

Effectiveness of Some Ameliorants to Reduce CO₂ and N₂O Emission at Corn Planting in Peat Land

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ABSTRACT

Amelioration is very important in supporting plant growth in peat land. The use of low greenhouse gases emissions ameliorant will support the sustainability of agricultural system in peat land. The research is intended to study the effectiveness of some ameliorants in reducing CO₂ and N₂O emission in corn planting in peat land. The research was conducted in April to October 2013, in Kalampangan Village, Palangkaraya District, Central Kalimantan. Ameliorant materials were chicken manure fertilizer, dolomite, mineral soil, paddy husk biochar, coconut shell biochar. Ameliorant treatments applied were the type of ameliorant compositions, those (w/w) were (A1) 80% chicken manure fertilizer + 20% dolomite, (A2) 20% chicken manure fertilizer + 20% agricultural weeds + 20% spodosol mineral soil + 20% "purun tikus" (*eleocharis dulcis*) compost + 20% dolomite, (A3) 19% chicken manure fertilizer + 9% dolomite + 72% mineral soil, (A4) 100% coconut shell biochar, (A5) paddy husk biochar, (A6) farmer's way (20% ash + 40% spodosol mineral soil + 40% chicken manure fertilizer) and control. Experiment design used a Randomized Factorial Block Design, with 3 repetitions. Ameliorant dosage used was 7.5 t/ha. The crop used was hybrid corn. Parameters which were observed periodically were emission of CO₂ and N₂O, ground water level height, soil pH and Eh, once a month for 5 periods. The research result showed that ameliorant was capable of reducing emission of both CO₂ and N₂O in corn planting in peat land. Coconut shell biochar could reduce emission of CO₂ up to 26% as compared with control, whereas paddy husk biochar could reduce emission of N₂O up to 52% as compared with control.

Key words: ameliorant, emission of CO₂ and N₂O, peat

INTRODUCTION

Agricultural activity in peat land needed to observe environmental aspect in addition to the effort to increase land productivity. One of the efforts to increase peat land productivity was through amelioration. Ameliorant or "soil enhancement" constituted substances to be added into the soil in order to improve root environment for plant growth (Attiken et al., 1998). Ameliorant agent could act as nutrient source, to increase soil pH and contribute cation that could act as bridge cation in peat land (Supriyo, 2006).

Agricultural activities such as land clearing and the construction of drainage canal could increase emission in peat land. The application of certain ameliorant not only could improve peat land fertility but also could suppress CO₂ and N₂O emission in peat land. According to research of Nykanen (2003) N₂O emission in virgin peat land was categorized as low (<4mg N₂O/m²/year), that was caused by low nitrite availability. Drainage or opening of peat land highly influenced peat ecosystem. Ammonification and nitrification in peat land increased with the lowering of ground water level (Regina et al., 1998). This meant that draining of peat forest would increase N₂O emission potential.

The affectivity of ameliorant agent in improving peat land fertility depended on the substance quality especially the chemical substance composition. Ameliorant in peat land for improving land fertility had already

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been researched much, among others ameliorant containing polyvalent cations (Fe, Al, Cu, and Zn) such as steel slag, laterite mineral soil or river mud that was very effective in reducing the negative impact of phenolic acid (Dohong, 1999; Sabiham et al., 1997). The addition of polyvalent cations such as Fe and Al would create tread sorption for phosphate ion so that it could reduce the loss of P nutrient through cleansing (Rachim, 1995). The application of mineral soil with high iron content could improve the growth and production of paddy plant (Mario, 2002; Dohong, 1999; Subiksa et al., 1997). The formulation of ameliorant agents of 80% chicken manure fertilizer and 20% dolomite with the dosage of 10-20 t/ha was also effective in improving the fertility and productivity of peat land (Maftu'ah, 2012).

Some ameliorants were also capable of reducing greenhouse gases emissions, as stated by Kartikawati et al. (2012). The application of ameliorant in peat land that was converted into wet rice field in South Kalimantan could reduce CH₄ emission up to 40-50%, whereas CO₂ emission was reduced up to 5-30%, and the most effective ameliorant agent in reducing CO₂ emission was manure fertilizer. The application of dolomite and manure fertilizer could suppress CO₂ emission in "palawija" or second-crop planting in peat land (Sopiawati et al., 2014). The research is intended to study the effectiveness of some ameliorants in reducing CO₂ and N₂O emission in corn planting in peat land.

METHODS

The research was conducted in peat land in Kalampangan Village, Sebangau Sub-District, Palangkaraya District in April-October 2013. The treatment given was of ameliorant types as follows:

- 1) Ameliorant A1 = 80% chicken manure fertilizer + 20% dolomite
- 2) Ameliorant A2 = 20% chicken manure fertilizer + 20% in situ agricultural weeds + 20% Spodosol soil mineral + 20%

"purun tikus" (*eleocharis dulcis*) compost + 20% dolomite

- 3) Ameliorant A3 = 19% chicken manure fertilizer + 9% dolomite + 72% mineral soil
- 4) Ameliorant A4 = 100% coconut shell biochar
- 5) Ameliorant A5 = 100% paddy husk biochar
- 6) Ameliorant A6 (farmer's way) = 20% peat ash + 40% Spodosol mineral soil + 40% chicken manure fertilizer
- 7) Control (without ameliorant)

The treatment was managed in a Randomized Block Design with 3 repetitions. Before application ameliorant was first incubated for 2 weeks covered with tarpaulin. Plot size used in the experiment for each treatment was 4 m wide and 5 m long so that the area width of each plot was 20 m². Planting distance used was 20 x 75 cm and in each planting hole was for 1 corn crop. Ameliorant dosage used was 7.5 t/ha. Planting was done after 2 weeks of ameliorant application. The research used corn crops. Basal fertilizer used was Phonska NPK 300 kg/ha. Nutrient contents of NPK were 9% N, 13.5% P₂O₅ and 10.9% K₂O. Supplement urea fertilizer with the dosage of 300 kg/ha was given gradually at 2 weeks after planting (WAP), 3 WAP and 4 WAP. In this research *Piezometer* was installed for measuring the height of ground water level at the time of research.

Parameters observed were the initial soil characteristic, and CO₂ and N₂O emission, and the height of ground water level as well as soil pH and Eh in monthly basis for 5 months periods. The gas emissions were measured by placing closed chamber (measuring chamber width 17 cm, length 50 cm, height 35 cm) above ground which were equipped with a thermometer and fan wind inside the chambers. Chamber placed in the hallway between corn plants. Gas sample was taken by using a syringe of 10 ml then analyzed by using type CP 4900 micro GC. Flux calculation at each treatment was used the equation as follows:

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

Where:

E = flux CO₂/N₂O (mg/m²/day)

V = cover volume (m³)

A = cover base area (m²)

T = average air temperature in the containment (°C)

δCsp/δt = change rate of gas CO₂ and N₂O concentration (ppm/minute)

Bm = CO₂/N₂O gas molecule weight in standard condition

Vm = gas volume in stp (standard temperature and pressure) condition i.e.

22.41 liter at 23°K

Data analysis was done to study the impact of independent variable upon dependent variable by using diversity analysis at trust level of 5 and 1%. Inter treatment difference for each parameter was DMRT tested $\alpha = 0.05$. The relation closeness among variables was correlation and regression tested (Gomez and Gomez, 1995). Data analysis used Minitab software for Windows and SAS software.

RESULTS AND DISCUSSION

Peat Characteristics

Peat characteristics researched can be seen in Table 1. Chemical analysis result showed that the peat researched had a very high acidity with pH (H₂O) of 3.49 and pH (KCl) of 3.33. Concentration of H-exc was 1.80 cmol⁽⁺⁾/kg and Al-exc was 2.50 cmol⁽⁺⁾/kg. This condition showed that basal cations leaching occurred at upper layer in big amount, so that exchange complex was saturated by acid cation i.e. H⁺ and Al³⁺. This condition was supported by the value of KCl pH of 3.33 that showed the high concentration value of H⁺ of organic acids dissociation that was quite strong. It was presumed the content of peat 80 to 95% was caused by carboxylate and phenolic clusters (Rachim, 1995; Tan, 2003).

Input application both inorganic fertilizer and ameliorant such as chicken manure fertilizer could improve the value of peat EC (Utami, 2010). This condition was due to fertilizer and ameliorant contain material that

were easily soluble and mineralized that produced cation and anion. Organic C content of 45.89% was still considered high. Peat land used for the research was peat land that had been intensively cultivated for 5 years. The level of total N was about 0.448%, this was because the level of total N had dropped if compared with N total in peat land that had not been cultivated by 1.05 – 1.08% (Maftuah, 2012). Organic nitrogen found in peat was not easily available for plants, because of its high C/N ratio (Dohong, 1999; Jali, 1999). In peat that had been cultivated however the level of total N evidently dropped (by about 0.6%), so that C/N ratio was high. This condition indicated that there had been a high nitrogen mineralization of peat material as a result of land's function conversion into cultivated land through addition of ameliorant agents and fertilization (Suhardi, 2005).

The availability of K in peat researched was considered medium (0.342 cmol⁽⁺⁾ kg⁻¹). The level of K was lower as compared with the research result of Dohong (1999) that was the K content could be changed in Central Kalimantan peat soil of about (0.29 – 1.13 cmol⁽⁺⁾ kg⁻¹). The K content in peat land varied depending on the level of peat decomposition and mineralization. Mineralization process of peat material could influence the K availability (Koretsky et al., 2007). According to Andriesse, 1997 in Purnamayani et al. (2004) generally peat land was deficient in K. Potassium had monovalent load, so it was loosely bound by peat and vanished faster in root area.

Table 1. Peat soil characteristics in Kalamancangan Village, Central Kalimantan, 2013

Peat Characteristics	Value
pH H ₂ O	3.49
pH KCl	3.33
EC (mS/cm)	0.279
Total N (%)	0.448
Organic C (%)	45.89
K-exc (cmol(+)/kg)	0.342
Ca-exc (cmol(+)/kg)	4.784
Mg-exc (cmol(+)/kg)	6.068
CEC (cmol(+)/kg)	70.00
Al-exc (+)/kg)	2.50
H-exc (cmol(+)/kg)	1.80
Total P (mg/100g)	0.134
P-available (ppm)	15.45
Humic acid (%)	38.22
Fulvic acid (%)	5.35
Peat maturity level	saprist

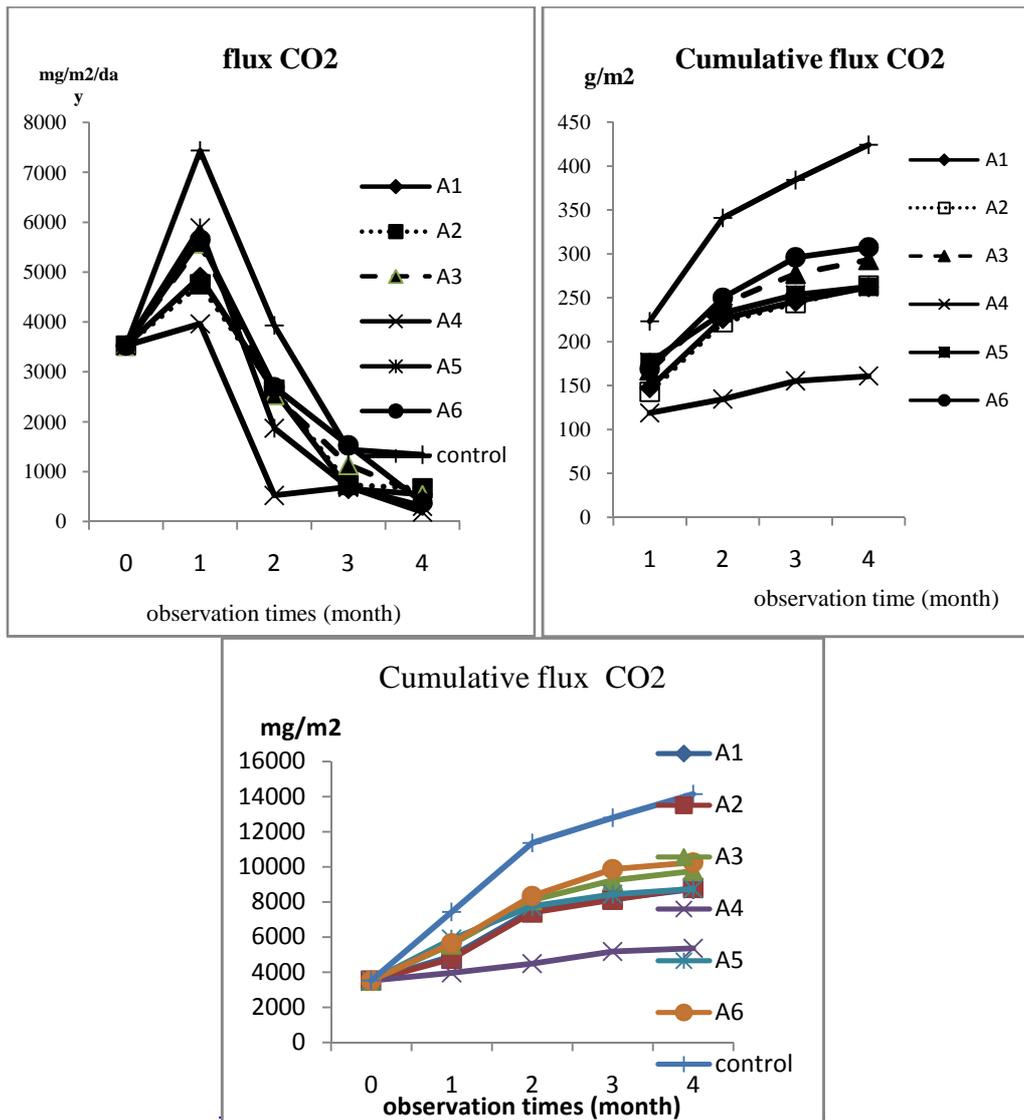
Ca-exe concentration in the research location was considered low. The low concentration of Ca-exe was also related to the low soil pH. According to McLaughlin and Webster (2010) at the time of low pH the consumption of Ca would increase, so its concentration decreased. Peat land management by applying ash input that was normally done by farmers would increase Ca concentration in peat land being cultivated. Vaneklass (1990) and Sulistiyanto et al. (2007) reported the different concentration of Ca-dd in peat land was caused by the difference of input (ash) given.

Acidity source of peat land researched was dominated by H⁺, whereas Al³⁺ normally only found in upper layer. The H ion came from organic acids dissociation that was commonly dominated by fulvic and humic acids (Widjaya-Adhi, 1988; Rachim, 1995). Organic acid gave obvious contribution towards the low pH of peat land (Charman, 2002). Organic material that had experienced decomposition had reactive clusters. The reactive clusters were among others carboxylate (-COOH) and phenolate (C₆H₄OH) that dominated exchange complex and could have the quality as quite strong organic acids so they could be dissociated with and produced H⁺ in big amount. The

cause of acidity in hydrophobic layer was also a result of Al ion existence. Al concentration in acid pH would increase, and the concentration would decrease with the increase in soil pH, because Al would settle to form Al(OH)₃ in pH 5 (Tan, 2010).

Emission of CO₂ and N₂O

The measurement results of CO₂ and N₂O gas emission taken once a month were shown in Figure 1 and 2. The first month showed an increase in CO₂ emission at all treatment from 4460 mg/m²/day to 7435 mg/m²/day. At the second month observation there was an emission reduction that was quite significant until the end of observation. CO₂ emission increased in the first month observation period was presumed as a result of the increase in decomposition of both ameliorant agent and peat. Subsequent period saw an emission reduction due to lower peat decomposition. Decomposition increase in the first month could happen as a result of ameliorant and NPK fertilizer addition that increased the decomposer microorganism activity. CO₂ emission reduction in the second month was presumed also as a result of the increase of ground water level (Figure 1)



Explanation:

A1 = 80% chicken manure fertilizer + 20% dolomite, A2 = 20% chicken manure fertilizer + 20% agricultural weeds + 20% spodosol mineral soil + 20% “purun tikus” (eleocharis dulcis) compost + 20% dolomite, A3 = 19% chicken manure fertilizer + 9% dolomite + 72% mineral soil, A4 = 100% coconut shell biochar, A5 = 100% paddy husk biochar, A6 = farmer’s way (20% peat ash + 40% spodosol mineral soil + 40% chicken manure fertilizer), control =without ameliorant.

Figure 1. CO₂ emission as a result of ameliorant treatment at several observation periods.
 Cumulative CO₂ emissions referred to the fluxes multiplied by observation periods

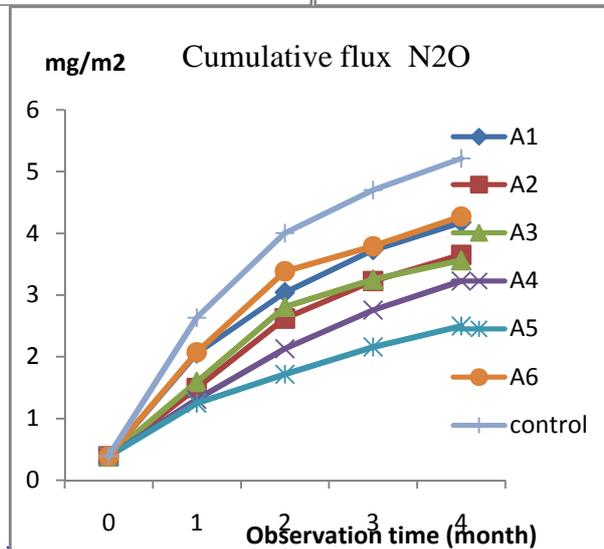
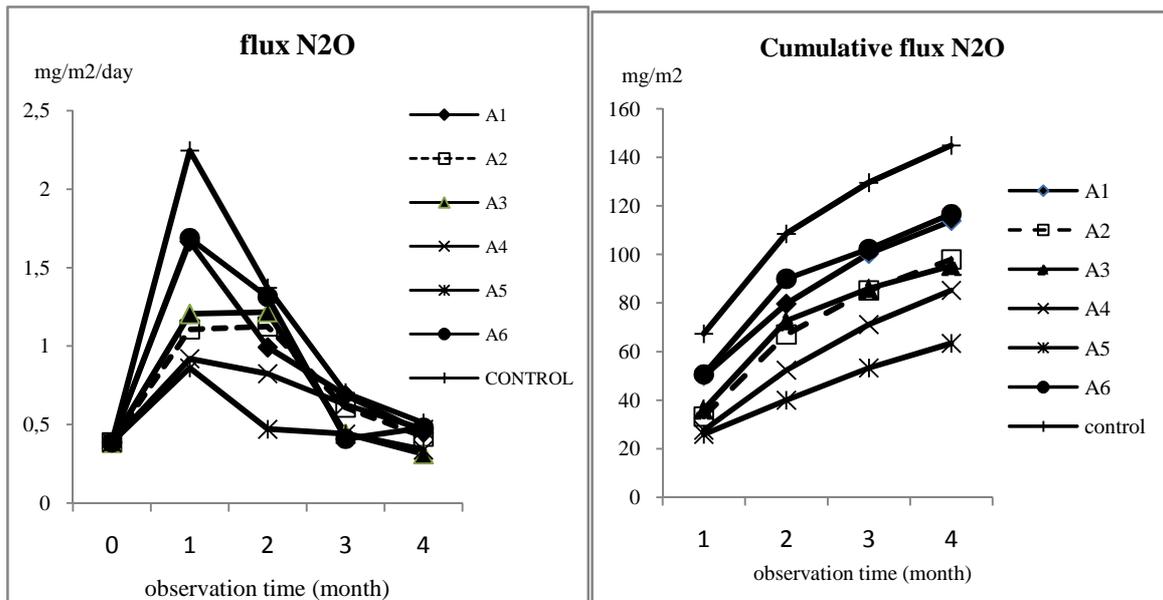
All ameliorant treatment given was capable of reducing CO₂ emission. The biggest emission reduction during all observation period was shown by ground coconut shell biochar ameliorant (A4). Ameliorant A5 (paddy husk biochar) in the second month observation period, still shown the highest emission as compared with other ameliorant, but as observation time went by there was an emission reduction. Quite significant CO₂ emission reduction was also shown by Ameliorant A1 during observation period.

The research of Nursyamsi et al. (2011) suggested that ameliorant application in the first season could reduce CO₂ emission of about 28-45%, and the biggest emission reduction was found in the treatment of paddy husk ash.

Ameliorant treatment given was also able to reduce N₂O emission. Generally there was an N₂O emission increase during the first month, and in the second month until the last observation there was a reduction. Emission reduction in the second month was caused by

the increase of ground water level (Figure 3). As reported by Tauchnitz et al. (2008), there was an N₂O emission increase in peat land due to the reduction of ground water level so the condition was more oxidative. According to Maljanen et al. (2001), N₂O emission was not related to the plant age. Unlike CO₂

emission, N₂O emission increase of the soil that was caused by land management could be compensated by CO₂ absorption by plants (Minkkenen and Laine, 1998). N₂O emission increase could also occur as a result of urea fertilizer addition (Reddy and DeLaune, 2008).



Explanation:

A1 = 80% chicken manure fertilizer + 20% dolomite, A2 = 20% chicken manure fertilizer + 20% agricultural weeds + 20% spodosol mineral soil + 20% "purun tikus" (eleocharis dulcis) compost + 20% dolomite, A3 = 19% chicken manure fertilizer + 9% dolomite + 72% mineral soil, A4 = 100% coconut shell biochar, A5 = 100% paddy husk biochar, A6 = farmer's way (20% peat ash + 40% spodosol mineral soil + 40% chicken manure fertilizer), control = without ameliorant.

Figure 2. N₂O emission as a result of ameliorant treatment at several observation periods. Cumulative N₂O emissions referred to the fluxes multiplied by observation periods.

Ground water level height in the research location was closely related to the amount of rain precipitation (Figure 3). This was because the research location was of tidal marsh land overflow type D that was not influenced by sea water tide. The more the rain precipitation the higher the ground water level height would be (approaching the land surface). Ground water level fluctuation

influenced transformation and transportation of nutrient element in peat land. Lower water level depth caused the soil condition to become more aerobe so increased the rate of decomposition and mineralization (Strakovo et al., 2011). Different decomposition and mineralization would influence CO₂ and N₂O emission during observation period.

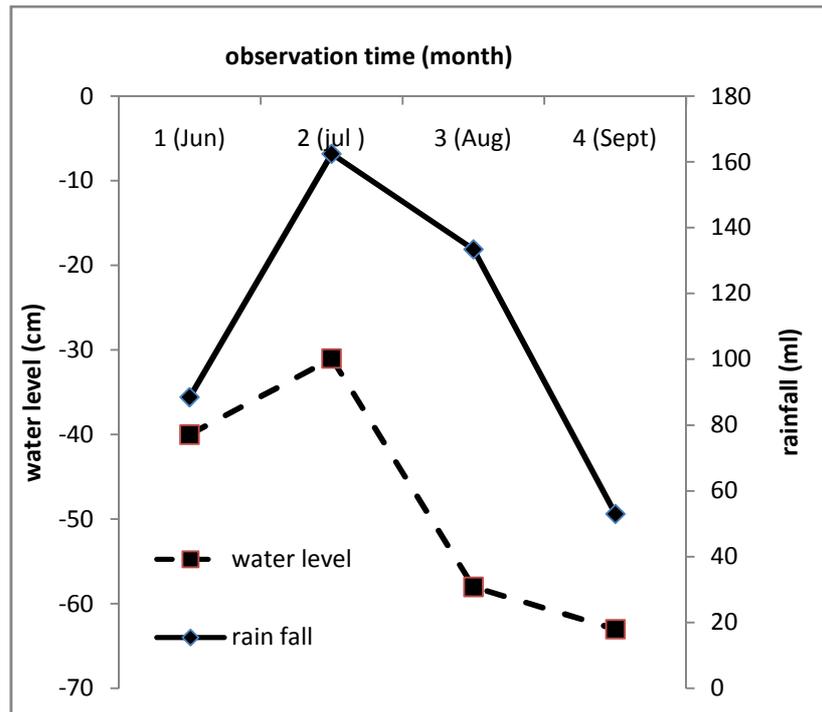
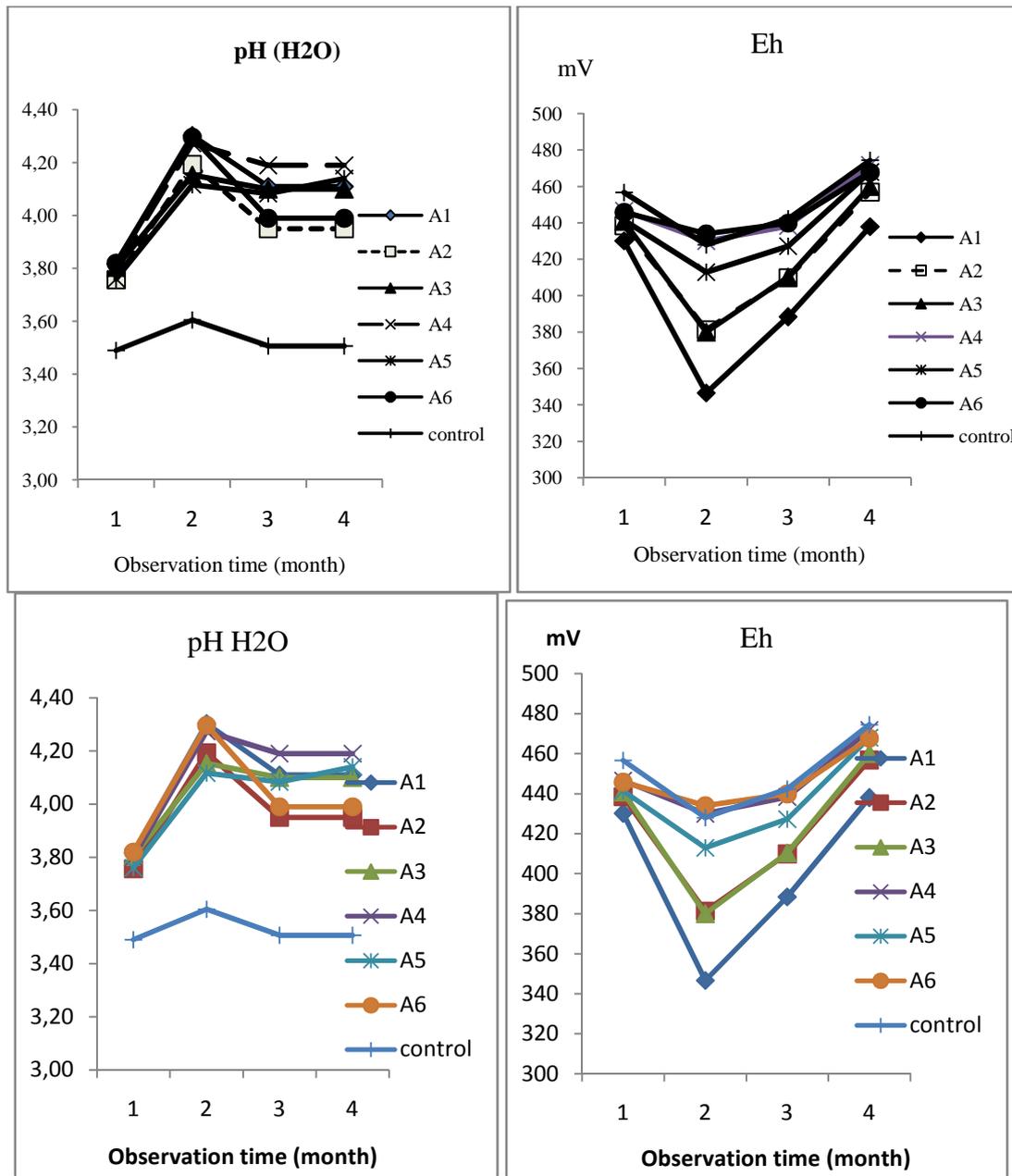


Figure 3 Rain precipitation and ground water level height

Apart from influencing emission, rain precipitation also influenced the transportation of nutrient element, this was due to ground water level height changes that brought along nutrient element from upper layer to the lower layer, or vice versa. Transportation not only occurred in nutrient element, but also in dissolved C. There was an obvious relation between the loss of P element and the loss of dissolved C carried by leaching (Waldron et al., 2009).

Change of pH (H₂O) and Soil Eh

Change of pH (H₂O) and soil Eh was observed once a month (Figure 4). There was an increase in soil pH in the first month of observation and in the second month then lowered with increasing time of observation. Every treatment tended to show the same pattern. The highest pH increase until end of observation was shown by ameliorant A4 treatment (coconut shell biochar) followed by A1.



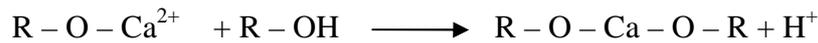
Explanation:

A1 = 80% chicken manure fertilizer + 20% dolomite, A2 = 20% chicken manure fertilizer + 20% agricultural weeds + 20% spodosol mineral soil + 20% "purun tikus" (eleocharis dulcis) compost + 20% dolomite, A3 = 19% chicken manure fertilizer + 9% dolomite + 72% mineral soil, A4 = 100% coconut shell biochar, A5 = 100% paddy husk biochar, A6 = farmer's way (20% peat ash + 40% spodosol mineral soil + 40% chicken manure fertilizer), control = without ameliorant.

Figure 4. Change of soil pH and Eh during observation period

Generally pH increase occurred only until the second month after ameliorant application. This condition described that until the second month equilibrium in soil solution had not been reached, peat re-released H⁺ into the soil solution. This was

presumed due to the occurrence of conversion reaction between Ca²⁺ and phenolic cluster that released H⁺ so soil acidity increased again, as seen in the following reaction (Suryanto, 1994).



The highest soil pH increase was shown by the A4 (coconut shell biochar) treatment, followed by ameliorant A2 that consisted of 20% chicken manure fertilizer + 20% agricultural weeds + 20% spodosol mineral soil + 20% "rat-rush" (*eleocharis dulcis*) compost + 20% dolomite. The influence of soil pH increase was concomitant with the ameliorant characteristic given.

The observation result of Eh value was periodically presented as seen in Figure 4b. There was a drop in Eh value in the second month as a result of ground water level increase. F1 treatment gave the least influence towards soil Eh consistently in every observation period. Soil Eh influenced the activity of microorganism both decomposer microorganism and nitrification bacteria that influenced N₂O formation (Reddy and De Laune, 2008). Water level increase was not only caused by ameliorant influence but also

influenced by rain precipitation. In the second month rain precipitation increased, causing soil humidity to also increase and Eh value to decrease.

CONCLUSSION

Ameliorant could reduce emission of both CO₂ and N₂O emission in corn crop in peat land. The most effective ameliorant in reducing CO₂ emission in corn crop in peat land was coconut shell biochar, whereas paddy husk biochar was effective in reducing N₂O emission. Coconut shell biochar was capable of reducing CO₂ emission up to 26% as compared with control, whereas paddy husk biochar was able to reduce N₂O emission up to 52% as compared with control. Soil pH increased in the second month and decreased in the third and the fourth month, the opposite occurred in soil Eh pattern.

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