	K-dd (Cmol/Kg)*	Al-dd (Cmol/Kg)*
1	TS1	4.63 R	5.25 T	0.24 SR	9.90SR	0.38 S	4.12
2	TS2	4.69 R	6.83 T	0.38 SR	19.65S	0.38 S	4.68
3	TS3	4.96 R	2.78 S	0.18 SR	11.10R	0.51 S	2.52

(Criteria is based on CSR/FAO 1983). SR = Very Low, R = Low, S = Moderate, T = High, ST = Very High
Source: Analysis from Soil Chemical, Biological and Fertility Laboratory, Soil Sience Department, Faculty of Agriculture, Sriwijaya University (2018).

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DISCUSSION

Water management for rice in the first planting season (October-January)

Rice planted at pilot plot is Impara 32 variety with seeds requirement of 80 kg. Seeds requirement is relatively abundant because planting system conducted by using direct seeds spreading method (TABELA). Seeds spreading was period done since early October. Seeds spreading for pilot plot conducted in 15, 16 and 17 October 2020. Early fertilizing step for rice having 7 days age is using SP36 as phosphorus source. Fertilizer dose used in this case is 200 kg SP36/ha. Subsequently urea fertilizing as nitrogen source applied at 20 days after planting. Urea dose used in this case is 200kg/ha. Farmers use Ponska fertilizer as potassium source at dose of 200 kg/ha which is applied after rice having 45 days age.

Initial step in rice cultivation done by land preparation through soil tillage. The land does not require abundant water in this phase so that water control gate operation is in open fashion. The required condition for soil humidity is field capacity. Water control gate operation is in open fashion. Rainfall is start occurring in October and water is not stored, but water thrown away into canal to clean acid substance and toxic substances available in root zone. Farmer start to conduct soil tillage in this period. Soil that already been tilled is left for 1-2 weeks to facilitate flushing and evaporation processes. Subsequently, soil destroyed and first ed until ready for planting. Soil is ready to spread with rice seeds at the second-third weeks.

Water management at first planting season period (wet) has an objective to prevent land from flooding or prolong puddling. This condition occurred because rainwater is excessive and rainfall occurred since October (initial planting). Thus the tertiary gate operation was opened to promote the water free for sullay and drainage. By using this system, high tidal water is entering to replace poor water in canal and excess water from rainfall can be flow out through two PVC pipe having diameter 0,30 m (12 inch) during low tidal period. However, water level height in canal kept at 50 cm (controlled drainage) so that water table on land can be maintained and soil is in water saturate condition. By using controlled drainage drainage (Figure 12), water level in canal is at 40 cm depth. The land at paddy field area is not in flooding condition, but soil has water content above field capacity.

Rice crop at initial growth period requires water, but water control gate operation is in open fashion and high tidal water has good quality so that it may enter. Figure 10 showed high tidal water condition and canal is full of water. Because canal is full of water, then there is no seepage and flow from the land. Thus, rainfall can be stored in the land that is flooded by water as seen in the figure. This condition is require by rice crop in which tidal lowland is similar as irrigated land. At open water control gate condition, water can be flow out during low tidal so that water flooding in land can be reduced. Reported by Rerkasem (2015) Pady growth will be optimum in conditions of standing water in the land of 5-10 cm. And produce maximum production. Even so, there are several days when the water level must be lowered to the ground level.

The water control gate is opened during vegetative phase and facilitate the flow in and flow out of water (Figure 11). Controlled drainage at 50 cm level in tertiary canal provide column space of 50 cm from average soil surface and this is potential to drain water in the land (Table 4). The flooded land can be dry if no rainfall for 4 days period. This condition is proper for rice growth and produce land condition as intermittent irrigation. This condition will improve soil aeration and capable to increase productivity of rice crop. The study by El-Ghannam et al. (2020) showed that controlled drainage method in wet land is capable to produce better rice yield than that of conventional system. In addition, controlled drainage can reduce water pollution due to water flowing that carry nitrogen and phosphorous. This in turn will produce better fertilization efficiency (Zhang et al., 2020).

Water table control is conducted by using controlled drainage in which water level in canal is maintained at minimum depth of 50 cm using L gate in opened operation so that high tidal water is freely flow-in and flow-out during low tidal period resulting in relatively stable condition of soil water and not always flooded as well as water table even drop to depth of -5cm to -20 cm. Flooding phase does not last long and this condition is favourable because soil water is relatively stable at depth of -5cm to -10cm at vegetative period and can be

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Figure 9. Condition of water control gate operation and initial growth of rice crop in land at 6 October 2020.

Figure 10. Condition of water control gate operation and rice growth in 29 October 2020.

Figure 11. Condition of water control gate operation and rice growth in 28 November 2020.

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Table 5. Monthly water control gate operation at MT1 in C type land Primary 8 Telang

Months	Land use	Water management objective	Water control gate operation
October	Land preparation	Controlled drainage 50 cm	Open
November	Planting	Controlled drainage 50 cm	Open
December	Vegetative period of rice	Controlled drainage 50 cm	Open
January	Vegetative and generative periods of rice	Controlled drainage 50 cm	Open
February	Harvest	Controlled drainage 50 cm	Open

Table 6. Water table condition at every crop growth phase as impact of water control gate operation.

Phase	Period	Water table (cm)		Gate operation
		Wells 1	Wells 2	
Vegetative	13 Oct 2020 - 26 Oct 2020	-4.5	-9.5	Opened
	27 Oct 2020 - 9 Nov 2020	-1.78	-7.14	Opened
	10 Nov 2020 - 23 Nov 2020	4.07	2.07	Opened
Reproductive	24 Nov 2020 – 7 Dec 2020	3.57	-0.5	Opened
	8 Dec 2020 – 21 Dec 2020	-2,28	-4.28	Opened
Maturation	22 Dec 2020 – 4 Jan 2021	-3.35	-8.57	Opened
	5 Jan 2021 – 18 Jan 2021	-9.85	-17.78	Opened
Harvest	19 Jan 2021 – 30 Jan 2021	-15.41	-24.66	Opened
Average		-3.69	-8.79	

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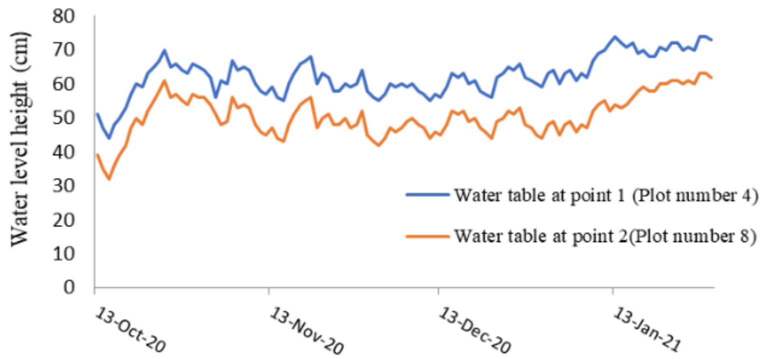

Figure 12. Dynamics of canal water level at MT1 (Period of October 2020-January 2021)

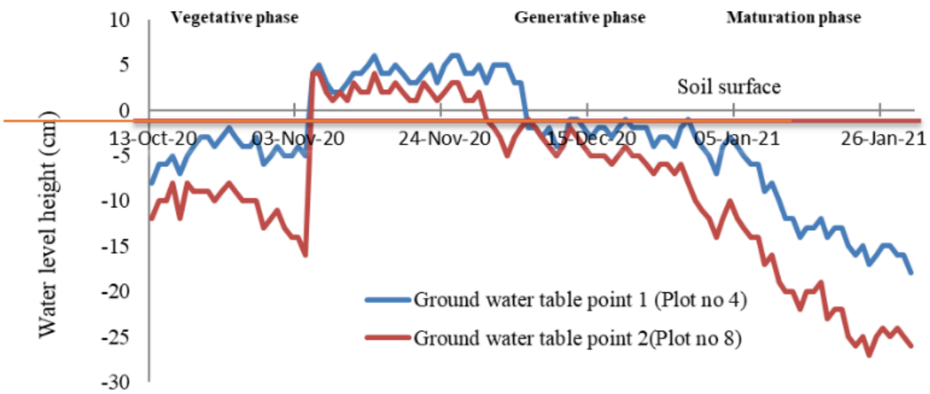

Figure 13. Water table dynamics in a tertiary block of tidal lowland agriculture

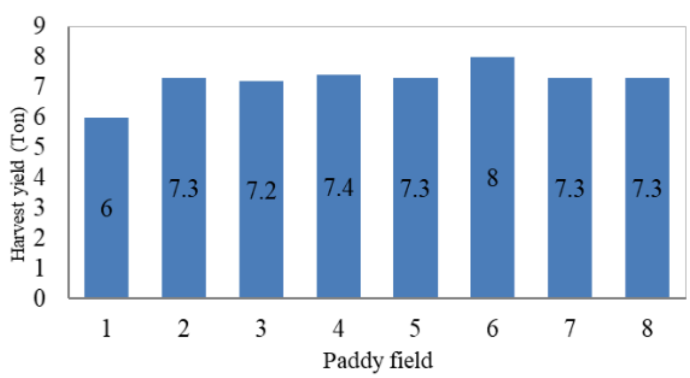

Figure 14. Graph of harvest yield at land of tertiary 8 in first planting season (MT 1)

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Table 7. The relationship between water dynamics and rice production yield

Treatment	Max water table (cm)	Cummulative value of SEW -20	Average water table (cm)	Rice production yield (ton/ha)
Experimental plot 1	-15.41	1817	-3.69	7.2
Experimental plot 2	-24.66	1644	-8.79	7.3

at depth of -20cm prior to harvest phase (Table 6). This condition make pore space filled with oxygen (oxygenation) and will improve nutrients uptake and fertilization efficiency. Nitrogen uptake will increase with provision of drainage treatment at rice cultivation period (Rahman et al., 2013; Gao et al., 2018) have added that regular drainage treatment gave better yield than that of full irrigation. Nutrients uptake become better because of higher crop root distribution.

Evaluation of water status and rice crop production in the First Planting Season (MT1:November-February)

Water level dynamics for tertiary canal at first planting season in October 2020 up to January 2021 are presented in Figure 12. There is two daily observations, i.e. at plot number 4 and 8. Water level fluctuation in tertiary canal at plot number 4 is higher than that of plot number 8 because plot number 4 is nearer to secondary canal so that it has more water supply. Water level average in canal at plot number 4 is 60-70 cm height and it was 45-55 cm height at plot number 8. Water level fluctuation in canal was significant effect to the availability of soil water in a tertiary block. In addition, rainfall effect is very dominant for C type land (Imanudin et al., 2019). This condition is shown in Figure 13, i.e. water table can drop if rainfall is decreasing although soil water condition at plot number 8 is lower than that of plot number 4 according to water level dynamics in tertiary canal. Thus, both rainfall and water level condition in canal has significant effect.

Soil Excess Water Analysis (SEW-20). SEW -20 is the summation result of water table with depth of 20 cm for rice crop cultivation and it is expressed with unit of cm per day. Number 20 cm is used as rice crop indicator to know determine water shortage or water excess by using root zone concept approach (Phuoc et al., 2015; Ardian et al., 2018; Imanudin et al., 2019a). This method is used to evaluate water status within soil. Data used in this method is data based on water table fluctuation which is observed during fisrt planting season (MT1) at agricultural land in tertiary block number 8 (TC8). Telang Jaya Village, Muara Telang Subdistrict. According to Imanudin et al. (2021), water table fluctuation at tidal lowland is affected by rainfall, temperature and high and low tidal water within canal. Intense and long rainfall can give more water for fulfilling soil water. Water control gate operation at tertiary level can also affect water table fluctuation on the land. Controlled drainage operation has caused relatively stable water level in tertiary canal so that soil water fulfilling highly influenced by rainfall.

Table 8. showed cumulative calculation result in Oktober 2020 up to Januari 2021 that indicate average of cumulative calculation summation with magnitude of 1,817 and 1,644 for well 1 and well 2, respectively. The different values between well 1 and well 2 is affected by well position from tertiary canal. Position of well 1 is nearer to tertiary canal (SPD estuary) so that water is flowing faster than that of well 2 which located farther from tertiary canal (SPD estuary).

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Table 8. Calculation of SEW-10 Cummulative Value on tertiary block land

Month	Observation points (cm)	
	wells 1	wells 2
October 2020	295	191
November 2020	687	978
December 2020	577	470
January 2020	258	5
Total	1,817	1,644

Water table analysis based on SEW-20 showed that water table height is mostly on position of above -20cm and indicate that water table height in the land is still has normal height and safe for rice crop growth. This is in accord to the study results by Arif et al. (2017) and Ardian et al. (2018), which showed that test of several rice varieties gave good respond at water table depth in the range of -10cm to -20 cm. The study by Jalindar et al. (2019) showed that water table depth in the range of -5cm to -10 cm was the best depth for rice cultivation in term of water supply that capable to save water of 26-35% and achieve production of 7.2 ton/ha. The study by Tuyishime et al. (2020) showed that effort to lower water table (drainage) also increase N nutrient uptake up to 90% and capable to increase rice production. Added by Norsuwan et al., (2020) that generally rice in irrigated land has low nutrient absorption, especially nitrogen. Improvement of soil physical properties and drainage will increase nutrient uptake.

Control drainage system that applied in rainfe rice was promote the wet and dry irrigation (WD) system. The model was able to applied a water-saving irrigation technique that is appropriate to be applied in dealing with water scarcity problems. This system facilitates the improvement of soil aeration, thereby increasing nutrient uptake by crop (Hadi, 2021), Added by Shekhar et al., (2022) the WD system is able to save 20-30% water and 15-20% fertilization efficiency.

Nevertheless, it is better if the land receive water in condition of 0 cm depth or inundated condition up to 5 to10 cm (Rerkasem,& Rerkasem, 2019). The fulfilling of water table to provide inundation of the land should be done by using pump if no rain occurring for more than 10 days. The study result by Talpur et al. (2013) showed that maximum rice yield can be produced if rice receive a water supply of 10 cm during generative growth period.

CONCLUSION AND RECOMMENDATION

CONCLUSIONS

The conclusions from this study are as follows:

1. Rainfall harvesting model combined with controlled drainage model are proper model for water supply effort for rice crop. Tertiary water control gate operation is maintained at height of 50 cm during first planting season (MT1). Water supply using pumping technique from canal during high tidal period is only conducted if no rainfall occurring for more than 10 days, which is occurred at initial and flowering phases.
2. Field experiment model of controlled drainage operation and rainfall harvesting at rice cultivation of Inpari 32 variety showed the best production with dry unhealed rice yield of 7.0 ton/ha in average. This condition showed that tidal lowland of C type is capable to achieve productivity similar to A-typology land and technical irrigation land.

RECOMMEDATION

Network operation model for C type land is rainwater retention combined with controlled drainage. This model is capable to supply water requirement. However in order to achieve maximum rice production, other production inputs such as balance fertilizing, amelioration, selection of adaptive superior variety are required. Relatively high content of Al-dd necessitate farmer to apply lime additional input at land preparation stage.

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