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Predicting peatland groundwater table and soil moisture dynamics affected by drainage level

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ABSTRACT

Excessive drainage of peatlands can cause subsidence and irreversible drying; therefore, it is necessary to predict groundwater levels in peatlands to ensure adequate water for crops and control excessive water loss simultaneously. This study aimed to predict the peatland groundwater level and soil moisture affected by drainage. This research was conducted in a peatland located in Rasau Jaya Umum, Kubu Raya Regency, West Kalimantan Province, Indonesia from February to December 2016. Three treatments of drainage setting were established with maize cropping: without drainage (P0) and drainage channel with water level maintained at depths of 30 cm (P1) and 60 cm (P2) from the soil surface. The results indicated that a polynomial regression model is a good approach to predicting groundwater table level and soil moisture in peatlands, with R^2 values ranging 0.71-0.96 and 0.65-0.93, respectively. For agricultural purposes, maintaining the water level at 30 cm from the soil surface in the drainage channel appears to be the ideal level as adequate soil moisture is provided for annual cash crops and drying is prevented simultaneously.

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1. Introduction

Indonesia has 21 million ha of peatlands that are spread over the islands of Sumatra, Kalimantan, Papua, and parts of Sulawesi (Agus & Subiksa, 2008). Peatlands in West Kalimantan cover 1.73 million ha (BPS Provinsi Kalimantan Barat, 2011). These wetland habitats are widely used for agriculture, plantations, and housing. In agriculture, crops (mainly maize) and horticulture (fruits and vegetables) are generally grown on peatlands. Peatlands have two types of pores – the macropores between the fibers and within the fibers – and the dominant type depends on the weight of the contents. Total peat porosity includes relatively large, inter-particle pores that can actively transmit water and relatively small pores formed by remnants of plant cells (Hayward & Clymo, 1982; Kremer, Pettolino, Bacic, & Drinnan, 2004).

Peat soil is a heterogeneous and anisotropic porous media, where hydraulic conductivity greatly influences the movement of water in the soil (Beckwith, Baird, & Heathwaite, 2003b). Peat soils have vertical (Kv) and horizontal (Kh) saturated hydraulic conductivity, and the Kh value is greater than Kv, which accelerates the leaching of nutrients into the drainage channels. The Kh/Kv value of the Humberhead Peatlands in England is reportedly 3.55 (Beckwith, Baird, & Heathwaite, 2003a) and 1.8 (Whittington & Price, 2013). The saturated hydraulic conductivity (Kh) of peat soils in Rasau Jaya, West Kalimantan is 4.67 cm hour^{-1} (Chandra, 1989) and 41.67-125 cm hour^{-1} in Sarawak (Ong & Yogeswaren, 1992).

The average underground water level during the wet period is greater than the dry period due to the contribution of rainfall (Manghi et al., 2009). The peatland groundwater level should be maintained at 50-70 cm for perennial crops. Maintaining a water level of 70 cm in the drainage channel raised peat groundwater level to 30 cm from the soil surface (Imanudin & Bakri, 2016). Extending the drainage channel from 30 to 50 m raised groundwater level only 2-3 cm from 40-50 cm (Tarigan, 2011).

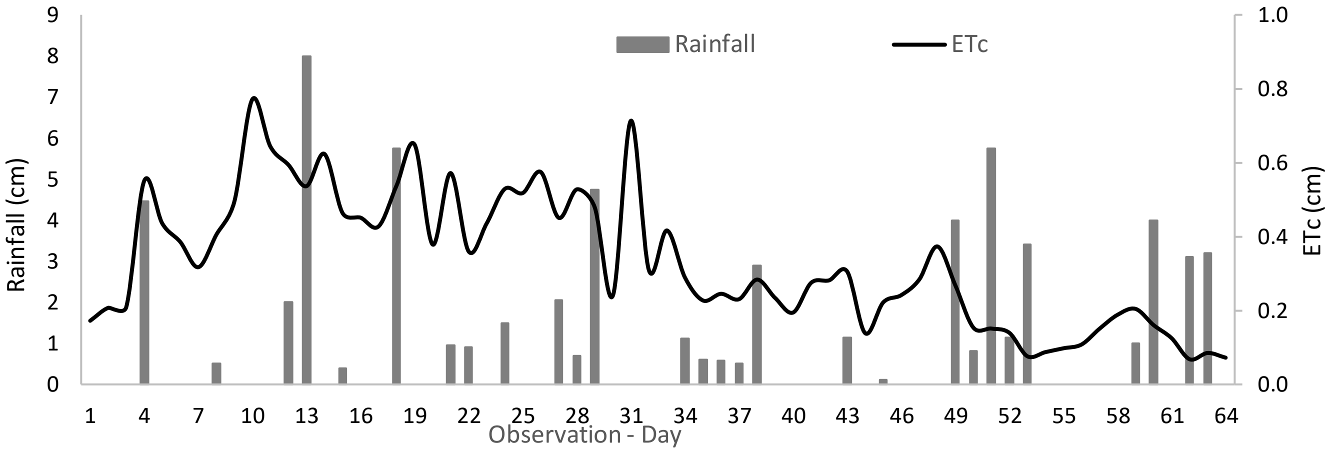

Figure 1. Daily rainfall and potential evapotranspiration during 66 observation days

Water balance models (based on the calculation of incoming and outgoing water) are widely used by hydrologists for various purposes, such as estimating soil moisture and planning irrigation. The water intake component includes the percentage of rainfall, surface flow, irrigation water, percolation water, and subsurface water, while the water outflow component includes evaporation, consumptive use, and groundwater flow (Manghi et al., 2009). Water balance models have been conducted to estimate actual evapotranspiration rates (Xu & Singh, 2005; Jassas, Kanoua, & Merkel, 2015) and the dynamics of underground water under mineral soil (Manghi et al., 2009; Getirana et al., 2014; Yihdego & Khalil, 2017). Currently, few studies have predicted peatland groundwater level dynamics and soil moisture content under maize farming. Hence, the purpose of this study is to determine the accuracy of predicting groundwater level dynamics and soil moisture content under maize farming in peatlands.

2. Materials and Method

The study was conducted in the Rasau Jaya Umum village in the Rasau Jaya District, Kubu Raya Region, West Kalimantan Province, Indonesia located at 0°13'49.02"S, 109°23'57.03"E. Daily rainfall was observed using a typical rainfall gauge (ombrometer). Climate data (air temperature, relative humidity, and wind speed) were observed in the field, while solar radiation data was taken from the nearest climate monitoring station (Supadio Airport, Pontianak). Climatic data were used to calculate reference levels of evapotranspiration. Daily reference evapotranspiration was calculated using the radiation equation. Potential crop evapotranspiration was calculated by multiplying the maize plant coefficient with reference evapotranspiration (Allen, Pereira, Raes, & Smith, 1998). Daily rainfall and evapotranspiration are presented in Figure 1. From the 64 days observed, rainfall occurred on 28 days with total precipitation reaching 66.06 cm and a mean potential evapotranspiration of 0.343 cm day^{-1} (Figure 1). The average wind speed, air temperature, relative humidity, and photoperiodicity were 1.39 m s^{-1}, 29.51°C, 78.05%, and 5.36 hours, respectively.

The research site had previously never been cultivated and was initially occupied by native, shrub-like vegetation. Peat soil in the research area varies in thickness ranging from 290-670 cm, has a maturity level of the hemis to a depth of 100 cm, and consists of the Haplohemist soil type. Land clearing and drainage channel construction were carried out over 2 months starting on February 8, 2016. Fourteen tons of sea mud were taken and dried for 3 months. The destruction of sea mud and sifting (5 mesh) was carried out for 2 months. Maize plants were grown from September 10 to December 20, 2016.

For the treatments, water depth in the drainage channel was maintained at three depths – 0 cm (P0, control, without drainage), 30 cm (P1), and 60 cm (P2) from the soil surface. The size of each plot was 0.2 ha (40 m × 50 m). The layout of the experimental site and pictures of the water level regulating gates and drainage channels are presented in Figure 2. Figure 2a shows that the length of each plot was 50 m, with a buffer zone of 10 m between plots. Drainage channels had a width of 60 cm (Figure 2b), and the depth varied according to the treatment (no drainage channel for P0, 30 cm for P1, and 60 cm for P2). Semi-permanent water doors (Figure 2c) were made from wood to maintain the water depth in the drainage channel.

Land preparation began by applying 8 tons ha^{-1} of sea sludge in an array manner (Suswati, 2012). The maize cultivar selected for the study was Pioneer 21. One seed of the cultivar was planted manually in each hole with a spacing of 25 cm × 75 cm. The fertilizers applied were urea (400 kg ha^{-1}), SP 36 (300 kg ha^{-1}), and KCl (100 kg ha^{-1}) (Suswati, 2012). Fertilizers were applied in three periods; the first period was 5-7 days after planting (dap) with the application of urea, SP 36, and KCl (40, 100, and 50% of the dose, respectively). The second period was 28-30 dap with the application of urea and KCl (30 and 50% of the dose, respectively). In the last period, only urea was applied 40-45 *dap*.

The prediction of groundwater-surface changes and soil moisture content due to the influence of rainfall and evapotranspiration was based on the below polynomial regression equation of "r" (Chandra, 1989).

$\Delta DR = a0 + a1R + a2R2 + \text{---------} + arRr$ ....(1)

$\Delta DE = a0 + a1E + a2E2 + \text{---------} + arEr$ ....(2)

$\Delta WR = a0 + a1R + a2R2 + \text{---------} + arRr$ ....(3)

$\Delta WE = a0 + a1E + a2E2 + \text{---------} + arEr$ ....(4)

Where:

ΔDR: Changes in groundwater surface affected by rainfall (cm day^{-1})

ΔDE: Changes in groundwater surface affected by evapotranspiration (cm day^{-1})

ΔWR: Changes in groundwater content affected by rainfall (% vol.)

ΔWE: Changes in groundwater content influenced by evapotranspiration (% vol.)

R: Rainfall (cm day^{-1}) results of field measurements

E: Potential evapotranspiration (cm day^{-1})

a0, a1, a2, ------ ar: constants

The prediction of groundwater-surface changes and soil moisture content due to the influence of rainfall and evapotranspiration was based on the below polynomial regression equation of "r" (Chandra, 1989).

$D = D_{init} + \Delta DR - \Delta DE$ ....(5)

Where

D: Predicted groundwater table level (cm)

$D_{init.}$: Groundwater table level at the beginning of measurement (cm)

The calculation of soil moisture content is a combination of Equation (3) and (4), resulting in the equation below.

$W = W_{init.} + \Delta WR - \Delta WE$ ....(6)

Where

W: Predicted soil moisture (% vol.)

$W_{init.}$: Initial soil moisture at the beginning of measurement (% vol.)

Groundwater depth was observed by establishing holes 10 cm in diameter and 150 cm deep at three observation points in each plot. Groundwater table levels were monitored daily using a meter. Soil moisture was measured by taking daily disturbed soil samples at 0-15 cm and 15-30 cm depths at all plots and at 30-45 cm and 45-60 cm depths at P3 only using the gravimetric method in the Soil Physics and Conservation Laboratory, Faculty of Agriculture, Tanjungpura University, Indonesia. Predicting groundwater table levels and soil moisture was done using linear regression analysis and t-test.

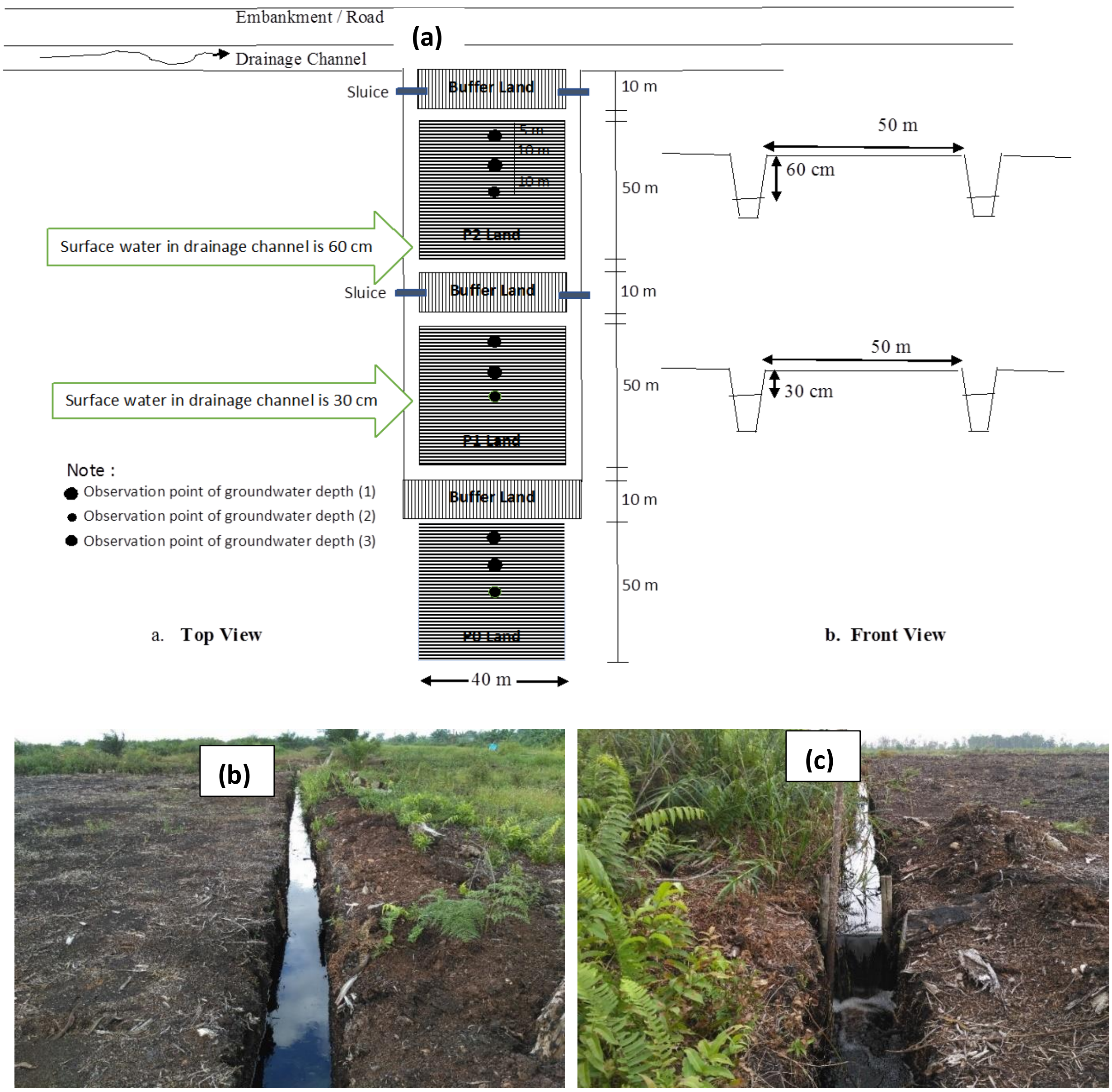

Figure 2. Plot experiment design (a); drainage channels (b); semi-permanent sluice (c)

3. Results

3.1. The dynamics of groundwater table level and soil moisture

The dynamics of the groundwater table level are presented in Figure 3, where the fluctuation was in accordance with rainfall. The fluctuation of the groundwater table level was higher under P0 and ranged from 8 cm to 49 cm from the soil surface. Meanwhile, groundwater table levels ranged 16-52 cm and 42-62 cm from the soil surface under P1 and P2, respectively. The groundwater table level under P0 and P1 exhibited similar fluctuating daily levels. In general, average groundwater table levels from the highest to the lowest were P0> P1> P2 (-30.38 > -33.59 > -49.50 cm, respectively). Figure 4 shows that the groundwater table level under P1 was higher than P2, where the equation of groundwater table level (Y) according to the distance (X) from the drainage channel are Y = - 0.004 x2 + 0.22 x - 35.75 and Y = - 0.011 x2 + 0.62 x - 55.67 for P1 and P2, respectively.

Soil moisture dynamics under each treatment at each depth are depicted in Figure 5. The fluctuation of soil moisture was in accordance with rainfall. As displayed in Figure 5, soil moistures were higher at deeper soil layers than at the surface. Without drainage (P0), soil moisture ranged from 58.80-82.37 (mean 73.89) and 65.76-86.84 (mean 79.68) % vol. at 0-15 cm and 15-30 cm soil depth, respectively. For P1, soil moisture ranged from 48.21-85.07 (mean 67.58) at 0-15 cm and 53.51-80.66 (mean 68.16) % vol. at 15-30 cm soil depth. For P2, soil moisture fluctuated from 35.76-76.62 (mean 52.72), 45.84-78.20 (mean 60.46), 52.21-76.21 (mean 66.45), and 66.77-84.47 (mean 77.38) % vol. at 0-15 cm, 15-30 cm, 30-45 cm, and 45-60 cm soil depth, respectively.

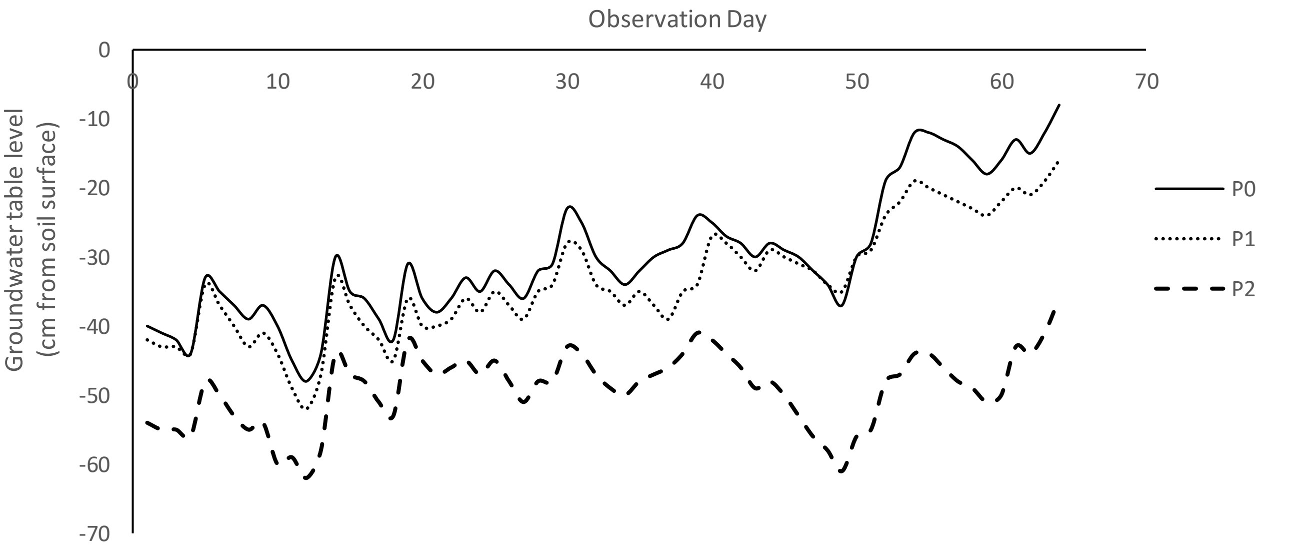

Figure 3. The dynamics of groundwater level at each treatment (P0= without drainage channel; P1= water depth maintained in the drainage channel 30 cm from soil surface; P2= water depth maintained in the drainage channel 60 cm from the soil surface)

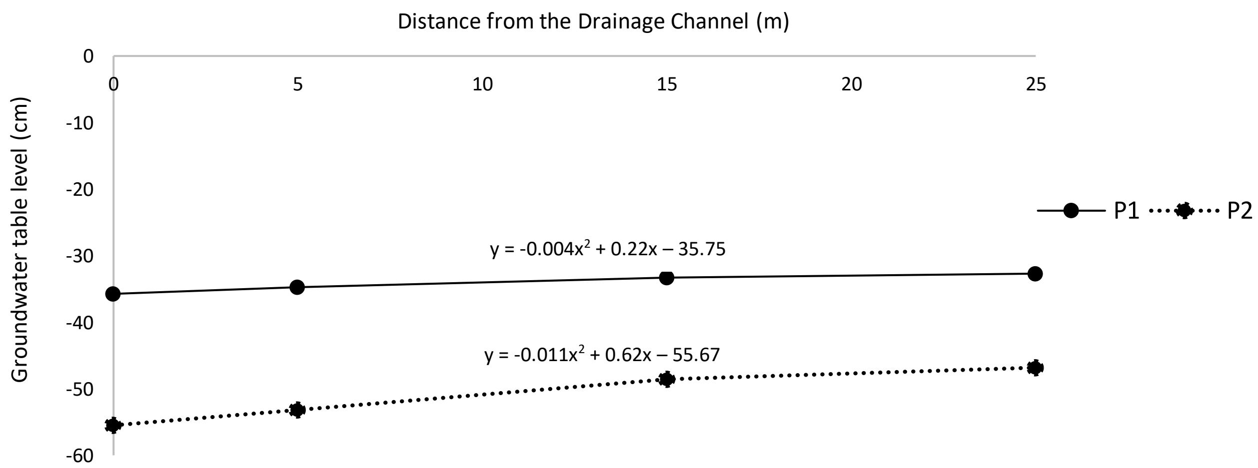

Figure 4. Mean groundwater table level according to the distance from drainage channels (P1= water depth maintained in the drainage channel 30 cm from soil surface; P2= water depth maintained in the drainage channel 60 cm from soil surface)

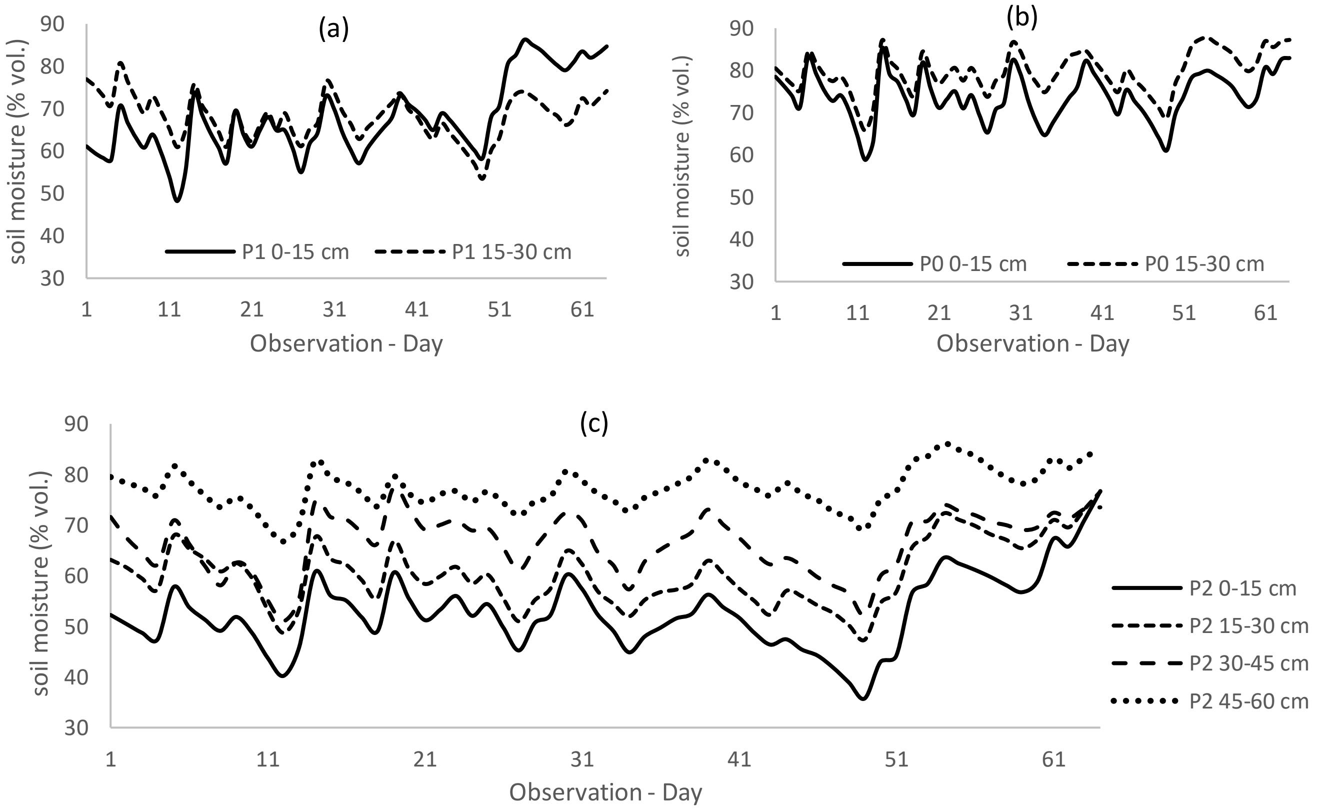

Figure 5. Soil moisture dynamics in P0 (a), P1 (b), P2 (c) at each depth (P0= without drainage channel; P1= water depth maintained in the drainage channel 30 cm from soil surface; P2= water depth maintained in the drainage channel 60 cm from soil surface)

Table 1. Predicting groundwater table level fluctuation

Treat.	**Evapotranspiration**		**ΔD_E**	
	equation	**R^2**	**equation**	**R^2**
P0	ΔD_R = - 0.0263 R^4 + 0.4012 R^3– 1.8169 R^2 + 4.1509 R – 0.4782	0.9133	ΔD_E = -53.51 E^4 + 112.52 E^3 – 71.816 E^2 + 20.777 E – 0.4723	0.7881
P1	ΔD_R = - 0.0189 R^4 + 0.3365 R^3– 1.7926 R^2 + 4.2447 R – 0.4155	0.8116	ΔD_E = 122.55 E^4 – 211.2 E^3 + 128.17 E^2 – 26.305 E + 2.6522	0.8230
P2	ΔD_R = - 0.0084 R^4 + 0.1283 R^3– 0.5141 R^2 + 1.9106 R – 0.0929	0.8925	ΔD_E = -57.9 E^4 + 93.675 E^3 – 52.073 E^2 + 14.35 E + 0.2715	0.4719

Notes: ΔD_R= Changes in groundwater table level affected by rainfall (cm.day^{-1}); ΔD_E = Changes in groundwater table level affected by evapotranspiration (cm.day^{-1}); R= Rainfall (cm); E= Evapotranspiration (cm); R^2 = coefficient of determination; P0= without drainage channel; P1 = water depth maintained in the drainage channel 30 cm from soil surface; P2 = water depth maintained in the drainage channel 60 cm from soil surface

3.2. Predicting the Groundwater Table Level and Soil Moisture

By employing Equation (1) and (2), the equations for predicting groundwater table level at each treatment were produced and are presented in Table 1. In general, rainfall was sufficient for predicting groundwater table rise (ΔDR), which is indicated by a high coefficient of determination (R^2). The order of highest to lowest R^2 for predicting ΔDR from rainfall was P0>P3>P2, which corresponds to 0.9133, 0.8925, and 08116, respectively. Additionally, Table 1 shows that evapotranspiration was rather good for predicting groundwater table level decline (ΔDE) at P0 and P1 (R^2 = 0.7881 and R^2 = 0.8230, respectively), but not good for P2 (R^2 = 0.4719).

The predicting equations in Table 2 were obtained by processing the daily rainfall and evapotranspiration data with Equations (3) and (4), respectively, to predict soil moisture at each treatment. Rainfall was sufficient in predicting soil moisture addition (ΔWR) at all depths of P0, where the R^2 values were 0.751 and 0.7260 at 0-15 cm and 15-20 cm, respectively. Similarly, the R^2 values of P1 were also high (R^2 = 0.7594 at 0-15 cm and R^2 = 0.7032 at 15-30 cm). Higher R^2 values were produced at P2, corresponding to 0.9442, 0.8915, 0.7941, and 0.8995 at 0-15 cm, 15-30 cm, 30-45 cm, and 45-60 cm depths, respectively.

Table 2 also shows that evapotranspiration was rather accurate in predicting soil moisture depletion (ΔWE), especially at 0-15 cm and 15-30 cm depths. This is indicated by the R^2 of P0 at 0-15 cm and 15-30 cm depths (R^2 = 0.7931 and R^2 = 0.8381, respectively) and of P1 (R^2 = 0.8700 at 0-15 cm and R^2 = 0.7678 at 15-30 cm). Furthermore, the R^2 for P2 at 0-15 cm, 15-30 cm, 30-45 cm, and 45-60 cm were 0.724, 0.8330, 0.5118, and 0.4840, respectively.

Table 2. Predicting soil moisture fluctuation

Treat.	Depth (cm)	ΔW_R equation	R^2	ΔW_E equation	R^2
P0	0-15	$\Delta W_R = -0.0035 R^4 + 0.118 R^3 - 0.7422 R^2 + 2.7148 R + 0.565$	0.7521	$\Delta W_E = -217.76 E^4 + 391.37 E^3 - 238.37 E^2 + 62.828 E - 2.9972$	0.7931
	15-30	$\Delta W_R = -0.0316 R^4 + 0.5172 R^3 - 2.46 R^2 + 4.7353 R - 0.2727$	0.7260	$\Delta W_E = -75.808 E^4 + 141 E^3 - 84.679 E^2 + 23.276 E - 0.214$	0.8381
P1	0-15	$\Delta W_R = -0.0358 R^4 + 0.5671 R^3 - 2.6187 R^2 + 5.2273 R - 0.107$	0.7594	$\Delta W_E = -54.68 E^4 + 64.839 E^3 - 17.461 E^2 + 6.1837 E + 0.8268$	0.8700
	15-30	$\Delta W_R = -0.0377 R^4 + 0.559 R^3 - 2.4623 R^2 + 4.4622 R + 0.2183$	0.7032	$\Delta W_E = -35.87 E^4 + 55.781 E^3 - 34.846 E^2 + 15.349 E + 0.1928$	0.7678
P2	0-15	$\Delta W_R = -0.0184 R^4 + 0.2692 R^3 - 1.1786 R^2 + 3.5039 R - 0.3027$	0.9442	$\Delta W_E = -6.2556 E^4 + 14.426 E^3 - 12.918 E^2 + 10.511 E + 0.2855$	0.7204
	15-30	$\Delta W_R = -0.024 R^4 + 0.3805 R^3 - 1.8369 R^2 + 4.4702 R - 0.6824$	0.8915	$\Delta W_E = -96.898 E^4 + 184.16 E^3 - 112.34 E^2 + 30.832 E - 0.9663$	0.8330
	30-45	$\Delta W_R = -0.0177 R^4 + 0.3083 R^3 - 1.3806 R^2 + 2.6848 R + 0.5747$	0.7941	$\Delta W_E = 26.31 E^4 + 12.611 E^3 - 45.357 E^2 + 24.789 E - 1.0477$	0.5118
	45-60	$\Delta W_R = -0.0025 R^4 + 0.077 R^3 - 0.4986 R^2 + 1.8661 R + 0.1848$	0.8995	$\Delta W_E = 21.343 E^4 - 39.608 E^3 + 28.881 E^2 - 6.6733 E + 2.0953$	0.4840

Notes: ΔW_R =Changes in soil moisture affected by rainfall (cm day^{-1}); ΔD_E =Changes in soil moisture affected by evapotranspiration (cm day^{-1}); R = Rainfall (cm); E = Evapotranspiration (cm); R^2 =coefficient of determination; P0= without drainage channel; P1= water depth maintained in the drainage channel 30 cm from soil surface; P2= water depth maintained in the drainage channel 60 cm from soil surface.

All of the daily rainfall data were processed with the equations according to each treatment in Table 1 and Equation (5). The t-test used to compare the daily predicted groundwater table levels with the actual measurements yielded non-significant (P> 0.05) differences for all treatments (Table 3). High R^2 values for the linear regression were also found, especially at P0 and P1 (R^2 = 0.96 and R^2 = 0.91, respectively) and at P2 (R^2 = 0.71), indicating that the formulas in Table 1 and Equation (5) can be used to predict groundwater table linearly. The same procedures were implemented for the daily evapotranspiration data with equations in Table 2 and Equation (6), resulting in a good R^2 range from 0.65 to 0.93 (Table 4). Table 4 distinctly shows that predicted soil moisture was more accurate at the upper layers (0-15 cm and 15-30 cm) with an R^2 range of 0.81-0.93 than at deeper layers (30-45 cm and 45-60 cm) with R^2 ranging from 0.65-0.68.

Table 3. Accuracy of predicted groundwater table level

Treat.	Groundwater table level (cm from soil surface)		P-value (*t*-test)	R^2
	Predicted	Actual		
P0	34.45	30.38	> 0.05^{ns}	0.96
P1	38.29	33.59	> 0.05^{ns}	0.91
P2	52.79	49.50	> 0.05^{ns}	0.71

Notes: P0= without drainage channel; P1= water depth maintained in the drainage channel 30 cm from soil surface; P2= water depth maintained in the drainage channel 60 cm from soil surface

4. Discussion

The polynomial regression model developed by Chandra (1989) was employed to predict groundwater table level and soil moisture in accordance with regulating the drainage channel and its water depth at the peatland study site. Results from the model were linearly accurate as indicated by the high P-value of the t-test (P > 0.05) and the R^2 values ranging from 0.65 to 0.96 (Table 3 and 4).

Table 4. Accuracy of predicted soil moisture

Treat.	Depth (cm)	Soil Moisture (% vol.)		P-value (*t*-test)	R^2
		Predicted	Actual		
P0	0-15	69.45	73.89	> 0.05^{ns}	0.79
	15-30	76.71	79.68	> 0.05^{ns}	0.84
P1	0-15	61.53	67.58	> 0.05^{ns}	0.93
	15-30	65.24	68.16	> 0.05^{ns}	0.81
P2	0-15	48.68	52.72	> 0.05^{ns}	0.93
	15-30	55.62	60.46	> 0.05^{ns}	0.88
	30-45	62.29	66.45	> 0.05^{ns}	0.68
	45-60	74.91	77.38	> 0.05^{ns}	0.65

Notes: (R^2= linear regression; P0= without drainage channel; P1= water depth maintained in the drainage channel 30 cm from soil surface; P2= water depth maintained in the drainage channel 60 cm from soil surface)

The non-significant P-value of the t-test ($\alpha > 0.05$) signifies that no significant differences were found between the actual daily observations and the predicted groundwater table level and soil moisture content obtained from the polynomial regression model in Table 1 and 2. Especially for groundwater table level, the prediction resulted in high R^2 values for P0 (without drainage) and P1 (drainage channel with water level maintained at 30 cm from the soil surface), as displayed in Table 3. On the other hand, the prediction resulted in rather low R^2 values in P2 (drainage channel with water level maintained at 60 cm from the soil surface). This is due to the higher R^2 of predicted groundwater table level from evapotranspiration linearly at P0 and P1 (0.7881 and 0.8230, respectively) compared to the very low R^2 of 0.4719 at P2 (Table 1). However, the groundwater table level and soil moisture strongly depended on meteorological factors – specifically rainfall (Abdullahi & Garba, 2016; Runtunuwu et al., 2011; Fan, Oestergaard, Guyot, & Lockington, 2014) – as indicated by the high R^2 between rainfall and groundwater table level rise and soil moisture increase (Table 1 and 2).

The higher R^2 of the linear regression of predicted groundwater table level from evapotranspiration at P0 and P1 compared to P2 (Table 1) may be attributable to maize evapotranspiration, which was supplied from the groundwater through capillary force. This is a result of the vertical capillary force downward due to gravity (Fraser, Roulet, & Lafleur, 2001) surrounding the maize root zone (mainly 0-30 cm depth). Thus, the favorable groundwater table provided for the root zone was P0 and P1, where the groundwater table levels were 8-52 cm below the soil surface (Figure 3), rather than the deeper P2. This is in line with the study by Lafleur et al. (2005), where the evapotranspiration rate appeared unaffected by the water table level below 65 cm. The smaller distance from the groundwater table level to the root zone led to lower capillary rise and lower hydraulic gradient and, thus, lower hydraulic conductivity (Schwärzel et al., 2006). The large porosity of the peatland may cause a small capillary force that can bind a lot of water yet release the water quickly.

Soil moisture depends on meteorological factors (e.g., rainfall and evapotranspiration) and groundwater table levels (Chandra, 1989). Our results indicated high R^2 values of soil moisture increase and decline due to rainfall and evapotranspiration (Table 2), which illustrates the dependence of soil moisture on rainfall and evapotranspiration. Moreover, the soil moisture content at 0-15 cm and 15-30 cm under P0 and P1 tended to be higher than at P2 (Figure 5), likely because of the higher groundwater table level (Figure 3). The lower groundwater table level resulted in lower dependence on meteorological factors – specifically evapotranspiration on soil moisture fluctuation as shown by low R^2 of soil moisture decline at 30-45 cm and 45-60 cm depth in P2. This is likely attributable to the differential head response of peat (lower layer) to changes in the water table elevation (Fraser et al., 2001).

In general, the results confirmed that setting the drainage channel and maintaining the water level at particular depths on peatlands distinctly contributed to the groundwater table level and soil moisture. The lower water level in the drainage channel consequently resulted in lower groundwater table levels and soil moisture (Figure 4). The setting of the drainage channel should be adjusted according to land-use and land-cover planning, especially for agriculture and plantation crops. For agricultural purposes, maintaining the water level at 30 cm from the soil surface in the drainage channel seems to be the ideal setting, as this level provides adequate soil moisture for annual cash crops while simultaneously preventing droughts. The polynomial regression model used in this study is a good approach to predicting desired groundwater table levels and soil moisture to determine the drainage channel dimensions. However, while discrepancies between the actual and predicted values cannot be avoided, the accuracy of prediction can be increased by taking into account intra-flow influences (Querner et al., 2010).

5. Conclusion

Polynomial regressions are a valid approach to predicting groundwater table levels and soil moisture in peatlands according to drainage channel implementation and its water level setting. Predicted groundwater table levels were 0.71-0.96 linear with the actual observations, while they were only 0.65-0.93 linear with predicting the soil moisture due to low evapotranspiration influences at lower layers. Overall, maintaining water levels at 30 cm from the soil surface for peatland preservation alongside agricultural cultivation purposes appears to be the most ideal setting because it may provide sufficient water for plants and prevent drought.

Declaration of Competing Interest

The authors declare no competing financial or personal interests that may appear and influence the work reported in this paper.

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