Analysis of hydrology parameters in a tropical wetland as an early approach to identify a drought risk in a peatland area

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Analysis of hydrology parameters in a tropical wetland as an early approach to identify a drought risk in a peatland area

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Abstract. The hydrological condition can be determined by investigating local data or analyzing historical climatological records. Several methods can approach the wetland condition, including peatland in general. The definition of physical properties to assess critical groundwater table depths is one of them. Another way is to define the requirements in the area that can be approached by determining the condition of the wetland area for general. Understanding and assessing the wetland state is necessary to measure and evaluate the wetland situation, and it can be done by analyzing wetland hydrology parameters. Due to the necessity to mitigate change conditions in a wetland, it is common to know that either flood or drought will derive a difficult situation both in a wetland and a peatland but especially for a peatland, drought condition is severe. This study aims to observe the wetland condition and identify whether the wetland area has drought risk potential, especially in the peatland site. The study was conducted by directly taking data from the study location and downloading satellite data from local and regional websites: the local climatology agency Badan Meteorologi, Klimatologi dan Geofisika (BMKG Indonesia), and the Jaxa website. The data from satellite needs to be used related to the limitation of ground data in the study location. The result showed that the satellite has an excellent relationship to the ground data with a pretty low root mean square error (RMSE) number. In addition, it showed the correlation between the amount of monthly rainfall and evapotranspiration with the water table elevation. It can be concluded at the initial conclusion that the decreased rainfall and the high evapotranspiration in a particular month can be expected the drought risk potentially will happen.

Keywords*: wetland condition, hydrology parameter, rainfall, evapotranspiration, water table elevation, drought risk*.

1. Introduction

The advantages of wetlands include improving water quality, biodiversity, unique flora and fauna habitat, and other ecological benefits on a broader scale [1]. Wetlands are believed to be productive areas because of the types of plants and fish in them, so the reduced volume of wetlands both in number and area brings losses to life in general [2–4]. This thought brings some researchers, including the United States and Europe, to study the restoration of damaged or unnatural wetlands. This study has become a concern, and research has been done to see whether a wetland restoration affects hydrological changes, including water balance [5–9].

The condition of a wetland can be seen from the presence of hydric soil, hydrophytic vegetation, and hydrology. The hydrological condition of the wetland can be analyzed by taking local data carried out at the desired place at a particular time or by analyzing local climatological records. They include recording rain data, flow data, temperature, evaporation, and groundwater levels. Wetlands are defined based on the presence of water and the representation of plants that can live in anaerobic soil and anaerobic conditions. The duration of anaerobic conditions, inundation height, or groundwater requirements for each swamp area is not the same [10,11]. The necessity to research in a tropical wetland becomes evident since the measuring data and the characteristics were also different [12].

Wetland inventory is the collection or investigative work of core information or obtaining or providing comprehensive information for wetland management, including providing an information base for specific assessment and monitoring activities [13–15]. Understanding the appropriate approach in a particular wetland will result in a good assessment covering multidisciplinary aspects [16]. Wetland assessment in a quick way needs to visit the site study to ensure that the method is suitable to the current situation [17].

One of the wetland classifications is peatland, recognized by the unique characteristics of the soil. Peatland is defined in two ways; those are by its chemical conditions or by hydrological state. Several methods had been developed to recognize whether the condition of a peatland needs to be responded. The definition of physical properties to assess critical groundwater table depths is one of them [18], and to use a certain number an index drought [19–21]. Another method is to define the conditions in that area can be approached by describing the situation of the wetland area for general [22,23] and human activities to the drought severity [24]. Water table elevation is determined by hydrology parameters: rainfall, evapotranspiration, and direct runoff [25]. Understanding the situation and assessing the wetland well is necessary to measure and evaluate the wetland situation. It can be done by analyzing wetland hydrology parameters and their correlation to water table elevation [26–28]. Due to the necessity to mitigate change conditions in a wetland, it is common to know that either flood or drought will derive a difficult situation both in a wetland and a peatland but especially for a peatland, drought condition is severe.

This research aims: 1) to observe the water table elevation in a particularly peatland area, 2) to analyze the hydrology parameters covering rainfall, evapotranspiration, and the connection two of them with the water table elevation and try to identify the drought risk by analyzing the relation between them.

2. Materials and methods

2.1. Study location and data availability

Research had been conducted in South Kalimantan for general and a particular peatland area in Dandajaya Barito Kuala district, Province of South Kalimantan. The location of the study and the distribution of peatland in South Kalimantan can be seen in Figure 1.

The data collection is divided into two parts, the primary data were obtained from installed equipment, and the secondary data were obtained from the related satellite. The secondary data were obtained from the Jaxa satellite for Kalimantan and will be compared to ground data from Syamsuddin Noor gauge. The primary data were collected from June to July 2021 in Dandajaya, Barito Kuala, South Kalimantan. This region, recognized as a peatland, has been drained for several purposes: agriculture and community plantation. Barito Kuala has been renowned as an orange product region for years. The study was conducted in a farming area called a drained peatland where the condition had changed from an intact peatland.

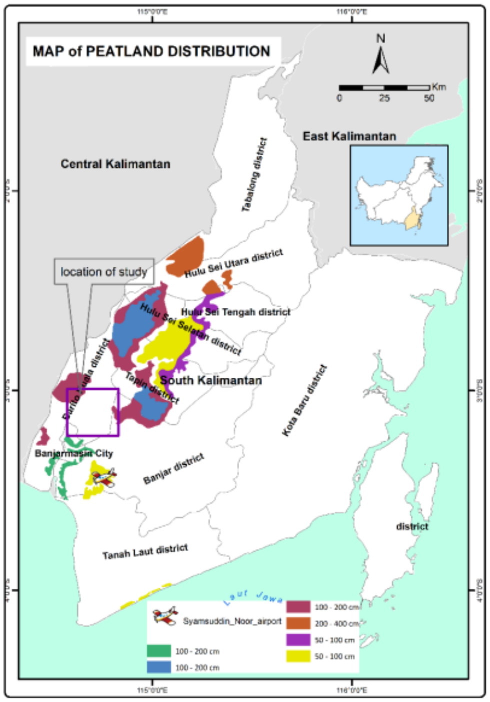

Figure 1. Location of study

The equipment had been installed for one and half months and been conducted to collect daily water table elevation. Since the equipment is in a simple shape, getting the data is obtained by manual measuring. A reader staff comes to the study site regularly twice a day, at 6 am and 4 pm, to get the data and record it in a data logbook. The data were separated between the morning and the evening data. Sketch and location of installed manual equipment can be seen in Figure 2. and Figure 3.

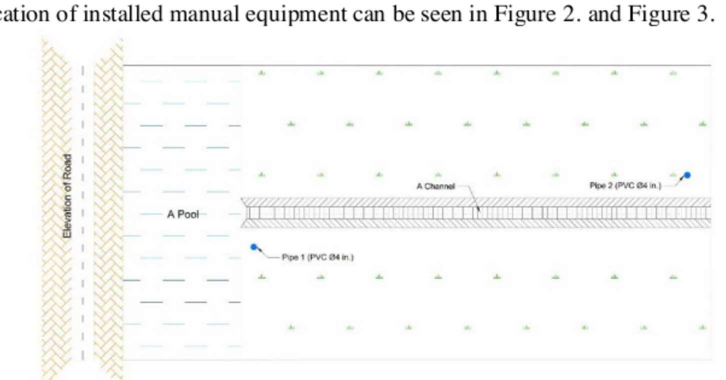

Figure 2. Sketch of installed equipment

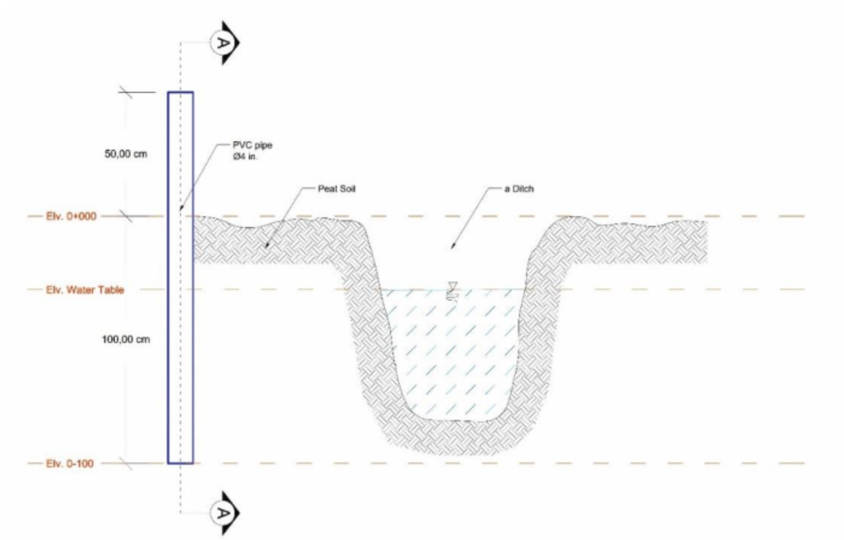

Figure 3. Cross-section of installed equipment

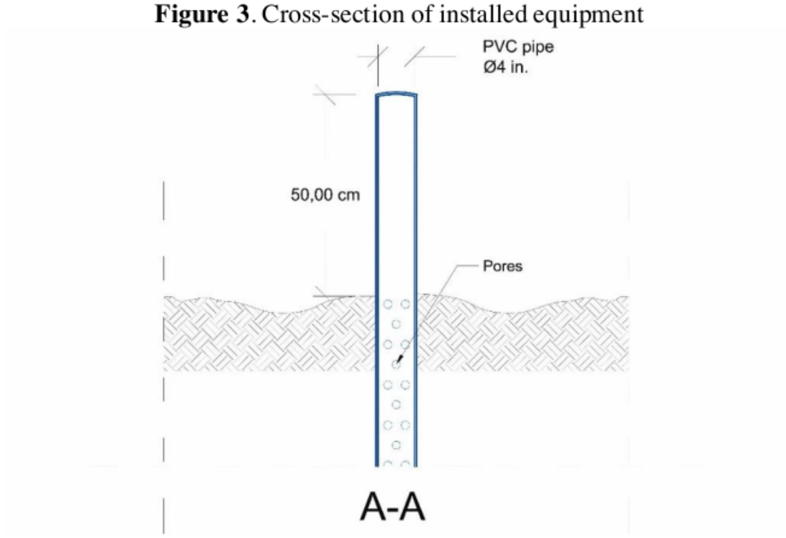

Figure 4. Details of pipe that was installed in the study side

Data obtained from the two pieces of equipment and be categorized as a daily water table elevation. Pipe 1 and pipe 2 in Figure 2 are the same as point 1 and point 2 in the description, and an example of it can be seen in Table 1 below.

Table 1. Daily water table elevation data

No	Date	Time	Observed data (cm)	Note
1	Saturday June 19, 2021	morning 07.00		
		evening 17.00	-74	
2	Sunday June 20, 2021	morning 07.00	-72	
		evening 17.00	-70	
3	Monday June 21, 2021	morning 07.00	-70	Rain
		evening 17.00	-70	
4	Tuesday June 22, 2021	evening 07.00	-71	Dry/hot
		evening 17.00	-70	
5	Wednesday June 23, 2021	morning 07.00	-72	
		evening 17.00	-70	
6	Thursday June 24, 2021	morning 07.00	-70	
		evening 17.00	-72	
7	Friday June 25, 2021	morning 07.00	-72	
		evening 17.00	-70	
8	Saturday June 26, 2021	morning 07.00	-71	
		evening 17.00	-70	
9	Sunday June 27, 2021	morning 07.00	-70	
		evening 17.00	-70	
10	Monday June 28, 2021	morning 07.00	-72	
		evening 17.00	-71	

2.2 Analyze evapotranspiration

One of the simple methods to measure evapotranspiration that can be applied in various areas, such as sub-tropics and tropics areas [29–31] which had been widely used in multiple studies, is the Blaney-Criddle method. It is suitable to the region with data provided limitations. The modified formula can be written below [31]:

$$ET_o = a + b[p(0.46T_{mean} + 8.13)] \quad (1)$$

with

$$a = 0.0043RH_{min} - \frac{n}{N} - 1.41 \quad (2)$$

$$b = 0.82 - 0.0041RH_{min} + 1.07\frac{n}{N} + 0.066U - 0.006RH_{min}\left(\frac{n}{N}\right) - 0.0006RH_{min}(U) \quad (3)$$

where:

ET_o : daily evapotranspiration (mm/day),
a and b : the coefficients depended on U, RH_{min} and n/N,
p : the ratio of mean annual percentage of daytime hours,
T_{mean} : mean daily temperature for a given month in degree Celsius,
RH_{min} : minimum relative humidity (%),

n/N : ratio of possible to actual sunshine hours,
U : mean daytime wind speed (m/s)

2.3 Rainfall analysis methods
Rainfall was analyzed by comparing the satellite from the Jaxa website to ground data from Syamsuddin Noor gauge during 2021. The study research did from last June until the end of July, and the water table elevation data was provided as well. Those data will be compared to determine whether the peatland area, especially the study area Dandajaya Barito Kuala South Kalimantan Province has a potential drought risk at the time. The root mean square error (RMSE) formula had been used in this analysis, and it is used to see how well a prediction data fit the actual data. The formula is described below:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(x_i - y_i)^2}{N}} \quad (4)$$

where:
R.M.S.E. : root mean square error
x_i : satellite data from the Jaxa web (mm)
y_i : ground data from Syamsuddin Noor gauge (mm)
N : number of data according to the total of days in a month

Secondary data were obtained from the Meteorological, Climatological, and Geophysical Agency website or Badan Meteorologi dan Klimatologi Geofisika (BMKG) in Indonesia language, which only provides data in Syamsuddin Noor gauge, mainly in daily rainfall. As an integrated approach, it will be required to have daily data for a whole Kalimantan Selatan, which does not become possible this time. The data for other gauges can only be obtained in months, not in days that are not very useful in hydrology terms, especially in explaining daily or hourly changes in hydrology parameters. On the other hand, it is possible to have daily or even hourly data from a specific website that serves hydrology data, especially rainfall data. One of them is data from t the Jaxa website. The Jaxa website provides hourly data and covers a broader specific place to be used to see how accurate they are compared to the ground data.

3. Results and discussion
3.1 Rainfall trends

Rainfall is the most crucial parameter when discussing hydrology conditions in a particular region, including a wetland area. The data comes from Jaxa Satellite cover the whole that can be seen in Figure 5 below. The primary and principal understanding of rainfall trends will be applicable to the management of water resources and sustainable agriculture that will be appropriate in any place in the world [32,33].

The relationship between the Jaxa Satellite data rainfall and ground data rainfall from Syamsuddin Noor showed during January-July 2021. The lowest of RMSE. is in July, and the highest of RMSE takes place in March. The graph for July can be seen in Figure 5. below.

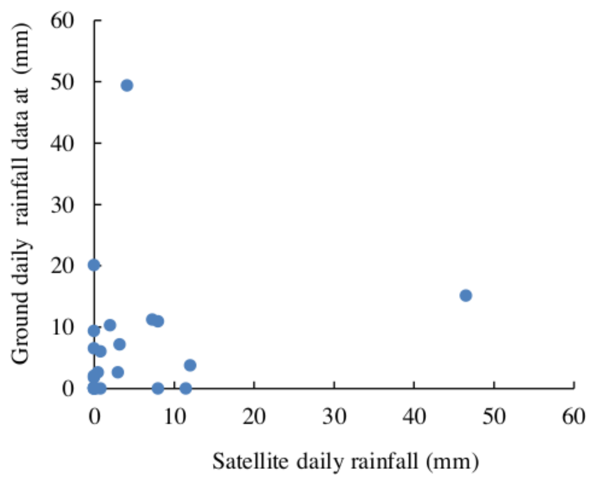

Figure 5. The relationship between the ground and satellite daily rainfall in July

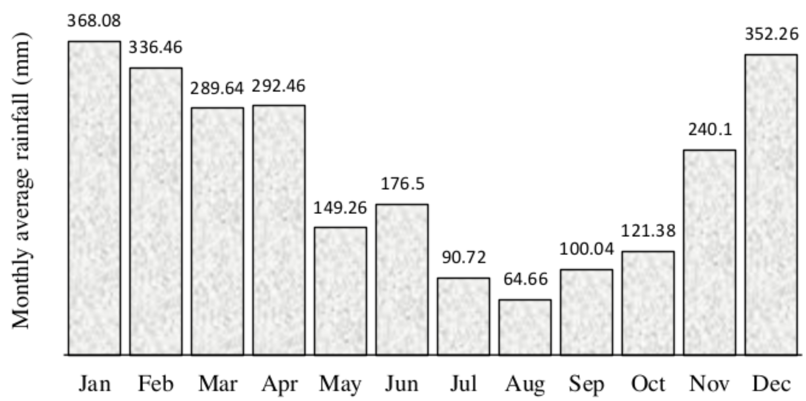

Figure 6. Average rainfall data 2016-2020 in Syamsuddin Noor gauge

From the average rain from 2016 to 2020 in Figure 6, it can be concluded that rainfall takes place almost all the year and the maximum rainy months are from December to February, with the minimum occurring in August. The peak took place in December, January, and February. The trends showed a similar trend to that in Sumatra, where rainfall occurs almost all the year. Monthly rainfall shows a pattern of peak fluctuations in dry periods in which there are two of them: February-March and June-July [26]. The result showed different trends in sub-tropics, which have four seasons where the maximum rainfall happened from June to September [32].

A study in the Kelantan Basin River Malaysia showed that both decrease and increase would happen so that flood and drought could occur at different times [34]. Even though there are several patterns for certain seasons, general Kalimantan experiences an increase in rainfall and a decrease in frequency below normal [35]. Rainfall availability will have a distinct effect on water table elevation due to avoiding drought to mitigate the fire risk. The number of hotspots has a correlation to the amount of rainfall, including the number of days without precipitation [37].

The relationship between rain and groundwater level needs to be investigated to see if the presence of rain can guarantee the occurrence of groundwater levels from excessive subsidence that can lead to drought in peat soils. Since the ground rainfall data were not available in the study location, and the relationship between the ground and satellite data in Syamsuddin Noor gauge has a quite enough relation, then the satellite data will be used in the location. The rainfall data in the study location had been downloaded from The Jaxa website, and its relationship to water table elevation data can be seen in Figure 7 dan Figure 8.

3.2 Water table elevation analysis

Water table level state is the crucial parameter for understanding the changes that occur in a wetland, including peatland area related to the effect to the hydrological condition [38–40]. The data from the observed field can be seen in Figure 7 and Figure 8 below.

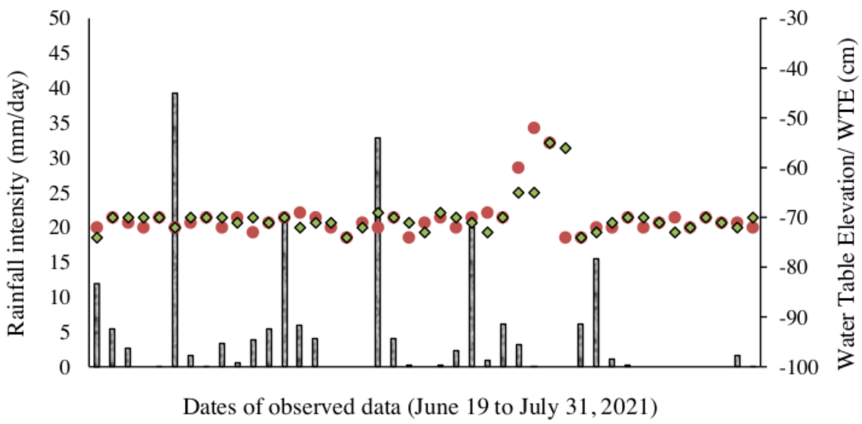

Figure 7. Daily water table elevation observed in point 1 at the study site

Water table elevation at the area showed that there was no significant alteration during the observation. The different phenomena at point 1 that occurred on July 18 and July 19 can happen because of several pieces of evidence. Since there is no significant rainfall happening in the area as shown in the rainfall satellite data, the situation occurred during lack of rain which showed the different case to other days. Another possibility is that the human error of calculation can happen since the observation and measuring had been conducted by manual equipment. The distinct difference value of water table elevation in point 1 and point 2 is likely to the values in point 2 deeper in general. The phenomenon might happen because point 2 is further from the ditch than point 1. This result confirms the previous study that areas with complex drainage systems will have higher water table elevation than those simple ones [26].

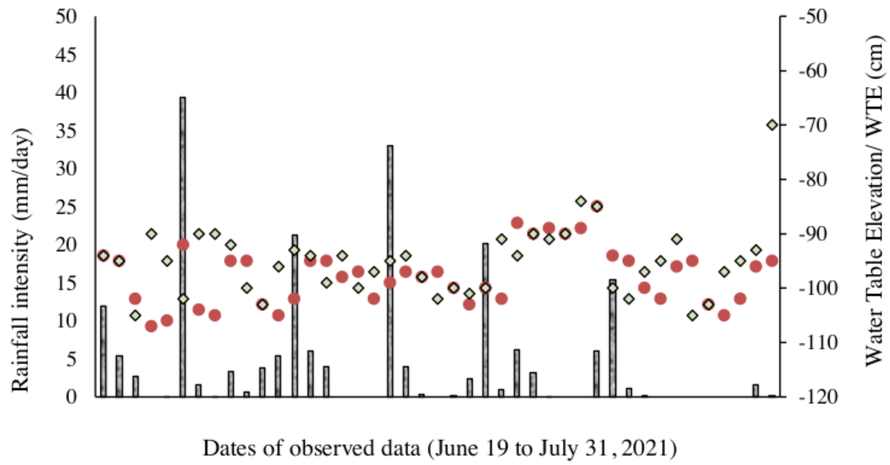

Figure 8. Daily water table elevation. observed in point 2 at the study site

3.3. Evapotranspiration analysis

Evapotranspiration is one of the hydrology parameters that are counted in all types of wetlands [10]. It is crucial to analyze to assess the condition of a wetland, including a peatland area. In this research, evapotranspiration was analyzed by Modified Blaney-Criddle formula, and the result can be seen in Figure 9 below.

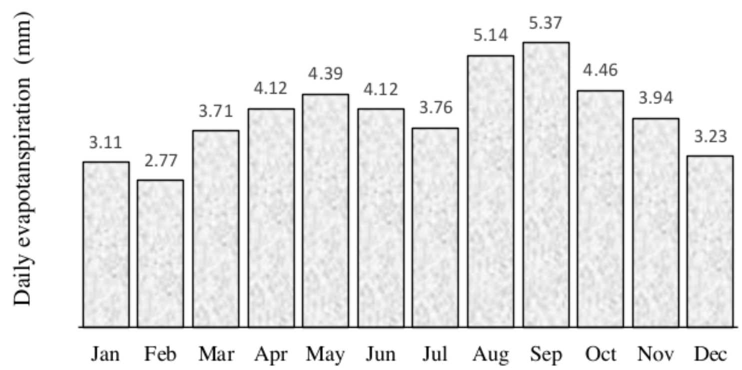

Figure 9. Daily evapotranspiration by Modified Blaney-Criddle Method

It can be concluded from Figure 9 that evapotranspiration varies from time to time based on different seasonal conditions, especially in Kalimantan, where space-variant means a lot [41]. They divided evapotranspiration to be four periods that are December-January-February (D-J-F), March-April-May (M-A-M), June-July-Aug (J-J-A), and Sept-Oct-Nov (S-O-N). They discovered that the highest evapotranspiration took place in the M-A-M periods. It showed a different phenomenon from this study, where the most increased evapotranspiration occurred in J-J-A and S-O-N periods. The differentiation may come from the cover of the study in this research, which is a tiny area compared to [41], which covers the whole of Indonesia

From the evapotranspiration analysis, the ETo that potentially happens will be pretty low compared to other months, which means the drying situation will not be expected to happen. The water table elevation analysis showed that the elevation in July is relatively high and bear to occur above 40 cm, which is the limit of government regulation. When the evapotranspiration occurs relatively in a small portion, but the water table elevation state is high enough, it will derive that the situation could be worse in other months, and it is required to mitigate the severe conditions.

4. Conclusions

Observation of the actual water table elevation showed that during the data monitoring, the value of the water table elevation was relatively deep even though the evapotranspiration was low, probably because the rainfall was also slight. Describing the hydrology parameters in a peatland area can help us understand the current situation due to the mitigation activity, especially the relation between the lack of rainfall and the optimum potential evapotranspiration. The correlation between those parameters can be used as an early approach to determine whether the particular area has a potential fire risk due to the drought possibility. This study will be more comprehensive and more function with another analysis in the evapotranspiration method with longer actual observation water table elevation data. In addition, it will be integrated when it can be compared to another peatland area.

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