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Research Article

Ground Water Table Monitoring in North Selangor Peat Swamp Forest, Selangor, Peninsular Malaysia

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Abstract

Monitoring of ground water table in North Selangor Peat Swamp Forest was undertaken for 3 years period from December 2013 to December 2016. This is part of the initiative to monitor GWL in a peat swamp forest under different vegetation i.e., logged over forest, degraded open peatland as well as other land use such as smallholder oil palm. The effect of drainage on the GWT is also analyzed. The result showed that GWT fluctuates throughout the year, often correlate with rainfalls. 2014 is the dry year comparatively and it was reflected in the lowest GWT recorded in all transects. Forested area showed highest GWT whereas oil palm smallholder cultivation area had the lowest GWT; relatively higher GWT recorded in degraded open area most likely due to loss of peat surface caused by repeated fire in the past. Drained canals that were located within the peat swamp forest negatively affected the GWT. Overall, GWT recorded in NSPSF show negative value in most of the months except for November and December, a typical result for a peat swamp forest which had been drained.

Introduction

In Southeast Asia, peatlands cover approximately 23.6milliom hectares, about 56% of tropical peatlands [1]. It is estimated that there are 2.5 million hectares of peatlands in Malaysia [2], with only 0.88 million hectares of peat swamp forest remained in Malaysia [3].

Despite being categorized as vulnerable ecosystem under the National Policy on Biological Diversity 2016-2015 [4] and classified as Environment Sensitive Area (ESA) under the National Physical Plan 3 [5], only a small percentage of the peat swamp forest in Malaysia is protected. Currently, there are 3 areas of peat swamp forest gazette as national park, all in Sarawak-Maludam National Park, Loagan Bunut National Park and Ulu Sebuyau National Park- with a combine total area of 82,591 ha (Forestry Department of Sarawak).

The remaining PSF are in Forest Reserve, although mostly fall under the status of production forest (2 notable example-Southeast Pahang Peat Swamp Forest and North Selangor Peat Swamp Forest (NSPSF)). Even Maludam National Park had been logged before prior to its gazettement. Peat swamp forest in its pristine condition is characterized by high water table; undisturbed and in its natural state, water level in a peat swamp forest is always closed to the surface for most of the year [6]. Peat has low bulk density, causing the peat to have high porosity and thus high water-holding capacity [7].

Lowland tropical peatlands are usually domed shaped where its water input is entirely depended on rainfall [8]. Fluctuation of water table in a peat swamp depends mainly on rainfall because evaporation and groundwater outflow are constant [7,9,10]. Under natural conditions, the groundwater table will rise due to rainfall and fall due to evapotranspiration and the outflow of excess rainfall by surface flow, groundwater flow, or interflow. This however, changed when artificial canals/ drains were introduced either as drainage or as transporting tool in the peatland ecosystem. These networks of canals if left un-blocked lead to constantly and continually of water loss from the ecosystem- resulting in the dercrease in GWT. Lowering of GWT because of drainages, leads to aeration of peat and oxidation or aerobic composition [11]. Drainages also lead to subsidence [12,13]. The lowering of the GWT subsequently affect the functions of the peatland ecosystem.

The objectives of the GWT monitoring are:

a) To compare the GWT in peat swamp forest (with different vegetation cover) and land use such as oil palm

b) To look at the effect of drainages on the GWT in a peat swamp forest

Past studies of GWT of peat swamp forest in Malaysia can be found in NSPSF [14,15], Southeast Pahang Peat Swamp Forest [16,17], Klias peat swamp forest [18]. The first year data of this study had been summarized in Integrated Management Plan for North Selangor Peat Swamp Forest [19].

Study Site

North Selangor Peat Swamp Forest (NSPSF) is located in the northwestern of Selangor, Peninsular Malaysia. Covering area of 81,304 hectares, NSPSF consists of 4 forest reserves, namely Raja Musa Forest Reserve, Sungai Karang Forest Reserve, Sungai Dusun Forest Reserve and Bukit Belata Extension (partial) Forest Reserve [19]. Most of the NSPSF has been subjected to intensive logging in the past resulting in extensive networks of canals [14]. It is estimated that there are about 500km of canals still exist today in NSPSF (Figure 1). Logging activities has since stopped but most of the canals remained unblocked.

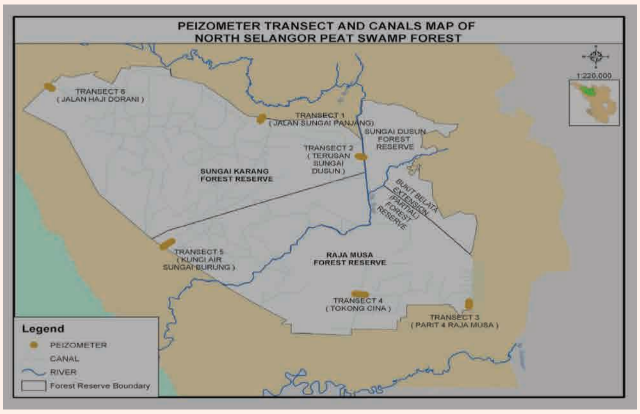

Figure 1: Location of piezometer transects and canals map of NSPSF modify from Selangor State Forestry Department (2014).

Methods

In this study, piezometers were installed in November 2013 where a total of 38 piezometers were established along 6 transects, all perpendicular to existing canals. Piezometers made of PVC pipe with perforated hole were installed permanently at the selected locations at the 6 transects. All PVC pipe were inserted at least 30cm into the underlying mineral soil layer beneath the peat. This is to ensure that there is no vertical movement of the pipe which could affect the reading. This is because the same PVC pipe will also be used for subsidence monitoring (the result will not be presented here).

All transects were selected perpendicular to the main canals with the exception of one which had a small canal running parallel to the piezometers. Piezometers were placed at pre-determined distance from the canal i.e. 5m, 50m, 150m, 250m, 500m etc, 1 transect also had piezometer installed at 750m and 1000m. Transect 1 (Jalan Sungai Panjang), transect 2 (Terusan Sg Dusun), Transect 4 (Tokong Cina_West) and Transect 5 is located within a logged over forest, whereas Transect 3 and Transect 4 (Tokong Cina_East) is located on a previously burnt peatlands and Transect 6 (Jalan Haji Dorani) is located inside an oil palm estate. See Figure 1 for the location of the 6 transects and Table 1 for the summary details.

Table 1: Summary of the piezometer establish in six transects in NSPSF

Transect Name	Vegetation	No of piezometer and distance to canal	Canal perpendicular to
1 Jalan Sungai Panjang/ JSP	Logged over/ secondary forest	5 (5m, 50m, 150m, 250m and 500m)	Boundary canal
2 Terusan Sg Dusun/ TSD	Logged over / secondary forest	5 (5m, 50m, 150m, 250m and 500m)	Boundary canal
3 Parit 4 Raja Musa North/ P4R_N	Shrub/ lallang grass	4 (5m, 50m, 150m and 250m)	drainage canal from farming
3* Parit 4 Raja Musa South/ P4R_S	Lallang grass	3 (50m, 150m and 250m)	drainage canal from farming
4 Tokong Cina West/ TC_W	Logged over/ secondary forest	5 (5m, 50m, 150m, 250m and 500m)	Big ex-logging canal
4Tokong Cina East/ TC_E	Ferns/ shrubs	4 (50m, 150m, 250m and 500m)	Big ex-logging canal
5 Kunci Air Sungai Burung/ KASB	Ferns/secondary forest/logged over forest	7 (5m, 50m, 150m, 250m, 500m, 750m and 1000m)	Main Irrigation canal
6 Jalan Hj Dorani/ JHD	Oil palm	5 (5m, 50m, 150m, 250m and 500m)	Oil palm field drain and collection drain

* P4R_N was destroyed by fire in February 2014

The monitoring periods is 3 years- from December 2013 to December 2016. The monitoring was carried manually by a team of staffs who went to the field once per month and follow the Standard Operating Procedure for measuring the GWT. The duration for data taking usually took 3 or 4 days. Whenever possible, readings were carried out in the middle of each month (13-17) so that the interval gap is consistent for the duration of the study. During the monitoring period, 6 piezometers were destroyed/ damaged, where data from 5 piezometers is not taken into consideration. (One is included in the analysis because it had one and a half year of data before it was destroyed)

Climate

Selangor (where NSPSF is located), experience tropical climate with high rainfall and humidity all year round. Rainfall can be varied even locally.

Rainfall

From 2009- 2016 for Raja Musa Estate rainfall station, the mean annual rainfall is 1745.3mm; the highest rainfall recorded is 2039.2mm (2011) and the lowest rainfall recorded is 1421.2mm (2014). The monthly rainfall showed great variation; the dry month is from Jan-Feb & Jun-July, whereas the wet season start in October to December and peak in November.

Evaporation

The evaporation rate was acquired from another station- Sg Burung Station since Raja Musa Estate Station only provided the rainfall data. The annual evaporation at is in the range of 860 to 900mm/ year. The daily rate of evaporation is ranging from minimum 2mm to maximum 10mm, with average of 2.3mm to 3.5mm. Monthly mean evaporation is rather consistent at 74.3mm. From Figure 2, in 2014 & 2015 there are 4 months where evaporation is exceeding rainfall. In 2016, there are 3 months where evaporation had exceeded rainfall.

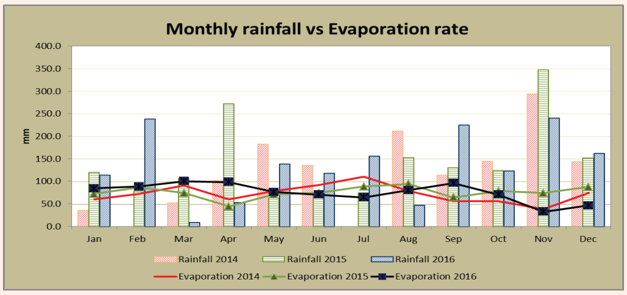

Figure 2: Monthly rainfall vs Monthly evaporation rate.

Result and Discussion

GWT observation

Comparing the data for 3 years, the mean GWT for all transects showed negative value with the exception of Transect 3/ P4R_S. 5 Transects recorded positive GWT with the highest recorded at 0.75m above peat surface. For Transect 6/ JHD, only negative GWT is recorded, with the lowest at 2.27m below peat surface (Table 2).

Table 2: Detail of the total of data recorded, mean, St Dev. and highest/ lowest GWT

Transect	Number of observation	Mean GWT (m)	St Dev (m)	Highest GWT (m)	Lowest GWT (m)
Transect 1/JSP	185	-0.3	0.22	0.05	-1.06
Transect 2/TSD	184	-0.21	0.18	0.33	-0.71
Transect 3/ P4R_S	108	0.05	0.17	0.25	-0.5
Transect 4/ TC_W	144	-0.32	0.28	0.75	-0.85
Transect 4/ TC_E	144	-0.26	0.23	0.65	-0.68
Transect 5/KASB	222	-0.25	0.4	0.31	-1.54
Transect 6/ JHD	184	-0.9	0.5	-0.03	-2.27

Positive value indicate GWT above peat surface; Negative value indicate GWT below peat surface Breaking down the data year by year (Table 3), mean GWT in 2014 showed the lowest, but in 2015, it goes back up only to dropped again in 2016, although not to the level in 2014.

Table 3: Mean GWT by year

Transect	Mean GWT (m)		
	2014	2015	2016
Transect 1/JSP	-0.39	-0.17	-0.32
Transect 2/TSD	-0.28	-0.15	-0.2
Transect 3/ P4R_S	-0.05	-0.05	-0.04
Transect 4/ TC_W	-0.33	-0.19	-0.33
Transect 4/ TC_E	-0.29	-0.16	-0.28
Transect 5/KASB	-0.54	-0.03	-0.18
Transect 6/ JHD	-1.22	-0.52	-0.93

Below are summary for each transects, see also Figure 3 for diagrammatic presentation.

Transect Jalan Sungai Panjang / JSP

Generally, GWT recorded in this transect is average for a forested site. 56% of the GWT is within the range of 0-0.30m below peat surface. About 4% of the data showed GWT above peat surface (during the wet months- especially in November). 21.6% is falls in the range of 0.31-0.50cm while about 18.4 dropped below 0.5m (with 82% coming from 2014, the dry year). 0.5% of the GWT dropped below 1m. The boundary canal was connected to a culvert where the water flowed to the other side of the road, so water is definitely being drained away. There is another canal located 800m away which could possibly have some effects on the overall water table in this area.

Transect Terusan Sungai Dusun/ TSD

Generally, GWT recorded in this transect is higher compared to the reading in JSP. 60% of the GWT is in the range of 0-0.30m below peat surface while 10% of the data showed GWT above peat surface. 21% of the GWT falls in the range of 0.30-0.50m. Only 8% of the GWT dropped below 0.50m but none dropped more than 1m. There are outlet points along the JPS bunds where water from the boundary canal can pass through to the JPS canal, which is draining the peat water.

Transect Tokong Cina_West / TC_W

Generally, water table recorded in this transect is low for a forested site. Close to 37% of the GWT falls in the range of 0-0.30m while about 13% of the GWT is above peat surface. 25% each of the GWT falls in the range of 0.30-0.50m & 0.50-1.00m. None of the GWT dropped below 1m. Although this transect may not have impacted by the secondary canal on the east side, however, considering the fact that this transect is located 4km into the forest reserve, this shows that the ex-logging canal is draining water away.

Transect Kunci Air Sungai Burung/ KASB

Generally, water table recorded in this transect showed great fluctuation for a forested area. About 34% of the GWT is above peat surface (mostly in 2015) while 29% of the GWT is the in the range of 0-0.30m. 12.6% of the GWT is in the range of 0.30-0.50m while 17.6% in the range of 0.50-1.00m. About 7% of the GWT is below 1m (all recorded in 2014). It appeared that the smaller canal parallel to this transect had significant impacts on the water table. Although the whole distance of this transect is 1000m from main irrigation canal, but the distance to the smaller canal is less than 100m.

Transect Tokong Cina_East / TC_E

Generally, water table recorded in this transect is high for an open and degraded area. About 38% of the GWT is in the range of 0-0.30m while 11% of the GWT is above peat surface. 36.8% of the GWT is in the range of 0.30-0.50m. About 14% of the GWT is between 0.50-1.00m. None recorded GWT below 1m. Historically, this area is subjected to repeated fire which resulted in peat lost. The lowering of the peat surface due to peat loss could be reason why the water table is high in TC_E.

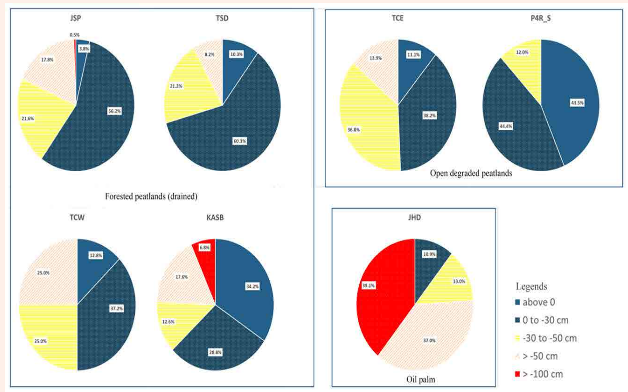

Figure 3: GWT breakdown by category.

Generally, GWT in this transect is high for open degraded area. 43.5% of the GWT is above peat surface, while about 44% of the GWT is in the range of 0-0.30m, and the rest of GWT is in the range of 0.30-0.50m. None of the GWT dropped below 0.50m. Historical this area was cleared illegally and planted with cash crops, with numerous drainage canals. It has also been subjected to repeat fire even after the illegal agricultural activities was stopped. Subsidence due to drainages and fire could lowered the peat surface significantly, thus gave an impression of high GWT. In addition, this area had undergone rehabilitation with most of the canals blocked; this also increase the GWT water table in this area.

Transect Jalan Haji Dorani/JHD

This transect recorded the lowest GWT during the monitoring period; Only 11% of the GWT is in the range of 0-30m while 13% of the GWT is between 0.30-0.50m. 37% of the GWT is between 0.5-1.0m below peat surface and 39.2% of the data showed GWT more than 1m below peat surface. In 2014, the "dry" year, WT dropped to more than 2m below peat surface. This transect is in a smallholder oil palm area, who doesn't practice good water management. It is not surprising to see GWT dropped to 1m, but it is not very often to see GWT dropped below 2m.

GWT relation to rainfall

Fluctuation of GWT greatly influence by rainfall. High GWT was recorded during the raining season (Nov-Dec) whereas low GWT were recorded during the dry season (July-Aug). In 2014, lowest GWT are recorded for all transects, incidentally, 2014 is also the 'dry" year, with rainfall totaling only 1421.2mm. As fluctuation of GWT water table in a peat swamp depends mainly on rainfall [9,10,12], the result suggested that NSPSF is falls into ombrogenous type where rainfall is the only water sources

GWT on forested area (drained)

The mean GWT for 4 forested transects (Transect 1/JSP, Transect 2/TSD, Transect 4/ TC_W & Transect 5/KASB) are ranging from -0.30m to -0.21m. GWT above peat surface were recorded during wet season. Lowest GWT recorded ranging from -0.85 to -1.54m below peat surface. It should be noted that the lowest GWT are all recorded in 2014 except one transect.

There are not many long term monitoring of GWT in peat swamp forest, particularly within the study area. Earlier GWT monitoring in the NSPSF was conducted from December 1997 to July 1998, during the 7 months period, piezometers were positioned in 2 transects perpendicular to a canal to measure the impacts of canals on water levels. None of the GWT is above peat surface and during dry period, reading more than 1m below peat surface was recorded [20]. In another study in 2000, GWT was measured from Oct to Dec 2000, and the result showed the lowest is at -31.5cm and the highest is at +22.6cm above the peat surface [15], as the study was conducted during raining season, the high water level most likely is the result of high rainfall.

GWT monitoring in other peat swamp forest in Malaysia also showed similar fluctuation; In Pekan PSF in Pahang, GWT was observed 20-50cm above peat surface during wet months, but falls to 40-90cm during dry months [16]. In Southeast Pahang PSF, GWT below 100cm to 200cm had been recorded during dry months (IMP SEPPSF, 2005). In Klias peat swamp forest in Sabah, the highest GWT recorded is 8cm above peat surface, but the lowest recorded is 172cm below peat surface [18]. GWT fluctuation (from Oct 2002 to Oct 2004) on top of a peat dome ranging from about 20cm above peat surface and 100cm below peat surface [18].

In Indonesia, record of GWT from Sebangau peat swamp forest in Central Kalimantan, GWT above peat surface were recorded [21-23], during rainy season but reached about 1m and beyond in dry season [21,22]. In Jambi, Sumatra, GWT in +(3-5) cm was recorded from peat swamp forest [24].

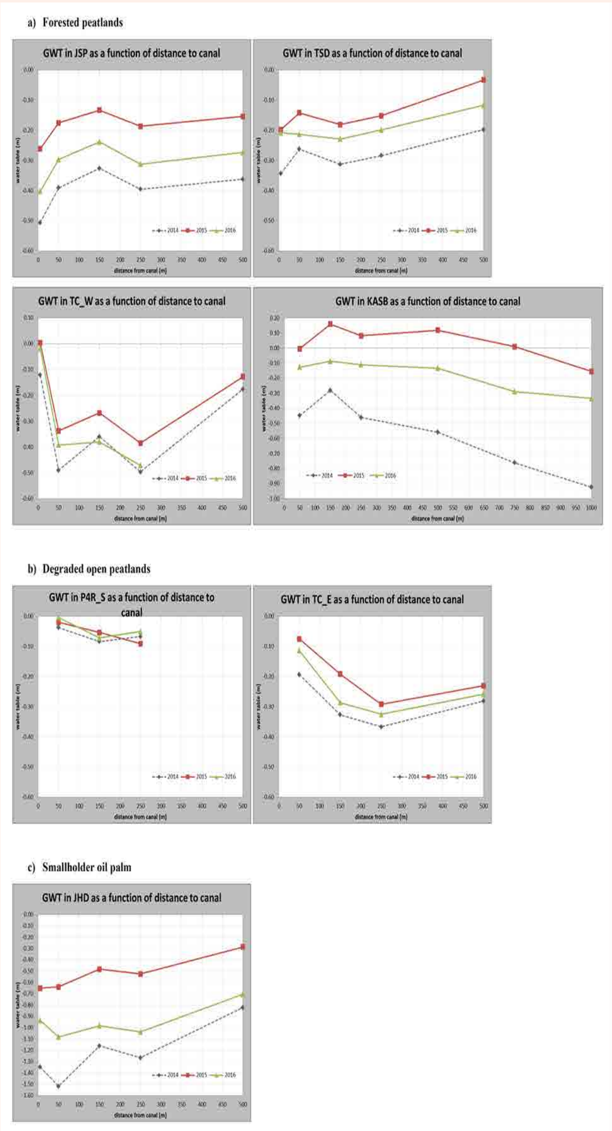

Figure 4: Annual average GWT plotted against distance from canals

GWT on degraded open peatlands

The two transects which was located on degraded peatlands, mean GWT is 5cm above peat surface and 26cm below peat surface. Highest GWT recorded is 25cm and 65cm above peat surface whereas lowest GWT is 50cm and 68cm below peat surface. As mentioned earlier, historical disturbance such as fire and subsidence may have lowered the peat surface, causing the area to be flooded in wet months. The result agreed with the monitoring of GWT in Air Hitam Laut catchment in Jambi, Sumatra where higher GWT (flooded) is found in burnt peat swamp forest [6]. However, GWT does not reach peat surface even on wet months in open peatlands [16].

GWT on oil palm estate

As expected, this transect had the lowest GWT during the monitoring period. Mean GWT of 90cm below peat surface does not represent good water management on the oil palm estate. The lowest GWT at 2.27m below peat surface is certainly not a good practice. While an oil palm plantation can maintained GWT at -0.56 ± 0.06m for 5 years old oil palm stands [25], some can even maintain water table at -0.37 ± 0.12m [26], however, it would not be possible for an oil palm smallholder to follow suit. They often cannot even maintain the recommended GWT set by RSPO manual on BMP for oil palm cultivation on peat [27] at 50-70cm.

Effect of drainage to GWT

Referring to the Figure 4, although drainages had had effect on the GWT, it is not very conclusive that GWT decrease towards canals as found in other studies found [15,20,28,29]. In fact, few of the transects showed higher GWT towards the canal. Again, one may have to look into the past to find the cause. Often, area immediately to canal tends to be subjected to repeated fire. Fire resulted in the loss of peat surface, causing the area lowered than the rest, thus giving the impression of higher GWT. In term of the drawdown effect of canal on GWT, it was shown that canal had effect on the GWT at least as far as 500m. Although in Transect KASB, GWT was significantly lowered in 1000m from the main canal, but it is likely that the smaller canal parallel to the transect had also impacted on the GWT. Previous study in 1999, GWT was shown to be reduced as far as 700m from the drainage canals [14] whereas impacts of drainage had been reported as far as 2km inside forest which is adjacent to an Acacia plantation [13].

Conclusion

Fluctuation of GWT depends mainly on rainfall received. Low rainfall in 2014 resulting in overall lowered GWT in all the transect monitoring points. Forested sites recorded higher GWT compared to non-forested site. As expected, smallholder oil palm area recorded the lowest GWT. Relatively higher GWT in some of the open areas likely due to the loss of peat surface from repeated fire. Overall, GWT recorded in NSPSF show negative value in most of the months except for November and December when the high rainfall increased the GWT. This result is similar to other peat swamp forest in Malaysia and Indonesia but with variable Even though NSPSF is a forest reserve, however, due to the presence of unblocked drainage canals- water continually lost from the system. Drainage canals, be it small or big, boundary canal or field drains, if water is being drained away from the peat ecosystem, it will have effect on the overall GWT. The complexity of the canal networks in NSPSF had made the result less conclusive. For example, it is not clear if the GWT in one area is affected by single canals or the effects of numerous canals in the vicinity.

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