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Application foaming agent following peat fire at Rimba Panjang Village, District Kampar, Riau

Pratiwi Dwi Susanti[a], Basuki Wasis[b], Bambang Hero Saharjo[c]

[a] Study Program of Silviculture Tropica, Graduate School, IPB University, Dramaga, Bogor, 16680, Indonesia [+62 81214561569]
[b] Department of Silvikultur, Faculty of Forestry, IPB University, Dramaga, Bogor, 16680, Indonesia [+62 81295496734]
[c] Department of Silvikultur, Faculty of Forestry, IPB University, Dramaga, Bogor, 16680, Indonesia [+62 8161948064]

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Corresponding Author:
Pratiwi Dwi Susanti
Study Program of Silviculture Tropica, Graduate School,
IPB University;
Tel. +6281214561569
Email:
Pratiwids@gmail.com

Abstract. *Extinguishing peat fires with water is less effective and efficient because the process of decreasing the temperature of the fuel does not occur immediately. There is a new extinguishing method by using a foaming agent from palm oil. This study was carried out on the burnt peatland area in Rimba Panjang Village, Riau. There are four spots that have the potential to reburn. The extinguishing process is carried out with a foaming agent in three plots, and one plot using water. The method using a foaming agent is done by extinguishing the fire using a fire extinguisher containing a mixture of NF 46 0.5 100 L m² solution. Furthermore, direct fire suppression was carried out on the plot and observed until the fire was completely extinguished. This study showed that extinguishing using a foaming agent for three months did not damage the ecosystem and had no negative impact on plant growth. IVI calculation shows that there are three dominant species in each observation plot, namely mackerel (Stenochlaena palustris) with an IVI of 89.40%, ferns (Pteris Sp.) with an IVI of 20.10%, and alang-alang (Imperata cylindrica) with an IVI of 30.85%. The results of the analysis show that the species diversity index (H') is 1.206, the species evenness index (E) is 0.524, and the species richness index (R) is 1.967. Extinguishing using a foaming agent can speed up the extinguishing process (3 to 4.6 minutes) compared to using water (50 minutes).*

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INTRODUCTION

Peat soils are generally formed in anaerobic, waterlogged, and high salinity conditions (Wasis, 2018). The type of peat soil can be identified based on its constituent, fertility level, climatic condition, formation process and environment, maturity level, and thickness of the layer of organic matter. Likewise, the thickness of the peat can represent the maturity and fertility level. In Indonesia, peat swamp forest can be considered tropical peat, defined as organic soil in tropical and subtropical wetlands areas between the 35° North and South latitude, including those at high elevations (Andriesse, 2003). Dry peat soil will be susceptible to fire. Peat fires will have an impact on decreasing the thickness of peat soil (subsidence) and damaging the physical, chemical, and biological properties of the soil.

Fire and land conversion for agricultural practices are some of the main threats that cause a critical impact on peatlands in Indonesia (Hansen *et al*., 2009; Yule, 2010). Fire and land conversion can reduce tree density and other growth rates (Yeager *et al*., 2003). In addition, the high intensity and frequency of fire will generate the domination of undergrowth species (Page *et al*., 2009). Forest and land fires will potentially result in a loss of several aspects, for instance: economic, social, health, biodiversity, and ecological aspect. Moreover, it could also cause a decrease in peat thickness, environmental damage, ecosystem changes, and a decrease in tourism income. Therefore, several actions are needed to prevent and control the forest and land fire that must be carried out intensively and sustainably.

Forest and land fires are usually extinguished using only water and tend to take a long time until the fire is completely extinguished. If a fire occurs on peatland, it will take a longer time to extinguish than the soil in common. The fires on peat soil occur underneath the soil surface, so it is quite difficult to put out the fire until it completely disappears. The longer fire burns and extinguishment are carried out, the higher the potential for peat subsidence. So that the extinguishing method using water is considered less effective and efficient if it is carried out on peat soil because the process of reducing the fuel temperature is hampered so that the water will be evaporated by high temperature on the surface. Therefore, an effective and efficient method in extinguishing peat fire is needed by accommodating all aspects. This study aims to analyze the utilization of foaming agents in the burnt peatland areas without damaging the ecosystem and examine the negative impact of applying foaming agents on plant growth responses and peat soil properties after the extinguishing processes.

METHOD

Research Site and Duration

The research was conducted from September to December 2019. This research consists of field experiments and laboratory analyses. The field experiment was conducted in Rimbo Panjang Village, Tambang District, Kampar Regency, Riau (0º27'7"N-201º20'54"E). Soil property analysis was carried out at the Environmental Biotechnology Laboratory (EBL) ICBB, Bogor.

Data Collection Method

Development of Research Plot

The selection of the research plot was done by purposive sampling method and carried out with a survey beforehand to observe the hotspots which occur on peatland and are susceptible to burning. The identification was done by using an infrared camera or observing the smoke from the peatland area. The plot with a size of 2x2 meters was made on burnt land, the plot can be seen in Figure 1. At the research site, four plots were made with different approaches of extinguishing method, including 3 plots using the foaming agent and a plot using the water. The data for each plot has been collected after three months of natural vegetation succession on peatlands after burning.

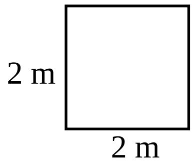

Figure 1 Design of research plot

Preparation

The preparation stage before the extinguishing process was done to measure some aspects including temperature and humidity using a digital thermometer, soil pH using a pH meter, wind using kestrel meters, fuel, heat temperature using thermocouple thermometers, and taking soil samples using a ring sample.

Furthermore, preparation for extinguishing fire was done using equipment named motopome mark 3, a mixture of NF 46 0.5 solutions as much as 100 L m², peat water, and metal steel sheets for plot barriers so that the fire does not come out of the plot, cameras, temperature gauges.

Burning

The burning stage is carried out when a fire occurs in each plot by measuring the temperature of the fire using thermocouple thermometers, the height of the fire, and the burning duration. Measuring the temperature of the fire is done by directing the thermocouple thermometer to the fire source from 1 meter away, then the temperature is recorded as displayed in the equipment. The measurement of the fire height is carried out using a measuring tape from the ground to the top of the flame, then the height is recorded. The burning duration is recorded when the fire occurs at the research site.

Fire Extinguishing

The fire extinguishing process is carried out when the preparation stage is ready for use. At this stage, fire extinguishing is carried out using a fire extinguisher as the equipment, which contains a foaming agent from a mixture of NF 46 0.5 solutions as much as 100 L m². Furthermore, the extinguishing was directly carried out using fire extinguishers in each plot with 4 to 7 people, it was carried out with the help of the Manggala Agni team. Then, the extinguishing process observed the duration to extinguish until the fire or smoke in the plot disappeared. During the process, a thermocouple thermometer was used to detect the decrease of heat temperature on the peat soil. After the fire and smoke have completely extinguished, and the foam has begun to sink into the ground, then the heat temperature is measured again, whether it is stable or not. After that, the plot can be analyzed the next day again to see the effect of the foaming agent used during the extinguishing process.

Observation and Data Collection

The parameters measured in this data collection are temperature, humidity, soil pH, wind, fuel, fuel height, fuel weight, peat thickness, extinguishing area, soil biota, physical properties, and chemical properties of the soil, which were carried out from September to December 2019.

Temperature, humidity, and wind

Measurement of temperature and humidity was done by putting the digital thermometer around the research plot. Wind velocity measurement was carried out by holding a caster meter with a direction of 45°C. These measurements were carried out to determine the conditions in the field and observe the effect on the fire.

Soil pH

Soil pH measurement was carried out before and after the extinguishing process by putting the pH meter in the burnt peat soil. The results were recorded when the value was constant.

Fuel

Measurement of fuel was done by measuring the fuel from the ground to the surface. After being measured using a ruler, the weight of the fuel was measured, and the type of fuel was identified.

Peat thickness

The procedure for measuring the thickness of the peat was carried out by cleaning above the ground litter. Then, the peat drill or eijkelkamp drill was injected into the peat layer. After that, the drill was lifted to examine the soil samples. If the drill had not reached the mineral layer, then the drilling process was continued. Every drill connection is recorded until it reaches mineral soil.

Extinguishing area

The measurement of the extinguishing area in each plot is different so that the measurement is carried out again using tape measurement.

Physical properties of soil

The physical properties of soil were analyzed by taking the soil using a ring sample before and after the extinguishing process on each plot with a depth of 0 to 5 cm. The physical properties of soil to be examined are bulk density, pF moisture content, peat fiber content, soil porosity, and soil permeability.

Chemical properties of soil

The chemical properties of soil were examined by taking the soil using a soil drill that has a depth of 0 to 50 cm. The soil sample was taken as much as 1 kg and then composited. The soil samples can be analyzed which can then determine the chemical properties of the soil such as soil pH, water content, C-organic, N-total, C/N ratio, and cation exchange capacity (CEC).

Plant succession and vegetation analysis

Observation of undergrowth succession was carried out by observing in each 2x2 meter plot which was examined for 3 months. Then a vegetation analysis was carried out by recording any undergrowth that grow, then counting the number, measuring the height and diameter of each species found in each plot.

Data Analysis Method

Bulk Density

Analysis of bulk density was carried out at the Forest Effects Laboratory, Department of Silviculture, Faculty of Forestry, IPB University. Bulk density analysis was carried out by putting the intact soil at a temperature of 105°C for 24 hours in the oven. The value of bulk density can be calculated using the formula (Hakim *et al*., 1986):

$$Vt = \frac{1}{4}\pi d^2 t, \quad BK = BK_1 - BR, \quad BI = \frac{BK}{Vt}$$

Note:
BI = Bulk density (g/cm^3)
BK = Dry soil weight without ring (g)
BK_1 = Dry soil weight (g)
BR = Ring weight (g)
Vt = Soil volume in the ring (cm^3)

Soil Organic Carbon (C-organic)

Soil C-Organic analysis was carried out at the Forest Impact Laboratory, Department of Silviculture, Faculty of Forestry, IPB. C-Organic analysis was carried out by taking the disturbed (burnt) soil with a weight of 5 g to the *fusible*. Then the sample was put into the oven two times at a temperature of 105°C and 500°C for 24 hours, respectively. The C-Organic value of the soil is calculated using the formula:

$$\text{C-Organik} = \frac{\text{BK1-BK2}}{\text{BK1}} \text{ x } 100\%$$

Note:
BK1= Dry soil weight at 105^{o}C
BK2= Dry soil weight at 500^{o}C

Important Value Index (IVI)

Important Value Index (IVI) is calculated to determine the dominance of one species over another. According to Ismaini *et al*., 2015), the IVI of plant species in a community is one of the parameters that shows the role of the plant species in the community. The presence of a plant species in an area shows the ability to adapt to the habitat and wide tolerance to environmental conditions. The formula is as follows (Soerianegara and Indrawan, 1988 in Syaufina, 2017).

$$IVI = \text{KR} + \text{FR} + \text{DR}$$

Density (K) $= \frac{\sum \text{Number of species}}{\text{Total area sampled } (\frac{\text{Ind}}{\text{ha}})}$

Relative Density (KR) $= \frac{\text{Density of a species } (\frac{\text{N}}{\text{ha}})}{\text{Total density of all species } (\frac{\text{N}}{\text{ha}})} \times 100\%$

Frequency (F) $= \frac{\text{Area of plots in which a species occurs}}{\text{Total area sampled}}$

Relative Frequency (FR) $= \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100\%$

RESULT AND DISCUSSION

Forest and land fires have an explosive impact to destroy forests and land in a short time with a wide-ranging area. As a result of forest and land fires, it can affect the quantity and quality of existing natural resources and ecosystems, such as reduced or loss of flora and fauna diversity as a source of germplasm and decreased soil quality which is difficult to return to the normal state (Saharjo, 2016; Wasis *et al*., 2018). Examining these impacts, the protection of forest and land areas is very important. The protection of forest and land can be carried out by means of prevention and control. Based on the distribution pattern and type of fuel, peat fire is categorized as ground fire because it burns the peatlands by spreading below the surface, which then burns organic material around the land with uncontrolled smoldering, and it is different from fires on land in common. Peat fires usually occur slowly because they are not affected by wind speed, so the distribution pattern is uncertain and it is difficult to determine the starting point or ongoing point of fires because the fires that occur on peatlands usually only indicate white smoke above the ground surface. Fires on peat soil can cause loss of biomass, litter, peat soil layers, an increase in soil porosity (Wasis, 2018). Peat soil that has been burned and dried cannot be recovered, and the result of burning peat soil causes damage that is largely irreversible as before (Wibowo, 2009).

The peat fire in Rimba Panjang Village, Riau is a large fire because it can destroy approximately 4 ha of land. The land was previously abandoned and was dominated by undergrowth and several large trees. Previously, a fire had occurred on the land, and it took approximately two weeks to extinguish the fire until the fire inside the surface was completely extinguished, but when a survey was carried out, the research location was not completely extinguished because white smoke was still visible on the ground surface which if left unattended would cause a fire and more fire in that area. From the survey results, four points will potentially reoccur. From the four points, the extinguishing process is carried out using existing methods and procedures. The extinguishing process is carried out using three plots using a foaming agent and fire extinguishers, and one plot using water. The water used in this extinguishing process was peat water that is available around the research site.

Peat Fire Parameters

There are several differences in the extinguishing process for each plot, which can be seen from the duration until the fire is completely extinguished. Several factors affect the process, such as temperature, humidity, peat height, wind speed, soil pH, depth of burning peat, and extent of extinguishing. From these factors, there can be some differences in the result because the plots are not close to one another. The result can be seen in Table 1 below.

Table 1 Factors of fire behavior and burning conditions

No	Parameter	Plot			
		1	2	3	4
1	Temperature (°C)	31.3	36.9	37.2	32.3
2	Relative density (%)	53	34	34	54
3	pH	4	4	4	4
4	Wind velocity ($m\ d^{-1}$)	0.4	1.2	1.1	0.4
5	Depth of burning peat (cm)	20	20	18	23
6	Extinguishing area (m)	2 x 2	1.5 x 2	1.1 x 0.9	1.2 x 2
7	Peat depth (cm)	46	45	65	164
8	Hot temperature (°C)	511.9	390.1	432.2	302
9	Fire height (cm)	35	-	-	-
10	Water content (%)	71.80	68.86	72.65	63.99
11	Extinguishing duration (minutes)	4.6	3	3	50
12	Solution ($L\ m^{-2}$)	100	100	100	154.17

Note: Plots 1 to 3 were extinguished using a foaming agent; plot 4 using water

The factors listed in Table 1 can be seen from the differences in the result of each plot. Plot 1 (one) is the longest in extinguishing compared to the three plots using a solution of foaming agent and fire extinguisher, with a time of 4.6 minutes. This is because plot 1 has the largest extinguishing area compared to the other two plots. Besides that, the hot temperature before extinguishing is the highest at 511.9°C, so that the fire extinguishing is the slowest compared to the other two. But with the foaming agent, fire suppression is more efficient and accelerate the extinguishing time because the foaming agent can immediately close and sink into the pores of the peat soil when the gel is applied so that the air circulation that enters the soil can stop and can remain the moderate heat occurs during a fire because the gel has a cold temperature and does not evaporate immediately. Therefore, the extinguishing process is shorter than using water. It took a long time to extinguish the fire using water in plot four because the water could evaporate more quickly and did not enter the pores of the soil, so the water was difficult to extinguish fires on peat soil, where the fire was below the soil surface.

Based on the depth of burning, the peat fires that occurred at the research site in plots 1 and 2 were 20 cm, while plots 3 and 4 were 18 cm and 23 cm, respectively. These results are included in the weak class, because each plot has a burning peat depth of less than 20 cm. Heat content can be influenced by several factors, including water content, bulk density, and the chemical content of the fuel. The results of Syaufina's research (2002) show that the heat content of peat varies greatly at various water content.

Physical Properties of Peat Soil

Physical property analysis of peat soil in the research site has resulted from a duration comparison which is shown in Table 2 without any treatment, where the soil is soil on burned land before extinguishing treatment using foaming agent and water. From these results, the highest bulk density value is in plot 4, which is 0.40, while the highest permeability value is in plot 2, which is 18.27, and the highest water content value is in plot 1, which is 52.08. The drainage pores on the peat soil at the research site are divided into two, namely fast and slow. The highest fast drainage pore is in plot 2 of 13.50, while the highest slow drainage pore is in plot 4 of 7.40. These results on each plot and related parameters, it does not produce significant values. The high-water content in each plot will bind the treatment to be carried out and accelerate the extinguishing process.

The analysis shown in Table 3 results are extinguishing treatment using foaming agent and water after being left for 24 hours on burning peat soil. Compared with Table 2, the result of the analysis showed a decrease and increased in each soil characteristic of each research plot, but there was no significant change. In the bulk density analysis using a foaming agent, there was a decrease, but it is in contrast to the control treatment because the water slightly increased by 0.20 in just one day. Unlike with water content, in experiments using a foaming agent and water, an increase occurred. According to Noor (2001), low soil density of peat can have a consequence of low bearing capacity on peat soil, then in general, the smaller the bulk density, the deeper the density of the soil. Soil density may vary over time or from layer to layer according to pore space or soil structure changes.

Table 2 Result of the physical property analysis of peat soil at the research site before the fire occurrence

No	Parameter	Plot 1	Plot 2	Plot 3	Plot 4
1	Bulk density (g/cm^3)	0.60	0.63	0.57	0.40
2	Permeability	13.29	18.27	16.77	15.51
3	Water content (%)	52.08	46.81	44.72	49.76
4	Fast drainage pore	11.20	13.50	9.40	11.90
5	Slow drainage pore	5.40	6.20	5.10	7.40

Note: Plots 1 to 3 were extinguished using a foaming agent; plot 4 using water

Table 3 Result of the physical property analysis of peat soil at the research site after extinguishing

No	Parameter	Plot 1	Plot 2	Plot 3	Plot 4
1	Bulk density (g/cm^3)	0.55	0.58	0.56	0.60
2	Permeability	15.25	14.29	15.36	16.63
3	Water content (%)	64.16	66.35	61.01	58.52
4	Fast drainage pore	8.80	10.70	9.40	7.90
5	Slow drainage pore	6.80	7.10	7.80	9.20

Note: Plots 1 to 3 were extinguished using a foaming agent; plot 4 using water

Table 4 Result of the physical property analysis of peat soil at the research site after 3 months

No	Parameter	Plot 1	Plot 2	Plot 3	Plot 4
1	Bulk density (g/cm^3)	0.53	0.55	0.54	0.55
2	Permeability	20.15	9.43	10.04	10.55
3	Water content (%)	71.80	68.86	72.65	63.99
4	Fast drainage pore	22.70	21.40	21.90	20.70
5	Slow drainage pore	9.40	9.20	8.90	9.50

Note: Plot 1 to 3 were extinguished using a foaming agent; plot 4 using water

The results of the analysis shown in Table 4 are the laboratory examination after being left for three months on burnt peat soil. Compared with Table 2 and Table 3, the difference is quite significant. There was a decrease in bulk density and permeability in each plot after three months of treatment. This happens because peat soil that has been damaged will gradually change due to soil compaction. The density of the soil depends on and can be seen from the level of compaction, such as the composition of botanical material, degree of composition, and mineral and water content.

As the rainy season continues, compaction can run quickly because there is sufficient water content to restore the soil, although it will not return completely to its original form. According to Noor (2001), low peat soil density can have an impact on low bearing capacity, and commonly the lower bulk density, the deeper the peat soil. Soil density may vary over time or from layer to layer according to changes in pore or soil structure. The value of water content and drainage pores that occurred after three months of treatment increased quite high compared to the previous one. This can happen due to ongoing climatic conditions. The peat soil can bind rainwater directly where the open soil pores will make it easier for rainwater to fall into the ground more quickly and restore damaged soil and cause soil compaction to take place quickly.

The peat soil permeability can be determined by the type of peat, level of peat maturity, and bulk density. Peat permeability at a depth of 0.5 m to 2 m has a value of 5.4 to 7.7 cm/hour, but this value is very different from the results obtained from field data. This is because the research area has peat that is not mature enough. According to Noor (2001), the higher the permeability rate, the more raw the peat will be. The impact of fires can decrease the groundwater holding capacity in the upper layers, such as a decrease in soil porosity, reduced soil water holding capacity, and soil permeability (Buliyansih, 2005). However, with the extinguishing treatment in this research, it can increase the water content after the occurrence of peat fires, so that with this treatment, it can be stated that it does not have a negative impact on peat soil.

Buffering Properties of Peat Soil

Based on chemical property analysis then linked to the criteria for the chemical properties of *ombrogenous* and *topogenous* peat in Indonesia (Driessen and Sudjati, 1984). Each of these results is distinguished several times, such as before the extinguishing process, after extinguishing, and after three months of extinguishing, which can be seen in Table 5, Table 6, and Table 7.

Table 5 Result of soil buffer analysis before burning

No	Parameter	Plot 1	Plot 2	Plot 3	Plot 4
1	pH	5.06	4.41	5.13	5.88
2	Water content (%)	52.08	46.81	44.72	49.76
3	C-organic (%)	44.76	50.33	38.32	22.21
4	KTK	62.81	105.07	52.97	23.04
5	Peat fiber (%)	32.70	33.10	34.40	31.80

Note: Plot 1 to 3 were extinguished using a foaming agent; plot 4 using water

Table 6 Result of soil buffer analysis after extinguishing

No	Parameter	Plot 1	Plot 2	Plot 3	Plot 4
1	pH	5.31	5.18	5.12	4.86
2	Water content (%)	64.16	66.35	61.01	58.52
3	C-organic (%)	49.34	43.70	44.56	37.76
4	KTK	84.18	118.40	124.38	97.69
5	Peat fiber (%)	34.20	36.70	34.60	33.20

Note: Plot 1 to 3 were extinguished using a foaming agent; plot 4 using water

The analysis shown in Table 5 shows the soil buffering carried out before the blackout treatment. These results can be seen that the pH value with treatment using a foaming agent is classified as very acidic, while the treatment using water is classified as acidic. In C-organic, the value is included in the low category, which is less than 50%, only in plot 2, which has a value exceeding 50%. The CEC results have very diverse values in each plot. Plot 4 has the lowest CEC value, while plot 2 has the highest CEC value. Peat maturity or peat fiber content is the main component of peat soil with the level of weathering in organic matter, which can determine peatland productivity because it affects soil fertility and nutrient availability (Dariah *et al*., 2014). The value of peat fiber content in plot 1 is 32.7% (sapric peat), plot 2 is 33.1% (hemic peat), plot 3 is 34.4% (hemic peat), and plot 4 is 31.8% (sapric peat). The value of peat fiber content obtained in each plot did not indicate a significantly different value; this means that each plot has a peat depth that is not much different.

The analysis shown in Table 6 shows the soil buffering after extinguishing and being left for one day. Compared with the results of the analysis in Table 5, the pH values obtained in each plot increased compared to the previous one. This also happened to the results of CEC and peat fiber content analysis. However, unlike the case of C-organic, only in plot 2 there was a decrease, although not too significant. This can occur due to the extinguishing process, resulting in changes in the value of each parameter. From this value, it can also be seen that the results are not much different from extinguishing using water or control treatment by extinguishing using a foaming agent. The peat fiber content has different results, in plot 1 it is 34.2% (hemic peat), plot 2 is 36.7% (hemic peat), plot 3 is 34.6% (hemic peat), and plot 4 is 33.2% (hemic peat).

Table 7 Result of soil buffer analysis 3 months after extinguishing

No	Parameter	Plot 1	Plot 2	Plot 3	Plot 4
1	pH	5.52	5.13	4.77	4.68
2	Water content (%)	71.80	68.86	72.65	63.99
3	C-organic (%)	49.99	36.54	52.17	38.57
4	KTK	77.12	80.34	158.44	91.86
5	Peat fiber (%)	15.83	15.50	16.10	83.62

Note: Plot 1 to 3 were extinguished using a foaming agent; plot 4 using water

The result of the analysis shown in Table 7 is the soil buffer after 3 months of extinguishing using foaming agent and water. If each parameter is compared with Table 5 and Table 6, the pH in plot 4 has decreased and has a very acidic value, while in plot 1, plot 2, and plot 3, there is an increase from very acidic to acidic with a pH value ranged between 5.12-6.30. This can have a good impact on the soil and environment on the utilization of foaming agent solution in extinguishing fire compared to using water. This has no effect on the acidity of the peat soil. The result of C-organic value analysis found that in plot 2, which decreased during the extinguishing test using a foaming agent, different from the other plots. Only plot 3 has a value of more than 50%, while in the other plots, it is less than 50%, so it is categorized as low value.

The results of CEC analysis in each plot showed a very drastic change before and after the extinguishing. But after three months there was a decrease again. After treatment, the CEC value experienced a significant increase and could be categorized into eutrophic (fertile) with a value ranging between 48.96-124.38. There is a difference in bases saturation so that it has two categories, in plot 1 it is classified as eutrophic (fertile) while plot 2, plot 3, and plot 4 are classified as oligotrophic (infertile). From that category cannot give impact on undergrowth plants to grow in each plot.

Each point in the peat depth has different fiber content, but if it is the same depth with different points, it may have almost the same fiber content and peat maturity. According to Susandi *et al*. (2015), peat is categorized as fibric if the V2/V1>66%, hemic if the V2/V1 between 33% to 66%, and sapric if the V2/V1<33%. The results of the analysis in Table 5, Table 6, and Table 7 show that there are changes in each plot for three months. The peat fiber content after three months of extinguishing changed, including in plot 1 it changed to 15.83% (sapric peat), plot 2 was 15.5% (sapric peat), plot 3 was 16.1% (sapric peat), plot 4 was

83.62% (fibric peat). From these results, in plot 4 the extinguishing method using water or control results in raw peat, while in plots 1 to 3 the extinguishing method using a foaming agent is different from the control can change the type of peat to mature again. This indicates as successful because peat that has returned to maturity has a relatively higher nutrient availability, which can be beneficial for plant growth (Dariah *et al.*, 2014).

Analysis of Undergrowth Vegetation

Three months of research on each research plot with different treatments can produce a variety of plant growth. Three months after burning will only result in the growth of seedlings or undergrowth plants or residual saplings which were previously existed in the plot before burning. The types and numbers that grow on each plot can be seen in Table 8.

Table 1 Result of undergrowth vegetation analysis three months after burning

Plot	Local name	Latin name	Total
Plot 1	Kelakai	*Stenochlaena palustris*	11
	Paku-pakuan	*Pteris* Sp.	4
	Leunca	*Solanum americanum*	3
	Bayam belanda	*Pitolacca americana*	1
Plot 2	Kelakai	*Stenochlaena palustris*	15
	Paku-pakuan	*Pteris* Sp	2
	Kumbuh	*Scirpus mucronatus*	1
Plot 3	Kelakai	*Stenochlaena palustris*	3
Plot 4	Alang-alang	*Imperata cylindrica*	23
	Anakan macaranga	*Macaranga gigantea*	1
	Kelakai	*Stenochlaena palustris*	30
	Rumput setawar	*Spermacoce alata* Aubl.	1
	Maman ungu	*Cleome rutidospermae*	1
	Rumput teki	*Cyperus rotundus*	1

Note: Plot 1 to 3 were extinguished using a foaming agent; plot 4 using water

Three months after the treatment of foaming agent and water to extinguish the fire on peat soil, it can be seen the impact on the research site. These results can be seen from the growth rate and soil properties that occur in each plot. In the first three months, the growth rate is usually only undergrowth plants and some remaining saplings. From this growth, can be examined the impact of soil properties on future sustainability because the occurrence of forest fires can result in changes in succession patterns and vegetation resources, such as industrial wood, animal food, and wildlife habitat. The condition of each plot shows that extinguishing using a foaming agent on peat soil does not have a bad impact and inhibits plant growth. This can be seen by the growth of plants in each plot, and it is not significantly different from extinguishing using water which can be seen in Table 8.

Table 8 shows that plot 1 is dominated by various undergrowth plants compared to the other two plots that use the foaming agent as the treatment. This is because in plot 3 where the plot is flooded by rainwater so that there is less undergrowth compared to the other plots. Meanwhile, in control plot 4 where the fire was extinguished using peat water but it was overgrown with various types of undergrowth which were dominated by alang-alang (*Imperata cylindrica*). The growth of plants in each of these plots can be examined the fertility of the soil after extinguishing using a foaming agent, although the results obtained are not the same for the number of undergrowth plants and are not much different from extinguishing using water, so it is still not possible to conclude whether using a foaming agent on burning peat soil on a large scale will see the difference or not.

Important Value Index (IVI)

The results of the vegetation analysis can be supported by the value of the species diversity index (H'), the species evenness index (E), and the species richness index (R) as well as the IVI values for the three dominant tree species as presented in Table 9.

Table 9 Dominant plant species based on IVI values and various indices

Plot	Vegetation index			Dominant species	IVI (%)
	H'	E	R		
2 x 2	1.206	0.524	1.967	*Stenochlaena palustris*	89.40
				Pteris Sp.	20.10
				Imperata cylindrica	30.85

There is a diversity of dominant species found in the research site. The dominant species is determined through the Important Value Index (IVI), which is a quantitative parameter used to indicate the level of species dominance in vegetation (Ardhana, 2012). The results of the IVI for each type of plant will be different, this can be a reference for determining the dominant plant species. This determination can be made by calculating the IVI of all plant species in the vegetation analysis (Table 5) at the research site. According to Renta *et al*., (2016), a high IVI in a plant species can indicate that the species can compete with environmental conditions and is a dominant species, but on the contrary, if a plant species has a low IVI, it can indicate that the plant species is less able to compete with other species and adapt in the environmental conditions. Based on the results of the IVI calculation, there are three dominant species, such as male (*Stenochlaena palustris*) with an IVI of 89.40%, ferns (*Pteris* Sp.) with an IVI of 20.10%, and alang-alang (*Imperata cylindrica*) with an IVI of 30.85%.

The results of the IVI calculation will obtain the value of the species diversity index (H'), the species evenness index (E), and the species richness index (R). In the species diversity index (H'), there is a calculation that the higher the value of H', the species diversity in the community is more stable and resistant to disturbance. Conversely, the lower the value of H', the lower the level of stability of species diversity in the community (Odum, 1996). The results of H' at the research location with a value of 1.206 and have a fairly stable diversity of species. In the species evenness index (E), according to Soerianegara and Indrawan (1998) and Odum (1996), the higher the value of E, the more stable the evenness of species in a community and vice versa. Based on the calculation results, the value of E in the research location has a value of 0.524 and has an evenness of species in the research location that can be categorized as fairly good. The species richness index (R) at the research site produces a high species richness by having the number of plant species found as many as ten undergrowth species which produces an R-value of 1.967.

CONCLUSION

Based on the results of property analysis of burnt peat soil, the foaming agent could be applied to firefighting activities on peat soil on a scale of 2x2 m. Foaming agents on firefighting activities resulted that it was able to accelerate the process of fire extinguishing, so the subsidence could be decreased. Fire extinguishing using a foaming agent took 3 minutes to 4.6 minutes. Furthermore, fire extinguishing using water could take up time until 50 minutes. Besides, using foaming agents can reduce water usage in the process of firefighting. According to the soil physical analysis, extinguishing using a foaming agent does not have a negative impact on the environment since the results showed that the use of a foaming agent could improve soil structure compared to extinguishing using water. The three months of vegetations observation in the study field shows that the usage of foaming agents has no negative impact on the growth of plants. The observation of soil and vegetation in this study was held only for three months. Therefore, a longer time for optimizing the results of the soil and vegetation growth analysis is needed. Since these analyses aim to determine soil properties changes, expectantly in a longer study period, the result could be more significantly valid. Finally, further research is needed to compare the foaming agent usage to other firefighter products.

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