

WATER TABLE VARIABILITY AND FLOW RESPONSE OF TROPICAL PEATLAND - A CASE STUDY

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ABSTRACT

Peatland is a type of soil that characterized by high water content. The use of peatlands, especially for agriculture and plantations is carried out by channel to control the water table level such that the water content in the root zone is in accordance by the variety of plant. Water table on drained peatlands will have a decline in groundwater level to a certain depth. Excessive continuous water table decreasing through below the surface of the land which occurs continuously can create irreversible dryness that causes land subsidence and increase the risk of fire (NOT CLEAR). The study aims to observe characteristics of water table level in the rainy season due to the construction of canal networks on peatlands.

The study was conducted in Pulau Padang Riau Province of Indonesia which is a drained peatland that has been developed for industrial crop cultivation. The land is managed by two different groups; those maintained by the local community and those by private companies. The analysis was carried out by using a balance of water budget on peatland specifically by calculating the dynamic interaction of the hydrological parameters of land and channels flow.

The results showed that the condition of water table elevation had changed during the period of data collection. The rainfall transformed quickly into overland flow and direct runoff. The decrease in the water table on local community management areas is higher than that occurring in companies land with a variety in the value of the up and down is greater.(NOT CLEAR) This phenomenon occurs because there are no canal blocks on the peatland, which is managed by the local community so that the rise and fall of the water surface occur naturally. In addition, since it is located in the downstream area, the state of the flow will be influenced by the flow in the upstream. When the upstream flow is retained, hence no current flows to the downstream, and as a result, the water table level continues to decrease.

Keywords : peatlands, water table depth, rainfall, direct runoff.

1. INTRODUCTION

Deforestation, especially peat forests, has received attention from researchers. Some of the research articles cover the forest point of views such as the quantity area of forest loss, the amount of carbon decomposed into the atmosphere and the reduced number of specific plants. Others present hydrology altering characteristics widely and consistently such as changes in hydraulic conductivity and changes in the type of peat layer (Curran et al., 1999; Curran et al., 2004; Wösten et al., 2013). The significant role of peatlands including swamp, for instance, the ability to store carbon stocks, as a source of water and even as an alternative to decreasing floods (Holden, 2005; Acreman and Holden, 2013), trigger it to be an essential research object. The

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proper analysis of how to manage peat soil is needed to provide benefits that are greater than the losses incurred due to the converting function.

Management of peatlands requires channel to achieve a water table level that is appropriate for plants. According to its characteristics, the flooded or watery swamp area with peat soil requires special handling before it is used as plantation or agricultural land, which is carried out canalization. Peatlands need channels to prepare them so that those have a water content that is following the types of plants to be planted (Mitsch and Gosselink, 2015). Water channelization of peatlands causes various effects such as, altering the composition of the acrotelm-catotelm in the top layer, changes in groundwater level, , changing the fluctuation of overflow and carbon reduction (Grand-Clement, et al., 2015; Daniels, et al., 2008, Holden et al., 2006, Holden, 2005).

Tropical Peatlands in Indonesia has been a concern and subject of research for a long time. Peatlands are distributed in Sumatra Island, Kalimantan Island and, a little in Papua Island. Sumatra peatlands as in Kalimantan include high in depth, and some have undergone drainage, but the level of research is not as much as research on Kalimantan peatlands (NOT CLEAR) (Page et al., 2002). One of them is research on the Pulau Padang (Brady, 1997). Some of them are intended to provide recommendations for other tropical countries that have not yet converted much of their peatlands, such as Peru and the Republic of Congo (Murdiyarto et al., 2019). Others are to see what influence is dominant in Kalimantan forest loss (Curran et al., 2004) or the amount of carbon released by peatlands in the fires that occurred during 1997 (Page et al., 2002).

Research on peatland areas in the tropics such as Indonesia has differences with the other four season countries, such as very thick peat depths of up to more than 12 meters like those on the Pulau Padang Riau Province (Brady, 1997). Pulau Padang is a deep peatland (peat depth of more than 3 meters) that has been converted into a variety of plantations (Karyanto, 2000). Detailed local research is needed in certain peat areas to understand how a land transformation and their use cause changes in ecological interactions (Curran et al., 2000) especially on land that has experienced canalization such as Pulau Padang. As a peat area that has been canalized, has felt need for research to see the changes in hydrological characteristics with the presence of canals and for using the peatlands for plantations. The study aims: 1) to compare the state of the water table elevation on peatland that are managed by the community and maintained by the company, 2) to analyze the state of the groundwater fluctuations and 3) to describe the process of runoff in channelled peatlands during rainfall.

2. METHODS

2.1 Location of study: Pulau Padang district Riau Province

The study was conducted on one of the drained tropical peatlands in Riau Province and carried out for two months, from November to December 2017 and arranged it at two location points representing community-managed land and the company's concession area. The more explanations are in the description below.

Pulau Padang is one of a series of four main islands within the Meranti Islands Regency, Riau Province, which consists of two sub-districts, namely Merbau District and Tasik Putri Puyu District. Pulau Padang is a Peatland Hydrological Unity (Kesatuan Hidrologi Gambut KHG) with entirely area is 1.114,04 km². Geographically Kepulauan Meranti district is located 0° 42' 30"- 1° 28' 0" N dan 102° 12' 0"- 103° 10' 0" E. The climate in Pulau Padang as well as in the Kepulauan Meranti district region

Of all the fields on Pulau Padang, 31% of them are conservation spaces. The area of 347.11 km² includes Tanjung Padang Wildlife Reserve /Suaka Margasatwa Tanjung Padang 48.57 km², PT GCN Pulau Padang licensed restoration range 204.37 km², and PT RAPP licensed permit area 94.17 km². Outside the region is under the management of local governments, most of which are used for local community activities as shown in Figure 2.



Figure 2. Mapping of conservation zone by every concession on Pulau Padang.

2.3 Field Measurements

Hydrological data needed are rainfall data, flow data, and water table elevation (WTE) data. Data collected is daily rainfall measured using automatic rain gauge (ARR) for 10 minutes series. The two sets of equipment are installed in Sei Hiu, Tanjung Padang Village, and Bagan Melibur Village. In addition to the two types of data, other meteorological data are also obtained such as wind speed and air humidity that have been incorporated in the measuring instrument. Location and installation setting of the equipments in the sketch can be seen in Figure 3 and Figure 4 below.

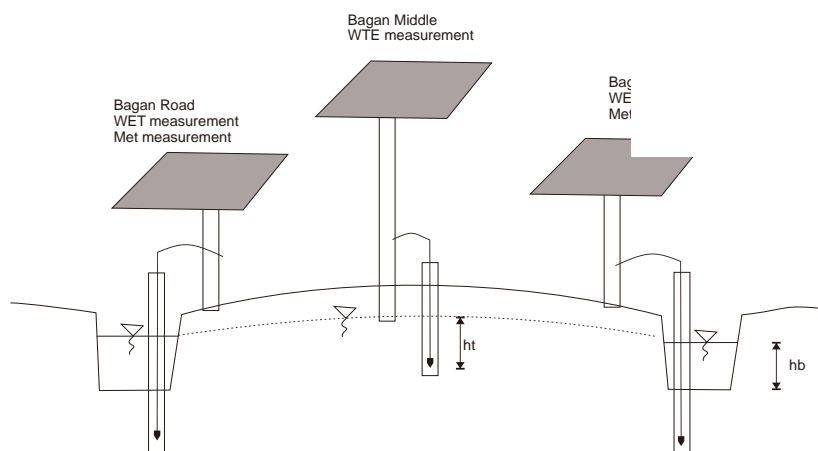


Figure 3. Sketch of the measurement



Figure 4. Location both of equipment setting

2.4. Review of Water Balance Equations on Peatlands and Discharge Analysis on the Channels

Water table elevation change data can be used to study the influence of the presence of channels and land cover on groundwater fluctuations. The water balance equation can analyze alteration in the groundwater level. The formulation will be different for drained peatlands with network systems with that are still intact. It happens because the presence of canals will significantly influence the groundwater fluctuations that are affected by the rate of groundwater wear by the process of subsurface runoff.

The general equation, based on the hydrometeorological cycle of water balance, is in a rainfall condition with the assumption that before the canal network is settled as follows.

$$\Delta S = P - ET - RO - I$$

where:

- P :rainfall (mm/day),
- ET : evapotranspiration (mm/day),
- RO :surface flow (mm/day),
- I : infiltration (mm/day),
- ΔS :water storage change (mm/day).

The discharge that occurs for each rainfall event is calculated as the description below. The total runoff volume leading to the canal (VRO) is equal to the above-ground runoff volume (SRO) coupled with the subsurface runoff volume (SSRO) and changes in groundwater storage can be stated as follows.

$$\Delta S = \sum I - \sum O$$

$$\Delta S = VP - (VRO + VET)$$

by:

- ΔS :change in water storage volume (m^3),
 $\sum I$:total of *inflow* = volume of rainfall (m^3),
 $\sum O$:total of *outflow*= *runoff*+ evapotranspiration (m^3),
 VP :rainfall in volume (m^3),
 VET :evapotranspiration in volume (m^3),
 VRO : volume of total direct runoff total flow to canal (m^3).

3. RESULTS AND DISCUSSION

Peatland management carried out by two large groups will distinguish the peat hydrological conditions that have been managed. It managed by the community have simple characteristics, have not implemented a regular system and have almost no canal blocking. On the other hand, the land runs by the company have higher network density characteristics and regularity of the channel system including the presence of canal blocking.

3.1 Analysis of changes in groundwater level

The analysis used rainfall data from automatic rain gauges and water table level data from automatic water level recorder. The following is a graph obtained from the two pieces of equipment. Analysis of water table level and presentation of events is shown in Figure 5 below. Water table elevation and presentation of certain heights is carried out with steps like the following.

1. Sort all the water level data (for example in Bagan Melibur the water level data ranged from -1.888 m to -0.303m.
2. Making a data interval, in this case, made from smaller than -1.888 m until the upper one, i.e., 0.3 m.

The data range determines the length of the period. In Sei Hiu because data range is only in the of -0.6 m to -0.4 m, the interval value also ranges from those of it.

1. Calculate the amount of data on each interval.
Example: number smaller than -1.9 is 22 data from 5621 data and a range of 10 minutes.
2. Measure the percentage of each interval, for example for lower data (higher than particular interest).
 - a. $1.8 = (22/5621 \times 100\%) = 0.39\%$.
 - b. $1.7 = ((22+37)/5621 \times 100\%) = 1.05\%$ and so forth.

Figure 5 below shows the condition of water table elevations at the two locations where data was taken during the study. The noticeable difference is the antecedent of the groundwater wherein Bagan Melibur reaches a depth of -1.9 m while the Sei Hiu is only -0.7 m. The differences between both of them it is possible due to the presence of canal block that makes Sei Hiu only loss a little part of the water in the dry season compared to Bagan Melibur.

The graph in the figure 5. below shows that there are differences in the trend of changes in the water table level in the two areas. Bagan Melibur tends to have a high level of variability, namely the water table level from -0.6 m to -1.9 m while it in Sei Hiu only ranges between -0.4 m to -0.6 m. Compared to government regulations

regarding the maximum allowable depth for peatlands to be damaged, i.e., 0.4m, it can be concluded that Sei Hiu is still within safe limits while Bagan Melibur into hazardous areas even tends to be risky because at the beginning of the wet season it reaches up to -1.9m.

In the Bagan Melibur area, it can be seen that the water table level below 40 cm takes place less than 10%, which means that nearly 90% of the depth of the water table that happens is not at the recommended level. In the Sei Hiu area, the water table level lower than 40 cm occurs more than 70% so that the water depth limit that exceeds the allowable limit only occurs at a maximum of 30%.

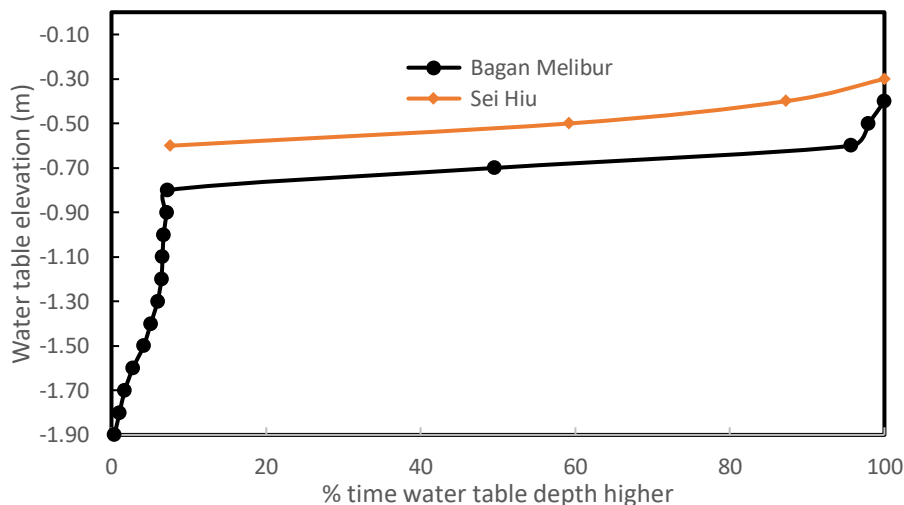


Figure 5. Water table frequency curves for Bagan Melibur dan Sei Hiu

Some of the differences between the two zones that can be mentioned as the causes of these facts are Bagan Melibur, which is a community managed area that does not yet have canal blocks. It means it does not have a scheme that can be used to hold water so that rainwater flowing as runoff directly flows to downstream and does not have time to influence the water table level change on the land. While Sei Hiu area which is located upstream has a canal block so that it has the opportunity to hold water for longer on the preferred channel section so that if the land started has begun to dry, the water is not allowed to flow downstream. This situation makes alterations in the water table level in Sei Hiu tend to be better than Bagan Melbur area. The presence of canal blocks in research on Central Kalimantan peatlands (Ritzema et al., 2014) has raised the water level significantly to elevations above -0.4 m after previously reaching below -1.22 m but unable to maintain the water level in the dry season. The trend of lower water level in the downstream area also occurred in this study.

There is a positive correlation between changes in water table level, and the presence of channels (Luscombe et al., 2016; Page et al., 2009) that is artificial drainage decreases the extent of the water table. In this study, both locations have a human-made channel, and the depth of the groundwater varies, but those are strongly influenced by the occurrence of rain which is consistent with research on peatlands in Kalimantan (Ritzema et al., 2014).

The hydrological response to the previous low groundwater conditions (antecedent) shows that the discharge rises rapidly while the groundwater level tends to be flat and

even static (Daniels, et al., 2008). In the rainfall event November 6th 2017, the antecedent height of water table level at Bagan Melibur and Sei Hiu are -1.9 m and -0.6 m respectively. In this study, the Pulau Padang state, when rainfall fell in Bagan Melibur then water table level rose rapidly to a height of -0.8 m with antecedent height was -1.9, then it took a long time to rise to an elevation of 0.7m. When the rain prolonged the water table only rose gently until it reached a stable state at 0, 4 m so that the situation was different from Daniels' 2008 study in South Pennines, UK.

3.4 Analysis of alteration in water table level and discharge generated

Drainage has a considerable influence on flow generation and groundwater spatial based (Holden et al., 2006) so that on a drained peatland like Padang Padang, it is necessary to do a spatial based flow analysis. Those are laid on different topography, i.e., Sei Hiu located upstream, and Bagan Melibur positioned in the downstream area. Some rain has occurred during the period of data collection, as follows in Figure 6 present the relationship between rain events with the generated discharge flow.

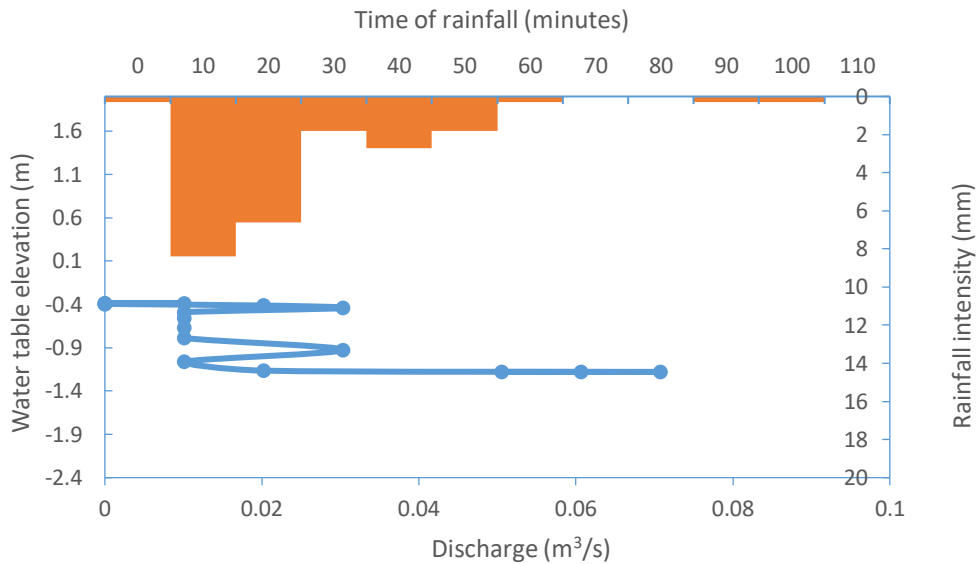


Figure 6. Profile of rainfall and discharge vs water table elevation on November 6th 2017.

It can be seen in this study that discharges do rise rapidly (Figure 6), in contrast to Daniels et al, 2008, the ground water level rises slowly or even tends to be static. On the other hand, it is rising rapidly as seen in the November 6th rain event. In this event the groundwater level was initially at position -1.2 m and in the first 10 minutes with a rainfall height of 6.3 mm, there is a discharge of 0.06 m³/s and the water table level is still in the number -1.2; then one hour later the groundwater level has become -0.8 with a total rainfall of 36.3 mm. The increase in water table level continues even though the rain begins to decrease and one hour later the water table level has reached 0.4 and after that the ground water level is relatively constant. The difference in response to hydrological conditions in an area is mainly determined by the heterogeneity of the region spatially and temporally and is included in the peculiarities of each peatland. It is possible due to the state of the composition of peat and differentiation of the depth layer of peat alongside the presence of canal blocking. Since there are difference between these both composition peatlands it will be needed a comprehensive study like the depth of peatland and the conductivity hydraulics.

4. CONCLUSIONS

Research on the location of Pulau Padang peatlands shows that there are significant changes in groundwater levels during the period of data collection, namely November to December 2017. Changes in water level are mainly determined by the incidence of rainfall and the condition of the initial water level at an elevation that exceeds the regulation recommended by the government, which is -0.4m. There are similarities and differences in the two locations of study. The hydrological response in the two regions, especially the flow rate in the channel looks the same only in the Sei Hiu there is no previous condition (antecedent) with an insignificant water table level. Further research is needed on the state of change in the dry season where the evaporation takes place and has a principal influence on the influence of thick peat on changes in land surface and flow response.

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