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Research Article

Biological properties of soils of former forest fires in Samosir Regency of North Sumatera

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Abstract: A study that was aimed to identify the impact of forest fires on the biological properties of soils was carried out at former forest fire areas in Samosir Regency of North Sumatera. Soil samples were collected from former forest fire areas of 2014, 2013, 2012, 2011, 2010. The composite soil samples were collected systematically using diagonal method as much as 5 points in each period of fire. The soil samples were taken at three plots measuring 20 x 20 m 0-20 cm depth. Soil biological properties observed were soil organic C content, total number of microbes, abundance of arbuscular mycorrhizal fungi, phosphate solubilizing microbes, and soil microbial activity. The results showed that organic C content ranged from 0.75 to 2.47% which included criteria for very low to moderate. Arbuscular mycorrhizal fungi spores were found belonging to the genus of *Glomus* and *Acaulospora*. Spore number increased with the fire period ranging from 45 spores (forest fire in 2014) to 152 spores (forest fire in 2010). The total number of microbes obtained ranged from 53.78 x 10^7 cfu/mL (forest fire in 2010) to 89.70 x10^7 cfu/mL (forest fire in 2013). It was found 29 isolates of phosphate solubilizing microbes that consisted of 14 bacterial isolates and 15 fungi isolates with densities ranging from 27.642 x10^5 cfu/mL (forest fires in 2014) to 97.776 x 10^5 cfu/ mL (forest fires in 2011). The isolates of phosphate solubilizing bacteria identified consisted of *Pseudomonas*, *Flavobacterium*, *Staphylococcus*, and *Mycobacterium* genus, whereas the isolates of phosphate solubilizing fungi obtained consisted of *Aspergillus* and *Penicillium* genus. Soil respiration ranged from 2.14 kg / day (forest fire in 2010) up to 3.71 kg / day (forest fire in 2013). The varied results were greatly influenced by the type or form of the fires and intensity of fires. In the study area the type or form of the fires were canopy fires with low intensity.

***Keywords**: bacteria, fungi, forest fire, soil organic C, total number of microbes*

Introduction

Soil is a natural resource that has many functions in the ecosystem. Among other functions is as plant growing media, as habitat for both macro and microorganisms and plays a role in nutrient cycles. The disruption to the ecosystem will lead to the undermining of the soil. According to Chandler et al. (1983), fire is one factor contributing to the deterioration of the ecosystem in which the response depends on the severity of the fire.

Forest fires can cause changes to soil physical, chemical and biological properties. The impact of forest fires on soil physical properties mainly due to the opening of the canopy, burned humus and litter, deterioration of soil structure which lead to erosion susceptibility (Certini, 2005; Ekinci, 2006). In terms of soil chemical properties, forest fires provide input of minerals contained in the ashes or charcoal to raise the soil pH and increase soil nutrients. However, this effect does not last long due to the opening of the canopy then leaching becomes more intensive (Chandler et al., 1983; Boerner et al., 2009; Aref et al., 2011; Ershad et al., 2013).

Forest fires have different effects for each nutrient as each nutrient has a different temperature threshold where nutrients will be volatilized. Effect of forest fires to the presence of organic materials give varying results depending on the intensity and type of fires, soil moisture, soil types and original burned materials (Certini, 2005; Ekinci, 2006; Verma and Jayakumar, 2012; Ershad et al., 2013). Neary et al. (1999) reported that in burned soil, the nitrogen content is lower than that of in the unburned soils, while calcium content is higher on burnt soil, and potassium, magnesium and phosphorus contents remain unchanged. Forest fires can cause loss of biodiversity and alter soil chemical and physical wealth, so they will affect the composition of soil microbes (Suciatmih, 2008).

Soil microbes have important role in the cycle of food that will then determine soil fertility and plant growth that are very sensitive to environmental changes. According to Verma and Jayakumar (2012), the effect of fire on soil microbial biomass is a drop in the number of microbes.

The purpose of this study was to identify the biological properties of soils of the former forest fire areas in Samosir Regency of North Sumatera.

Materials and Methods

Sampling of soils was conducted at forest areas that were burnt in 2014, 2013, 2012, 2011, and 2010. Samples of soils from the former forest fires of 2014 and 2011 were collected at village of Curaman Tomok Village of Simanindo District. Soil samples from the former forest fire of 2010 were collected from Sijambur Nabolak Village of Pangururan District, soil samples from the forest fire of 2012 were collected at Siogung-ogung Village of Pangururan District, and soil samples from the former forest fire in 2013 were collected at Sosor Dolok Village of Pangururan District. Identification of soil biological properties was carried out in the Laboratory of Soil Biology, Faculty of Agriculture, and North Sumatera University. The study was conducted from June to September 2014.

Soil sampling was done diagonally and then composited in three sample plots of each fire period. From each plot, soil samples taken from 5 points at 0-20 cm depth. Composite soil samples were then placed in a separate plastic bag and labeled for analysis of soil biological properties. Soil biological properties observed were organic C content using Walkley and Black method (CPM, 2005), total number of microbes using the plate count method (Anas, 1989), abundance of arbuscular mycorrhizal fungi using the strain technique (Brundret et al,. 1996), phosphate solubilizing microbes using the plate count method (Anas, 1989), soil microbial activity by measuring the respiration process using the jar method (Anas, 1989).

Results and Discussion

The results showed that the content of organic C in the soil ranged from 0.75% to 2.47% which included criteria for very low to moderate. The number of spores of arbuscular mycorrhizal fungi (AMF) obtained increased with the period of fire that ranged from 45 spores (forest fire in 2014) to 152 spores (forest fire in 2010). The total number of microbes obtained ranged from 53.78 x 10^7 (forest fire in 2010) to 89.70 x 10^7 cfu / mL (forest fire in 2013). Population density of phosphate solubilizing microbe ranged from 27.642 x 10^5 cfu / mL (forest fire 2014) to 97.776 x 10^5 cfu / mL (forest fire in 2011). Respiration ranged from 2.14 kg / day (forest fire in 2010) to 3.71 kg / day forest fire in 2013) (Table 1).

Table 1. Biological properties of soils of former forest fire in Samosir Regency

No	Soil Samples	Organic C (%)	Total Microbe (cfu/mL)	Spore Density of AMF	Population of PSB (cfu/mL)	Respiration (kg/day)
1	Fire in 2014	0.75 vl	59.94 x 10^7	45	27.642 x 10^5	2.71
2	Fire in 2013	1.65 l	89.70 x 10^7	56	75.858 x 10^5	3.71
3	Fire in 2012	2.47 m	67.40 x 10^7	62	34.373 x 10^5	3.43
4	Fire in 2011	1.62 l	66.98 x 10^7	129	97.776 x 10^5	3.43
5	Fire in 2010	1.19 l	53.78 x 10^7	152	82.606 x 10^5	2.14

Remarks: vl = very low; l = low; m = moderate; AMF = Arbuscular Mycorrhizal Fungi, PSB = Phosphate Solubilizing Bacteria

Organic C content

Data presented in Table 1 show that soil of the forest burned in 2014 had very low content of organic C. This was due to soil sampling performed 2 months after the fire, so the soil organic matter had not yet increased. In soils of the forest burned in 2010 until 2013, however, the soil organic C content increased because of the addition of organic matter to the soil through the growth of grasses. According to Neary et al. (1999), the effect of forest fire on soil organic matter varies greatly depending on the severity of the fire, drought of organic matter surface, vegetation type, soil texture and types of fire.

Low intensity fires typically produce little change in the soil carbon and high-intensity fires cause the loss of soil carbon. It has been reported elsewhere that after 2 weeks of fire there is no significant difference in soil C value from that from unburned soils (Ekinci, 2006). The increase of N and C contents in the topsoil was a direct result of forest fires and the increased amount of nitrogen-fixing bacteria after the fire (Johnson, 1992).

Microbial Activity and Total Microbes

Microbial activity can be measured through soil respiration based on CO_2 released by the microbes. In this study, respiration of microorganisms ranged from 2.14 kg / day to 3.71 kg / day (Table 1). The greater the value obtained, the more microbial activity was detected in the soil. Respiration is related to the presence of microorganisms in the soil, where the greater number of microbes in the soil, then its activity is also higher. The effect of forest fire on soil microbial varies depending on the severity of the fire, the changing nature of the soil and environmental conditions after the fire occurred and also depends on the type of microbes found in the soil. In soil, there are 10^8 to 10^{12} bacteria and other organisms (Hedo et al., 2014).

Results of this study indicated that the highest microbial population was observed in soils of 2013, while the lowest population was found in soils of former 2010 forest fire although the population was still around 10^7 cfu / mL. Microbial activity showed results in line with the microbial population. In soil of former 2014 forest fire, the respiration value of 3.71 kg / day was the highest respiration value compared to that in soil of 2010 forest fire that amounted to only 2.14 kg / day. The increase number of microbes will increase the microbial activity that relates to the presence of soil organic matter as source of energy for microbes. Soil microorganisms play an important role in maintaining the soil quality and keep the soil fertile. Soil microorganisms require a range of temperatures, and a certain pH, water availability, nutrient availability, and energy sources in order to survive (Subba Rao, 1994). Mataix-Solera et al. (2009) reported that respiration measured in burned soils was not different from that measured in unburned soils.

Phosphate Solubilizing Microbes

Phosphate solubilizing microbes play roles in increasing availability of P bound by soil components so it can be taken up by plants to improve plant growth. The highest population of phosphate solubilizing microbes was found in soils of 2011 forest fire, and the lowest was in soils of 2014 forest fire. After isolation, there were 29 isolates consisting of 14 phosphate solubilizing bacteria and 15 phosphate solubilizing fungi. The isolates of phosphate solubilizing bacteria consisted of four genuses, i.e. *Pseudomonas, Flavobacterium, Staphilococus* and *Mycobacterium* (Holt et al., 1994) (Table 2).

Data presented in Table 2 show that *Pseudomonas* was identified in almost all soils of the former forest fire except in 2010. *Pseudomonas* is a genus of bacteria that is most frequently encountered in various ecosystems such as peat ecosystem in Samarinda (Nurkanto, 2007), and banana palm ecosystem (Marista et al., 2013). The isolates of phosphate solubilizing fungi consisted of two genus, i.e. *Aspergillus* and *Penicillium* (Gilman, 1971; Gandjar et al., 1999) (Table 2). *Aspergillus* and *Penicillium* are cosmopolitan fungi commonly found in a variety of ecosystems. The fungi are known as the most widely used phosphate solubilizing fungi to improve the availability of P in soils.

Table 2. Isolated phosphate solubilizing microbes

Genus	Soil Samples				
	Forest Fire in 2014	Forest Fire in 2013	Forest Fire in 2012	Forest Fire in 2011	Forest Fire in 2010
Pseudomonas	√	√	√	√	-
Flavobavterium	-	-	-	-	√
Staphilococcus	-	-	-	-	√
Mycobacterium	-	-	-	-	√
Aspergillus	√	√	√	√	√
Penicillium	-	√	√	√	-

Remarks: √ = found, - = not found

The diversity of fungi the study area was influenced by the low-moderate content of soil C organic that ranged from 0.75% to 2.47%. Fungi are heterotrophic microbes which require organic matter as a source of carbon and energy. The low content of organic matter in the soils of former forest fires hindered other soil organisms to survive (Subba Rao, 1994).

Arbuscular Mycorrhizal Fungi

The number of arbuscular mycorrhizal fungi spores increased in line with the period of forest fire (Table 2). The fungi consisted of *Glomus* genus and *Acaulospora* genus. Glomus is the arbuscular mycorrhizal fungi most commonly found in various ecosystems because of its high adaptability in a variety of soil conditions (Brundrett et al., 1996.). Meanwhile, *Gigaspora* genus and *Scelerocystis* genus are commonly found in the tropics and *Acaulospora* genus is adaptable to the conditions of acid soil with a pH of <5. Forest fires affect the existence of mycorrhiza because of changes in soil conditions that alter their growth. Verma and Jayakumar (2012) reported in their study that although the total number of mycorrhizal spores in burned soils was almost similar with that in unburned soils, the number of living propagules in the burned soils was lower than that in the unburned soils. In the low intensity of forest fires where some plants still survive, the effect of fire on the population of mycorrhizal fungi is not significant and can be an improvement in the short to medium term (between 6 and 12 months in many cases) (Certini, 2005).

The effect of forest fires on soils depends on various factors such as the intensity of the fire, the severity of the fire, the duration of the fire, types of fires and soil moisture. High intensity, long period, and severity fires give direct impact to soil to a depth of more than 5 cm, while low intensity and short priode of fires do not give effect to soil of less than 5 cm depth (Certini, 2005; Barreiro et al., 2015). Types of fires observed in Samosir Regency were surface fires that became canopy fires with low intensity. Therefore, the effect of the fires varied for different periods of fires. According to Hedo et al. (2014), the quality of burned soils will wil similar to that of the unburned soils after 17 years.

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