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Soil CO_2 and N_2O emissions affected by ameliorant types and NPK fertilizer rates under chili cultivation on peatlands

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ABSTRACT

The use of peatlands for agriculture often causes controversy on Indonesia and allegedly increases greenhouse gas emissions caused by fertilization. Ameliorants are often used on peatland to increase productivity. The effects of ameliorant on GHG emissions depends on the characteristics of ameliorants. Determination of the type of ameliorant and the appropriate rate of NPK fertilizer is needed to mitigate CO_2 and N_2O emissions for red chili cultivation on peatland. This research was carried out on peatland in the village of Kalampangan, Sebangau District, Kodya Palangkaraya, Indonesia from June to October 2017. The treatments given were: Factor I; the types of ameliorant material (A1;100% cow manure, A2; 50% cow manure + 50% biochar A3; 50% cow manure + 50% compost from weed in situ; A4; 50% cow manure + 50% ash from weeds in situ), Factor II; the rate of NPK fertilizer (D0; No NPK, D1; 50% of recommended dose; D2; 100% of recommended dose, D3; 150% recommended dose). The treatments were arranged in a factorial randomized block design (RBD), with three replications. Recommended rates of urea (N), SP-36 (P_2O_5), and KCl (K_2O) were 100-200-120 kg/ha. Observation variables include soil pH, soil Eh, water contents, soil CO_2 and N_2O emissions were measured using closed chamber at the vegetative phase (1st month), the initial generative phase (2nd month), and the end of generative phase (3rd month), meanwhile the ground water level was measured using a Micro-GC gas chromatography (GC) every week during the course of this research. The results showed that CO_2 emission were more influenced by the type of ameliorant than the fertilizer dose, while N_2O emission was more influenced by NPK fertilizer rates. The lowest CO_2 emission was observed from the application of 50% cow manure + 50% compost from weed in situ, which could reduce CO_2 emissions up to 40% (1709 kg/ha/season) of the control treatment (100% cow manure) (3731 kg/ha/season). The highest N_2O emissions were shown by ameliorant A3 (50% cow manure + 50% compost from weed in situ) at dosage NPK 150% from recommendation (1,31kg/ha/season) and the lowest shown by ameliorant A4 (50% cow manure + 50% ash from weeds in situ) at no NPK fertilization (0.32 kg/ha/season). The recommended treatment is the treatment of ameliorant 50% cow manure + 50% compost from weed in situ at 100% NPK rate.

Key words: *CO_2 emission, N_2O emission, peatland, ameliorant type, NPK fertilizer dose*

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INTRODUCTION

Although peatlands cover only 6 % of the terrestrial surface of the Earth, they play a central role in the global carbon (C) cycle (Gorham *et al*. 2012). Managed peatlands are large sources of GHGs and C, but, if appropriate measures are taken, they can be turned back into GHG and C sinks within 15 years of abandonment and rewetting (Schrier-Uijl 2014). Tropical peatland could be a source of greenhouse gases emission because it contains large amounts of soil carbon and nitrogen (Inubushi *et al*. 2003). Tropical peatlands are an important terrestrial carbon pool, but they are highly vulnerable and have become a major source of carbon emissions that requires policy changes to allow mitigation measures to take place (Murdiyarso 2010).

The enhancement of GHG emission as result of conversion on peat forest to agricultural land is an environmental issue that becomes constraint on the development of peatland, especially tropical peatland for farming purpose (Hooijer *et al*. 2006, 2010; Joosten 2007). Agricultural activities in peatland needs attention to environmental aspects in addition to efforts to increase the peatland productivity.

Utilization ameliorant absolutely necessary in order to improve the management of peatland productivity (Maftu'ah 2012). The peatland amelioration that used the material which contains polyvalent cation, not only capable on overcoming the negative effect of high levels of organic compounds, but also could decreasing of GHG emission from peatland, so that could increase the peatland stability (Subiksa *et al*. 2009; 2012; Sabiham and Sukarman 2012). The effect of ameliorant on GHG emissions depends on the characteristics of ameliorants. Determination of the type of ameliorant and the appropriate dose of NPK fertilizer is needed to mitigate CO_2 and N_2O emissions for red chili cultivation on peatland. The aim of research to determine the effect of some type ameliorant and NPK fertilizer doses on chili cultivation in peatlands.

MATERIALS AND METHODS

The research was carried out on peat land in the village of Kalampangan, Sebangau District, Kodya Palangkaraya, Indonesia from June to October 2017. The treatments given were: (1) types of ameliorant material and (2) fertilizer dosage. Factor I; Types of ameliorant material (A1;100% cow manure, A2; 50% cow manure + 50% biochar, A3; 50% cow manure + 50% compost from weed in situ, A4; 50% cow manure + 50% ash from weeds in situ), Factor II; Dosage for NPK Fertilization (D0; No NPK, D1; 50% of recommended dose; D2; 100% of recommended dose, D3; 150% recommended dose). The treatment was arranged in factorial randomized block design (RBD), and repeated 3 times.

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Recommended doses of urea (N), SP-46 (P_2O_5), and KCl (K_2O) were 100-200-120 kg/ha (250 kg urea; 435 kg SP46, and 240 kg KCl ha^{-1}). Urea was given on the 3 stages, i.e. 1/3 on the initial planting time, 1/3 at the age of 1 month, and 1/3 at the age of 2 months. Red chili was planted in this research. Before planted on the field, seeds were sown on the polybags, using peat and manure for around one month. The seeds was ready if after 1 month having around 4- 5 leaves. After planted, seeds were watering in order to release the plant stress. Then, if not rainy, the plant was watered in the morning and afternoon, using artificial pipe.

Observation variables include soil pH, soil Eh, water contents, CO_2 and N_2O emissions were done at three time i.e. the vegetative phase (1st month), the initital generative phase (2rd month), and the end of generative phase (3rd month). Groundwater level was measured manually every 2 days using piezometers made of PVC at length of 2 m. Piezometers were installed at every plot of experiment.

CO_2 flux was measured on soil and plant using closed chamber that adopted from International Atomic Energy Agency (IAEA) (1992). Closed chamber method using a fiberglass of 50 cm length x 50 width x 100 cm height equipped with fan (12 VDC) and thermometer. The gas was taken using a syringe needle at 5 minute interval strating from time 0 to 3 minutes, in the morning at 6:00 - 8:00 pm. The CO_2 and N_2O gase were analyzed using a Micro-GC gas chromatography (GC). Emission rate was calculated using equation (IAEA 1992.):

$$E = \frac{Bm}{Vm} \times \frac{\delta Csp}{\delta t} \times \frac{V}{A} \times \frac{273.2}{T+273.2}$$

Where:

E	= flux of CO_2 ($mg/m^2/day$)
V	= cover volume (m^3)
A	= cover base area (m^2)
T	= average air temperature in the containment (^oC)
$dCsp/dt$	= change rate of CO_2 concentration (ppm/min)
Bm	= CO_2 gas molecule weight in standard condition
Vm	= gas volume CO2 in stp (standard temperature and pressure) condition 22,41 liter at 23^O K

Data were analyzed using F test, followed by the smallest real difference test (BNT). Correlation and regression analysis were conducted to evaluate the relationship between CO_2 flux with pH, Eh, moisture content and groundwater level (GWL).

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RESULT AND DISCUSSIONS

CO_2 emissions

CO_2 emissions measured are combined emissions of soil + plants. CO_2 flux is more influenced by the type of ameliorant than the dose of NPK fertilizer (Figure 1). The lowest CO_2 flux was shown by ameliorant from 50% cow manure + 50% compost (A3) and the highest was ameliorant 100% cow manure (A1) as shown in Figure 1 and Figure 2. The CO_2 flux pattern for each period as shown in Figure 1. Type of A1 ameliorants showed a decrease in CO_2 flux at the 2nd month in all fertilization treatments, while the A2 ameliorants increased CO_2 flux occurred only at 50% NPK (D1) and then on the 3rd month was decreased. A3 ameliorant type, at all fertilizer doses showed low CO_2 flux on every observation periodic, whereas in A4 ameliorant type showed CO_2 flux there was a decrease in the 3rd month.

The provision of cow manure in general has increased CO_2 emissions. Manure contains labile energy that was easily decomposed, thus increasing the measured CO_2 emissions. Increased C-labile concentration could increase microbial activity so that the released CO_2 also increased. Based on the general pattern, ameliorants that were able to reduce emissions i.e ameliorant A3 (50% cow manure + 50% compost) and A2 (50% cow manure + 50% biochar). As reported that the giving of biochar could reduce carbon emissions in peat soil (Balittra 2015). Biochar could increase the availability of P, soil pH, K and Ca-dd (Masulili *et al*. 2010). The effect of adding biochar to soil respiration and CO_2 emissions varies (Zimmerman *et al*. 2011), depending on the type of biochar, soil type and soil organic C content (Steiner *et al*. 2008).

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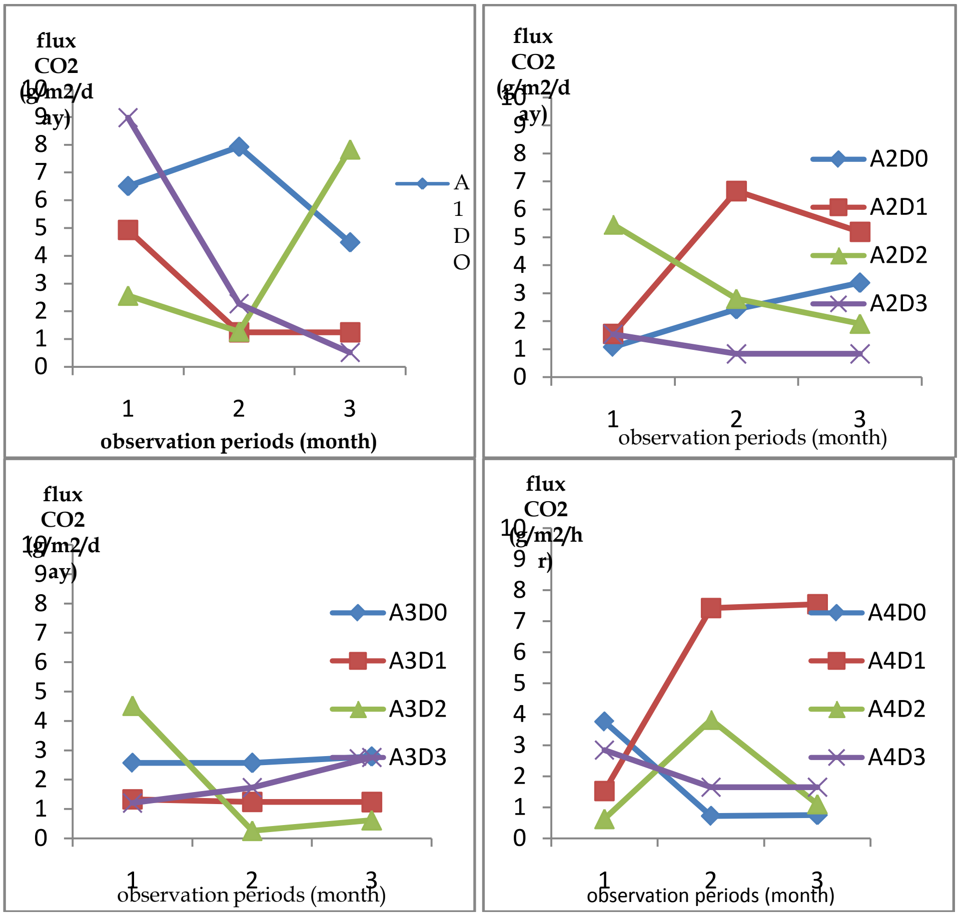

Figure 1. Effect of ameliorant types and dosage of NPK fertilizer on CO_2 flux in several observation periods

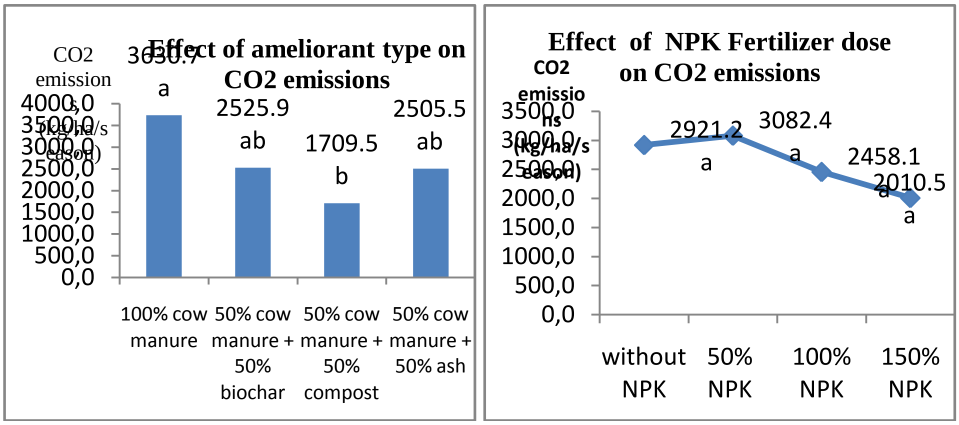

Figure 2. Effect of ameliorant type (A) and NPK fertilizer dose (b) on CO_2 emissions

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N_2O emissions

N_2O emissions due to the treatment of the type of ameliorant and the dose of NPK fertilizer as presented in Figures 3 and 4. N_2O flux tends to decrease with increasing time of observation (Figure 3). Interaction occurs between the type of ameliorant and the dose of NPK fertilizer on N_2O emissions. The highest N_2O emissions were shown by ameliorant A3 (50% cow manure + 50% compost from weed in situ) at dosage NPK 150% from recommendation (1,31kg / ha/season) and the lowest shown by ameliorant A4 (50% cow manure + 50% ash from weeds in situ) at no NPK fertilization (0.32 kg/ha/season) (Figure 4).

Nitrous oxide (N_2O) is produced by the process of nitrification and denitrification in the soil. According to Ehhalt *et al.* (2001) that peat soil was one of the N_2O emitters. N_2O emissions from the soil to the atmosphere are influenced by several factors, namely soil moisture, temperature, and availability of N in the soil (Maljanen *et al*. 2010). The combination of three important factors, namely the condition of peatlands, the presence of N fertilizer applications and relatively constant temperatures throughout the year, would accelerate the rate of N_2O emissions from peatlands to the atmosphere (Takakai *et al*. 2006; Jauhiainen *et al.* 2012). N_2O emission from tropical peatland soils was mainly controlled by a combination of soil moisture conditions and land use (i.e. forestry vs grassland vs agriculture). The effect of forest fires on N_2O emission from these soils was not clear. Agricultural practices may increase N_2O emission from tropical peatland soils as a result of nitrogen application and changes in the N_2O production potential of the soil.

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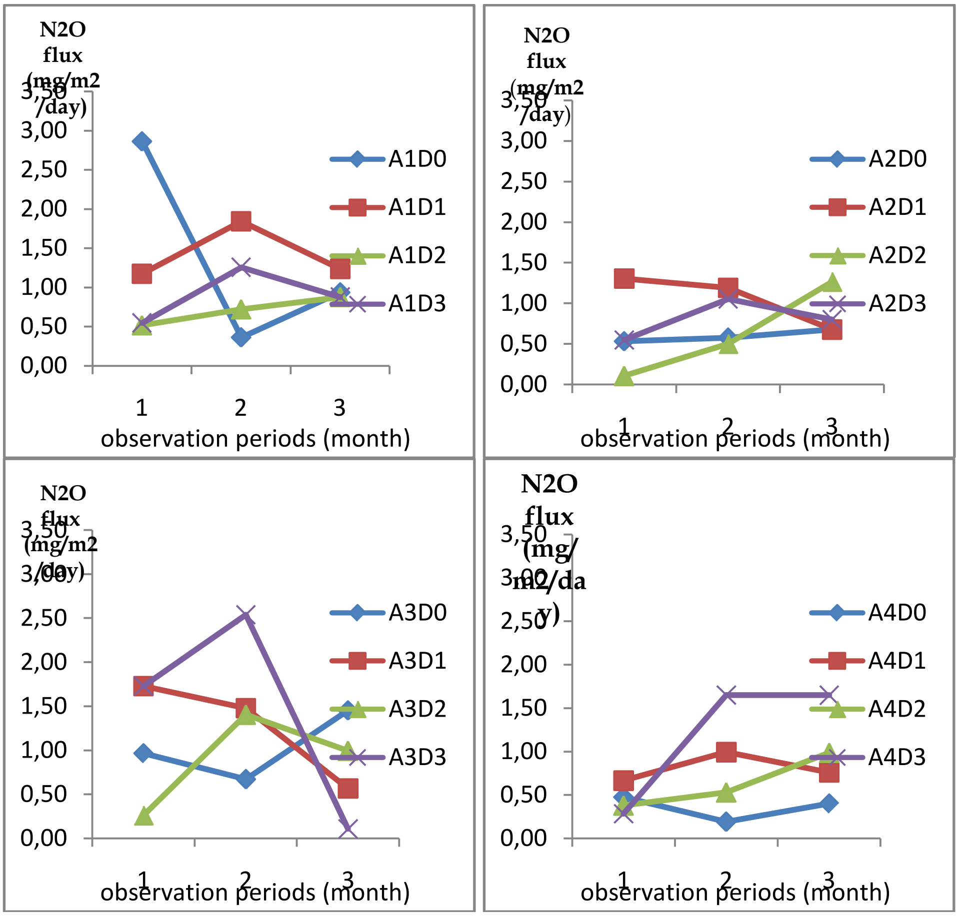

Figure 3. Effect of ameliorant type and NPK fertilizer dosage on N_2O flux in several observation periods

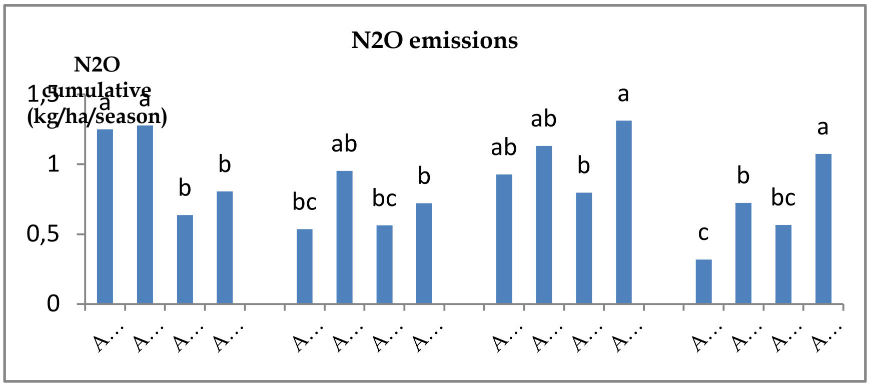

Figure 4. Effect of ameliorant types and dosage of NPK fertilizer on cumulative N_2O emissions in chilli crops for one season

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Soil Characteristics

Ameliorant types and NPK fertilizer doses affected soil pH H2O, especially at the 2nd and 3rd months (Figure 5). The highest soil pH (4.86) when the 3rd month was shown by A4D1 followed by A2D3 with a pH of 4.8, while the lowest was indicated by A1D0 treatment (pH 4.16). Ameliorant from A4 (50% chicken manure + 50% ash) could increase soil pH higher than other ameliorant treatments. Ash contained alkaline cations that are high enough to increase pH in a relatively fast time (Maftuah et al. 2012).

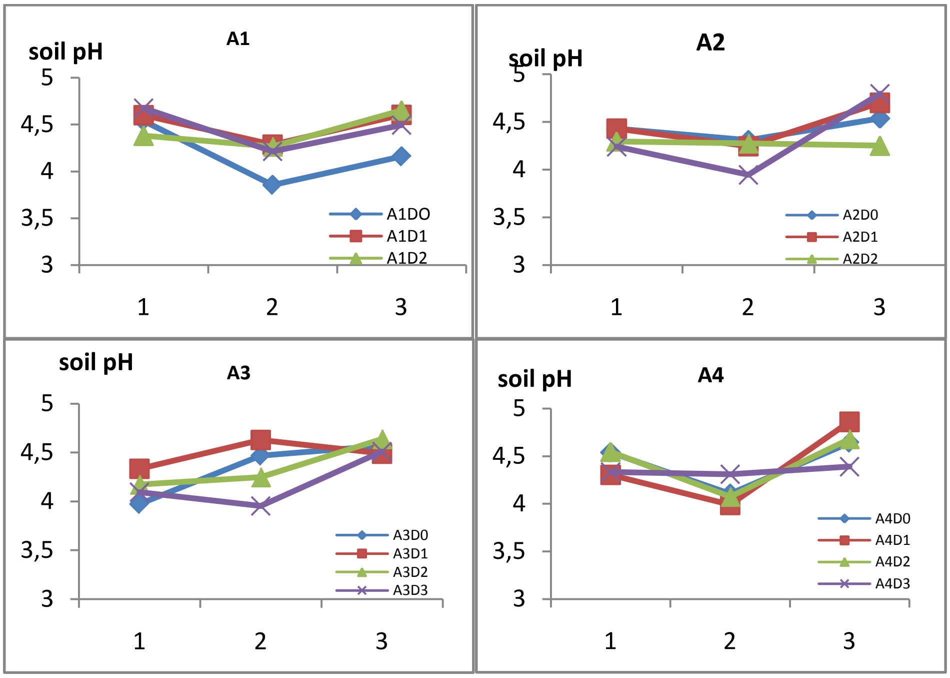

Figure 5. Soil pH due to ameliorant type treatment (A1, A2, A3, A4) and NPK fertilizer dosage

At the second month observation period, there was a decrease in pH and at the 3rd month the soil pH increased. At first month, pH increase is due to the ameliorant reaction which quickly releases base cations so that they could bind H+ and organic acids, the pH of the soil increases. Furthermore, the effect of complexation weakens, then the peat releases organic acid and H+ ions so that the soil pH decreased at phase seconds. In the 3rd month a several treatment shown a rise in pH, it is suspected the influence of biochar that assist released base ion in soil solution.

Redox (Eh) potential value in oxidative conditions with a range of 150-400mV as shown in Figure 6. The fluctuation pattern of Eh values was related to groundwater content (Figure 7). The oxidation reduction process had an

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important role in the availability of soil nutrients, biogeochemical processes of nutrient cycles and ecological functions. The redox potential value was related to soil water content, and affects CO2, CH4 and N2O emissions. Significant N2O emissions occur in oxidative soil conditions, but that were also found at Eh 150 mV (Swamy et al. 2011), also between 120 mv to 250 mV (Yu et al. 2001). The critical limit for denitrification was Eh 300 mV (Kralova et al. 1992).

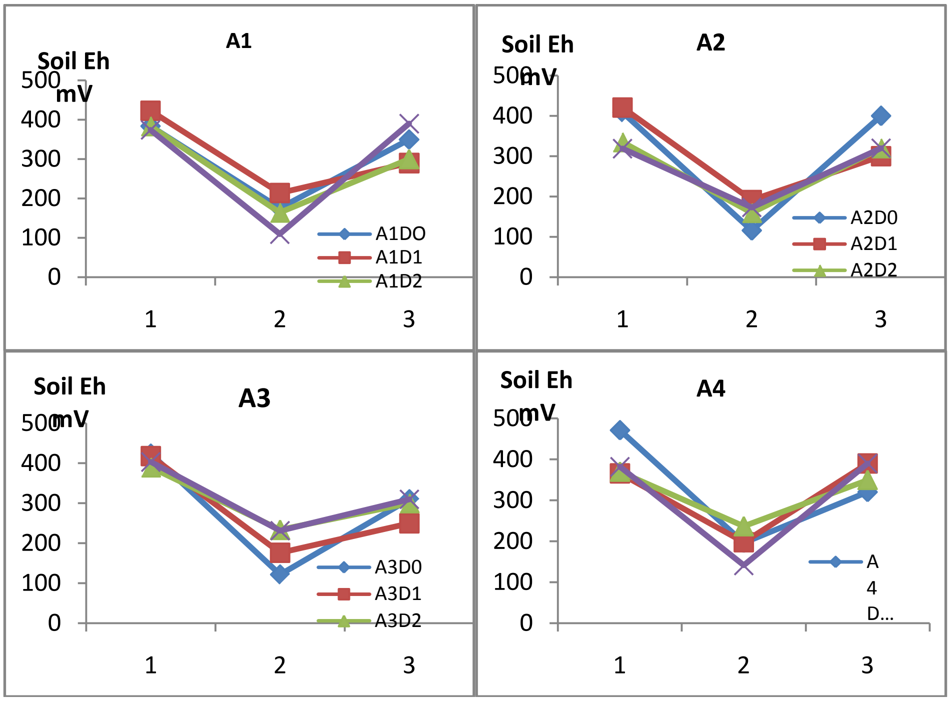

Figure 5. Soil Eh due to ameliorant type treatment (A1, A2, A3, A4) and NPK fertilizer dosage

The effect of treatment on soil water content as shown in Figure 7. In general, there was a decrease in soil water content at observations of the 2nd month, and increased at the 3rd month. Fluctuations of soil water content were closely related to the groundwater level that is affected by rainfall. Soil moisture levels affected soil oxidation and reduction conditions, as well as nutrient availability for plants.

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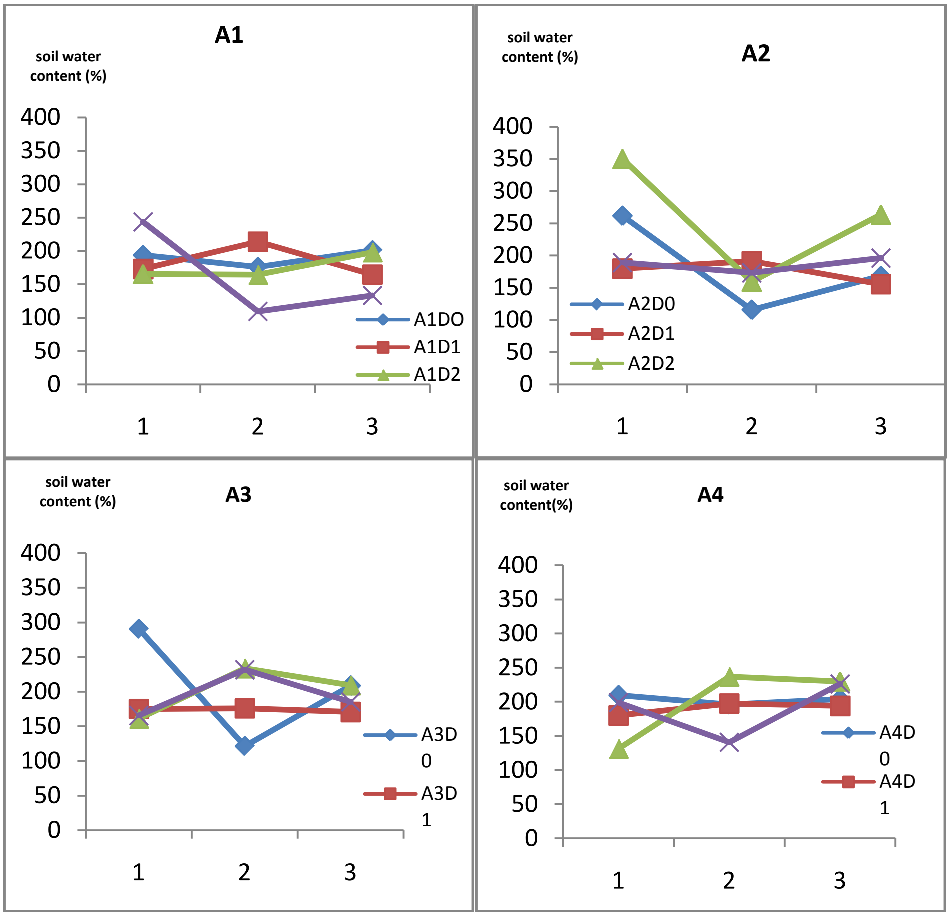

Figure 7. Groundwater levels in several types of amelioran (A1, A2, A3, A4) and NPK fertilizer dosage

Ground Water Level

Fluctuations of groundwater level during the study are shown in Figure 8. In the first month (August) it was seen that the water level approached the surface around 20-30 cm from the surface, whereas in the 2nd month (September) the water level was decreasing to 40- 70cm from the surface, and in October it reaches 20-50 cm. The research location is classified as typology D of peat swamp land, so that the ground water level fluctuations that occur at the research location depend on the rainfall that occurs at the research location.

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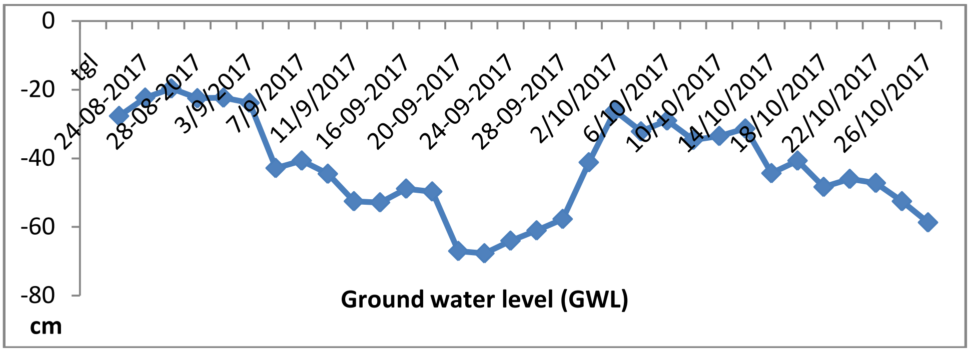

Figure 8. Groundwater level at the research location

The relationship between soil pH, soil moisture content, groundwater level with CO_2 and N_2O emissions

Based on Figure 9 there was a positive relationship between soil pH with CO2 and N2O emissions, but not significant. There was a linear negative relationship between CO2 emissions and soil water content, while N2O emissions with soil water content form a quadratic equation (Figure 9). The relationship pattern between soil with CO2 emission shown a positive relationship even though it was not significant, while the N2O did not shown a correlation (Figure 9).

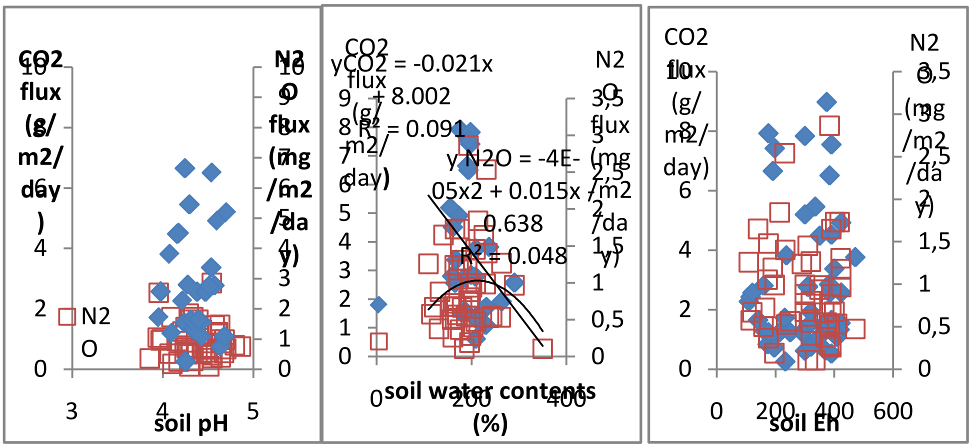

Figure 9. The relationship between soil pH, soil moisture content, with CO_2 and N_2O emissions

Emission of greenhouse gases is likely influenced by precipitation directly and indirectly. Soil moisture is one of the most important controlling factors for biological reactions in soil, including heterotrophic microorganisms and plant roots, which produce CO2. Therefore precipitation generally enhances CO2 emission (Inubushi et al. 2003).

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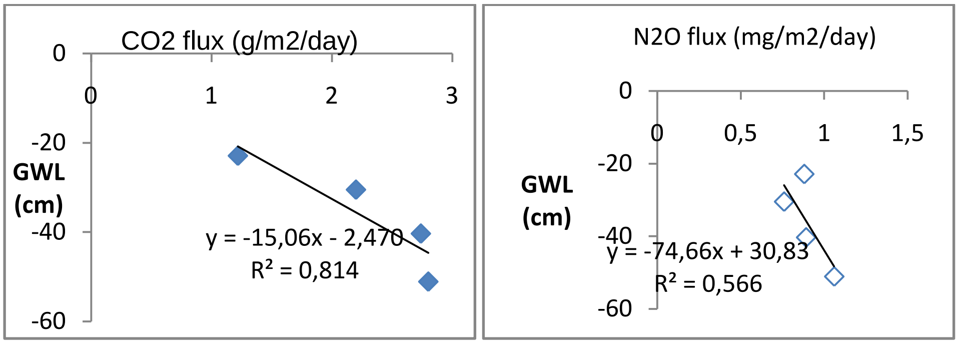

Figure 10. Relationship between ground waterlevel (GWL) with CO_2 and N_2O emissions

Groundwater levels were negatively related to CO2 flux but positively related to CH4 flux (Furukawa et al. 2005). The temporal variation in CO2 fluxes could be explained by seasonal temperature variations, whereas N2O fluxes could be correlated to groundwater level and soil carbon content (Danevic et al. 2010). There is a positive correlation between mean long-term water table depth and peat oxidation CO2 emission (Jauhiainen et al. 2012).

CONCLUSIONS

CO_2 emission were more influenced by the type of ameliorant than the fertilizer dose, while N_2O emission was more influenced by NPK fertilizer rates. CO_2 emission from the application of 50% cow manure + 50% compost from weed in situ, which could reduce CO_2 emissions up to 40% (1709 kg/ha/season) of the control treatment (100% cow manure) (3731 kg/ha/season). The highest N_2O emissions were shown by ameliorant A3 (50% cow manure + 50% compost from weed in situ) at dosage NPK 150% from recommendation (1,31kg/ha/season) and the lowest shown by ameliorant A4 (50% cow manure + 50% ash from weeds in situ) at no NPK fertilization (0.32kg/ha/season). There was a linear negative relationship between CO_2 and N_2O emissions and soil water content and ground water level (GWL). The recommended of treatment is the ameliorant in from 50% cow manure + 50% compost from weed in situ at 100% NPK rate (A3D2) that able to reduce CO_2 emissions up to 251% and N_2O up to 36% compared to the ameliorant in the form of 100% cow manure without NPK fertilizer (A1DO)

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