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Effect of wildfires on tropical peatland vegetation in Meranti Islands District, Riau Province, Indonesia

SINTA HARYATI SILVIANA[1,♥], BAMBANG HERO SAHARJO[2], SIGIT SUTIKNO[3]
[1]Tropical Silviculture Program, Graduate School, Institut Pertanian Bogor. Jl. Lingkar, IPB University Campus Dramaga, Bogor 16680, West Java, Indonesia. Tel.: +62-251-8628448, ♥email: sintaharyatis@gmail.com
[2]Department of Silviculture, Faculty of Forestry, Institut Pertanian Bogor. Jl. Ulin, IPB University Campus Dramaga, Bogor 16680, West Java, Indonesia
[3]Department of Civil Engineering, Faculty of Engineering, Universitas Riau. Jl. Pekanbaru-Bangkinang Km 12.5, Kampus Bina Widya Panam, Simpang Baru, Pekanbaru 28293, Riau, Indonesia

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Abstract. *Silviana SH, Saharjo BH, Sutikno S. 2019. Effect of wildfires on tropical peatland vegetation in Meranti Islands District, Riau Province, Indonesia. Biodiversitas 20: 3056-3062.* Wildfires are one of the main causes of forest destruction, disturbing forest sustainability. Wildfires are mainly caused by human activities, such as land clearing, wood harvesting, draining, etc. Wildfires could induce the loss of vegetation. This study was aimed at assessing the effect of wildfires on both vegetation biomass and necromass on coastal peatland ecosystems in Sungaitohor Village, Tebing Tinggi Timur Sub-district, Meranti Islands District, Riau Province, Indonesia. Analysis of vegetation and both above and below the ground biomass composition were performed. The approach used a paired sample with 4 replications (n = 4 burnt, n=4 unburnt). The variables observed in every research sites was analyzed using Student-T test. Models were generated and then validated to understand the effect of fires on biomass. The results showed that there was a significant difference in the studied parameters between the unburned area and burned area (P <0.01). Wildfires affected the quantity of living plants (biomass) which was indicated by the fact that biomass is unburnt and burnt areas were in the ratio of 2.67 : 1. The quantity of dead plants (necromass) was greater in the burned plots than in the unburnt plots. All these findings suggest that high intensity of forest fires had occurred in the study sites.

Keywords: Biomass, burned peatlands, fire, necromass, unburned peatlands

INTRODUCTION

Wildfires which can highly influence the condition of forests have become one of the topics that are attracting international attention. Historically, fires that hit Indonesia in 1997-98 were the most severe forest fires in the world (Byron and Gill 1998). Peatlands are water-saturated lands that provide a variety of ecosystem services and support valuable biodiversity (Rieley et al. 2008). Riau Province has peatlands of around 4.04 million hectares which accounts for 56.1% of the total area of peatlands on the island of Sumatra (Muslim and Kurniawan 2008). Nowadays, human activities are increasing which are causing the degradation of peatlands, one of which is the making of drainages (Page et al. 2011; Koh et al. 2011; Huijnen et al. 2016). Land clearing by burning is a process that occurs during wildfires (Saharjo 2005). The important cultivating plants that are actually more suitable to be cultivated in dryland results growing in degraded peatlands (Verwer et al. 2008). Fires that are very dangerous for humans and the environment occur every year in Indonesia, which demands the development of programs in forest fire management (Thoha et al. 2019). Wildfires in the forest and land are one of the serious problems that have not been overcome properly and they are increasing year after years. Fires have a considerable impact on human losses, both material and immaterial.

The effect of wildfire is felt directly by all elements of the community exposed to the haze disaster. The very obvious impact of a fire is the loss of potential forest benefits such as standing forest trees. Fires result in irreversible loss of biodiversity, even though burnt land has the ability to recover. The production of biomass from vegetation will be an organic material for every plant to grow and all biomass produced is the fuel that is in the forest (Kauffman et al. 1994) Fire is a flame event due to the availability of fuel in the forest, other than oxygen and sources of fire, where a combination of these three elements cause a flame or what is called the triangle of fire (Clar and Chatten 1954). Peatland fires are a result of the condition of peatlands that are very dry due to the lack of rainfall during a certain time (dry season) and overflowing of the area due to the existing drainage. In addition, the effects of fire cause irreversible hydrophobic nature of peat and eliminate the ability of peat to store and absorb water (Ritzema 2007). This research aims to study the effect of wildfires on the vegetation composition and above and below-ground biomass of peatlands, by calculating and comparing the living and dead plants (necromass) present in burnt and unburnt research plots. The approach used was fire treatment applied on paired samples with 4 replications. The observed variables from each research location were analyzed to study the effect of wildfires on vegetation biomass on the peatlands of this region.

MATERIALS AND METHODS

Research site

This research was conducted from November 2018 to May 2019 in the coastal peatlands at Sungaitohor Village, Tebing Tinggi Timur Sub-district, Meranti Islands District, Riau Province, Indonesia (Figure 1).

Research design

Data collection and measurement were carried out both on burned (n=4) and unburned peatlands (n=4). The rubber plantation and secondary forests were used to represent the unburned peatlands.

Data collection

Data collection was carried out using transects and sampling plots. Each sampling plot was a square of 20 m x 20 m and the distance between squares in the transect was 10 m, 50 m, 150 m, 250 m, and 350 m. Data was collected with the national standard of Indonesia (also called as SNI no. 7724 issued in 2011) which deals with the calculation of carbon stocks. A medium plot (10 m x 10 m) was made inside the bigger square. A small plot (5 m x 5 m) was made inside a medium plot and then a very small plot (2 m x 2 m) was made inside a small plot (Figure 2).

Biomass plant calculation

Observation and analysis of vegetation data

Parameters observed or measured in vegetation inventory referring to Soerianegara and Indrawan (1998): (i) Tree-level vegetation (diameter > 20 cm), (ii) Pole-level vegetation (diameter 10-19 cm), (iii) Sapling-level vegetation (young trees with a minimum height of 1.5 m (diameter 5-10 cm), (iv) Seedling-level vegetation (saplings of rejuvenation less than 1.5 m height (diameter < 5 cm).

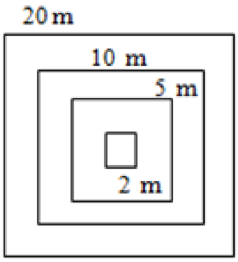

Figure 2. The size of the vegetation sampling plot (square) on the transect line

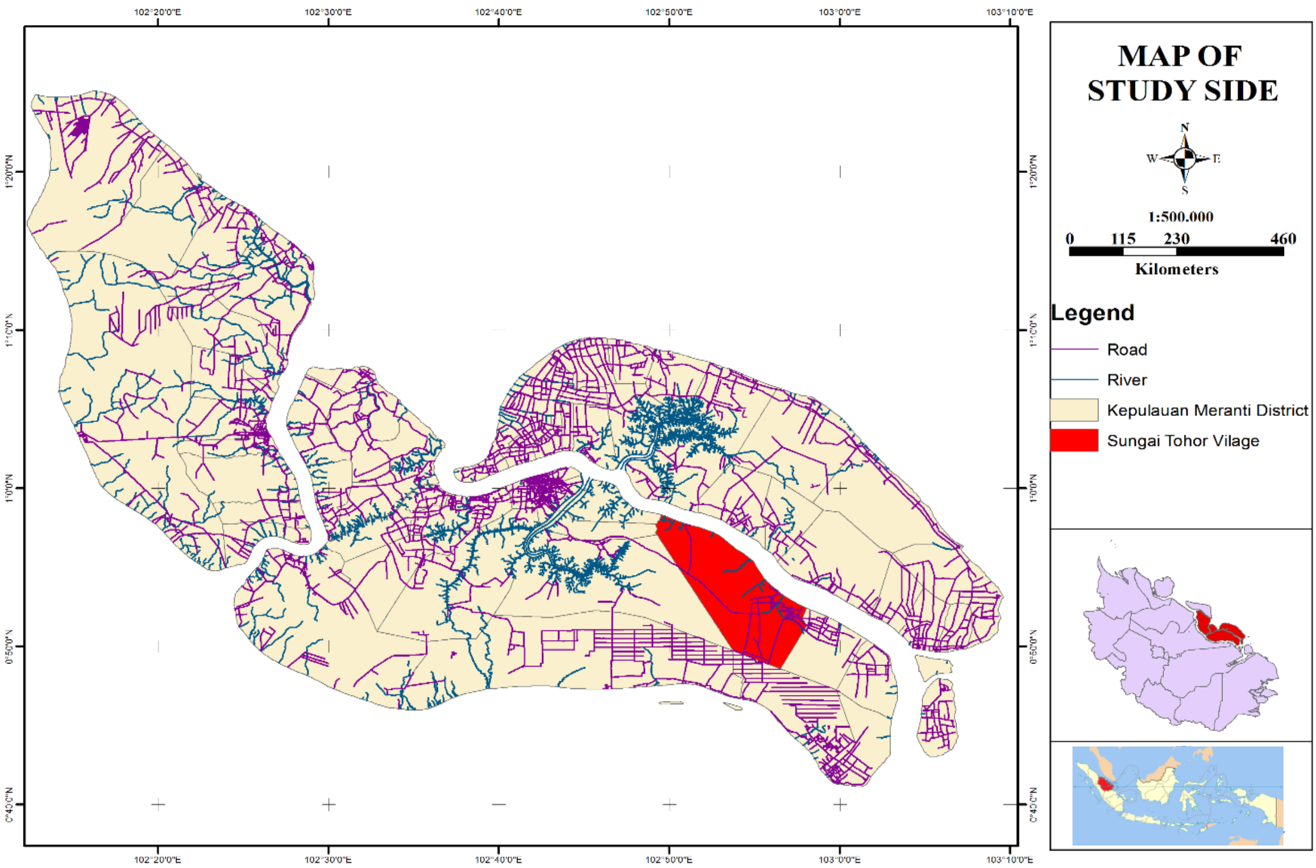

Figure 1. Map of the study area in Sungaitohor Village (marked in red), Tebing Tinggi Timur Sub-district, Meranti Islands District, Riau Province, Indonesia

All species in the plot were recorded with species names (local and scientific). Variables measured for tree-level included diameter, height, species name, and the number of individuals. Tree circumference was measured at a height of 1.3 m from ground level, so as to obtain diameter data at breast height (DBH). The diameter data is calculated by the formula D = C/3.14. The data that has been obtained in the field is used to calculate the vegetation biomass, as given below:

Calculation of above-ground biomass

Calculation of above-ground biomass obtained has been done in two methods i.e. non-destructive and destructive sampling. For non-destructive sampling used to calculate vegetation by category of trees, poles, and saplings. Biomass was calculated from trunk/ diameter of vegetation included in the category from trunk biomass:

Above-ground biomass from trees, poles, and sapling was estimated using allometric equations developed by Manuri et al. (2014):

$$AGB_{est} = 0.242 \times DBH^{2.473} \times WD^{0.736} \quad \text{.................... (1)}$$

Where:
AGB : Above-ground biomass (kg)
WD : Wood density (g cm^{-3})
DBH : Diameter at breast height (cm)

For destructive sampling used to calculate vegetation by category undergrowth (seedlings). the calculation was done by cutting all parts of the vegetation above the surface of the soil. This weight was recorded as wet weight. A 200-gram sub-sample was taken and dried at 80^0C for 2 x 24 hours or until the weight remains constant. After that, the sample is weighed again to obtain the dry weight (DW) and total moisture content biomass seedling (BS). Above-ground biomass from seedling was calculated by SNI 7724 (2011)

$$BS = WW/200 \times DW \quad \text{…...................................... (2)}$$

Where:
BS : wet weight (kg)
DW : dry weight

Calculation of below-ground biomass

Calculation of below-ground biomass from root vegetation by category trees, poles, and saplings. Root biomass was calculated considering the shoot: root biomass ratio of 1: 0.37.

$$B_{root} = 0.37 \times AGB \quad \text{..…. (3)}$$

Where:
B_{root} : root biomass (kg)
AGB : above-ground biomass (kg)

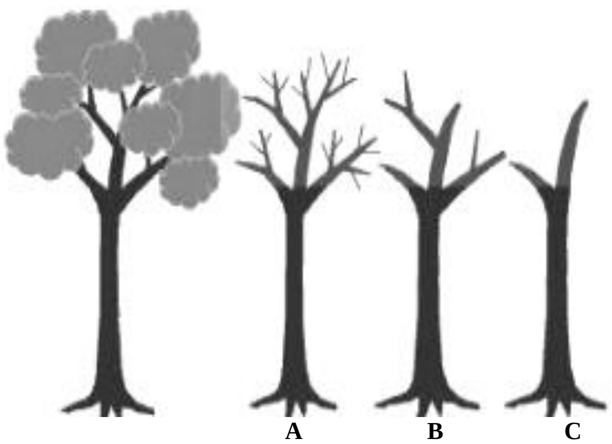

Figure 3. The level of integrity of vegetation with a correction factor: (A) 0.9, (B) 0.8, and (C) 0.7 (Source image: SNI 7724 of 2011)

Dead plants calculation (necromass)

Calculation from dead plants (necromass) has been done in two methods i.e. non-destructive and destructive sampling. For non-destructive sampling was used to measure of the dead trees. Dead tree biomass was calculated by measuring the dead tree DBH, then looking at the integrity of the tree. The calculation was made using the allometric equation which is then multiplied by the correction factor based on the level of integrity of the dead tree (Manuri et al. 2014).

For destructive sampling was used to measure the litter. Calculations by litter a plot measure 2 m x 2 m by referring to SNI 7724 (2011). Litter measurements are the same as measurements undergrowth (seedlings).

Data analysis

The collected data and impact of wildfire on vegetation density was done using Student-T test. The impact of wildfires on living plants (biomass) consists of above and below ground) and dead plants (necromass) was statistically tested using Mann-Whitney U Test.

RESULTS AND DISCUSSION

Geographical location and administration

Sungaitohor is a Village with an area of 9,500 ha which is located in the east of Riau Province with a distance to the provincial capital of approximately ± 166 km. The Village of Sungaitohor is located at coordinates 0048'35"-0058'19" LU and 102049'10"-102058'3" BT. Sungaitohor Village is located on the coast and is a peat area with a flat topography with a slope of 0-8% with an average height of about 1-6.4 m above sea level (BPS Meranti 2014).

Overview of research locations

This research was conducted in Sungaitohor Village which is one of the villages in Tebing Tinggi Timur Sub-district. This sub-district was the result of the expansion of the Tebing Tinggi Sub-district, where Sungaitohor Village is located in the east coast of Tebing Tinggi Island.

Sungaitohor Village cannot be separated from sago trees (*Metroxylon sagu* Rottb.) and peatlands, making it one of the largest sago-producing villages in Tebing Tinggi Timur Sub-district (BPS Meranti 2014). Sago plants have been the main source of the people's economy since 1970 (Profil Desa Sungaitohor 2018). Ecological use of sago plants in peatlands was considered highly potential because sago is a plant that grows in habitats with high water content, like wetlands. Watanabe (1986) said that sago plants can grow in swamps and tidal areas where other plants find it difficult to grow. This is in line with Presidential Regulation No. 1 of 2016 (PP 1/2016) in the restoration of peatlands. The existence of sago saplings that grow forming clumps will maintain soil moisture so that the peat will remain in a wet/humid condition. Besides sago, there are also other plants such as rubber, areca nut, coconut as other sources of livelihood for the village community.

During the last decade, wildfires have engulfed the region and caused huge losses. Fires that occur here cannot be separated from various interests. Murniati and Surhati (2018) stated that fire incidents can be related to activities such as land clearing for land preparation. Land preparation is done by draining drainage or canals so that peatlands are easily planted with other plants. This happens in Sungaitohor Village, where drainage canals were built, which dried the peats and made them vulnerable to fire. In the early to mid-2014, there were large fires in this sago-producing region, which can be seen from hotspot data (Figure 4). Hotspot distribution map (Figure 4.A) shows that the number of hotspots was highest in 2014 when a large fire occurred in this area (Figure 4.B). Peatland fires are a result of the conditions of peatlands that they are very dry, there is an overflowing area of existing drainage, etc. The fires occur not only in open fields but also in sago plantations which are a source of community livelihood. Fire does not only affect this region but reaches other provinces and even neighboring countries.

Impact of wildfires on vegetation

Wildfire in the forest and land can be seen from the types of fires. Paysen et al. (2000) divide the fires into three types, namely ground fires, surface fires, and crown fires. The results of field measurements show that fires that occurred in Sungaitohor Village included all the three types. Fire removes vegetation by consuming existing fuels in the form of organic material that is below the surface of the soil, above the soil surface and canopy of trees. In the ground, fire consumed organic material in the layers of peat litter. Fires resulted in a reduction of existing plant species. This is because plant species cannot survive and fires burn organic material and reduce seeds (Kimmins 2004). Research by Garen (1943) and Chandler (1983) showed that plants of swamp species will die during the dry season and roots near the surface of the soil also die. This is also due to the adaptation of plants where swamp vegetation is usually regenerated with stolons or rhizomes. This organ is very sensitive to heat generated by fire.

On the peat surface, the fire burns all the vegetation including those that have overgrown various types of plants, such as rubber, sago and other trees. The surface fires burn the canopy of trees. Fire destroys the canopy, leaves, branches/branches of trees which also removes vegetation in this area. The fire spreads up so that it enters the crown fire.

Observations showed that there was a difference in the density of vegetation between unburnt areas and burnt areas (Figure 5). The difference in the amount of vegetation in this region is used as a basis for determining the severity of a fire event. The severity of the fire is assessed from the overall vegetation in the burnt area, as stated (DeBano et al. 1998. Land fires consume all the fuels in the forest, in this case, forest vegetation.

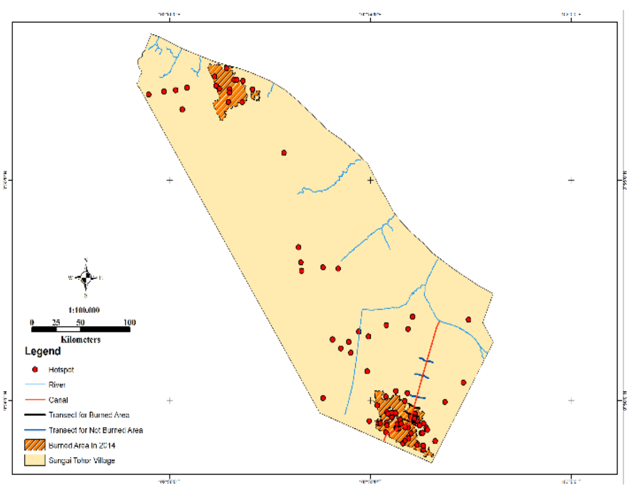

Figure 4. A. Hotspot distribution in Sungaitohor Village, Meranti Islands District, Riau Province, Indonesia

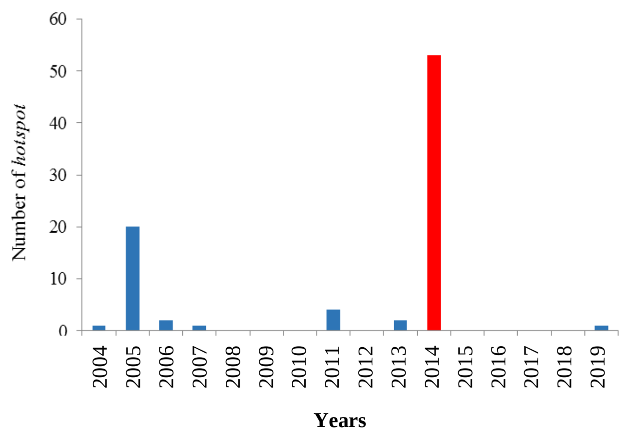

Figure 4.B. The number of hotspots in Sungaitohor Village, Meranti Islands District, Riau Province, Indonesia

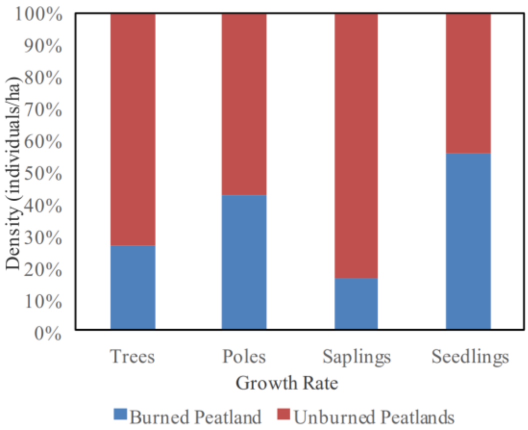

Figure 5. The density of individual vegetation found in the study plot area.

Table 1. Number of biomass and necromass at the study site (ton ha^{-1})

Parameter (Average)	Unburnt peatlands	Burnt peatlands	Sig.
Above-ground biomass-trees	9.01	1.38	0.001
Below-ground biomass-trees	3.30	0.51	0.001
Biomass total-trees	12.31	1.89	0.001
Above-ground biomass-poles	0.19	0.06	0.011
Below-ground biomass-poles	0.07	0.02	0.011
Biomassa total-poles	0.25	0.08	0.012
Above-ground biomass-saplings	0.04	0.003	0.009
Below-ground biomass-saplings	0.01	0.001	0.009
Biomass total-sapling	0.05	0.004	0.005
Seedlings	1.53	3.34	0.001
Dead plants (necromass)	12.70	13.68	0.526
Total mass	26.83	18.99	0.002

The amount of vegetation recorded in the unburned land is approximately two times more than that of the number of individuals in the and burned land, the ratio was almost 2.23:1. This difference is due to the high intensity and frequency of fires, which destroys the existing vegetation. Meijaard et al. (2006) said that the intensity and frequency of fires that occur are related to the amount and nature of the fuel as the effect of the fire on vegetation. For the category of trees, the amount of vegetation in unburned plots was almost four times more (density of 744 individuals/ha) compared to burned land (density of 272 individuals/ha). A similar condition was observed of poles also, unburned plots were (density of 995 individuals/ha) and in sequentially burned land (density of 737 individuals/ha). In the sapling category, it was found that around (density of 5240 individuals/ha) existed on non-burnt land and only (density of 1033 individuals/ha) on burnt land. The large proportion of the amount found is due to the sapling level is still a young plant that affects the ability of the shoots to survive. Darwiati and Faisal (2010) reported that young plants will die from the fire because they have not formed special adaptation organs to survive fires. In contrast, trees that are older than the saplings have shoots that are protected by leaves and located higher on the tree so that it can survive the fire. Other findings in the field show that for the seedling category on burnt land, more numbers were found (density of 184583 individuals/ha) compared to unburnt land (density of 146500 individuals/ha). The seedlings were present due to the fact that, after the fire, the ecosystem had just recovered again. On burned land, vegetation will begin to grow which will contribute to the addition of C reserves

in the form of biomass and increased ecosystem productivity. In addition, given that the data collection was carried out after 5 years of the occurrence of forest fires, trees have grown in the burned area. Ruokolainen and Salo (2009) say that burnt land has the ability to improve itself naturally through a process of succession as well as getting many types of pioneers in the succession of degraded land after a fire. Shade conditions will also affect the growth of existing under vegetation. Burnt land generally has more open conditions compared to unburnt land. In open fields, plant species get direct sunlight which is a favorable condition to grow and develop properly. This is consistent with the opinion of Syafei (1990) which stated that in the closed stands there are fewer ground cover plants than open stands.

Most burnt areas in this study were found to be dominated by thickets with ferns and other undergrowth that appear after burning. The undergrowth was much denser with higher seedling growth rates compared to unburnt land. Some pioneer plants that often emerge after the peat swamp forest ecosystem is burned are cebuk ferns (*Nephrolepis biserrata*), miding ferns (*Stenochlaena palustris*), and for pole and tree-level species, Senduduk (*Melastoma malabathricum*) and Mahang (*Macaranga* spp.).

Effect of fire on vegetation

Fire is an event that plant mass, which consists of living plants (biomass) to dead plants as well (necromass) as fuel in the forest. In this study, the calculation of the mass of vegetation was done to compare the unburned land and the burned land. The results showed that there was a significant difference in the biomass between unburned and burned lands ($P<0.01$) (Table 1). The difference in the quantity of existing biomass proves the effect of the intensity of the fire that occurred. The high intensity of the fire will affect the amount of biomass that exists in such a land. Fuller (1991) says that in the case of forest fires, fire consumes vegetation in the forest.

On the unburnt land, total vegetation biomass was 14.14 tons ha^{-1}, while on the burned land was only 5.30 tons ha^{-1}. The difference in quantity of existing biomass proves the effect of the intensity of the fire that occurred. Forest and land fires are a major cause of biomass loss. The mass of vegetation on unburned land was 26.83 tons ha^{-1}, while on burning land only 18.99 tons ha^{-1} was obtained. The high biomass in unburned land is obtained because in this land it has a high tree density compared to burned land.

Therefore, it is not surprising that the quantity of biomass present in unburned land is significantly greater compared to unburnt land. The biomass produced from vegetation will be organic material for each plant to grow and all of it is fuel that is in the forest (Kauffman et al. 1994). On burnt land the number of seedlings was found to be greater at 3.34 tons ha^{-1} compared to unburned land at 1.53 tons ha^{-1}. The process of fire will trigger the growth of seedlings so that many small diameter vegetations are found. In addition, this data collection was carried out after 5 years after the fire, so that plants began to grow in this burned area. Saharjo (2016) said that former burnt land has the ability to improve itself naturally through a process of succession. Therefore, on burned land found many pioneer plant species.

In this study, it was found that the quantity of dead plants (necromass) on burnt land was more dominant compared to unburnt land. The presence of a lot of necromasses is an important factor as fuel which determines the level of vulnerability to fire (Baeza et al. 2002). The amount of necromass quantity compared to biomass is related to differences in the rate of accumulation of biomass through growth and the rate of decomposition of necromass. Wilson and Loomis (1967) said that generally forest vegetation is relatively short-lived. Plants that have died cause interruptions in the process of accumulation of biomass. Plants that have died require a relatively long process of decomposition. Krishna (2017) said that necromass requires a long process of decomposition depending on the environmental conditions. The presence of litter produced by vegetation will also contribute to improving the condition of peat soils as a nutrient provider that can increase soil organic matter content (Basuki et al. 2018).

In conclusion, wildfires had a significant effect on the existence of biomass, by comparison, such as 2.67 : 1 ($P<0.01$). The quantity of necromass was greater than biomass ($P<0.01$). The higher amount of necromass on a site, the more vulnerable it is to forest fire, especially with the presence of trigger factor such as extremely dry weather during El-Nino years.

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