The Preliminary Study for Increasing the Productivity of Unit Tamban Lowland Irrigation Area based on Fact Findings of Observations

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Abstract. Unit Tamban is a fork system of lowland irrigation areas in Kapuas District. It has three primary canals, and each of them has a settling pond at the end. Most of the 3,506 ha planting area still apply once a year cropping patterns. A quick assessment based on field observations is carried out to determine the existing problems, including water management, water quality, and soil quality. The problem in the water management system is silting in the primary and secondary canals. The settling pond at the primary canal was no longer functioning, and it makes the silting worse because the water flow became uncontrolled. Water quality is measured with pH and TDS, the average pH at canal water was 4.22, and TDS was 71 mg/l. The soil type is mainly acid sulphate with pyritic materials, mostly 70 cm below the surface. Increasing cropping patterns twice a year requires improving the water circulations and increasing the soil pH higher than five. The problem in the secondary canal is expected to solve by changing the flow pattern from two way to 1-way flow is needed to avoid dead spots of water so that the leaching processes can work well.

Keywords: Lowland irrigation area, silting, water quality, soil quality, canal rehabilitation

1. Introduction
The Indonesian government has been opening up a tidal area that can become agricultural land since 1969 to realize a food self-sufficiency program. Tidal areas in Indonesia are spread over three large islands, namely Sumatra, Kalimantan, and Papua. Based on a Presidential Directive in 1995, a one million hectares Mega Rice Project (MRP) project was initiated in Central Kalimantan Province to convert peat swamp forest into rice fields. The MRP area consists of four working areas, namely block A, block B, block C, and block D. The MRP is located between Palangkaraya City (Kahayan River) to the east through a 187-kilometer main canal (SPI) crossing the Barito River in Mangkatip. In the west, the location of the MRP stretches from Palangkaraya City to the south along the east of the Sebangun River to the south until it empties into Sebangun Bay in the Java Sea. While in the east is bordered by the Barito River, along the Barito River and Kapuas Murung River to the south passes through Kuala Kapuas to the mouth of the Kapuas River, which empties into the Java Sea [1].
Unit Tamban is one of the lowland irrigation areas parts of block D. This irrigation area was developed in early 1980 with the Proyek Pembukaan Persawahan Pasang Surut (P4S). Before being developed by the government, local people cultivated crops using the traditional digging a canal upright the river to reclaim tidal land. The canal is called handil, which functions to remove excess water in the land for agricultural activities. Most of the agricultural productivity in the Unit Tamban is still applying the once a year of cropping pattern with local rice varieties. This research aimed to determine the existing problems at Unit Tamban and find solutions based on a quick assessment of field observations data so that the cropping patterns can be increased to twice a year. Several issues that need to be resolved are water management, water quality, and soil quality.

2. Materials and Methods
The water management system developed by the government at Unit Tamban is a fork-type of canal network with a settling pond at the end. The main primary canal is divided into three branches: the left pond primary canal, middle pond primary canal, and right pond primary canal. With a 3,506 ha functional area, the irrigation service of the Unit Tamban covers two sub-districts, namely Bataguh and Tamban Catur, as shown in Figure 1. The agricultural area is divided into 7 villages namely Sei Jangkit, Tamban Luar, Bangun Harjo, Warna Sari, Sidomulyo, Sidorejo and Bandaraya. The focus of this research is on the middle pond primary canal, especially in Sidomulyo village.

![Figure 1. Scheme of the Unit Tamban lowland irrigation area](image)

This study conducted a rapid assessment based on field observations related to problems in the Unit Tamban. Observations were made by testing the water and soil quality and collecting facts in the field consisting of the existing conditions of settling ponds, primary canals, secondary canals and water control structures. The study of factual findings, including the results of farmer interviews, focused on the initial study of the interaction between the physical condition of the canal and water control structures, circulation of water flow, water quality and soil quality parameters, as well as non-physical factors that affect the performance of the Unit Tamban irrigation area.
The option to solve the problem of low water management performance is based on considering the hydraulic aspect so that irrigation water supply and drainage can be improved, especially with dead spots. It is necessary to manage the flow direction and the water level in the canal network by adding the proper water gates and pumps at certain locations based on hydrological and hydraulic considerations.

3. Results and Discussion

3.1. Water System Management

After about 40 years of development, all the settling ponds at the end of primary canals were no longer functioning and filled with sediment and shrubs, as shown in Figure 2. Efforts to rehabilitate or restore the function to its original condition cannot be carried out because it will accumulate toxins deposited over decades in the settling ponds. The settling ponds filled with sediment make silting in the primary canal worse because the water flow becomes uncontrollable. The settling pond was built to control the flow and accommodate soil leaching material that cannot come out because the tide is pushed back. The silting of the primary canal disrupts the water flow. The tidal flow that is entering the secondary canal to supply irrigation is also hampered.

The main functions of the canals are drainage of excess water, supplying fresh water from the river, leaching and diluting the acid solution resulting from oxidation of acid sulphate soil [2]. However, dead spots were found at several points in the Unit Tamban secondary canal where water could not flow. The supply and drainage process is not as expected, causing water quality to deteriorate. Tidal water is trapped and cannot come out at low tide so that the leaching process does not run and causes water quality to worsen. This is exacerbated by sedimentation in the secondary canal; tidal water cannot flow to the end of the secondary canal, so that agricultural land becomes a rainfed cultivation field that does not receive water from the canal, only relying on rainwater. The water control structures such as water gates are mostly no longer functioning due to lack of maintenance and age, as shown in Figure 3. At the same time, the water gates in secondary canals have an essential role in controlling the incoming tidal water that can be saved in the canal as needed and not come out at low tide.

Acidity (pH) and Total Dissolved Solid (TDS)

The water and soil quality in tidal lowlands indicates that the leaching process has not been fully completed. It can be seen from the large number of grass that thrives in the primary and secondary canals. A pH meter is used to find out how the quality of water and soil in the canal. Meanwhile, a peat drill and hydrogen peroxide were used to see the pyrite depth and the peat thickness.

The book of Research and Development of Swamp Land [3] states that the level of soil acidity (pH) in swamplands ranges from 3.5–5.0. In flooded acid sulphate soils, the soil pH can reach > 4.0, but when
drying occurs, it drops drastically to < 3.5. Meanwhile, Total Dissolved Solid (TDS) is measured to see the level of turbidity in the water. High TDS is not toxic, but if it is excessive, it can increase the value of turbidity and inhibit the penetration of sunlight into the water column and affect the photosynthesis process in the waters [4]. Generally, if the pH > 5, the maximum allowable TDS limit for agriculture is 2000 mg/l. The results of water and soil quality sampling carried out at high tide are as follows.

Table 1. Water sampling of pH and TDS in the secondary canal of Sidomulyo village

| Canal name | Distance from primary (m) | Water in canal pH | TDS (mg/l) |
|------------|--------------------------|-------------------|------------|
| Secondary 1| 0                        | 4.56              | 27.8       |
|            | 50                       | 4.2               | 29         |
|            | 100                      | 4.61              | 27.5       |
|            | 150                      | 4.5               | 28.8       |
| Secondary 3| 0                        | 4.65              | 28.6       |
|            | 50                       | 4.4               | 27.4       |
|            | 100                      | 4.2               | 36.6       |
|            | 250                      | 4.1               | 29.8       |
| Secondary 5| 0                        | 4.65              | 50.4       |
|            | 50                       | 4.6               | 32.3       |
|            | 100                      | 4.7               | 38.8       |
|            | 150                      | 4.35              | 45.5       |
| Secondary 7| 50                       | 4.06              | 69.2       |
|            | 100                      | 3.22              | 235        |
|            | 150                      | 3.04              | 334        |

Table 2. Water sampling of pH and TDS in the rice field of Sidomulyo village

| Canal Name | Distance from primary (m) | Water in the rice field pH | TDS (mg/l) |
|------------|--------------------------|-----------------------------|------------|
| Secondary 1| 50                       | 4.24                        | 33.6       |
|            | 100                      | 4.6                         | 26.1       |
|            | 150                      | 4.49                        | 25.5       |
| Secondary 3| 50                       | 4.5                         | 40.6       |
|            | 100                      | 4.25                        | 67.3       |
| Secondary 5| 50                       | 4.57                        | 41.4       |
|            | 100                      | 4.3                         | 77.2       |
|            | 150                      | 4.49                        | 51.3       |
| Secondary 7| 50                       | 3.13                        | 540        |
|            | 100                      | 3.8                         | 80.5       |
|            | 150                      | 3.12                        | 533        |

Based on the survey results, the pH of the secondary canal water ranges from 3.04 to 4.70, as shown in Table 1. The lowest pH was found in secondary 7, while the highest was in secondary 5. For the water measurement in the rice fields, the pH value was obtained between 3.12-4.60 (Table 2), with the lowest pH found in secondary seven and the highest in secondary 1. In addition to canal and rice fields water, a test was also carried out on soil in the rice fields of Sidomulyo village. The soil pH values (in
over-saturated condition) ranged from 4.01-5.13 (Table 3). The lowest pH was in the fields in secondary seven, and the highest was in secondary 5.

The TDS measurement in the secondary canal water ranges from 27.40-334 mg/l, while water in rice fields is between 25.50-540 mg/l. Tests were also carried out on the soil in the rice fields of Sidomulyo village, with TDS measurement results obtained from 106-375. For TDS measurement, all water results in canals, water in rice fields, and soil in rice fields are below the maximum allowable TDS limit for agriculture.

**Table 3.** Soil sampling of pH and TDS in the rice field of Sidomulyo village

| Canal Name | Distance from primary (m) | The soil in the rice field |  |
|------------|----------------------------|-----------------------------|---|
|            |                            | pH  | TDS (mg/l) |  |
| Secondary 1| 50                         | 4.7 | 367        |  |
|            | 100                        | 4.2 | 375        |  |
|            | 150                        | 4.27| 211        |  |
| Secondary 3| 50                         | 4.88| 155        |  |
|            | 100                        | 4.9 | 117        |  |
|            | 250                        | 4.7 | 367        |  |
| Secondary 5| 50                         | 5.13| 122        |  |
|            | 100                        | 4.51| 110        |  |
|            | 150                        | 5.08| 160        |  |
| Secondary 7| 50                         | 4.01| 106        |  |
|            | 100                        | 4.7 | 151        |  |
|            | 150                        | 4.14| 317        |  |

3.2. **Pyrite Depth and Peat Thickness**

There are two main types of soil in tidal areas: mineral soils with water-saturated and peat soils [5]. Mineral soils are divided into potential acid sulphate soils and actual acid sulphate soils. Potential acid sulphate soil (SMP) is a land that has sulfidic material (pyrite) at a depth of > 50 cm from the soil surface, has a pH > 3.5, which is getting higher in line with the depth of the soil. While the actual acid sulphate soil (SMA) has a field soil pH of <3.5, it has a sulfuric horizon or signs of a sulfuric horizon caused by the oxidation of pyrite due to excessive drainage [6].

In the Guidelines for Sustainable Management of Degraded Peatlands published by the Agency for Agricultural Research and Development [7], it is stated that based on the level of maturity, peat is divided into sapric (ripe), hemic (half-ripe), and fibric (raw). Peat can store and absorb more water than mineral soils. The water content in peat soils can reach 300-3000% dry weight, much higher than mineral soils whose ability to absorb water is only around 20-35% dry weight [8]. The level of maturity determines the average water content of peat when it is flooded. At the fibric maturity level (very raw peat), peat is very nestable, so the space between the peat masses is filled with water. However, because most of the water is in macropores, the water will quickly disappear once the peat is drained. Water is stored at a higher sorption rate in more mature peat conditions because micro and mesopores begin to form [9]. On the other hand, peat can be very strongly acidic. It contains pyritic materials that have been oxidized upon reclamation [10].

The soil sampling results to determine the depth of pyrite and peat thickness can be seen in Table 4 below.
### Table 4. The results of soil sampling in the rice field of Sidomulyo village

| Canal Name | Distance from primary (m) | The soil in the rice field | Explanation |
|------------|--------------------------|-----------------------------|-------------|
|            |                          | Pyrite Depth (cm)           | Peat Thickness (cm) |
| Secondary 1| 50                       | 70                          | -            |
|            | 100                      | 70                          | -            |
|            | 150                      | 65                          | 12           |
| Secondary 3| 50                       | 80                          | 20           | fibric (raw) |
|            | 100                      | 70                          | -            |
|            | 250                      | 70                          | 43           | hemic (half-ripe) |
| Secondary 5| 50                       | 60                          | -            |
|            | 100                      | 70                          | 10           | hemic (half-ripe) |
|            | 150                      | 65                          | 15           | hemic (half-ripe) |
| Secondary 7| 50                       | 73                          | 14           | fibric (raw) |
|            | 100                      | 73                          | 53           | hemic (half-ripe) |
|            | 150                      | 70                          | 15           | fibric (raw) |

3.3. Proposed Problem Solving

A critical problem in the water system of the Unit Tamban is that there is silting in the canal, and there are several dead spots that indicate flow resistance. An option to overcome this problem is to change the flow pattern in the secondary canal from 2-ways flow to 1-way flow by connecting the two upstream ends of the secondary canal and adding water gates and water pumps. With this change, water can flow to the end of the canal by connecting the ends of the two secondary canals, as shown in Figure 4. The tidal water that enters the canal is allowed to flow to the end. Then at low tide, the water is held back to flow to the following secondary canal. It is expected the water circulation occurs in both secondary canals.

A water control structure, namely a flap gate, is needed to manage the water at high tide and low tide. The flap gate was chosen because it is suitable for 1-way flow and can be operated automatically. The door will open if there is a difference in height upstream and downstream of the door. When the tide comes in, the door will open, and water will enter the secondary canal. At low tide, the door will be closed so that the water will be stuck in the canal and flow into the secondary's connecting canal. The water will flow in the next secondary canal until it finally comes out to the primary canal. Therefore, the water circulation occurs, and the leaching process will work well.

![Figure 4. Illustration of 1-way flow regulation on the secondary canal](image-url)
The change of flow pattern to 1-way flow requires further hydraulics simulation using mathematical models. Simulation of unsteady flow within the canal network with flap gate and secondary canal connectors has to be carried out to see how far the incoming tidal water can flow and the ability of the canal to accommodate water. With a mathematical model of the unsteady flow simulation, the dimensions of the secondary canals and the connectors between the secondary canals can also be determined. The soil sampling results show that the average pyrite depth in the Sidomulyo village rice fields is 70 cm from the soil surface. This indicates that the soil belongs to the potential acid sulphate soil category, which means it is still safe for plant growth. Efforts to make the water flow in the canal unobstructed are also helpful for maintaining soil moisture so that the pyrite will not be oxidized, especially during the dry season.

Hemic and fibric peats are still found in some rice fields, varying from 7 to 53 cm thicknesses. Immature peat with high porosity will absorb water quickly. Some farmers also complained about water recede in the rice fields when the water in the canal recedes. This indicates a layer of peat in the subgrade layer of the secondary canal embankment, which causes seepage to come out of the rice fields. A waterproof layer can be used as a side barrier to the embankment to overcome the water recede in the fields.

4. Conclusions
To utilize land in tidal areas, the proper circulation in the water system is essential. The freshwater from the river must enter the canal and land, then be drained out at low tide by carrying substances from soil leaching. With the leaching process, the water and soil quality will improve to reaches pH > 5. Efforts to control the flow for water circulation in the secondary canal and change the flow pattern in the canal from 2-ways to 1-way flow can be more accurate by hydraulic simulation using a mathematical model. This will improve the performance of the water management system in the Unit Tamban irrigation area. The other effect of good circulation of a water system is the maintenance of soil moisture in reduced condition, so the sulphury horizon's pH in the rooting zone can be kept > 5. Another thing that needs to be considered is a layer of peat on land or canals because it will make water easily absorbed into the soil due to its very porous character. An alternative to overcome this problem is installing a waterproof layer on the side of the rice field embankment.

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