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Canal Influence on Peat Properties at Different Fire Frequency Areas

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Peat fire, Peat properties, Fire break canal, Forest reserves

Abstract

Peat in the tropical country was developed from accumulated dead plant materials. Due to frequent fire occurrences, a fire break canal technique is implemented as part of prevention measures to protect the forest reserve from fire spread. Although fire cases in peat swamp forest reserves in Malaysia are minimum, the occurrences can cause changes in the peat properties if they happen frequently. Therefore, this study focuses on determining the peat properties near the fire break canal in low and high fire frequency areas. Peat samples were collected from 0 cm (surface) to 150 cm at 50 cm intervals at 75 m to 300 m from the canal. The findings show that the peat properties were not affected by the presence of fire break canal for porosity (%), moisture content (%), bulk density (g cm3), ash content (%), organic carbon content (%), and organic matter content (%) for both study areas ($p<0.05$). However, peat's lignin and cellulose content from both study areas increased as the distance from the canal increased ($p>0.05$). Other than contributing to vegetation changes in both areas, the peat properties are also different. The High Fire Frequency also shows statistically different properties compared to the Low Fire Frequency area. In summary, fire break canal can reduce the fire spread to forest reserve area and improve the peat properties to protect the land from further degradation.

1. Introduction

Tropical country peat swamps are prone to have poor drainage and water-logging conditions where plant residues usually decay faster (Taufik *et al.* 2019). With the anthropogenic influence nearby the peat swamp area, there is a possibility of fire to spread into the forest reserve and thus may degrade the area. According to the statistics provided by the Annual Report of the Sabah Forestry Department (SFD 2020), it was reported that open burning and arson contributed to the cases of previous fire incidents spread to the forest reserve (FR). In the reports, forest reserves burnt annually for 706 ha (2015), 20,000 ha (2016), 60 ha (2017), 279 ha (2018), 1313 ha (2019), and 556 ha (2020). Additionally, the issue of owners clearing their land by setting it on fire has been the primary threat to the forest (SFD 2019; SFD 2020).

Forest fire in the peat swamp forest is associated with a smouldering fire. Smouldering fire damaged the ecosystem, which caused a slow recovery of the forest (Davies *et al.* 2013). This type of fire is very persistent and may last for a long time (Rein 2013; Rein and Huang 2021). For example, fire incidents that happened in 2016 lasted for six months during the El-Nino phenomenon and lasted for two months without El-Nino influence (SFD 2017; SFD 2020). The government enhanced their fire prevention measures, including constructing a fire break canal in the repeatedly burnt area in Sabah, Malaysia. The fire break canal is meant to reduce the fire spread to the FR and was efficient in Klias FR and then implemented in Binsuluk FR. At this point, it is crucial to observe the properties of peat near the fire break canal at both Klias and Binsuluk FR. Thus, this work studied the fire influence on the peat conditions at Klias and Binsuluk FR near the fire break canal and conveyed the

analysis of the peat properties further from the fire break canal at a different depth to explore if peat fire will influence up to 1.5 m below ground.

2. Methodology

2.1. Sampling method

This research involved two study areas represented the low fire frequency area (LFF), where vegetation is still intact (Klias FR), and the high fire frequency area (HFF), where less vegetation cover presents (Binsuluk FR). The study plots were established at 75 m, 150 m, 225 m, and 300 m from the canal. A total of 192 samples were collected at different levels, i.e. 0 cm, 50 cm, 100 cm, and 150 cm (Figure 1), using a bulk density ring for physical analysis purposes and a peat auger for chemical analysis purposes.

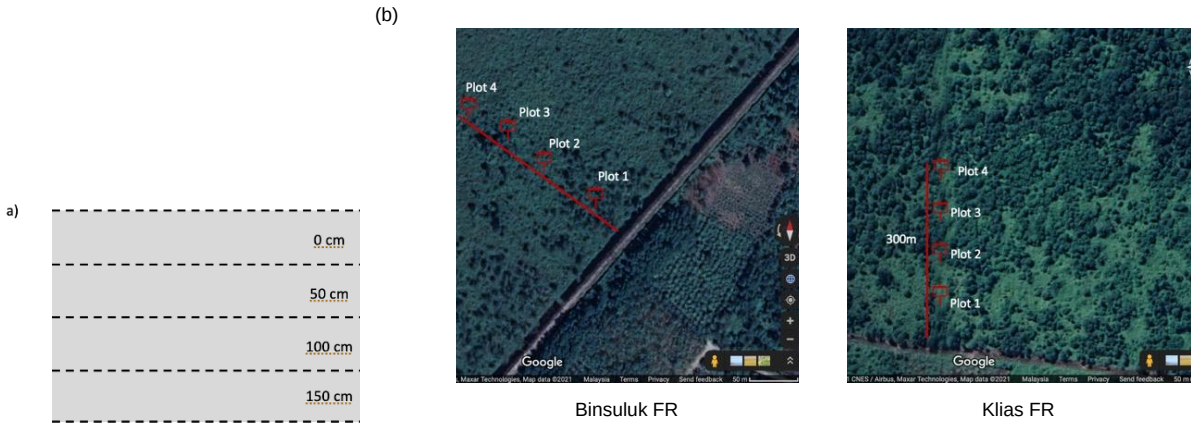

Figure 1- (a) Samples of peat collected at a different level, (b) Plot constructed at both study sites LFF and HFF) for peat samples collections.

2.2. Statistical analysis

The physical and chemical analyses involved are bulk density, moisture, porosity, organic matter, organic carbon, ash, lignin, and cellulose contents. Statistical comparisons between the plots and depths were made by using a two-way analysis of variance (ANOVA) at a 95% confidence level ($p<0.05$). A Pearson-correlation analysis is also done to determine the relationship between the variables.

3. Results and discussion

3.1. Physical properties of HFF and LFF areas

The physical properties studied in this work are bulk density, moisture content, and porosity. In this section, we want to understand how these physical properties were influenced by fire frequency. Also, the relationship between the properties will be presented in Figure 2. Based on analysis of variance analysis (Tukey's test) in the HFF area, peat at 150 m and 300 m further from the canal shows a significant difference in each variable ($p<0.05$) between the depth. In the HFF area, the porosity *has a reasonably strong relationship with bulk density (r=0.988) and a moderate relationship with moisture content (r=0.584). The peat surface has a moisture content of up to 1200% and* low vegetation cover with only tall grass and a few big trees spotted in the study sites. The rain will directly be pouring to the surface of the water. This situation will influence the significantly high moisture content on the surface (0 cm). *However, a fire frequently spreads to the area. A new fire break canal construction does not dry the area to the furthest 300 m from the canal. Because of the frequent fire, the porosity level and moisture content have a moderate relationship (0.584) but still indicate that the three fundamental properties of peat are dependent on each other. However, the higher moisture content on the surface indicates that weak peat can retain the water (Perdana et al. 2018) known as a hydrophobic condition because of a previous fire event.*

The LFF area experienced peat fire, but it was not frequent as the fire break canal was implemented in this area to prevent the fire from spreading. The peat properties in this area were not similar to the HFF area, as the fire

did not change the peat properties too much. The moisture content and porosity have a strong correlation-coefficient of 0.838, or 70% of the moisture content is dependent on the porosity of the peat. Similarly, the peat's bulk density and compaction are 78% dependent on the peat porosity for Klias Forest Reserve. However, the surface moisture content of the peat ranged from 180-400%, which was statistically lower than HFF surface moisture. The highest mean moisture content was 900% at 100-150 cm below the surface. 150 m further from the canal shows a significant difference in variables between the LFF area depth and 225 m further from the canal (p=0.002).

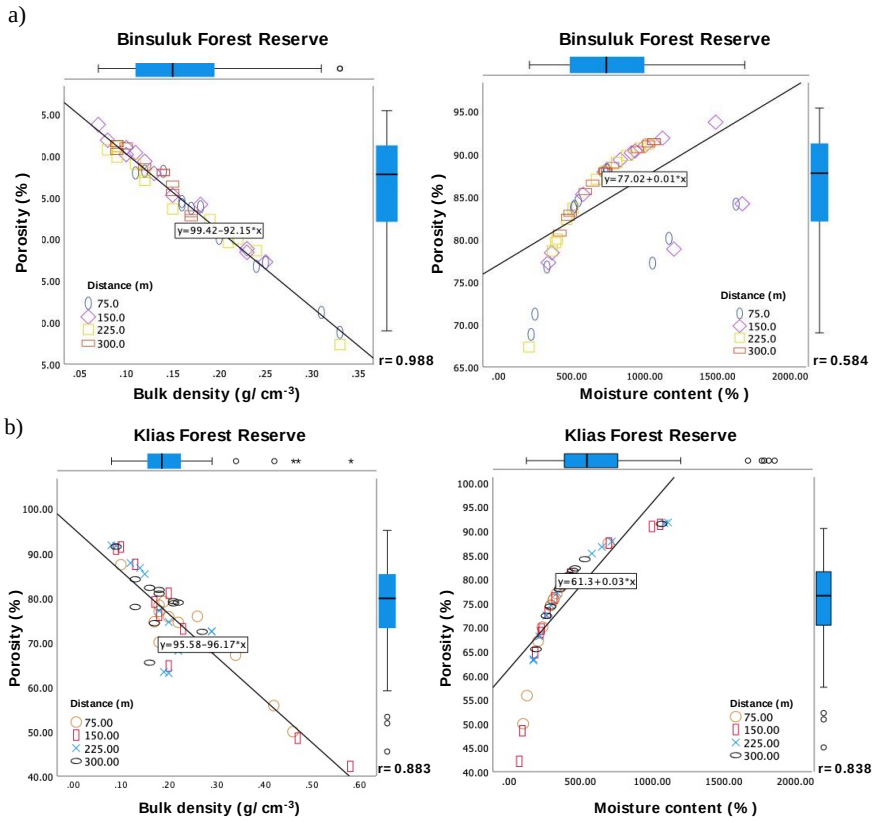

Figure 2- Influence of distance on peat physical properties of porosity (%), bulk density (g/cm3), and moisture content (%) of the a) Binsuluk Forest Reserve (HFF) and b) Klias Forest Reserve (LFF).

3.2. Chemical properties of LFF and HFF areas

The chemical properties studied were organic matter content (OMC), organic carbon content (C_{org}), Ash content, lignin, and cellulose. The analysis of correlation regression (Figure 3) between the chemical content indicates that all variables have a strong correlation for both forest reserves (r=0.998, r=1.000). The findings suggest that all chemical variables are dependent on each other. Ash content studies to identify the area burnt before the show that it was present from 0 cm to 150 cm and up to 300 m further from the canal. Based on the analysis of variance, the significant difference between the depth for the HFF area was shown at 150 m, 225 m, and 300 m further from the fire break canal.

The correlation regression analyses were used to relate each chemical properties studied. The peat's total organic matter content in the HFF area varied from 71.43% to 98.04% at a 75 m distance from the canal, which indicates no significant difference (p>0.05) between the depths. In the Pearson-correlation analysis, the HFF area shows a strong correlation (r=0.998, 0.998, 1.000) for OMC, C_{org}, and Ash content relationship. The findings were similar to LFF, where the variables have a strong (r=1.000) relationship and were expected to have no difference within the depth despite the distance from the canal (p>0.05). The LFF area findings do not influence much of the chemical peat properties on these content, organic carbon content and organic matter content.

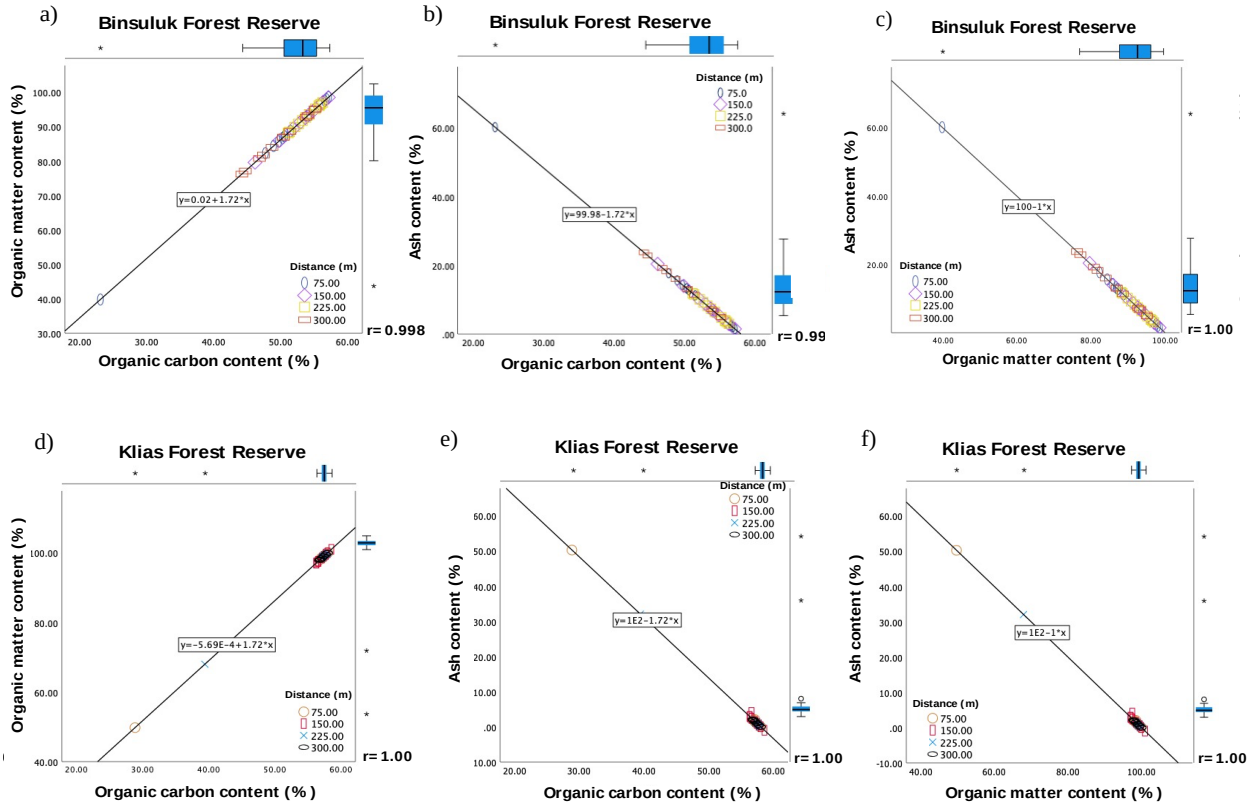

Figure 3- The correlation-regression of the chemical properties of peat-based on the distance from the canal in both Binsuluk Forest Reserve (HFF) - a) OMC (%)-Corg (%); b) Ash content (%)-C_{org} (%); c) Ash content (%)-OMC (%) and Klias Forest Reserve (LFF) - d) OMC (%)-C_{org} (%); e) Ash content (%)-C_{org} content (%); f)Ash content (%)-OMC (%).

The lignin and cellulose content were studied to determine the influence on the moisture content of the LFF and HFF area (Table 1). Based on the findings, the lignin and cellulose content have a significant difference between the plots, where the further the plot from the canal, the higher the cellulose and lignin content ($p<0.05$). The correlation regression analyses were used to relate the lignin and cellulose to moisture content. The findings show that cellulose has a fair relationship with moisture content in the HFF area. Burning the dead material might contribute to these changes as the LFF shows no relationship between the moisture content with lignin and cellulose content.

Table 1 - Pearson-correlation for lignin and cellulose with moisture content

Variable	Moisture content (%)	Lignin (g/kg)	Cellulose (g/kg)
Moisture content (%)	1.000	**-0.280** *0.451*	**-0.062** **0.692*
Lignin (g/kg)		1.000	***0.783** **0.828*
Cellulose (g/kg)			1.000

Note:
*: is used where the relationship between the variable was detected (<0.001, 2-tailed)
Font: Italic is HFF area, Bold is LFF

4. Conclusion

In conclusion, this research focuses on the peat properties nearby the firebreak canal of two other forest reserves and the influence of the canal on the properties. The samples taken were peat from Binsuluk FR, representing the HFF peat, and peat samples from Klias FR, representing the LFF frequency areas. The smouldering fire releases a substantial amount of carbon into the environment to aid the carbon emission in the area (Davies *et al.* 2013). The moisture content was found to be higher in the HFF area and there were ash in each plot indicates

the carbon has been lost during the burning. The repeatedly burnt peat consisted of high lignin and cellulose content, almost similar for 75 m from the canal to 300 m further from the canal. The LFF otherwise have significantly different results between the plots. The further the peat samples from the canal, the higher the cellulose and lignin content. Fire cases is found to influence the fibre content. The changes in peat properties will make it more vulnerable to fire occurrences when the fire from outside spreads to this area.

The importance of this research represents the protected peat swamp forest in Malaysia. This work provides information on soil properties near fire break canals in different hydromorphic settings to identify type-specific threats and derive implications for conservation, cultivation and restoration (e.g. rewetting) (Gabriel *et al.* 2018). When peat is repeatedly burnt, the peat properties will change along with its structure. Therefore, this work could help understand the changes made by a fire outbreak and how the peat will influence the re-occurrences of fire in the future. As a result, this will increase the vulnerability of the land to future fire incidents. The restoration effort and minimum fire incidents might improve the peat properties. Knowing the physical and chemical properties near the fire break canal will provide soil scientists and land managers with important information on these properties of the peat soil.

5. References

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