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PATTERN OF BIOLOGICAL ACTIVITIES IN VARIOUS CONDITIONS OF PLANTED *ACACIA CRASSICARPA* ON PEATLANDS IN RELATION TO CARBON EMISSION

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SUMMARY

Research on carbon emission that emphasizes on roles of soil biological activity is still lacking. We conducted a research to determine pattern of biological activity under various conditions of natural and planted *Acacia crassicarpa* on peatlands in relation to water level and carbon emissions. Results show that rate of soil respiration, microbe and soil fauna populations decrease with peat depth. The downward decrease is attributed to decrease of oxygen and substrate supplies. Biological activity was found to be limited at depth of about 50 cm and more regardless of water table level. Low biological activity resulted in reduced decomposition of organic matter and lower carbon (CO_2) emission.

KEY WORDS: Biological activity, Carbon emission, Peatlands, Plantation forest.

INTRODUCTION

Recent research show that peatlands utilization causes high emissions of carbon dioxide that is positively correlated with water level, decomposition stage (hemic, fibric, sapric), and depth of peat (Jauhiainen *et al*., 2011; Couwenberg *et al*., 2010; Hooijer *et al*., 2010). The estimation was drawn using theoretical base saying that rate of decomposition of organic material of peat will sharply increase at opened peatlands. This theoretical base is clearly weak since decomposition process of organic matter is not merely physical and chemical reactions but it involves great rules of biological activities in the rhizosphere (Raydin and Jeglum, 2005).

Decomposition is largely a consequence of the feeding activity of soil animals (fragmentation) and heterotrophic microbes (chemical alteration). Controls over decomposition are therefore best understood in terms of the controls over the activities of these organisms. The ecosystem consequences of decomposition are the mineralization of organic matter to inorganic components (CO_2, mineral nutrients, and water) and the transformation of organic matter into complex organic compounds that are recalcitrant (resistant to further microbial breakdown). In other words, decomposition occurs to meet the energetic and nutritional demands of decomposer organisms (Chapin III *et al*., 2002).

Growth and population size of soil microbes and fauna depend on soil conditions including oxygen supply, moisture, temperature, concentration of H^+ in the soil solution, nutrient availability and the characteristics of organic matter. Fungi are the main initial decomposers of terrestrial dead plant material and, together with bacteria, account for 80 to 90% of the total decomposer biomass and respiration. Fungi account for 60 to 90% of the microbial biomass in forest soils, where litter frequently has a high lignin and low nitrogen concentration. They have a competitive advantage at low pH, which is also common in forest soils. Most fungi lack a capacity for anaerobic metabolism and are therefore absent from or dormant in anaerobic conditions (Chapin III *et al.*, 2002)

Soil animals influence decomposition by fragmenting and transforming litter, grazing populations of bacteria and fungi, and altering soil structure. The microfauna are made up of the smallest animals (less than 0.1mm). They include nematodes; protozoans, such as ciliates and amoebae; and some mites (Lousier and Bamforth 1990; Wallwork 1976). The mesofauna consist of a taxonomically diverse group of soil animals in the size range of 0.1 to 2mm in length. The mesofauna have the greatest effect on decomposition. Mesofauna species fragment and ingest litter coated with microbial biomass, producing large amounts of fecal material that has greater surface area and moisture-holding capacity than the original litter. This altered litter environment is more favorable for decomposition (Lavelle *et al*., 1997). The macrofauna are a taxonomically diverse group of soil animals between 2 mm to 20 mm in length, such as earthworms and termites, and are ecosystem engineers that alter resource availability by modifying the physical properties of soils and litter (Jones *et al.*, 1994). Some of them fragment litter, for example mesofauna species (Lavelle *et al.*, 1997). Termites eat plant litter directly, digest the cellulose with the aid of mutualistic protozoans in their guts, and mix the organic matter into the soil.

According to Chapin III *et al.* (2002) the soil fauna is critical to the carbon and nutrient dynamics of soils. So variations in predation rates of microbes (contain 70 to 80% of the labile carbon and nitrogen in soils) by soil animals dramatically alter carbon and nitrogen turnover in soils. Soil animals have high respiration rates and metabolize much of the microbial carbon from their food to CO_2 to support their high energetic costs of movement. As a result, the microbial nitrogen and phosphorus acquired by soil animals generally exceeds their requirements for growth and reproduction. Soil animals account for only about 5% of soil respiration, so their major effect on decomposition is their enhancement of microbial activity through fragmentation (Wall *et al.*, 2001), rather than their own processing of energy derived from detritus.

Based on the facts above and research on carbon dioxide emission that emphasizes on roles of soil biological activity is still lacking. We carried out a research to investigate the pattern of biological activity in natural peat swamp forest and peatland converted to *Acacia crassicarpa* plantation in relation to water level and carbon dioxide emission.

MATERIAL AND METHODS

The research was conducted in Bukitbatu Natural Peat Swamp Forest and in three blocks of *A. crassicarpa* plantation of different ages in the PT Bukitbatu Hutani Alam concession, in Riau Province, Sumatra, Indonesia. Sampling of soil fauna was undertaken by hand sorting method by removing peat from a 1 x 1 m^2 area to a depth of 20 cm. Peat samples were taken to a depth of 60 cm, by layer of 10 cm, depend on plant age (the depth of peat sample depend on water table). Litter samples (0-2.5 cm) were also taken. The peat samples were put in plastic bag and then were kept in coolbox with ice packs. After samples arrived in the laboratory, the samples were stored in refrigerator at 4º C. The peat samples were used to determine soil chemical properties, soil microbes and soil respiration. Soil microbes (fungi and bacteria) were determined by plate count method using soil extract media and soil respiration was determined in the laboratory by closed chamber method (modification of Öhlinger, 1996). Peat bulk density of each 10 cm layer in three years old *Acacia* was determined using iron box 10 x 10 x 10 cm^3. Root distribution of *Acacia* was also observed in the field.

Litter production was measured on the field using litter net 1 x 1 m^2 and sample was taken every month. Rate of litter decomposition was measured by using litter bag method. Each litter types were placed in the bags, which were then buried in the peat or placed on the surface, and the mass loss was measured every month. Weight and chemicals properties of litter samples were analyzed in the laboratory

RESULTS AND DISCUSSION

The results show that:

(i) The soil fauna were more numerous in the Acacia plantation than in the natural peat swamp forest (Table 1). This is due to fact that peat soil in the plantation is going better in nutrient content as compared to the peat soil in the natural forest. *A. crassicarpa* is leguminoceae plant, it can fix nitrogen from air and was fertilized at planting. Therefore it can produce higher amount of litter and better quality biomass than natural peat swamp forest. Average production of litter in *Acacia* 6.38 ton/ha/year as compared with 5.52 ton/ha/year in natural peat swamp forest. Laboratory analysis result showed nitrogen content of *A. crassicarpa* litter is 3.38% and natural peat swamp forest litter is 1.30%. Soil fauna are obligate aerobe, so they thrive better in the place with higher oxygen content such as in the plantation which ground water level is controlled, as compared to the natural peat swamp forest that most of the time saturated by water.
Root distribution of *Acacia* was found mostly in the upper layer (0 – 10 cm), decrease significantly with the depth. This was due to the fact that most nutrients were abundant in the litter layer (data not shown).

Table 1. Soil Fauna Abundance in Two Ecosystem

Order	Ecosystem			
	Natural Forest		Plantation Forest	
	Family	∑ Individual	Family	∑ Individual
Araneae			4	44
Anellidae			1	8
Blattodea	2	5	2	20
Centipedes			2	39
Coleoptera	1	3	5	17
Geophilomorpha			1	5
Hymenoptera	2	47	3	115
Isoptera	2	55	3	1296
Isopoda	1	3	2	19
Milipedes			1	37
Pseudoscorpion			1	9
Symphyla			1	19
Trombidiformes			1	1
Total	8	113	27	1629

(ii) Rate of soil respiration, size of microbe populations, and the amount of soil fauna decrease with depth in the peat (Table 2). The downward decrease is attributed to decrease of oxygen, nutrients and substrate supplies with depth. The most active in biological processes were found in the upper layer of the soil, namely in the litter (0 – 2.5 cm). That means that CO_2 emission mostly come from litter decomposition not from peat decomposition. Peat contains recalcitrant carbon substance that is very difficult to breakdown (Chapin III *et al*., 2002), on the other hand litter contains high amount of easily decomposable carbon materials and contain higher nutrients (as peat analyzes results shown).

Table 2. Relationship between Microbe Population with Soil Respiration at Various Depth in Acacia Plantation in Bukitbatu

Sample code	Depth (cm)	Propagules	Fungi	Soil Respiration
		10^8 CFU/dm^3 soil	10^6 CFU/dm^3 soil	mg CO_2-C/dm^3/day
A. crassicarpa 3 yrs	0-2.5	4.04	2.23	330.29
A. crassicarpa 3 yrs	0-10	2.45	5.6	146.21
A. crassicarpa 3 yrs	10-20	1.63	3.21	128.17
A. crassicarpa 3 yrs	20-30	0.81	1.88	83.08
A. crassicarpa 3 yrs	30-40	0.20	1.93	60.76
A. crassicarpa 3 yrs	40-50	0.11	1.41	53.17
A. crassicarpa 3 yrs	50-60	0.05	1.02	43.44
A. crassicarpa 1 yr	0-2.5	3.43	3.08	183.95
A. crassicarpa 1 yr	0-10	2.06	2.02	78.80
A. crassicarpa 1 yr	10-20	1.24	0.32	72.16

The biological activities as shown by soil respiration were found to much more limited at depth of about 50 cm and more regardless water level of the land (Fig. 1). Low biological activities have in turn limited decomposition of organic matter and hence released carbon (CO_2) would also be low. This clearly indicating that the deepest the water level (drainage) of cultivated peatlands is not necessarily the highest the carbon emission.

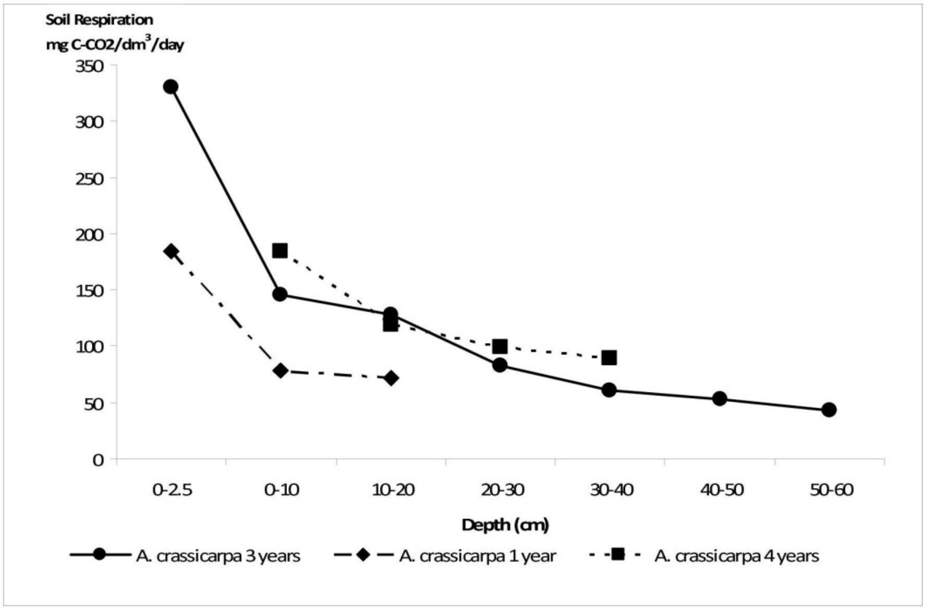

Figure 1. Relationship between soil respiration and soil depth at various plants age (plant ages regulate water level).

With the depth of peat soil samples, the bulk density of the peat soil also decrease and the turn over rate of the peat soil is increase (Fig. 2). The litter was decomposed seven times faster as compared to peat soil at the depth 50 – 60 cm, this was not due to lack of oxygen or saturated with water, because the measurement was done in the laboratory at field capacity. This is in agreement with the fact that tropical peat soil is actually the rest of the decomposition of woody plant materials as parent material of the peat soil. Therefore tropical peat soil contain a lot of lignified materials a recalcitrant carbon substance that is very difficult to be decomposed by soil microbes.

Better management namely ground water control and fertilization make peat soil more fertile therefore can thrive more abundance living organism including the plants themselves. Better plants growth will produce more biomass and around 40 % of this biomass (in form of leaves, small branch, twigs and roots) will be left on the peat and adding organic matter to the peat. The plantation harvests only the main stem of Acacia plant, which comprises around 60 % of the total biomass (according to the information collected in the field during this research). Organic matter addition can be observed in the field in form of litter accumulation in the peat surface (in 3 years old *Acacia* on average 2.5 cm thick, comprises of new litter and old litter that already difficult to identified as leaves, branches or twigs).

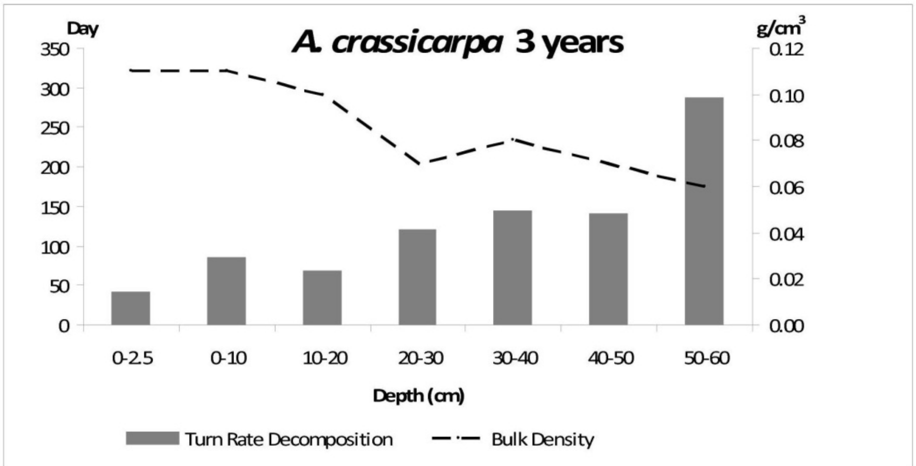

Figure 2. Relationship between turn over rate of peat soil and soil bulk density at various soil depth.

CONCLUSION

Utilization of peatland as *Acacia* plantation can increase soil organism biodiversity.

Most of soil organisms' included plant root activities take place in the litter layer where nutrient and food are most abundant.

Most of CO_2 emission from peat soil comes from the root activity (respiration and the decomposition of the litter than the decomposition of peat soil.

Better management of plantation is important for peat sustainability and the plantation itself.

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