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Controlling factor of carbon dioxide flux from tropical peat soil in palm oil at central Kalimantan, Indonesia

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This study aims to measure the rate of CO_2 emissions and the effect of several types of vegetation on environmental parameters at the location of oil palm plantation companies on tropical peat lands, in Central Kalimantan, Indonesia. The measurement of Carbon dioxide emission rate uses the open and closed Chamber method. The parameters measured include water table, soil temperature, soil moisture, and pH of groundwater. The experimental design used was a randomized block design, with 3 replications. The treatment was 6 treatments. The findings in this study obtained the average CO_2 emissions rate varies depending on changes in vegetation types, the highest on the conservation forest vegetation equal to 358.46 mg C m^2 Hr^1. The findings based on the influence of several types of vegetation in the oil palm plantation area towards the Water Table parameters obtained the conservation forest vegetation type with the highest water table average of 35.21 cm, 4 cm temperature parameters obtained grass land vegetation types (28.01^{0}C), 10 cm temperature parameters obtained vegetation types of palm oil plants aged 5 Years (27.13 ^{0}C), pH parameters of groundwater obtained vegetation type of Palm oil plants aged 6 Years (4.669). The relationship of the rate of CO_2 emissions with several environmental factors in the vegetation type, shows that the higher the rate of CO_2 emissions, the deeper the water table, lowering the temperature 4 cm, temperature 10 cm and soil moisture with the magnitude of the diversity coefficient equal to 33.74%, 27.50%, 26.33%, and 23.92% respectively. Meanwhile, the higher the CO_2 emissions, then pH of groundwater increases.

Keywords: Tropical Peatland, Global Warming Potential, CO_2 emission rate.

INTRODUCTION

Peat land in tropical region comprise nearly 10-12% of total global peat land (Rieley et al., 2008), and it covers approximately 27 Mha (Hooijer et al., 2010). Hooijer et al., (2010) estimated at least 42 Pg of carbon (C) is stored in Southeast Asian peat land assuming peat C content of 60 kg m^{-3}. Increasing carbon dioxide (CO_2) concentration in atmosphere is considered as a one of the reasons of global climate change (IPCC, 2007), and loss of C from tropical peat land can impact on the variation of atmospheric CO_2 concentration. Indeed, approximately 0.2 Pg C in peat was released by burning in Central Kalimantan, Indonesia, and it corresponded to 3.2% of the mean annual global C emissions from fossil fuels (Page et al., 2002).

Peat land in Southeast Asia has been disturbed by human activity such as drainage, burning, and cultivation (Page and Hooijer, 2016). Hooijer et al., (2010) reported that deforested and drained peat land was approximately 48% (13 Mha) of peat land in Southeast Asia in 2006. From those peat lands, 355-855 Tg C has been lost by decomposition of which 82% come from Indonesia. Those losses of C will continue and contribute to increase atmospheric CO_2 concentration while peat land is on aerobic condition, though C loss by burning was temporal C emission. More than 83% (23 Mha) of peat land in Southeast Asia was distributed in Indonesia (Hooijer et al., 2010) . The research findings Warren et al., (2017) This estimate is about half of previous assessments which used an assumed average value of peat thickness for all Indonesian peat lands, and revises the current global tropical peat carbon pool to 75 GtC. Yet, these results do not diminish the significance of Indonesia's peat lands, which store an estimated 30% more carbon than the biomass of all Indonesian forests (Warren et al., 2017).

More than 14% (3.1 Mha) of peat land in Indonesia was distributed in Central Kalimantan, Borneo Island (Hooijier et al., 2010). However, 1.5 Mha of peat swamp forest in Central Kalimantan was pioneered (deforested and drained) from 1996 to 1999, as a part of Mega Rice Project (MRP). Though MRP was frustrated in 1999, most of those opened peat land was remained and often burned. Those drained and burned peat land have potentially been emitting large amount of C induced by peat decomposition and/or burning. On the other hand, cropland is also distributed in Central Kalimantan. Hooijer et al., (2010) reported that cropland (crop and shrub) corresponded to 22 % of the peat land, which was larger than that in drained shrub land (19%). Not only C loss, but also subsidence is important issue for agriculture. Subsidence by peat decomposition and compaction means diminishing plow layer essential for agriculture. There may be Pyrite (Fe_2S) in mineral soil under the peat layer. It makes soil acidic when it is oxidized on aerobic condition. It will be difficult to grow for crop if soil layer containing Pyrite under peat layer is close to plow layer.

As above, suppressing C loss from peat should be subjected to conservation of natural peat swamp forest, recovery of the forest after drainage and burning in disturbed forest, and reduce peat decomposition in agricultural field. To solve the issue, it is necessary to quantify how much C was lost in each land use type and understand the controlling factor of CO_2 emission in all land use type including agricultural field. Those will make clear which land use type potentially release large amount of C and what should be treated for reducing C emission by peat decomposition. Until now, some study was reported related to the factors controlling CO_2 emission from tropical peat land. From the reviewing study, it has been reported that rising up ground water table increased CO_2 emission from tropical peat land (Hooijer et al., 2010). Moreover, Melling et al., (2005) reported the environmental variables explaining the variation of CO_2 flux could be classified into three components, climate, soil moisture, and soil bulk density by PCA analysis in peat swamp forest, sago and oil palm plantations in Malaysia (Melling et al., 2005). Jyrki et al., (2008) constructed dams to rise up ground water table and verified the effect of it on CO_2 emission in drained and/or burned forest in Indonesia. However, CO_2 emission from those sites did not reflect the differing hydrological conditions the year before and after the dam construction (Berger et al., 2018, Luan et al., 2018, Green et al., 2018, and Assahira et al., 2017). Those suggest that controlling factor for explaining CO_2 release from tropical peat land is still unclear. Thus, we conducted the study about CO_2 emission from tropical peat land at different land use type.

MATERIALS AND METHODS

Description of Research Location

This research was carried out in oil palm plantation companies on peat land, Kota Besi sub-district, East Kotawaringin Regency, Central Kalimantan Province, Indonesia, which was held from November 2016 to October 2017. Field surveys at company sites on the plots of conservation forest (S:02° 26' 20.45", E:112° 54' 03.70"),grass land (S:02° 24'23.58" , E:112° 56' 31.01") and oil palm plants with 3 years of planting age (S:02° 26' 20.45", E:112° 54' 03.70") , oil palm plants 4 years planting age (S:02° 24' 07.76" , E:112° 59' 43.47"), oil palm plants with 5 years planting age (S:02° 26' 14.76" , E:112° 54' 08.72"), and oil palm plants with 6 years planting age (S:02° 26' 22.11" , E:112° 54' 05.23")

CO_2 Emission Measurement

Measurement of CO_2 emissions using the open closed chamber method for each research plot. Open closed chamber method with three replications. Gas fluxes were measured monthly from November 2016 to October 2017. Methods of sample retrieval and analysis of CO_2 gas using the method by Takakai et al.,(2006), Nakano et al., (2004), Toma and Hatano(2007), and Toma et al., (2011).

Supporting data

Low height measurements of groundwater level use PVC pipe that was made and entered into the ground in each measurement plot. The soil temperature is measured at depth (0-4 cm) and (0-10 cm) using the thermometer thermistor and pH of groundwater using Pocket PH/mV Meter-Laqua Twin PH11.

Statistical analysis

Statistical analysis using a randomized block design with 3 replications, and 6 treatments namely the use of conservation forest land, grass land and oil palm plants with planting age (3,4,5 and 6 years).

RESULTS AND DISCUSSION

Carbon Emission Pattern in various vegetation

The average pattern of CO_2 emissions in various types of vegetation at the location of oil palm plantations is shown in Figure 1.

Figure 1. Shows the highest average emission rate on conservation forest vegetation equal to 358.46 mg C m^2 Hr^1 , oil palm plants aged 6 years amounted to 33.45mg C m^2 Hr^1, oil palm aged 5 years equal to 303.34 mg C m^2 Hr^1, oil palm plants aged 4 years amounted to 247.63 mg C m^2 Hr^1 , srub/ grass land equal to 197.78 mg C m^2 Hr^1, and the smallest average on oil palm plants aged 3 years equal to 147.66 mg C m^2 Hr^1 Pearland's are a place for carbon accumulation (*carbon reservoir* or *carbon storage*). The release of CO_2 into the air from reclaimed natural peatlands for agricultural activities is a process of oxidation and reduction of its organic matter. In a reductive environment, the rate of decomposition of peat is very slow and many toxic organic acids and methane (CH_4) are produced, whereas on the oxidative state, the release of C increased, especially in the form of CO_2. The type of land use affects the ability of the soil to store CO_2. Types of land use plays an important role in controlling the flux of CO_2 in the atmosphere, means controlling global warming.

The opening of peat swamps for agriculture and plantations is always followed by the destruction of the hydrological system and causes problems related to the physical, chemical and biological properties of the soil. Page et al., (2002), Canadell et al., (2007), Hirano et al., (2007) said the opening of tropical peat on a large scale would result in a sudden and permanent change in the carbon ecosystem balance. Meanwhile Limin (2006) said that changes in the hydrological status of peatlands due to the construction of drainage, would cause changes in the type of vegetation that would be adaptive in the region.

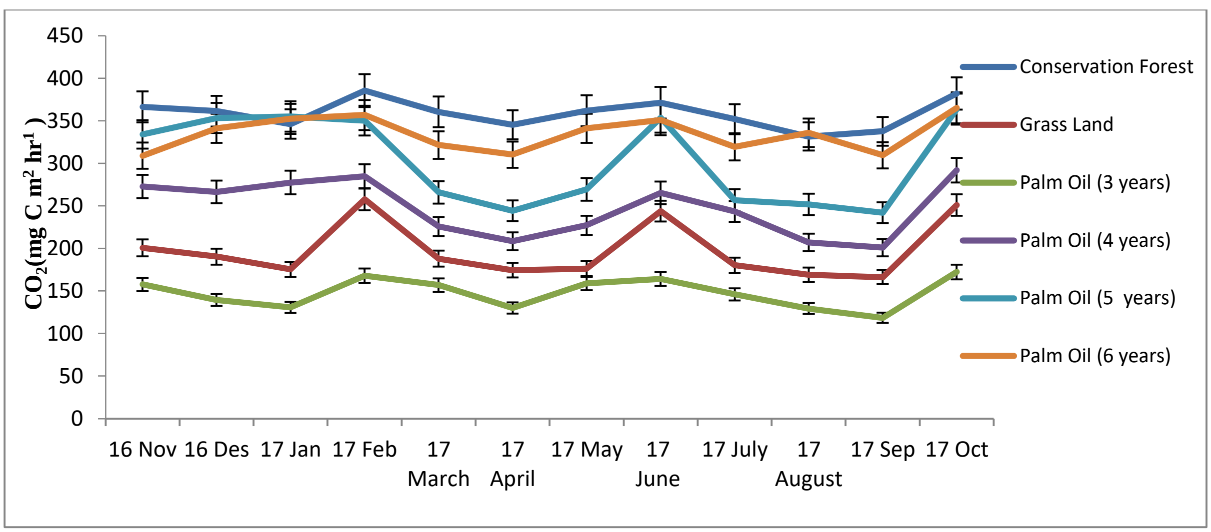

Figure 1. Average pattern of CO_2 emissions (mg C m^2 Hr^1) in various types of vegetation

Water Table (cm)

The results of variance analysis showed that the treatment of vegetation types was significantly different on the water table (cm) at the error level of 5% (P>0.05). Table 1, show the type of land use in the conservation forest vegetation type was the highest average water table equal to 35.21 (cm) but not significantly different from other vegetation types, while the lowest on oil palm plants aged 3 years amounted to 32.37 (cm). These findings obtained factors that influence the high average CO_2 emissions are environmental factors, especially groundwater, soil temperature and soil moisture. Research by Rumbang et al., (2009) suggests that the average value of CO_2 emissions released by peat lands is influenced by environmental factors, among others groundwater level depth, air temperature, soil temperature, peat properties such as peat pH, KPK, organic C content and microorganisms. Vegetation type (land cover/canopy) will affect the average temperature under the canopy which will automatically affect CO_2 emissions in different vegetation types.

Table .1 the Average Effect of Several Vegetation Types in Palm Oil Plantation Areas on Water Tables (cm)

Vegetation Type	Water Table (cm)
Conservation Forest	35.21 a
Grass land	35.08 a
Oil Palm plants aged 3 years	32.37 a
Oil Palm plants aged 4 years	33.94 a
Oil Palm plants aged 5 years	34.42 a
Oil Palm plants aged 6 years	34.57 a

Information: Numbers accompanied by the same letters on the same row and column are not significantly different from the Duncan test 5% ($p>0.05$).

The increase in CO_2 emissions is also caused by root respiration. The type and age of the plant will affect the size of root respiration. Research results from Jauhiainen et al., (2012) shows that root respiration contributes 21% from total CO_2 emissions on acacia plantations cultivated on peat land in Jambi. The findings of this study indicate that there was a high average CO_2 emission in conservation forest vegetation amounted to 358.46 mg C m^2 Hr^1, because the vegetation in conservation forests are quite large, have different types and ages of plants and root systems. The number of roots in the conservation forest will affect the total CO_2 emissions from the area. Hirano, et al., (2009) said the key to the difficulty in describing carbon flows in various land uses was caused by; (i) CO_2 emissions and root respiration are not separated from emissions caused by decomposition, (ii) lack of historical information / description about the location used for research, and (iii) peat hydrology is often poorly monitored. In addition, the characteristics of forest vegetation (composition and volume of vegetation) as well as the characteristics of micro-topography (bumps and hollows) are not very much considered in the placement of measuring devices for emissions, which will affect CO_2 emissions.

The research findings show that the highest average value of CO_2 emissions is found in conservation forest vegetation types amounted to 358,46 mg C m^2 Hr^1 which may be caused by the incorporation of CO_2 emissions and root respiration. Root respiration and rhizosphere is one of the main components that affect soil CO_2 emissions. Estimated to contribute, ranging from 10 to 90% (Boone et al., 1998, Rochette et al., 1999, Zhou et al., 2018, Savage et al., 2018 and Qu et al., 2018). The amount of root respiration and rhizosphere is dominated by root biomass from certain soil layers. Pietikainen et al., (1999) and Widen and Majdi (2001) found the highest respiratory activity in the boreal forest in the organic layer close to the soil surface where the highest amount of fine root biomass. However, the level of CO_2 production by roots at different depths also depends on the proportion of new and old roots.

The lowest average value of CO_2 emissions is found in the 3-year-old oil palm vegetation type equal to 147,66 mg C m^2 Hr^1, this is due to groundwater conditions that not too far from the surface. Hirano et al., (2012) said that the ground water and the flow of carbon has a linear relationship. The decline in groundwater every 0,1 m will emit carbon flow of 0,27 $\mu mol.m^{-2}.second^{-1}$. In the condition of ground water close to the surface of the soil will cause the activity of microorganisms to decrease in the process of decomposition of peat. Jauhiainen, et al., (2005, 2008, 2012) said that in the condition of saturated water in the rainy season the total CO_2 emissions of tropical peat lands are very low and increase as the groundwater decline during the dry season. Also added, if the ground water is close to the surface for a long time, there will be heterotropic carbon emissions that happened so fast along with changes in the depth of the ground water, at this time there will also occured a non-linear relationship between groundwater and moisture. Hirano, et al., (2012) also said the increase in the flow of carbon or peat oxidative decomposition at low ground water condition is due to thickening of the unsaturated soil zone and results from the increase in aeration.

Soil Temperature 4, 10 cm (^{0}C)

The results of the variance analysis showed that the treatment of vegetation type had a significant effect on soil temperature 4 and 10 cm at the error rate of 5% ($P<0.05$).

Table 2, shows the type of land use at temperature 4 cm indicates that the grass land vegetation type with an average temperature 4 cm was the highest amounted to 28.01^0 C and significantly different from conservation forest vegetation types, Oil Palm plants aged 4 years and Oil Palm plants aged 6 years but not significantly different from vegetation type of Oil Palm plants aged 3 years and Oil Palm plants aged 5 years. The lowest average temperature 4 cm was found in the type of conservation forest vegetation equal to 24.58 ^{0}C. The average temperature 10 cm due to the influence of vegetation type indicates that the vegetation type of Oil Palm plants aged 4 years with an average temperature 10 cm was the highest amounted to 27.13 ^{0} C and significantly different from other treatments. While the lowest average temperature 10 cm was found in the type of conservation forest vegetation amounted to 24.22 ^{0}C. Changes have a direct influence on sunlight, the temperature of the soil will increase with increasing radiation from the sun. The increase in temperature from direct sunlight on peat soils depends on the vegetation (land cover / canopy) that grows on the peat. Research findings of Rumbang et al., (2009) said that the size of the canopy on peat land will affect the air temperature under the canopy. Lee et al., (2018), Seitz and Puig (2018), Gómez et al., (2018), and Hirano et al., (2009) also said that solar radiation and land cover conditions would affect soil temperature. The findings of this study obtained the highest average soil temperature 4 cm found in grass land vegetation equal to 28,01 ^{0}C. The vegetation of the grass land is very open and there is no large canopy to cover the peat land, sunlight directly on the ground. Whereas on conservation forest vegetation the average soil temperature is lower at 24,58 ^{0}C, because the conservation forest vegetation is dominated by trees with a large enough canopy to cover and keep the temperature below it low by resisting direct sunlight.Hirano et al., (2012) said that the level of CO_2 emissions from the incubation samples of the Sumatran tropical peat surface was also doubled at temperatures between 25^{o}C and 35 ^{o}C. The two studies above found that an increase in temperature has a greater effect on the level of CO_2 emissions from moisture and groundwater.

Soil Moisture (%)

The results of the variance analysis showed that the treatment of vegetation types had a significant effect on soil moisture at an error rate of 5% ($P<0.05$). Duncan's post-test of the effect of vegetation type on soil moisture is shown in Table 3.

Table 3, show the type of land use is significantly different on the average soil moisture. The highest average soil moisture was found in conservation forest vegetation types 0.6664% and significantly different from other vegetation types. The smallest average soil moisture found in grass land vegetation type equal to 0.4848%. Soil moisture will always be inversely proportional to soil temperature, the higher the average value of soil moisture, the lower the average soil temperature. In accordance with the findings of this study that the average soil moisture in conservation forest vegetation has the highest value equal to 0.6664 (%), the minimum amount of sunlight reaching the ground due to the canopy of trees will cause soil moisture to rise. Whereas in the open vegetation, sunlight directly shines on the peat land and causes the peat soil to dry out and the soil moisture to decrease, as in the grass land vegetation type with an average value of humidity/ moisture equal to 0.4848 (%).The findings of Jauhiainen et al., (2012) said, on peat lands with high groundwater levels and without good drainage control there is a strong relationship between the depth of groundwater and moisture. Both of them rise during rainy season and fall during the dry season.

PH of Groundwater

The results of the variance analysis showed that the treatment of vegetation type had an effect on the pH of the groundwater at an error rate of 5% ($P<0.05$). Duncan's post -test due to the effect of treatment on pH of groundwater is shown in Table 4.

Table 4, shows the type of land use is significantly different to the average pH of groundwater, The highest average pH of groundwater is found in the vegetation type of oil palm plants aged 6 years amounted to 4.669 but it is not significantly different from the vegetation type of oil palm plants aged 5 years.

Table 2. The Average Effect of Several Vegetation Types in the Palm Oil Plantation Area On the Soil Temperature 4, 10 cm (^{0} C)

Vegetation Type	Temperature 4 cm(^{0} C)	Temperature 10 cm(^{0} C)
Conservation Forest	24,58 a	24.22 a
Grass land	28,01 d	26.51 b
Oil Palm plants aged 3 years	27,94 cd	26.58 bc
Oil Palm plants aged 4 years	27,78 c	27.13 e
Oil Palm plants aged 5 years	27,88 cd	27.01 d
Oil Palm plants aged 6 years	26,79 b	26.67 c

Information: Numbers accompanied by the same letters on the same row and column are not significantly different from the Duncan test 5% ($p<0.05$).

Table 3. The Average Effect of Several Vegetation Types in the Area of Oil Palm Plantation On the Soil Moisture (%)

Vegetation Type	Soil Moisture (%)
Conservation Forest	0.6664 e
Grass land	0.4848 a
Oil Palm plants aged 3 years	0.5232 b
Oil Palm plants aged 4 years	0.5382 bc
Oil Palm plants aged 5 years	0.6038 d
Oil Palm plants aged 6 years	0.5548 c

Information: Numbers accompanied by the same letters on the same row and column are not significantly different from the Duncan test 5% ($p<0.05$).

Table 4. The Average Effect of Several Vegetation Types in the Area of Oil Palm Plantations on the pH of Groundwater

Vegetation Type	pH of groundwater
Conservation Forest	4.417 a
Grass land	4.408 a
Oil Palm plants aged 3 years	4.547 b
Oil Palm plants aged 4 years	4.539 b
Oil Palm plants aged 5 years	4.528 c
Oil Palm plants aged 6 years	4.669 c

Information: Numbers accompanied by the same letters on the same row and column are not significantly different from the Duncan test 5% ($p<0.05$).

The lowest average pH of groundwater is found in grass land vegetation types and not significantly different from conservation forests. The acidity of peat groundwater is strongly influenced by the content of organic matter, which has a close relationship with the decomposition rate of organic matter, the pH value will be higher if there is faster decomposition (Murayama and Zahari, 1992). Decomposition occurs because of the activity of microorganisms, increasing when there is fertilization treatment.

The difference in the average value of pH of groundwater in each vegetation type is more influenced by the treatment of each type of vegetation. Findings In this study, the highest average pH of groundwater was found in the vegetation type of oil palm plant aged 6 years amounted to 4,669. Treatment on this vegetation type of Oil Palm Plant aged 6 years is fertilizing with organic or non-organic material and will automatically increase the pH of groundwater. Meanwhile the average value of the lowest soil pH is found in grass land vegetation type equal to 4.408, wherein this location has never been treated.

The loss of peat surface might reduce the flow of carbon compared to that in unburn peat lands. In addition, fires change the properties of peat chemically, physically and microbiologically. As a result of fire, organic carbon and a decrease in total nitrogen in the peat remain, meanwhile mineral nutrients, pH and bulk density increase (Dikici and Yilmaz, 2006;. Smith et al., 2001). The increase in pH can increase soil microbial activity and potentially increase peat decomposition (Moilanen et al., 2012).

Relationship of CO_2 Emissions with several environmental factors in several types of vegetation

The relationship of CO2 emissions with several environmental factors in vegetation types is shown in Figure 2. Indicates that the higher the CO_2 emissions, the deeper the water table, lowering the temperature 4 cm, temperature 10 cm and soil moisture with the magnitude of the diversity coefficient equal to 33.74%, 27.50%, 26.33%, and 23.92% respectively, while the relationship of CO_2 emissions with pH of groundwater shows that the higher CO_2 emissions will increase soil pH with a large diversity of 71, 18%.

The opening of peat swamps for agriculture and plantations is always followed by the destruction of the hydrological system and causes problems related to the physical, chemical and biological properties of the soil. Page et al., (2002), Canadell et al., (2007), Hirano et al., (2007) said the opening of tropical peat on a large scale would result in a sudden and permanent change in the carbon ecosystem balance. Whereas Limin (2006) said that changes in the hydrological status of peatlands due to the construction of drainage, would cause changes in the type of vegetation that would be adaptive in the region.

Jauhiainen, et al., (2005) said that the area of tropical peat swamp forest, groundwater has a more important role than temperature, because it acts as an abiotic control of the flow of gas between peat and the atmosphere. Peat swamp forest has a very large biomass content every year. Vegetation converts CO_2 in the atmosphere into organic compounds, and at the same time this process releases CO_2 in respiration. The quality and amount of carbon varies in the part of the litter / peat surface, in organic matter which is carried out beneath the surface of the peat, and roots rot, but they form the main carbon supply to decompose biotically. Depending on abiotic conditions in the soil, carbon bound to biomass is usually released back into the atmosphere as CO_2 or CH_4 during decomposition, or stored as a semi-decaying organic substrate known as peat

The continuity of the presence of peat is very much determined by its status which must be saturated with water so that it continues to accumulate, although it is decomposed slowly, it will be disrupted if there is a change in hydrological status, or drought occurs in the upper layer of peat. Respiration is a biochemical process that occurs in cells in all living organisms. Based on the sources of carbohydrate substrate supply, CO_2 production in the soil can be derived from (1) root respiration, (2) microbial respiration in the rhizosphere, (3) decomposition of litter and soil organisms; and (4) oxidation of soil organic matter (Luo and Zhuo, 2006; Moyano et at, 2010). The range of magnitude of root respiration varies widely, ranging between 10-90% of the total soil respiration. However, on average it almost reaches 50% from total land respiration (Hanson et al., 2000 in Luo and Zhou. 2006).

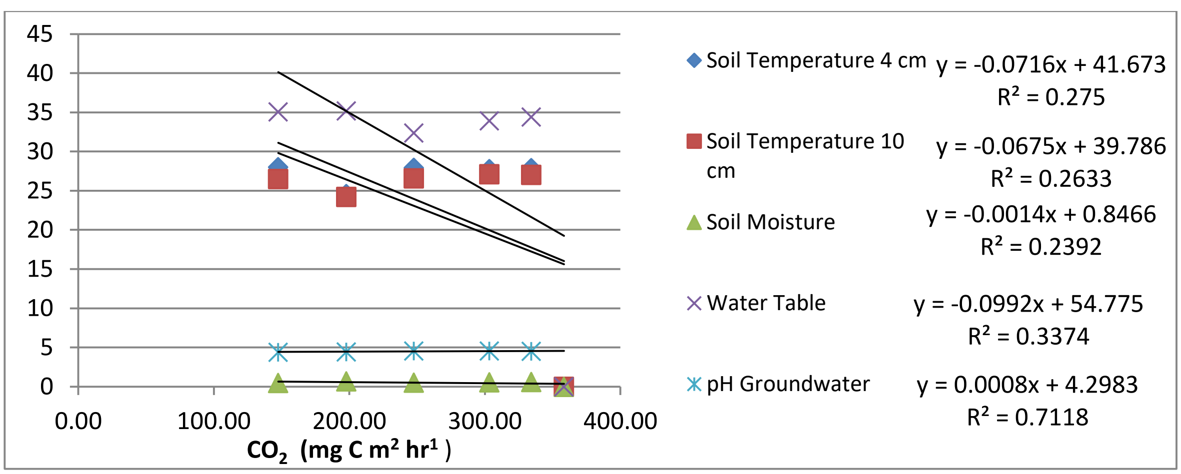

Figure 2 . Correlation of CO_2 Emission Rate to Environmental parameters.

According to Moyano et al., (2010) that CO2 emissions from root respiration may be greater in number than respiration originating from the decomposition of soil organic matter. The amount of CO_2 production from root respiration is determined by root biomass and specific root respiration rate (Pausch et al., 2018, Jarvi et al., 2018, and Verlinden et al., 2018). Root biomass in an ecosystem depends on ecosystem production and the pattern of allocation of plant species (Tonkin et al., 2018, Winkler, 2017, Sesnie et al., 2018, Byrnes et al., 2018, and Salin et al., 2018). Forest has biomass of around 5 kg/m^2, while agricultural land and its kind has lower biomass and usually less than 1,5 kg/m^2 (Jackson et al, 1996 in Luo and Thou, 2006). Results of research by Jauhiainen et al., (2012) on Acacia plantations in Sumatra show that the emission originating from roots is 21% from total emissions.

Root respiration increases with increasing temperature. Temperature sensitivity affects the reaction of catalysts of enzymes involved in respiration and increased ATP, along with increasing metabolism. Temperature stimulation on the respiration is also needed in increasing energy to support the increased rate of biosynthesis, movement and supply of proteins (Busch et al., 2018, Piñol et al., 2018).

Respiration of microorganisms is largely determined by the availability of carbonaceus (mucilage, sloughed and exudate) in the rhizosphere (Verma, 2018, Kodjo, Luo and Zhou, 2006). Rizosphere is a meeting zone between the surface of the root and the soil, where there is an interaction between plants and microbes (Moyano et al., 2010). Rizosphere is the most beneficial habitat for microorganism life. Interactions between plants and microorganisms in the rhizosphere play a role in regulating microbial activity, nutrient availability, decomposition of organic matter and the dynamics of soil organic matter (Luo and Zhou, 2006, Verma et al., 2018, Luo et al., 2018, Hao et al., 2018 and Aung et al., 2018).

CONCLUSION

Changing of the land use conversion of tropical peat land for oil palm plantation activities plays a very important role in the pattern of changes in the rate of emissions from the surface of peat lands, controlling the rate of CO_2 emissions in the atmosphere, means controlling global warming. Changes in peat land use in oil palm plantations, the findings obtained the rate of CO_2 emissions vary widely depending on changes in vegetation types, the highest on conservation forest vegetation equal to 358.46 mg C m^2 Hr^1 , palm oil plants aged 6 years amounted to 33.45 mg C m^2 Hr^1, palm oil aged 5 years equal to 303.34 mg C m^2 Hr^1, palm oil plants aged 4 years amounted to 247.63 mg C m^2 Hr^1, grass land vegetation equal to 197.78 mg C m^2 Hr^1, and the smallest average on oil palm plants aged 3 years equal to 147.66 mg C m^2 Hr^1.

The findings based on the influence of several types of vegetation in the oil palm plantation area towards the Water Table parameters obtained the conservation forest vegetation type with the highest water table average of 35.21 cm, for 4 cm temperature parameters obtained grass land vegetation types with the highest average temperature of 28.01^0 C, 10 cm temperature parameters obtained vegetation types of palm oil plants aged 5 Years with the highest average temperature of 27.13^0 C, for the soil moisture parameter obtained vegetation type of Conservation Forest with the highest average moisture 0.6664%, whereas for pH parameters of groundwater obtained vegetation type of Palm oil plants aged 6 Years with the highest average groundwater pH equal to 4.669. The relationship of the rate of CO_2 emissions with several environmental factors in the vegetation type, shows that the higher the rate of CO_2 emissions, the deeper the water table, lowering the temperature 4 cm, temperature 10 cm and soil moisture with the magnitude of the diversity coefficient equal to 33.74%, 27.50%, 26.33%, and 23.92% respectively. Meanwhile, the higher the CO_2 emissions, then pH of groundwater increases. To reduce the rate of CO_2 emissions at the location of oil palm plantation companies, limit the making of drainage channels to maintain the water table so that it can maintain soil temperature and moisture that affect the rate of CO_2 emissions from tropical peat lands. For further research activities, how is the influence of distance and width and depth of the making of drainage channels to the rate of CO_2 emissions in the location of oil palm plantations on tropical peat lands.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

The article is part of the Dissertation of Doctoral and all the authors have contributed: UD conducted experiments, data collection, data analysis and writing manuscript, Prof. SM contributed to the experimental design, the determination of the research treatment and the field survey, Dr. CP and Prof. SD contributes to experimental design, determination of research treatment and review of manuscripts.

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