Fire risk analysis based on groundwater level in rewetting peatland, Sungaitohor village, kepulauan Meranti district, Riau province

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Abstract. The hydrological condition of peatlands is one of the important factors affecting peatland's vulnerability to fire. The groundwater level (GWL) of peatlands or so-called groundwater depths is an indicator in determining the hydrological balance of peatlands. In normal conditions, peatlands are not prone to fire because they are able to hold and absorb water. Drainage on a large scale on peatlands causes the peat water level to drop so that the peat experiences water loss and is prone to fire. The disruption of the hydrological balance of peatlands can be seen in the wet month, when the water level is not much different from the conditions on a dry moon, which is still below the surface, causing peat to become flammable. The focus of this study was to determine the level of risk of fire vulnerability based on groundwater levels in peatlands, which was carried out restoration efforts, in the form of rewetting. This study, as a piece of early warning information on forest fires on GWL measurements of >40 cm, especially in the peatlands of Sungaitohor Village, Tebingtinggi Timur District, Kepulauan Meranti Regency, Riau Province. Groundwater level measurements were carried out directly in the field by installing 66 monitoring well points placed on different land uses (33 in unburned areas and 33 in burnt areas) during February - June 2019. The results showed that this region, in general, had a high level of risk of forest and land fires. The highest level of fire risk based on GWL >40 cm (danger category) was 99.63% in March. The high value of GWS >40 cm in this region made very susceptible to forest fires. In addition, extreme weather worsened the condition of peatlands into drought and was prone to fire.

1. Introduction
The increase in forest and land fires in Indonesia in the past few decades has been an unresolved problem. Various parties felt an interest in tackling the problem of forest and land fires in Indonesia because of its very large impact. Fire affects the loss of biodiversity, global warming, health, and the loss of economic opportunities for society. One of the causes of forest and land fires is deforestation, especially its conversion to Industrial Plantation Forest [1]. Fire events can be related to activities such as land clearing [2]. The land conversion followed by the construction of canals and drainage on a large scale causes a decrease in the water table, so that it is vulnerable to fire, especially in the dry season [3].
Forest and land fires often occur on peatlands, peat drought caused by the presence of canals has an impact on its vulnerability to fire. In the early to mid-2014, there had been a large fire in the area in Sungaitohor Village, Kepulauan Meranti Regency, Riau Province. Peatlands fires as a result of very dry peatlands conditions due to the sequestration of the area from existing canals. Therefore, it is said that canal construction is the initial cause of peatlands drying out, making it susceptible to fire supported by a long dry season.

This recurrent fire is a problem that must be resolved by the government. Various initiatives are carried out by villagers who also work together with other agencies both government and NGOs. The Government of Indonesia issued Government Regulation (PP) No. 71/2014 in an effort to prevent peatlands damage. Land use and management of peatlands for protection must maintain the hydrological function of peatlands. Based on PP No. 71/2014, that peatlands are said to be damaged if in the protected function drainage networks are made, whereas in peatlands the cultivation function is declared damaged if the groundwater level (GWL) is more than 40 cm below the surface. In this case, the government has obligatory to maintain the GWL at the level of 40 cm so that the peatlands remain at a safe level. In 2015, after a year of the fire, efforts were made to avoid fires in this area by building a canal blocking. Peatland was degraded because the canal opening could be attempted to be re-wetted by closing the canal (canal blocking) [4],[5]. The condition of degraded peat swamp forests caused by fires can be improved with restoration efforts, namely by restoring ecosystems back to their natural structure and function [6]. One of the restoration efforts is carried out by rewetting through canal blocking. Canal blocking either in the whole or in part canal is expected to increase the groundwater level. Efforts to rewetting peatlands (rewetting) with canal block construction have been and are still being conducted in Sungaitohor Village, Tebingtinggi Timur District, Meranti Islands Regency, Riau Province (Meranti Island Peat Hydrology Unit). Rewetting will maintain the groundwater level at the desired condition so that the peat will always be moist. Research on fire risk analysis based on the water level in restored peatlands is conducted with the rewetting method. Rewetting efforts in Indonesia and tropical peat are still very few and are in its initial stages [7]. Therefore, it is necessary to study the condition of the peat water level in the face of peat water as information in the early warning of forest and land fires.

Figure 1. (a) Map of research location (b) Monitoring point of groundwater level in unburned and burned land and hotspot distribution in 2014.
2 Methods

2.1 Place and time of research
The study was conducted in Sungaitohor Village, Tebingtinggi Timur District, Kepulauan Meranti District, Riau Province (Fig 1). Data collection and measurement carried out on peatlands post hydrological restoration in the form of rewetting with the construction of canal blocking. Measurement of groundwater level was carried out in different land uses on unburned and burned land. The unburned land was in sago plantations, rubber plantations, secondary forests. Measurement of groundwater level data was carried out in February - June 2019. Measurement of the groundwater level was conducted every 2 times a month.

2.2 Research design
Retrieval of groundwater level data was carried out on a canal flow using repetition on unburned and burned land. The total number of monitoring wells was 66 monitoring well points, which were divided into 33 points each on burned and unburned land (Table 1).

Table 1. Design of the research

| Parameter                  | Unburned Peatland | Burned Peatland |
|----------------------------|-------------------|-----------------|
|                            | Sago Plantation   | Rubber plantation | Secondary Forest |
| Number of sampling location| 1                 | 1               | 1                |
| Number of monitoring well/side location | 11               | 11              | 11               |

2.3 Tools
The tools used in this study were as follows:
1. Monitoring wells were used for the following purposes:
   - For monitor peat groundwater level, using a float and put a meter pipe on it. The scale of water level reading could be directly read above ground level.
2. Sensory Data Transmission Service Assisted by Midori Engineering (SESAME) which was a field of near-real-time monitoring of field data transmission hydrological conditions located in the area of this study.
   - For measurement of groundwater level in real-time
   - For rainfall calculation

2.4 Materials
The monitor well model was made of a 2.5-inch piezometer pipe with a float-equipped with a groundwater level gauge. In addition, monitoring wells were equipped with upper and lower pipe caps, collars (wooden plates 20 cm x 20 cm) buoys, measuring pipes, meters (Fig 2).
2.5 Research procedure
Measurement of groundwater level was conducted based on Government Regulation (PP) No. 71/2014 in an effort to prevent damage to peatlands. The level of risk of fire on peatlands referred to the minimum threshold of GWL of 40 cm and then divided into 3 classifications (Fig 3), namely:

1. Safe 0 – 25 cm
2. Fire alert 26 – 40 cm
3. Danger > 40 cm

The research was carried out through several stages including data collection, data processing, and data analysis presented in the research flowchart (Fig 4).
3. Results and Discussion

3.1 Dynamics of Groundwater Level

Groundwater level fluctuation calculation is done directly in the field, where GWL fluctuation measurements are carried out in February 2019 - June 2019. Measurements are made manually once every two weeks. This is, according to the Minister of Environment and Forestry Regulation (Permen KLHK) No.15/2017 that manual measurement of GWL is done at least once every two weeks, while automatic measurements are carried out at least once a day. Knowledge about the dynamics of GWL in peatlands is absolutely necessary to know the condition of the land or for further management. Field measurements show that the dynamics of groundwater levels vary greatly on unburnt peatland: sago plantations (Fig. 5a), rubber plantations (Fig. 5b), secondary forests (Fig. 5c), and burnt peatland: burnt peatland 1 (Fig. 5d), burnt peatland 2 (Fig. 5e), burnt peatland 3 (Fig. 5f).

The frequency of water level in the land is very related to the decomposition of peat composting materials, its cover and hydrological conditions. In addition, external factors such as climate change, rainfall, and sunlight intensity are influential. The existence of this relationship will be very important as an early warning system in fire information. Dry peatland will act as a material that is ready to be burned or burned so that the area is prone to fire. The availability of water in a study area is described by the volume of rainfall, while the potential for temporal distribution of water is expressed by the number of rainy days. The results of rainfall calculations at SESAME during the months of February 2019 - June...
2019 found that every month there was an increase in the amount of rainfall. The amount of rainfall in February was 16 mm/month, March 39.50 mm/month, April 119.50 mm/month, May 138.50 mm/month, and June 130.11 mm/month.

![Groundwater level fluctuation and rainfall](image)

**Figure 5.** Groundwater level fluctuation and rainfall (a) Sago Plantation; (b) Rubber Plantation; (c) Secondary Forest; (d) Burnt Peatland 1; (e) Burnt Peatland 2; (f) Burnt Peatland 3

Information:
SP1-SP11: Deep well 1 – Deep well 11; SR1-SR6: Sago Right 1 – Sago Right 6; SL1-SL5: Sago Left 1 – Sago Left 5; KR1-KR6: Rubber Right 1 – Rubber Right 6; KL1-KL5: Rubber Left 1 – Rubber Left 5; FR1-FR6: Secondary Forest 1 – Secondary Forest 6.
GWL is influenced by rainfall as a source of water availability. Low rainfall intensity in March resulted in a reduction in GWL. If we see the correlation between GWL and rainfall, there is a relationship, but rainfall does not directly increase GWL. The increase in GWL on peat soils that have high drought must be followed by high rainfall intensity as well. Thus, the greater the rainfall that occurs, the greater the increase in GWL. The inherent nature of peatlands makes peat very sensitive to environmental changes. Sarwono [9] said that the inherent nature of tropical peat is irreversible drying and subsidence. When drying occurs in this case the low rainfall, which is a factor in the availability of water in peatlands causes peat colloids to be damaged so that changing peat to dry is not back. In addition, the level of soil saturation is a factor preventing water entry. If the soil has a high level of drought, then the water supply which must fill the pore space of the soil must also be high. This can happen because rainwater has to fill a lot of empty pore space in peat soil. When the soil is saturated, even though the rainfall is categorized as small to moderate, it is able to raise the GWL to exceed the soil surface. Firmansyah and Mockhtar [10] said that peatlands generally experience drought in the surface layer during the dry season, this causes a decrease in GWL on peatlands so it is vulnerable to fire hazards.

Weather greatly affects the level of vulnerability to fire dangers, dry hot weather will cause fires. The nature of the weather affects the occurrence of fire [11]. Fire weather is defined as weather conditions that affect the start of a fire. In February the rainfall is at the lowest among other months with 3 days of rainfall, while on other days there is no rainfall or 0 mm/day. The duration of heat intensity and solar radiation this month also causes the air temperature to increase. Areas with high temperatures will cause the fuel to dry out quickly and facilitate fires [12]. Air temperature is an important weather factor that causes fires [13]. Constant air temperature is a factor that influences the temperature of the fuel and the ease of the fuel to burn. [14] In the morning with a fairly low temperature of around 20°C coupled with low wind speeds keep the fire from developing so it is concentrated at one point. While during the day with a temperature of 30 - 35°C, while the water content of the fuel is quite low (<30%) making the combustion process take place quickly and the form of the fire was not a single point, but changing because of the influence of the wind. In the following month, there was an increase in rainfall. High rainfall will affect the groundwater level so that soil moisture is also high and the condition of vegetation which is a fuel in the forest as well If the fuel moisture is high then it will be difficult to fire [12]. Months with little rainfall, the drought index is quite high conversely, in the months with high rainfall, the drought index is low, even reaching zero. This shows that rainfall affects the water content of fuel [15].

3.2 Risk of Fire in Peatlands Based on Groundwater Level

The results of the analysis of the risk of forest fires based on the highest groundwater level or at danger level (GWL> 40 cm) occurred in March - April (Table 2). Danger category in March reached 99.63% and April reached 97.58%. The high level of this category was caused by very extreme weather factors in this area. The absence of rain made the peatland dry. In March, this risk was influenced by the factor of low rainfall in the previous month, February. In February, the rainfall was only around 16 mm/month - 33 mm/month with the number of rainy days 3-7 days a month. Besides the low rainfall that occurred in the previous month, this month was also followed by a low amount of rainfall, so that the GWL category of >40 cm was the highest. This resulted in an effect on the level of fire risk in April, which was also high even though the level of rainfall had started to be high. The dry season occurring in the previous month resulted in a very large shrinkage of the groundwater level and made peatlands lose a lot of water. Drought-affected peat results in reduced soil moisture content. If a long drought occurs continuously
results in total drought in this area and the peat cannot be re-wet or undergoes an irreversible drying process. In addition, the ability of peat will change from very high in absorbing water (hydrophilic) into rejecting water (hydrophobic). [14] Decreased peat's ability to absorb water is related to the availability of hydrophilic compounds in peat materials, namely carboxylates and OH\textsuperscript{-} Phenolates. Therefore, peat which is in dry condition causes the ability to absorb water to not work.

Table 2. Recapitulation of fire risk percentage based on groundwater level

| Measurement Month | Groundwater level category (cm) | Total area (m\textsuperscript{2}) | Fire Risk (%) |
|-------------------|---------------------------------|----------------------------------|--------------|
| February          | 0 - 25                          | 51138.38                         | 1.35%        |
|                   | - 40                            | 284588.94                        | 7.50%        |
|                   | >40                             | 3456639.09                       | 91.15%       |
| March             | 0 - 25                          | 0.00                             | 0.00%        |
|                   | 26 - 40                         | 14125.94                         | 0.37%        |
|                   | >40                             | 3778240.47                       | 99.63%       |
| April             | 0 - 25                          | 26393.41                         | 0.70%        |
|                   | 26 - 40                         | 65384.39                         | 1.72%        |
|                   | >40                             | 3700588.61                       | 97.58%       |
| May               | 0 - 25                          | 48589.59                         | 1.28%        |
|                   | 26 - 40                         | 133902.13                        | 3.53%        |
|                   | >40                             | 3609874.69                       | 95.19%       |
| June              | 0 - 25                          | 105194.15                        | 2.77%        |
|                   | 26 - 40                         | 517825.70                        | 13.65%       |
|                   | >40                             | 3169346.56                       | 83.57%       |

The dry season that occurs not only causes a decrease in the surface of the groundwater, but it also causes the peat to burn more easily. In addition, the existence of making drainage or trench that is too wide has an impact on the lack of ability of peat to store water and the process of peat decomposition. Peat turns into available fuel because the organic matter in the peatland has dried up. When there is a fire igniting above ground level in this area (land burning), it allows fires to take place quickly. Because peat as a fuel has been in a dry condition. [2] The lower the water content or the lower wetness level, the more fragile the peat is. The level of fire risk is shown in (figure 6). February (Fig. 6 a), March (Fig. 6 b), April (Fig. 6 c), May (Fig. 6 d), June (Fig. 6 e).

Measurement of water level data in the field can also be used as an indicator of the level of fire risk in the dry season (dry month). Results of groundwater level measurements obtained in general have a high level of risk of forest fires. The difference in rainfall intensity that occurs is not much different among months that have high or low rainfall, where in general rainfall remains below the surface of the land, causing peatlands to become flammable. Data management in May and June reveals a decrease in the danger category (GWL >40cm) by 18.45%. This is caused by the rainfall this month is quite high since April - May ranging between 119.5 mm/month and 130.1 mm/month. An increase in rainfall makes the water source on this peatland. Good condition on peatlands is <40 cm because in this condition peat is difficult to burn. Water level will affect the level of peat water, while rainfall will affect the water level of peatlands.
Figure 6. Fire risk map based on groundwater level in Sungaitohor Village, Kepulauan Meranti 2019 (a). February; (b) March, (c) April; (c) May; (d) June.

4. Conclusion

Groundwater level (>40 cm) can be used as an early warning system for the risk of forest and land fire dangers. The highest level of fire risk based on GWL of >40 cm (danger category) is 99.63% in March. In the dry season, the rainfall was lower, so that peat water is very dry resulting in higher fire risk. Peatland
fires are preceded by low water content in peatlands. In this situation, peatlands are very dry and prone to burning.

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6. References

[1] Najiyati S L L, Muslihat, Suryadipura 2005 Bogor: Wetlands International-Indonesia Programme and Wildlife Habitat in Canada.
[2] Syaufina L 2008 Kebakaran Hutan Dan Lahan Di Indonesia. Malang: PT. Bayu Media Publishing.
[3] Verwer C P, van der Meer, Inabuurs G 2008. Review of carbon flux estimates and other greenhouse gas emissions from oil palm cultivation on tropical peatlandsIdentifying the gaps in knowledge. Alterrapport 1731. Alterra. Wageningen. 44.
[4] Suryadiputra I N N, Dohong A, Waspodo R S B, Muslihat L, Lubis I R., Hasudungan 2005 A guide to the blocking of canals and ditched in conjunction with the community. Bogor: Wetlands International Indonesia Programme and Wildlife Habitat Canada.
[5] Ritzema H, Limin S, Kusin K, Jauhiainen J, Wösten H 2014 Catena. 114, 11-20.
[6] Page S E, Rieley J O, Banks C J 2011 Global Change Biology. 17(2), 798-818.
[7] Giessen W, Sari E N N. 2018 Tropical Peatland Restoration Report: Indonesian Case. Millennium Challenge Account – Indonesia. 82p.
[8] Sutikno S, Nasrul B, Gunawan H, Jayadi R, Rinaldi, Saputra E, Yamamoto K MATEC Web of Conferences. 276
[9] Fuller M 1991 Forest Fire: an Introduction to Wildland Fire Behaviour, Management, Fire Fighting and Prevention. Wiley Nature Edition. New York: JohnWiley and Sons, Inc.
[10] Direktorat Jendral Perlindungan Hutan dan Pelestarian Alam. 1994a. Surat Keputusan Dirjen PHPA Nomor 244/Kpts/DJ VI/1994 Tentang Petunjuk Teknis Pemadaman Kebakaran Hutan. Departemen Kehutanan. Jakarta.
[11] Young R A, Giese RL 1991 Introduction to Forest Fire. John Wiley and Sons Inc. Toronto Canada.
[12] Saharjo B H 1997 Mengapa Hutan dan Lahan Terbakar. Harian Republika.
[13] Syaufina L 2014 Peran strategis sektor pertanian dalam pengendalian kebakaran lahan gambut. Risalah Kebijakan Perti rtan dan Lingkungan I : 35-39
[14] Sabiham S 2000 J. Tanah Tropika. 11, 21-30.
[15] Saharjo B H, Syaufina 2015 Kebakaran Hutan dan Lahan Gambut. Center for International Forestry Research. Bogor. Indonesia.