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The Rate of Carbon Dioxide (CO_2) Emission in Various Ages and Conditions of Balangeran Plant (*Shorea Balangeran*) at Ombrogenous Peatlands in Central Kalimantan

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ABSTRACT
Drainage of peatlands all around the world for agricultural or forestry purposes has resulted in extensive land degradation, in this case the result of changes in soil physical properties resulting from an increase in the rate of microbial decomposition. Changes in the use of tropical peatlands as agricultural or plantation lands will cause an increase in CO_2 emissions into the atmosphere. The clearing of peatlands which is preceded by the construction of channels (drainage) will cause the water table in the peatlands to become far away from the surface, this will drive the decomposition rate of organic matter by microorganisms, which finally, the peat becomes susceptible to burning (*fires*). Therefore, the understanding of CO_2 emissions is very important for planning the drainage systems, in order to conserve peatland. The balance of C in the peat ecosystem is the amount of flux or loss of C, which is influenced by fluctuations in the water table or groundwater content and the characteristics of the changing peat, as well as other environmental factors. The results of this study show that: CO_2 emission fluctuations are between 126.51±16.22 mg C m^{-2} $hour^{-1}$ to 753.23±307.57 mg C m^{-2} $hour^{-1}$. The highest CO_2 emission is found in plot P1 (open land conditions and only dominated by shrubs, while the lowest CO_2 emission is found in plot P3 (plants aged 3 - 4 years). This condition is different in different season conditions, where the highest CO_2 emissions found in revegetation locations with *Shorea balangeran* plant species aged 3 – 4 years (P3), then followed by revegetation locations with *Shorea balangeran* plant species aged 1 – 2 years and the open location (*open area*) and changes in land cover will affect CO_2 emissions, because the root system of each plant will be different.

Keywords: Drainage, peat, CO_2 emissions, and Balangeran plant.

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INTRODUCTION

Drainage of peatlands all around the world for agricultural or forestry purposes has resulted in extensive land degradation, in this case the result of changes in soil physical properties resulting from an increase in the rate of microbial decomposition. (Stephens *et al*., 1984; Rojstaczer & Deverel, 1993; Syvitski *et al*., 2009; Hirano *et al*., 2012). In addition to degradation of peat soils and their associated habitats, these ecosystems have become a source of globally significant carbon dioxide (CO_2) emissions to the atmosphere, as large amounts of carbon (C) are lost to the atmosphere from oxidation. (Armentano, 1980; Drösler *et al*., 2008; Couwenberg *et al*., 2010). The relationship between soil properties and aerobic biological activity, which is usually measured as respiration of CO_2, is usually related to soil depth (Paul and Clark, 1996; Fang and Moncrieff, 2001; Fierer *et al*., 2003).

The peat ecosystem is one of the ecosystems that has an important role and benefits for human life, which is currently being used for various development activities. These benefits among others: water supply and flood control, tourism potential, local community livelihoods (agriculture, plantations, fisheries), climate stability, biodiversity, as well as education and research. In this case, more than half (24.8 Mha) of the total area of tropical peat is in Southeast Asia (56%), especially in Indonesia and Malaysia, which based on its thickness (average > 5 m) is able to store C amounted to 77% (Page *et al*., 2011). Based on data from the Directorate General of Forest Protection and Nature Conservation (2012), Indonesia ranks 4th in the world's largest area for tropical peat, after Canada, the Soviet Union and the United States from the world's total peat area. Peatlands in Indonesia are estimated to be 14.9 million hectares (ha) spread across Sumatera Island 6.4 million ha (43.18%), Kalimantan Island 4.7 million ha (32.06%), Irian Island 3.6 million ha (24.76%), and the rest is spread across the islands of Sulawesi, Halmahera, and Seram. In the Kalimantan region, most of the peat is located in the Provinces of West, Central and South Kalimantan. The area of peatland in Central Kalimantan is 2.65 million ha or 16.83% of the total area of Central Kalimantan (BBSDLP, 2013).

One of the ecological functions of peatlands is as a carbon storehouse (C). However, if the natural condition of the peat is disturbed, then it will accelerate the decomposition process, so that the C stored in the peat will be emitted to form greenhouse gases, especially carbon dioxide (CO_2). In tropical peatland ecosystems occurred C cycle which is quite important for the system on earth. Approximately 50% of total C will be used for plant growth and development in the photosynthetic process. The rest of the dead plants will be decomposed back into the soil system to become a source of nutrients and some will be emitted into the atmosphere in the form of CO_2. Under normal conditions, this cycle always forms a carbon balance in the biosphere. The large capacity of peat in carbon storage will be very effective in overcoming the rate of carbon emissions. The results of calculations carried out by Maltby and Immirizi (1993) show that C reserves in peatlands in the world are 329-525 Gt (35% of the world's total carbon). Peat in Indonesia stores 46 Gt (note: 1 Gt = 10 tonnes) or 8-14% of total carbon on peatlands. In addition, it is based on the results of carbon reserve research conducted on ombrogenous peat in Malaysia by Melling *et al*. (2008) namely amounted to 3,771-ton C ha^{-1}. The amount of C contained in peatlands makes it the largest source and storage (*sink*) of terrestrial C. Therefore, it can be clearly seen that peat plays an important role in safeguarding global climate change. If these peatlands burn, or are degraded, they will emit various types of greenhouse gases (mainly CO_2, NO_2, and CH_4) into the atmosphere and change the global climate.

Utilization of the peat ecosystem in addition to being in accordance with the function of the ecosystem, must also be in accordance with the standard criteria for damage, among others maintaining the groundwater level in peatlands not exceeding 0.4 m (zero point four meters) below the peat surface and/or the exposed of pyrite sediments and/or quartz under the peat layer. Based on the experiences and problems that occurred in the Mega Rice Project (MRP)/Proyek Lahan Gambut (PLG) above, then interventions are needed to increase the carrying capacity of the peat ecosystem, particularly through restoring the function of the peat ecosystem, either through restoration or rehabilitation, to reduce the rate of CO_2 emissions into the atmosphere. Therefore, related to plant types that are suitable for carbon mitigation purposes (C), among them are plant types or species that have fast growing criteria so that they can compete with weeds in the field, have high adaptability, have pioneering properties that give a high chance of success, and the most important thing is to have a high C absorption capacity (Adjers and Otsamo, 1996). However, all of these successes are also determined by ecological and physiological characters that vary widely between species. In this case, the selection of tree species composition for revegetation/reforestation which is oriented towards greenhouse gases mitigation requires an understanding of the ecological and physiological properties of plant species and accuracy in plant species selection based on expected characteristics. For this reason, the evaluation of ecological and physiological characters is one of the appropriate indicators (Ashton, 1998), as well as the CO_2 emissions generated becomes an important thing to know.

Purpose

The purpose of this research activity is to determine the condition of land cover which planted with Balangeran (*Shorea balangeran*) plants towards the CO_2 emission rate at ombrogenous peatlands in Central Kalimantan.

RESEARCH METHODOLOGY

Time and Place

This research activity was carried out at a peatland revegetation location in Tumbang Nusa Village, Jabiren Subdistrict, Pulang Pisau Regency, Central Kalimantan Province, which was held for 1 (one) year starting April 2019 - March 2020. The research location is divided into 3 (three) types of land cover, namely: open peatland (open area) dominated by ferns and reed plant (P1), revegetation locations with *Shoreabalangeran* plant species aged 1 - 2 years (P2), and revegetation locations with *Shoreabalangeran* plant species aged 3 - 4 years (P3). For details, it can be seen in **Figure 1** below.

No.	Land Cover	Coordinate	
		South	East
1.	Open location (*open area*) (P1)	2°22'39.28"	114°7'21.51"
2.	Revegetation location aged 1-2 years (P2)	2°22'39.31"	114°7'22.22"
3.	Revegetation location aged 3 – 4 years (P3)	2°22'39.28"	114°7'22.96"

Figure 1. Research Location Map

METHOD

Empirical data to test the research hypothesis was collected by two series of studies. As for the parameters measured were the plant growth rate (stem diameter of the *Shorea balangeran* plant) in the revegetation area at different plant ages (2 - 3 years with code P2 and 4 - 5 years with code P3) with a distance from the drainage channel 50 m, 100 m, 150 m, 200 m, and 250 m. Measurements conducted in the dry season and the rainy season. In addition, measurements of CO_2 emissions and other environmental factors are also carried out (soil temperature, air temperature, soil humidity, air humidity, and water table). As a comparison, CO_2 measurements also carried out in areas that had not been planted with Balangeran plants (condition after burning) with land cover dominated by shrubs (ferns) with code P1.

Measurement of CO_2 emissions conducted by using the *Closed Chamber Method* (Toma and Hatano, 2007), in this case it is carried out 1 (once) a month along with the measurement of the stem diameter of Balangeran plant. CO_2 measurement activities carried out during the daylight between 13.00 - 15.00 WIB with CO_2 gas sampling time intervals of 0 minutes and 6 minutes.

Measurement of CO_2 emission concentration using *cylindrical stainless-steel chambers* with a diameter of 18.5 - 21 cm and a height of 25 cm. Gas monitoring uses a CO_2 sensor with the *closed chamber method*. *Chamber* is installed into the ground as deep as 10 cm to limit the air coming out of the chamber. When the chamber covers the ground surface, the CO2 concentration in the chamber will increase along with the release of flux by the soil. Measurements conducted once a year with three replications, namely two replications within the planting rows and one repetition between the planting rows. In the *closed chamber method*, the addition of concentration is calculated by subtracting the addition of the resulting concentration from the previous concentration at 0 minutes and 6 minutes. The concentration addition value is needed to convert the concentration value into a carbon emission rate (dc/dt) which is then used to estimate CO_2 emissions.

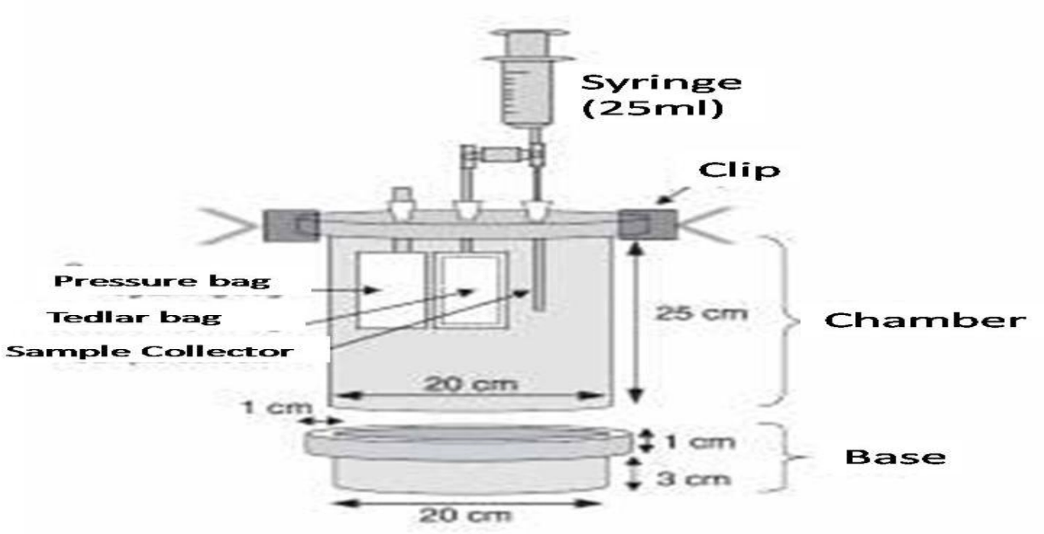


Figure 2. *Closed Chamber Method* (Toma and Hatano, 2007**)**

The CO_2 concentration from the measurement result in the laboratory is converted to CO_2 emissions using the equation used, namely:

$$E = \left(\frac{dc}{dt}\right) x \left(\frac{Bm}{Vm}\right) x \frac{V}{A} x \left[\frac{273{,}2}{273{,}2+T}\right] x\ 60$$

Information:

E = CO_2 Emissions (mg $m^{-2}hour^{-1}$),
dc/dt = change in CO_2 concentration per time (ppm $minute^{-1}$),
V = lid volume (m^3),
A = area of the chamber base (m^2),
Bm = CO_2 molecular weight (44),
Vm = CO_2 molecular volume (22,41)*,
T = air temperature in the chamber (˚C),
60 = time conversion from minutes to hours.

Note: *22,41 is the volume of CO_2 gas at the condition of STP (*Standard Temperature and Pressure*), namely at 0 ˚C and pressure 1 atm.

Environmental parameters measured in the field consist of soil temperature which measured at a depth of 5 and 10 cm, Soil moisture is measured using a thermistor thermometer (Amplitude Domain Reflectometry, ADR ML2 Theta Probe Delta-T Devices, Cambridge, UK), the ground water level (water table) is measured using a PVC (poly vinyl chloride) pipe with a diameter of ¼ inch which is inserted into the peat soil as deep as 2.5 m. The measurement of some of these parameters conducted simultaneously with the measurement of CO_2 concentration.

Data Analysis

Data from field and laboratory measurements were processed using Microsoft Excel for Windows ® and shown in tables and graphs. While the relationship between environmental factors (soil temperature, soil moisture, and water table height) and CO_2 emissions were analyzed using simple regression and correlation methods. As for the interpretation of the value of r can be seen in **Table 1** below.

Table 1. Interpretation of the Calculation of r Value from Regression and Correlation Analysis

r Value	Interpretation
0	Uncorrelated
0.01 – 0.20	Very Low
0.21 – 0.40	Low
0.41 – 0.60	Slightly Low
0.61 – 0.80	Moderate
0.81 – 0.99	High
1	Very High

Source: Husaini Usman and Purnomo Setiady Akbar (2006).

RESULTS AND DISCUSSION

Result

CO_2 Emissions at Various Land Covers During the Year

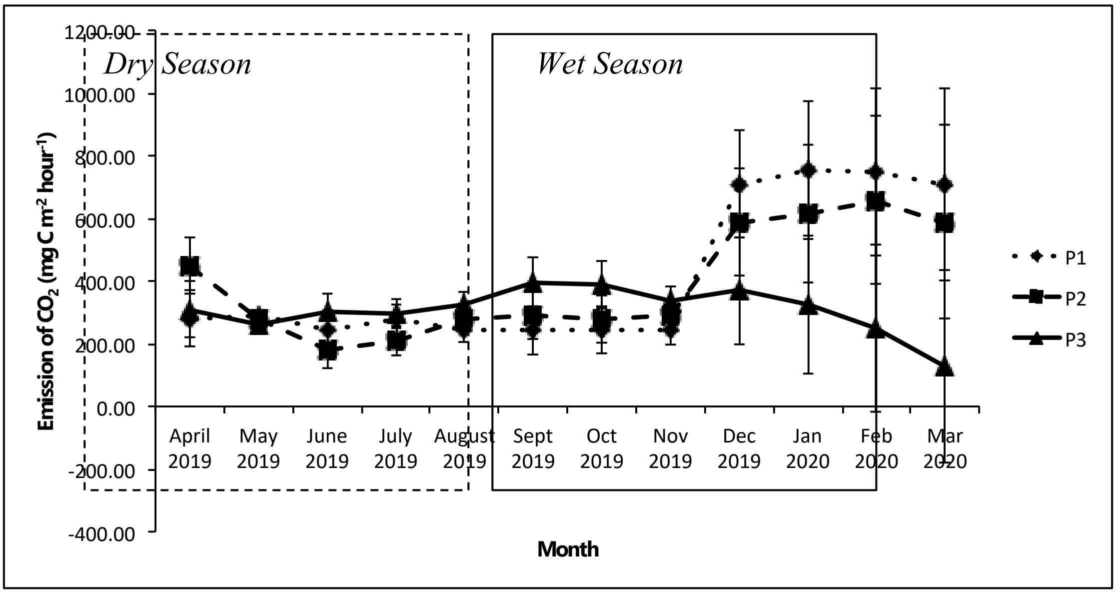


Figure 3. Graph of CO_2 Emissions in 3 (Three) Land Covers during the Year from 2019 - 2020.

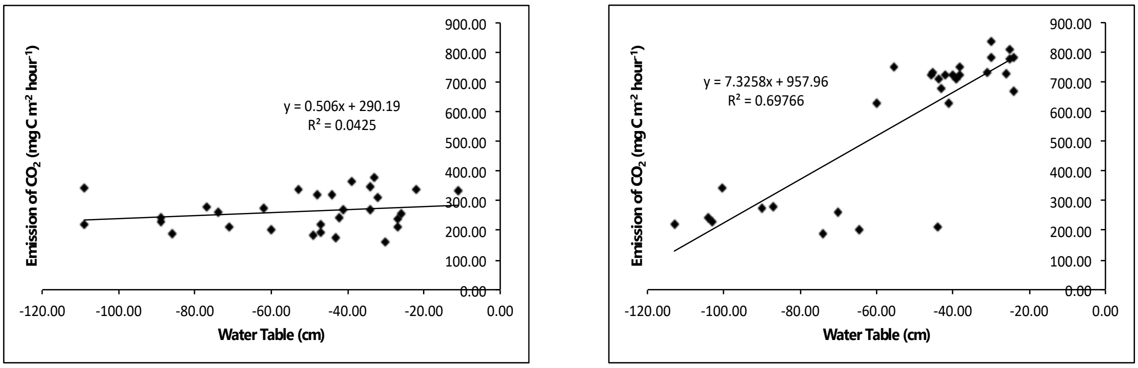
Based on **Figure 3** above, it can be seen that CO_2 emissions fluctuate from126.51± 16.22 mg C m^{-2} hour^{-1} to 753.23±307.57 mg C m^{-2} hour^{-1}. Where the highest CO_2 emissions are found in plot P1 (open land conditions and only dominated by shrubs, while the lowest CO_2 emissions are in plot P3 (plants aged 3 - 4 years). This condition is different in different season conditions, where the highest CO_2 emissions are found in revegetation locations with *Shorea balangeran* plant species aged 3 - 4 years (P3), then followed by revegetation locations with *Shorea balangeran* plant species aged 1 - 2 years and open location (*open area*). The high level of CO_2 emissions during the dry season at the P3 location is due to the influence of environmental factors, namely: soil temperature, soil moisture, and ground water level (water table). The above reality is slightly different as reported by Melling *et al.* (2005) stated that CO_2 emissions in tropical peat areas in Sarawak, Malaysia in *mixed peat swamp forest* areas ranged from 100 - 533 mg C m^{-2} hour^{-1}, at the sago planting location ranges from 63-245 mg C m^{-2} hour^{-1}, and in oil palm plantation locations ranges between 46 - 335 mg C m^{-2} hour^{-1}. Furthermore, Jauhiainen *et al.* (2005) reported that on tropical peat in Central Kalimantan, in this case CO2 emissions of the hummock peat ranged from 132 - 166 mg C m^{-2} hour^{-1} and on hollows peat ranged between 37.9 – 188 mg C m^{-2} hour^{-1}. However, this condition is still in the range of 2 (two) previous studies. The fact that the high CO2 emissions in open location (open area) or P1 is caused by root respiration and soil respiration, which in this case is driven by the water table conditions which are in the range -11 to -113 cm below the land surface (during 2019 - 2020). Adji *et al.* (2014) stated that the aerobic process caused by the low water table will drive the decomposition process of organic matter which will increase CO_2 emissions to the atmosphere. Hirano *et al.* (2009) added that the key difficulty in describing carbon flows across various land uses is because CO_2 emissions from root respiration are not separated from emissions caused by decomposition, as well as the characteristics of forest vegetation (composition and volume of vegetation) and micro-topographic characteristics (bumps and basins) also greatly affect carbon flow.

It is important to know that global warming as a result of greenhouse gas (GHG) emissions, namely: carbon dioxide (CO_2), methane (CH_4), and nitrogen oxides (N_2O), became the main issue that comes from agricultural activities. (Flessa *et al*., 2002; Smith *et al*., 2007). In this regard, revegetation of burned peatlands is very important, to become the sustainability of the peatlands.

CO_2 Emissions and Groundwater (Water Table) Level

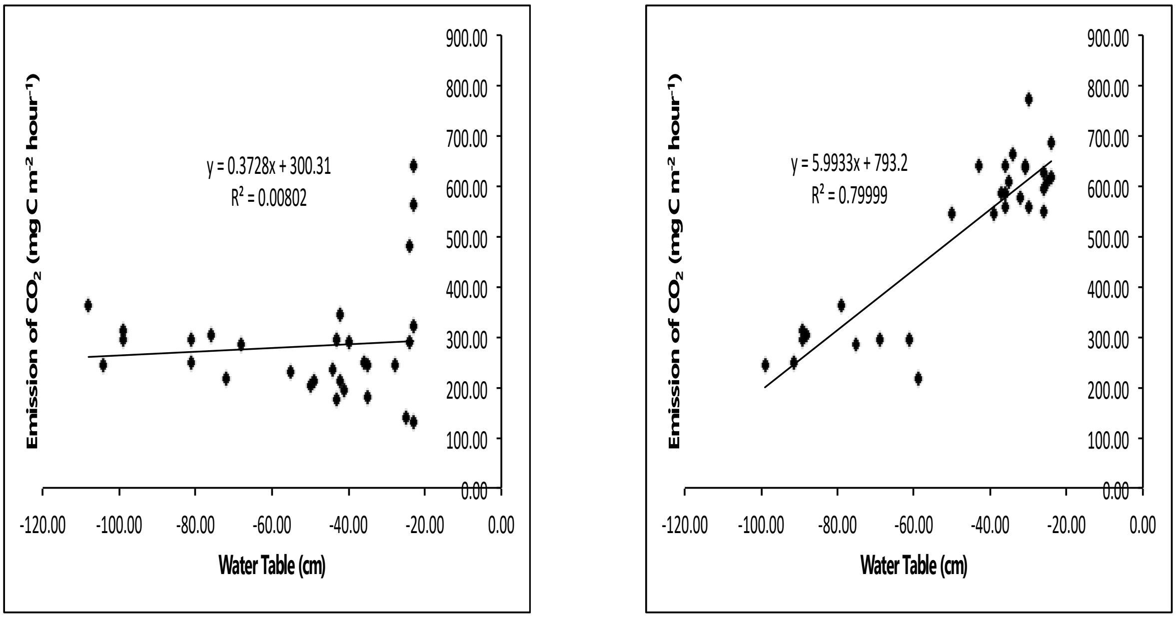
The results of the regression analysis and the correlation between CO_2 emissions and the water table level in open locations (*Open Area*) or P1, show that in the dry season there is no correlation with the value of R^2 = 0.0425, but in the rainy season, there is a fairly close relation of regression and correlation with the value of R^2 = 0.6976 for details, it can be seen in **Figure 4.** Then the results of regression analysis and the correlation between CO_2 emissions and groundwater level (water table) at the rehabilitation site for plant age 1 - 2 years (P2), it can be seen that during the dry season it does not show a strong relationship with the value of R^2 = 0.00802, but in the rainy season it shows fairly relationship with the value of R^2 = 0.7999 for details can be seen in **Figure 5**. While the results of regression analysis and the correlation between CO_2 emissions and the water table level in the rehabilitation area of 3 - 4-year-old plants (P3) during the dry season show a very low relationship with a value of R^2 = 0.2121, then during the rainy season it shows a slightly low relationship with the value of R^2 = 0.5743, please see Figure 6. Lal (1997) stated that CO_2 emissions that occur mostly come from the decomposition of organic matter, including: residues and litter. Furthermore, Hooijer *et al*. (2010) reported that more than 50% of CO_2 emissions from total CO_2 emissions in Indonesia came from peatlands and the forest land use change.

Peat quality, temperature and hydrological conditions are the most dominant factors in controlling the release of C into the atmosphere (Jauhiainen *et al.,* 2005). Added also from the results of previous studies that the water table level that is between -40 cm or more is a dangerous condition, where the surface layer of the peat soil will become dry and vulnerable or prone to burning. (Usup *et al*., 2004).



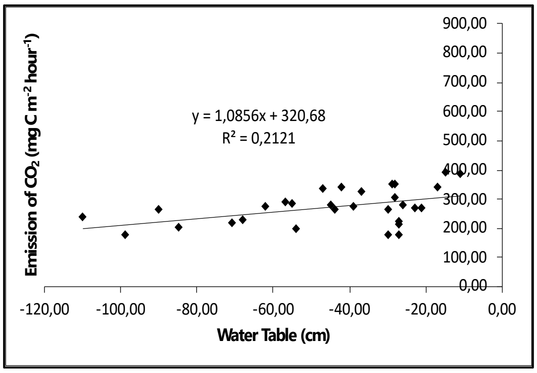
Dry Season (A) Wet Season (B)

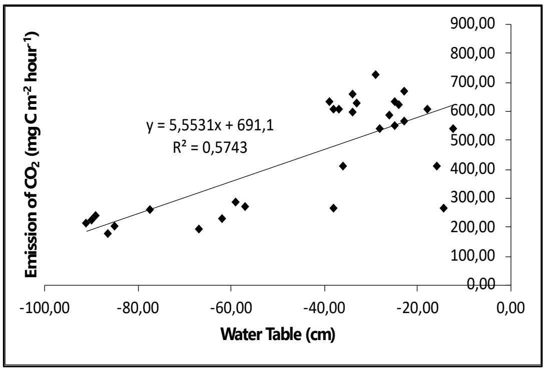
Figur e 4. Graph of Regression and Correlation of CO_2 Emissions and Water Table Level in Open Locations (Open Area) (P1) During Dry Season (A) and Rainy Season (B).



Dry Season (A) *Wet Season (B)*

Figure 5. Graph of Regression and Correlation of CO_2 Emissions and Water Table Level in the Rehabilitation Area for plant age 1 - 2 Years (P2) During Dry Season (A) and Rainy Season (B).



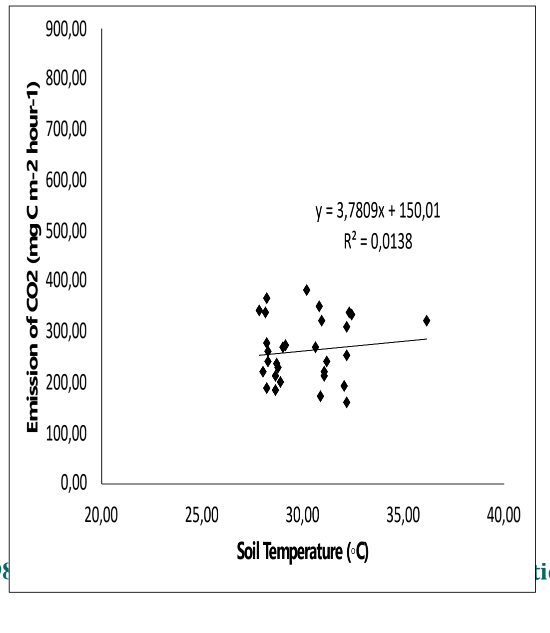


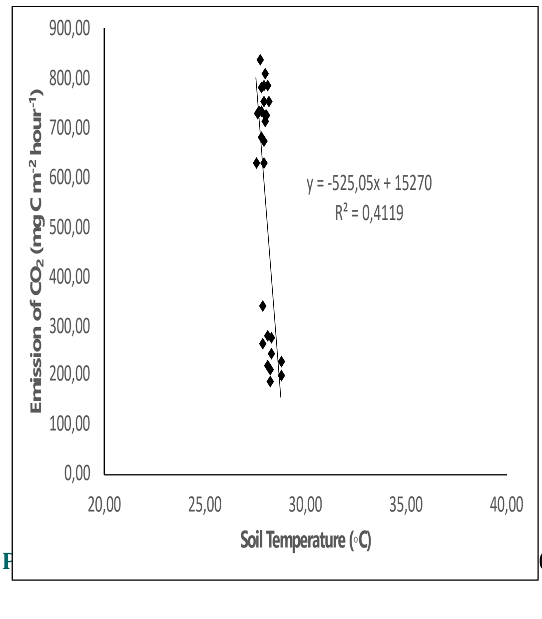
Dry Season (A) Wet Season (B)

Figure 6. Graph of Regression and Correlation of CO_2 Emissions and Water Table Level in the Rehabilitation Area for Plant Age 3 - 4 Years (P3) During Dry Season (A) and Rainy Season (B).

CO_2 Emissions and Soil Temperature and Soil Moisture

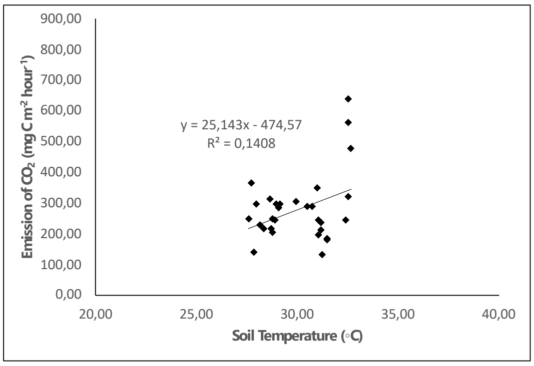
Based on the results of regression analysis and correlation in **Figures 7 - 12**, it can be seen that there is no correlation - there is a very high correlation from the relation between CO_2 emissions with soil temperature and soil moisture, either during the dry season and the rainy season. Climate change will cause changes in soil temperature and soil moisture, both of which will greatly affect the process of soil respiration (Raich *et al*., 2002). Changes in soil moisture as a result of climate change will often affect or increase CO_2 emissions as a result of an increase in soil temperatures (Saleska *et al*., 1999). This increase in CO2 emissions can be seen in the open area (P1), followed by the rehabilitation area for plant age 1 - 2 years (P2), and the rehabilitation area for plant age 3 - 4 years (P3). In general, the highest increase in CO_2 emissions occurs during the rainy season (wet season). The high level of CO_2 emissions in open areas (P1) is related to the condition of open land which is dominated by reeds and shrubs. This is expressed from the results of the research that, when the land cover is not existence (removed), then the assimilation process from the results of the photosynthesis process will decrease (Lytle and Cronan, 1998; Nakane *et al*., 1996). In addition, solar radiation will increase at ground level which will directly increase soil temperature. Added by Oke (1987), that low groundwater (water table) levels in peatlands will cause an increase in soil temperature as a result of the process of heat enhancement (*heat capacity*), in flooded conditions ranging from 4.02 x 10^6 Jm^{-3} K^{-1} compared to dry peat conditions which range from 0.58 x 10^6 Jm^{-3} K^{-1}. Furthermore, dry conditions indirectly stimulate the rate of decomposition due to changes in temperature regime (Laine *et al*., 2006; Lieffers, 1988).

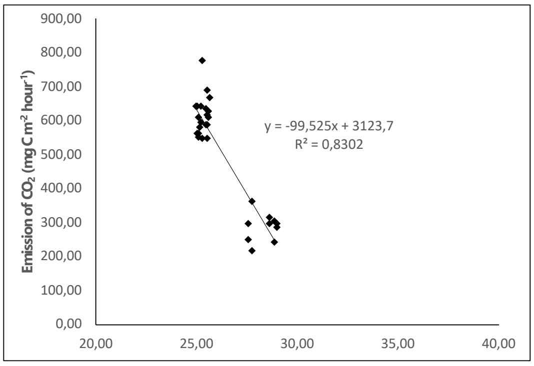




Dry Season (A) Wet Season (B)

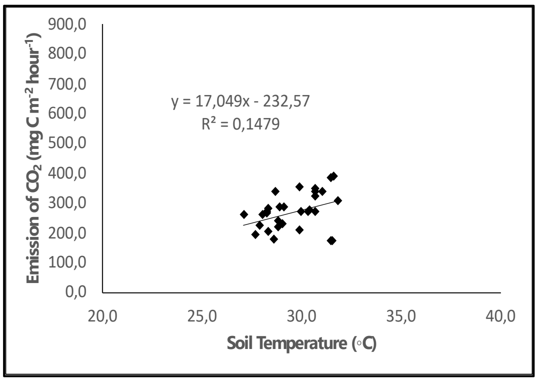
Figure 7. Graph of Regression and Correlation of CO_2 Emissions and Soil Temperature at Open Locations (Open Area) (P1) During Dry Season (A) and Rainy Season (B).

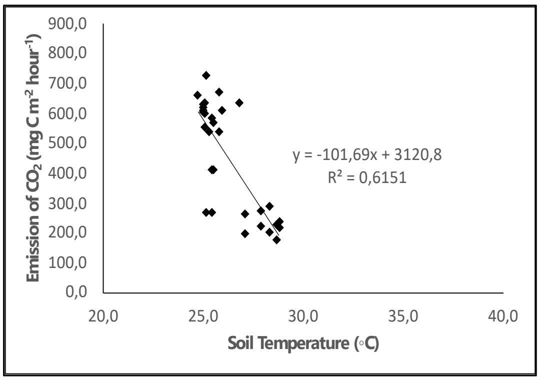




Dry Season (A) Wet Season (B)

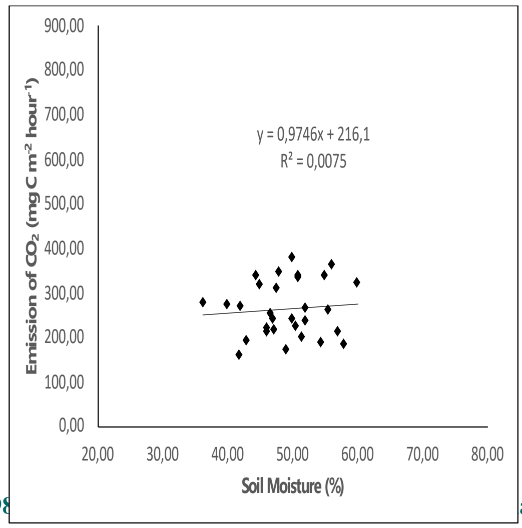
Figure 8. Graph of Regression and Correlation of CO_2 Emissions and Soil Temperature in the Rehabilitation Area for Plant Age 1 - 2 Years (P2) During Dry Season (A) and Rainy Season (B).

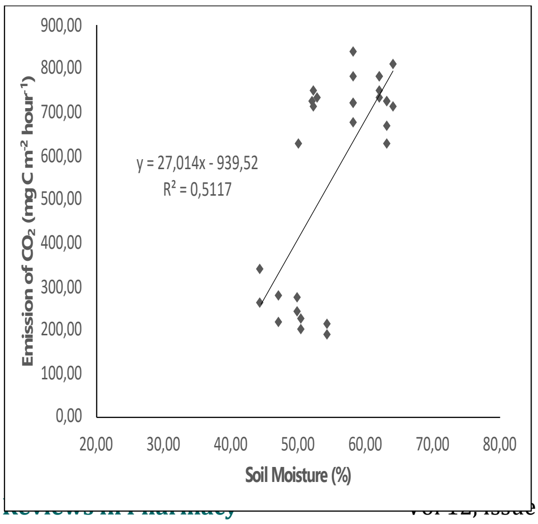




Dry Season (A) Wet Season (B)

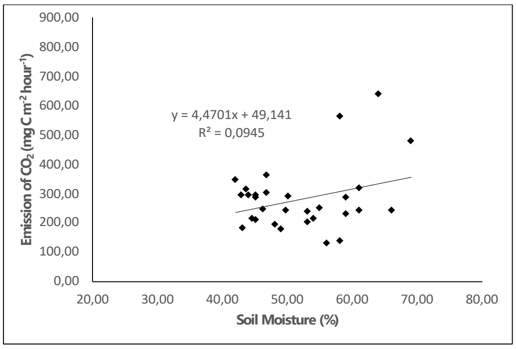
Figure 9. Graph of Regression and Correlation of CO_2 Emissions and Soil Temperature in the Rehabilitation Area for Plant Age 3 – 4 Years (P3) During Dry Season (A) and Rainy Season (B).



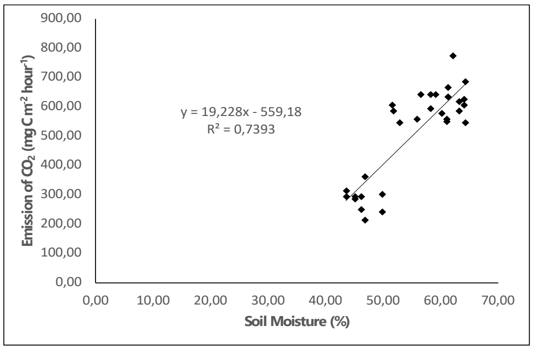


Dry Season (A) Wet Season (B)

Figure 10. Graph of Regression and Correlation of CO_2 Emissions and Soil Moisture at Open Locations (Open Area) (P1) During Dry Season (A) and Rainy Season (B).

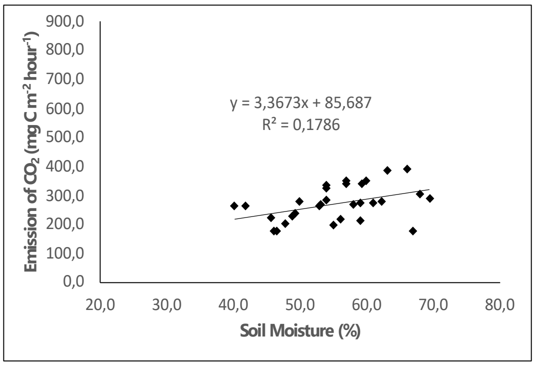


Dry Season (A)

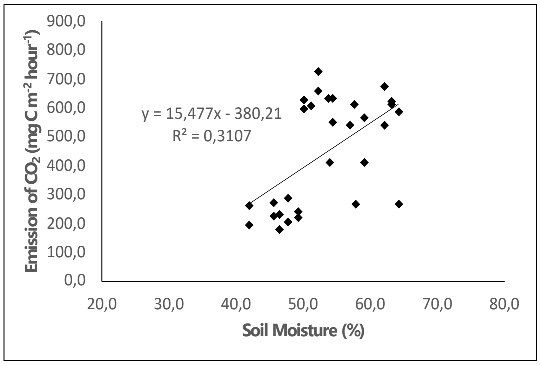


Wet Season (B)

Figure 11. Graph of Regression and Correlation of CO_2 Emissions and Soil Moisture in the Rehabilitation Area for Plant Age 1 - 2 Years (P2) During Dry Season (A) and Rainy Season (B).



Dry Season (A)



Wet Season (B)

Figure 12. Graph of Regression and Correlation of CO_2 Emissions and Soil Moisture in the Rehabilitation Area for Plant Age 3 – 4 Years (P3) During Dry Season (A) and Rainy Season (B).

Balangeran Plant Growth (Stem Diameter)

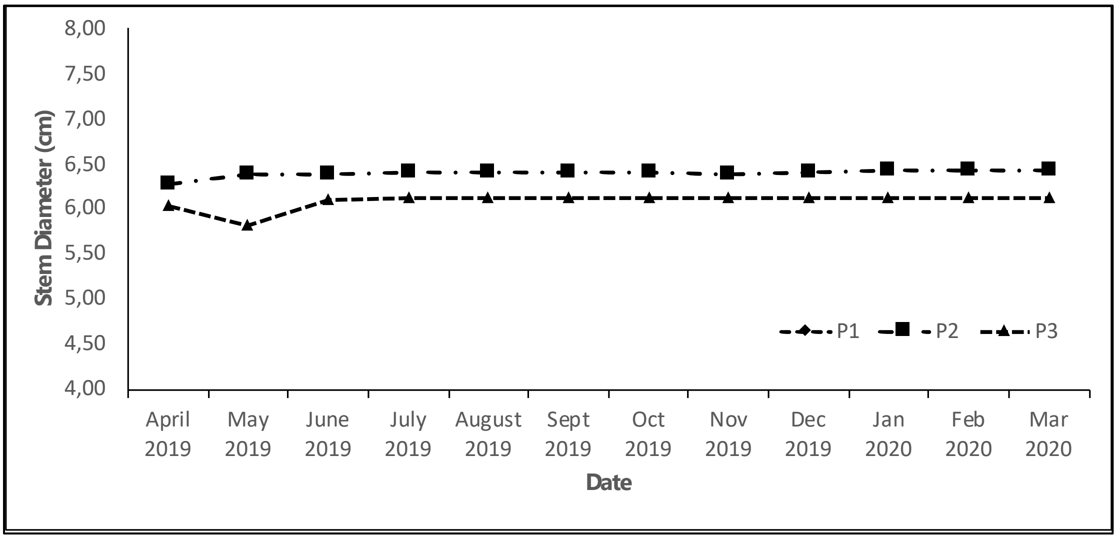


Figure 13. Graph of Plant Stem Diameter in 3 (Three) Land Cover During a Year (2019 - 2020).

Based on **Figure 13** above, it can be seen that during the period of 1 (one) year the growth of *Shorea balangeran* plant stem diameter was greater in the rehabilitation area of plant age 3 - 4 years (P3) than in the rehabilitation area of plant age 1 - 2 years (P2), with the exception of P1 (open area), which is a location with a land cover that is dominated by reeds or shrubs. If it is seen that the growth in stem diameter in the rehabilitation area (ex-burnt in 2015) at P2 and P3 is almost uniform for a year, this indicates that *Shorea balangeran* plants have high adaptability in this location. In line with that described by Suryanto *et al.* (2012) stated that *Shorea balangeran* plants have the ability to adapt to the environment in which they grow, especially in peatlands. However, its existence is currently under threat due to excessive logging and land conversion for other uses, as well as forest and land fires that often occur in this location. In addition, based on the results of measurements of the ground water level (water table) for a year, it shows that the water table level at location P2 ranges from -23 to -108 cm and at location P3 ranges from -11 to -110 cm below the soil surface. This is in line with Giesen's (2008) statement that *Shorea balangeran* can survive and grow well in moderate inundation conditions.

CONCLUSION AND SUGGESTION

Conclusion

1. CO_2 emission fluctuation between 126.51± 16.22 mg C m^{-2} $hour^{-1}$ to 753.23±307.57 mg C m^{-2} $hour^{-1}$. The highest CO_2 emission is found in plot P1 (open land conditions and only dominated by shrubs, while the lowest CO_2 emission is found in plot P3 (plants aged 3 - 4 years). This condition is different in different season conditions, where the highest CO_2 emissions are found in revegetation locations with *Shorea balangeran* plant species aged 3 - 4 years (P3), then followed by revegetation locations with *Shorea balangeran* plant species aged 1 - 2 years and open locations (open area).
2. Changes in land cover will affect CO_2 emissions, because the root system of each plant will be different.

Suggestion

Further research is needed to separate peat carbon dioxide (CO_2) emissions from root respiration and soil respiration.

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