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REPLACING SLASH AND BURN PRACTICES WITH SLASH AND COMPOSTING TO REDUCE CARBON DIOXIDE EMISSIONS FROM DEGRADED PEATLAND

Mengubah Praktik Tebas dan Bakar Menjadi Tebas dan Pengomposan untuk Mengurangi Emisi Karbon Dioksida di Lahan Gambut Terdegradasi

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ABSTRACT

Slash and burn are commonly practiced in opening new field in tropical peatland. This method, if uncontrolled, may cause peat fires and increase CO_2 emissions. Therefore, alternative method of peatland preparation for agriculture is needed. The study aimed to obtain peatland preparation technologies to prevent peat fires and reduce CO_2 emissions. The study was conducted at degraded peatland in Kalampangan, Central Kalimantan from June to October 2017. Split plot design with three replications was used. The main plot was the type of land arrangement, i.e. without and with raised beds. The subplot was the type of land preparation, i.e. slash and burn, slash followed by composting the weeds, slash and make the weeds as mulches, and slash followed by composting the weeds and accompanied by plastic mulch. Soil characteristics, fires vulnerability, and CO_2 emissions were measured before and after land preparation. Results showed that slash and composting reduced CO_2 emission from cultivated peatland. Slash and burn resulted 4.98 t CO_2 ha^{-1} emissions per season, which is four times higher than slash followed by composting that produced 1.20 t CO_2 ha^{-1} per season. Groundwater level, redox potential (Eh), soil pH, and soil water content affected CO_2 emissions. Groundwater level and water content negatively correlated with CO_2 emissions. The shallow water level and the high water content, the lower is CO_2 emissions. The Eh and soil pH positively correlated with CO_2 emissions. The high positive value of Eh indicates that the soil was in high oxidative conditions, resulting in high CO_2 emissions.

[**Keywords**: CO_2 emissions, groundwater table, peat cultivation, peat soil]

ABSTRAK

Sistem tebas dan bakar merupakan metode yang umum digunakan dalam membuka lahan pertanian di lahan gambut. Namun, metode tersebut dapat menyebabkan kebakaran lahan dan meningkatkan emisi CO_2. Oleh karena itu, metode alternatif penyiapan lahan gambut untuk pertanian sangat diperlukan. Penelitian bertujuan untuk memperoleh teknik penyiapan lahan gambut untuk mencegah kebakaran dan mengurangi emisi CO_2. Penelitian dilakukan di lahan gambut Kalampangan, Kalimantan Tengah pada Juni–Oktober 2017, menggunakan rancangan split plot tiga ulangan. Petak utama adalah cara penataan lahan, yaitu tanpa bedengan dan menggunakan bedengan. Anak petak adalah cara penyiapan lahan, yaitu gulma ditebas dan dibakar, gulma ditebas lalu dikomposkan, gulma ditebas dan digunakan sebagai mulsa, dan gulma tebas lalu dikomposkan dan menggunakan mulsa plastik. Karakteristik tanah, kerentanan kebakaran lahan, dan emisi CO_2 diukur sebelum lahan dibersihkan dan setelah ditata. Persiapan lahan dengan ditebas lalu dikomposkan efektif mengurangi emisi CO_2 dibandingkan dengan tebas dan bakar. Sistem tebas dan bakar menghasilkan emisi CO_2 4,98 t ha^{-1} per musim tanam atau empat kali lebih tinggi daripada gulma ditebas lalu dikomposkan (1.20 t CO_2 ha^{-1} per musim). Ketinggian air tanah, potensi redoks, pH tanah, dan kadar air tanah memengaruhi emisi CO_2. Kadar air tanah dan ketinggian air tanah berhubungan negatif dengan emisi CO_2; makin dangkal air tanah dan makin tinggi kadar air gambut, makin rendah emisi CO_2. Sementara pH dan Eh tanah berhubungan positif dengan emisi CO_2. Nilai positip Eh yang tinggi menunjukkan tanah dalam kondisi teroksidasi sehingga emisi CO_2 tinggi.

[**Kata kunci**: emisi CO_2, kedalaman air tanah, pengolahan gambut, anah gambut]

INTRODUCTION

Indonesia globally has the largest tropical peatland. Ritung et al. (2011) estimated Indonesia's peatland area of approximately 14.9 million hectares, which is about 80% of peatland in South-East Asia and 50% of the global tropical peatland (Ritung et al. 2011). However, improper management such as logging activities and land conversion has caused peatland degradation (Silvius and Diemont 2007). About 4 million hectares of Indonesia's peatland were covered by degraded forest (shrub) and most of this land could be restored for agriculture or some other productive uses (Agus et al. 2014). Degraded peatlands, especially shallow peat (<100 cm) can be utilized for growing food and perennial crops (Sabiham 2008). Furthermore, about 33% of Indonesian peatland distributed over the islands of Sumatra, Kalimantan and Papua, is suitable for agriculture (BBSDLP 2008). However, such utilization must consider the environmental problems, including peat fires and high CO_2 emissions.

Land preparation is one of determinant keys for peatland utilization. Improper land preparation and water management could lead to peat degradation (Masganti 2013; Masganti et al. 2014; Wahyunto et al. 2014). Also, excessive drainage of peatland potentially resulted in peat oxidation and caused peat irreversible drying (Wösten et al. 2008). It also increased peat vulnerability to fires (Hooijer et al. 2006), that significantly released CO_2 into the atmosphere (Page et al. 2002), especially in the extreme climate conditions of El Nino (Page et al. 2002; Ballhorn et al. 2009; Hooijer et al. 2010). Land fires more occurred frequently in shrubs land than that in cultivated land (Hoscilo et al. 2005).

Slash and burn land preparation is practiced widely to open peatland for agricultural purposes. It was chosen as the main method because of cheap and easy. However, this practice will increase peatland fires vulnerability, greenhouse gas (GHG) emissions, and accelerate peatland damage (Medrilzam et al. 2014) Medrilzam 2013). Therefore, appropriate land preparation techniques are needed to avoid excessive drainage of tropical peatland.

Red chilli is one of the strategic vegetables in Indonesia. Started in 2015, chilli becomes one of seven key commodities of the Indonesian Ministry of Agriculture to increase the production and achieve self-sufficiency. The high competition of fertile land use in Indonesia, as well as for agricultural development or other utilization, leads the government to utilize suboptimal land such as peatland to increase chilli production. Therefore, it is important to find the appropriate peatland management to increase chilli production and to minimize the environmental impact of peat utilization such as CO_2 emissions and peat fires vulnerability.

Factors causing changes in peat soil CO_2 emissions are soil temperatures, soil water content, and soil characteristics such as the availability of organic C (organic matter including quantity and quality), soil pH, and peat maturity (Nusantara et al. 2014). Therefore, this study aimed to obtain the alternative land preparation technologies, instead of slash and burn activities, to reduce CO_2 emissions in degraded peatland, which could be used for agriculture.

MATERIALS AND METHODS

Study Site

The study was conducted on degraded peatland in Kalampangan, Central Kalimantan, from June to October 2017 (one season of chilli planting). Prior to land clearing for chilli cultivation, the field was covered by shrubs and small acacia trees. The field has been opened for 10 years, but was left becoming idle as a shrub land. The field was defined as a degraded peatland because of land clearing by human activities and drainage constructions.

Experimental Design

The study was arranged in a split plot design with three replications. The main plot was the type of land arrangement, i.e. U1 = without raised beds and U2 = using raised beds. The subplot was the type of land preparation, namely A1 = slash and burn, A2 = slash followed by composting the weeds, A3 = slash and make the weeds as mulches, and A4 = slash followed by composting the weeds and accompanied by plastic mulch.

Slash and burn land preparation methods were carried out following the farmer's habit. The process was spraying the weeds with herbicides, collecting the dead weeds then burned and used as a soil ameliorant. Land preparation was conducted in accordance to the treatment. After land clearing, the field was tilled using a hoe at a depth of 30–40 cm until crumbly. The plot size for each treatment was 5 m x 6 m or 30 m^2 in total. Around the plots, small canal was made with a depth of 30 cm. For the raised bed treatment, the plot size was 1.2 m wide x 30 cm height, with the distances between the beds were 30 cm and the planting holes spacing was 50 cm x 40 cm.

Planting Methods

Hot red chilli varieties were used in this study. Before planting, seeds were soaked in the warm water for an hour to remove pests or diseases attached to the seeds, and to accelerate germination. Poor quality seeds that were usually floating in water were removed. Seeds were sown in the polybags, using peat and manure for one month. The seeds were transplanted after 1 month (having 4–5 leaves). Insecticide with an active ingredient of carbofuran was used 1 g per plant and was applied on the planting holes, two days prior to transplanting. After planted, seeds were watered to release plant stress. Then, if it was not raining, the plant was watered in the morning and afternoon, using an artificial pipe. During the 7 days after planting, the dead plants were replaced using a new plant.

Fertilization and Plant Management

Combination of organic and chemical fertilizer was applied in the field. The dosage of urea (N), SP-36 (P_2O_5), and KCl (K_2O) were 100, 200, and 120 kg ha^{-1}, respectively. Urea was split into three parts, 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. $CuSO_4$ of 10 kg ha^{-1} and $ZnSO_4$ of 10 kg ha^{-1} were also applied at 1-month age. While organic fertilizer (manure) was applied at the planting time. Plant management such as weeding, turf installation, leaf pruning, and pest and disease control were conducted regularly.

Soil Sampling

The soil was sampled at a depth of 0–20 cm from each plot. Totally, 32 composite soil samples were taken at four points of each plot for pH, soil moisture content, and Fourier Transform Infra-Red (FTIR) analyses. Ground redox potential (Eh) measurements were conducted in the field simultaneously with CO_2 gas sampling using Eh meter.

Groundwater Level Measurement

Groundwater level was measured manually every 2 days using piezometers, which was made from perforated PVC of 5.08 cm diameter and 2 m long. Piezometers were installed at every plot of experiment.

CO_2 Measurement

CO_2 flux was measured on soil and plant using a method adopted from International Atomic Energy Agency (IAEA) (1992). Closed chamber method using a fiberglass of 50 cm x 50 cm x 100 cm equipped with fan (12 Volts) and thermometer was used. The gas was taken using a syringe needle for every 5 minutes, in the morning at 6:00–8:00 am. Then, the gas was analyzed using Micro-GC gas chromatography (GC) with emission calculation using equation below:

$$\begin{array}{l} E = \underline{Bm} \times \underline{\delta Csp} \times \underline{V} \times \underline{273.2} \\ Vm.\delta t \qquad A \quad T.\delta 273.\delta \end{array}$$

Where:

Bm = CO_2 gas molecule weight in standard condition

Vm = CO_2 gas volume in standard temperature and pressure (stp) condition 22.41 liter at 23^O K.

Agronomic Observations

Observation of the growth of chilli plants was conducted to the height of plants at the age of 2, 4 and 6 weeks after planting, the number of fruits per plant, and the weight of chilli fruit.

Data Analysis

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

RESULTS AND DISCUSSION

Soil Characteristics

The observed soil characteristics were pH, KCl, soil moisture content and redox potential (Eh). Soil pH at the treatment without raised beds showed a decline pattern at the second measurement (September), but increased in the third month (October). In contrast, for raised bed treatment, pH increased at the second and third measurements. The highest increase in soil pH occurred in the first month in a U2A3 treatment (Figure 1). pH value increased in the first, second and third months compared to conditions before land clearing. In addition, the increased pH was caused by the application of 2 t ha^{-1} lime in all plots before planting.

In the second month, soil pH decreased due to the occurrence of alkaline cations leaching (Ca and Mg ions) in large quantities, especially in the treatment without raised beds. The leaching on raised beds was smaller than that without raised beds there by the pH tends to increase. Land without raised beds causes many ions leach out from root area, thus pH quickly decreases, whereas on the raised beds it takes longer.

In situ mulching of weeds increased soil moisture, especially on the without raised beds treatment (U1A3) in the first month even it was relatively the same for the next months (Figure 2a). On raised beds treatment, the highest water content was shown by plastic mulch (U2A4) treatment. The soil moisture content increased in the second month then decreased in the third month. This condition was closely related to the rainfall pattern at the study site. Soil water content as controlled by groundwater level greatly affects the large CO_2 emissions in the field. Soil water content determines biogeochemical processes in peat soil including oxidation and reduction conditions.

Redox potential (Eh) is used to measure the degree of soil wetting or the intensity of anaerobic conditions. Unlike the pH that measures the activity of the H^+ ions, Eh measures the activity of electrons (e^-) in the soil.

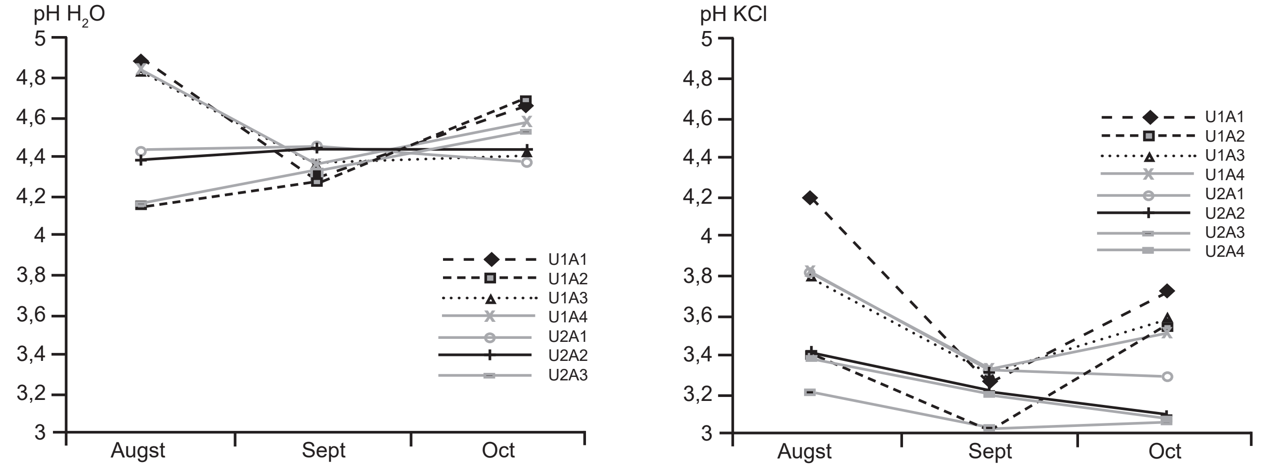

Fig. 1. Changes in soil pH as affected by the type of land preparation and management; U1 = without raised beds, U2 = using raised beds, A1 = slash and burn, A2 = slash followed by composting the weeds, A3 = slash and make the weeds as mulches, and A4 = slash followed by composting the weeds and accompanied by plastic mulch.

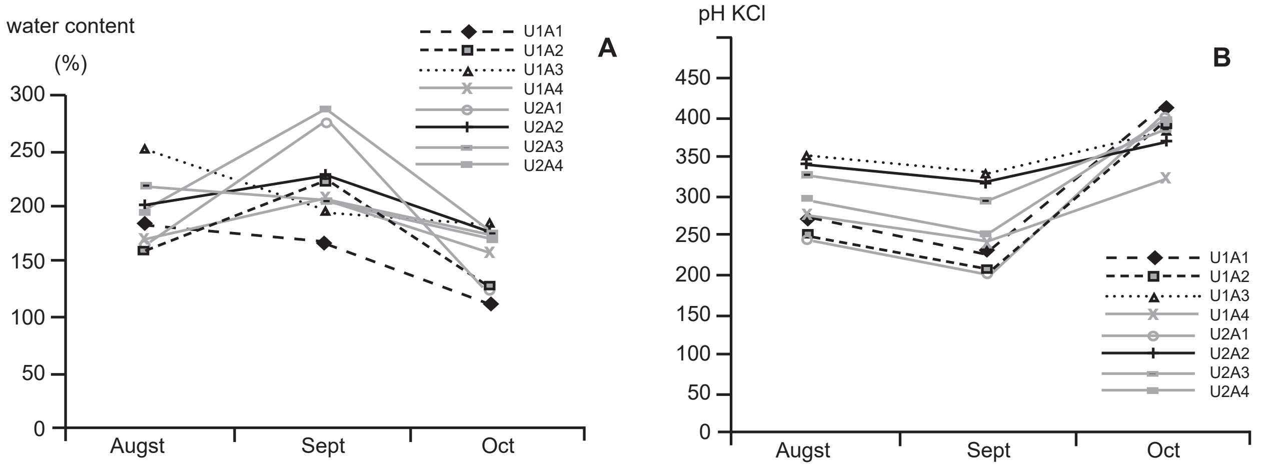

Fig. 2. Change in soil water content (A) and soil redox potential (B) as affected by the type of land preparation and management; U1 = without raised beds, U2 = using raised beds, A1 = slash and burn, A2 = slash followed by composting the weeds, A3 = slash and make the weeds as mulches, and A4 = slash followed by composting the weeds and accompanied by plastic mulch

The oxidation-reduction processes have an important role in the availability of soil nutrients, biogeochemical nutrient cycles, and ecological function of the ecosystem. Fluctuation in the Eh values was influenced by treatment that changes the soil condition and groundwater level. The value of redox potential was closely related to soil acidity (pH) and soil water moisture content. The values ranged from +200 to +390 mV, indicating the oxidative state (Figure 2b). This condition allowed oxidation of nitrate, Fe, and P which greatly affects the carbon emissions. In the oxidative conditions, microorganism activities increase the decomposition rate.

Degraded peatland could be observed directly in the field as associated to land cover. Peatland could be categorized as degraded land if it is opened and only covered with a shrub. Indicators of degraded peatland include: (1) existing logging, (2) logging roads, (3) fire traces, (4) dry/unfertilized soil conditions, and (5) ex-mining (Wahyunto et al. 2014). Based on chemical characteristics, the degraded peat was indicated by the presence of large hydrophobic functional groups of organic matter (more than 25%) (Maftu'ah 2012). This condition indicates that the ability of water holding capacity of peat material decreased as a result of the decrease in hydrophilic functional group of organic matter.

Groundwater level is highly correlated with the composition and structure of organic matter (Doerr and Thomas 2000; Ellerbrock et al. 2005). The hydrophilic property is represented by oxygen-containing functional groups, mainly phenolic hydroxyl and alcohols, and carboxylic or nitrogen functional groups, usually amine and amid groups, as well as heterocyclic N bonds. These clusters can form hydrogen bonds with water molecules.

The result of Fourier Transform Infra-Red (FTIR) analysis from peat material at 0–20 cm layer is shown in Figure 3 and Table 1. The wave number of hydrophobic functional groups at the peak area of 1265 cm^{-1} indicated lignin; the 1620 cm^{-1} indicated lignin, aromatic or aliphatic carboxylic; the 1712 cm^{-1} and 2345 cm^{-1} indicated carboxylic, ester or aromatic acids; and the 2,800–2,924 cm^{-1} indicated the fat, wax and lipids (Table 1, Cocozza et al. 2003; Artz et al. 2008). Peat soil at the site has partial hydrophobic groups achieving 48.32%, while the content of hydrophilic functional group is 46.78%. The presence of the hydrophobic functional groups indicates that peat is likely less ability to absorb water. Peatland dominated by hydrophobic functional groups is more susceptible to land fires (Nurzakiah et al. 2016).

The hydrophobic nature of peat soil is caused by: (1) humic acid content which naturally exhibits hydrophobic properties, since the particles are covered by wax; (2) the presence of non-polar groups such as ethyl, methyl and hydrophobic aromatic compounds, but less on hydrophilic groups, i.e. carboxylates and hydroxyl; and (3) absorption of hydrophobic compounds such as oils, fats and N-organic fractions on the surface of the humic fraction (Valat et al. 1991). The presence of functional groups as fragments in soil organic matter molecules affect chemical reactivity, uptake, and hydrophobicity of organic matter (Valat et al. 1991) (Ellerbrock and Gerke 2004).

CO_2 Emissions

CO_2 flux measurements were conducted four times: after field preparation (treatment), and at 1, 2 and 3 months after planting. The field treatment increased CO_2 emissions on degraded peatland from 3260 mg C m^{-2} day^{-1} to 11500 mg C m^{-2} day^{-1}, and continued to decrease to 7500 mg C m^{-2} day^{-1} after soil compaction due to bed construction (Figure 4). Raised bed construction reduced emissions by 35% compared to the time of soil tillage because the rate of peat decomposition becomes lower due to soil compaction. Moreover, the higher emission on soil tillage was occurred because soil tillage accelerates the oxidation

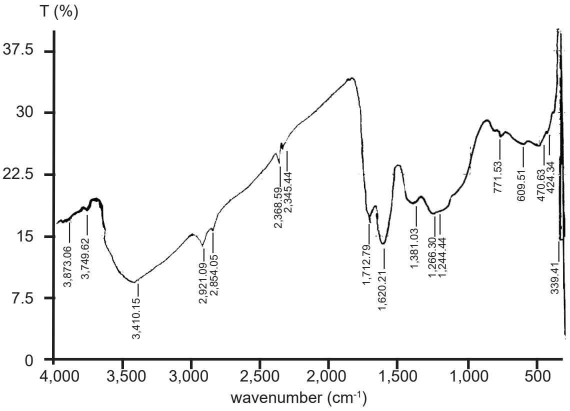

Fig. 3. Fourier Transform Infra-Red (FTIR) analysis results from peat materials at the study sites.

Table 1. Wave numbers, functional groups, and characters and the area of FTIR analysis.

Wave numbers (cm^{-1})	Functional group	Characterization/source*	Total area (%)	Reference
<900		Inorganic mineral	5.09	Zaccheo et al. (2002) Ibarra et al. (1996)
1265	C-O chain of phenolic OH, arylmetileter	Indicated lignin	17.36	Niemeyer et al. (1992) Ibarra et al. (1996)
1381	The symmetrical circuit of COO-, N-H deformation and C = N circuit	Protein	0.24	Niemeyer et al. (1992) Ibarra et al. (1996)
1620	The C = O circuit of the quinone, or C = O of the conjugated H-ketone bond, the C = C aromatic circuit, the -H bond at C = O	Lignin or other aromatic groups, aromatic or aliphatic carboxylic acids	15.35	Niemeyer et al. (1992) Cocozza et al. (2003)
1712	The C = O circuit of COOH and COOR	Carboxylic acid, aromatic esters	8.77	Niemeyer et al. (1992) Haberhauer et al. (1998)
2345	The C = O circuit of COOH and COOR	Carboxylic acid, aromatic esters	2.25	Niemeyer et al. (1992) Haberhauer et al. (1998)
2854	CH_2 syimetric	Fat, wax, lipids	0.23	Cocozza et al. (2003)
2924	Aliphatic C-H series, C-H2 antisymmetric	Fat, wax, lipids	4.36	Niemeyer et al. (1992) Cocozza et al. (2003)
3410	H group hichroxyl, carboxyl and phenol groups, primary amino	Cellulose	45.45	Cocozza et al. (2003)
3749	The Y (OH) stretched circuit N-H	Cellulose	1.09	Cocozza et al. (2003)

of organic matter by increasing the aeration that stimulates microbial respiration, increases the contact between soil and residue, and accelerates the decomposition of organic material initially protected by aggregates (Curtin et al. 2000).

Generally, CO_2 flux in the second month of measurement (September) increased, then decreased in the third month (October, Figure 5). The highest CO_2 flux is shown by the treatment of raised beds on slash and burn (U2A1) system. Because the source of emissions is soil + plant, the CO_2 emissions are combination of soil and plant respiration. Beside the soil condition, the higher emissions on U2A1 also occurred due the less optimal of plant condition that resulted higher emission compared to another plots.

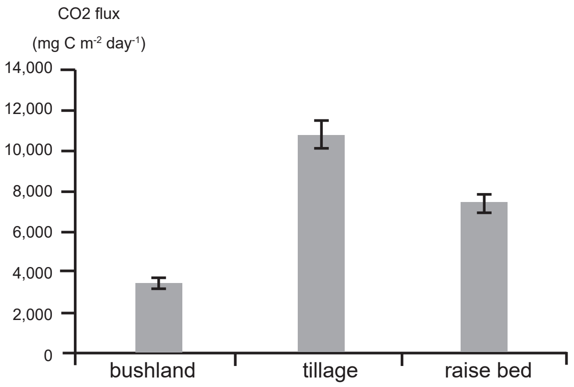

Fig. 4. Initial CO_2 flux after land preparation (soil tillage) based on measurement from Juneto July (n = 9).

The highest CO_2 emissions during one planting season was observed on U2A1 treatment, while the lowest was on U2A2 (Figure 5). In U2A treatment, weeds or grasses burning during land preparation increased CO_2 emissions due to the burning process and increasing ash content as a result of organic material burning. Land preparation with slash and burn system resulted in 4.98 t CO_2 ha^{-1} emissions during one planting season, which is about four times higher than slash and make the weeds for compost resulted in 1.20 CO_2 t ha^{-1} emissions.

The CO_2 flux is also affected by the depth of groundwater level (GWL) relative to soil surface (Figure 6). The deeper GWL causes the soil surface

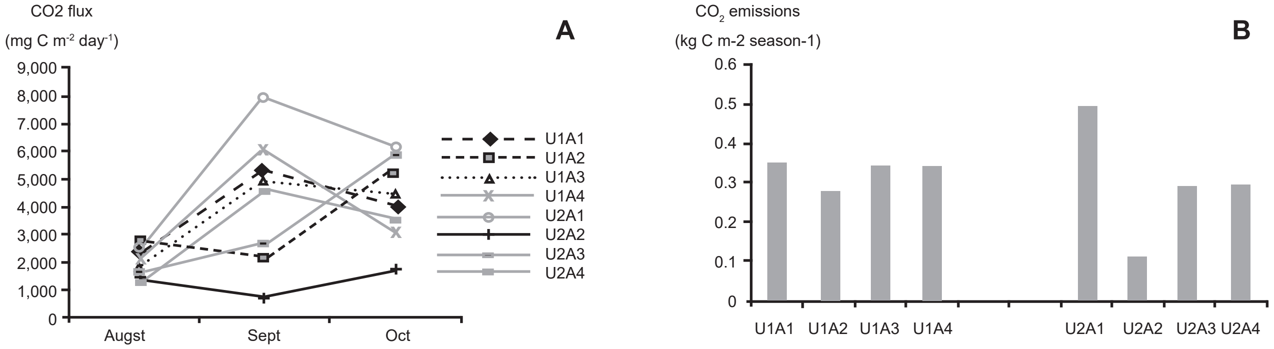

Fig. 5. Carbon dioxide (CO_2) flux at several observation periods (A), and cumulative CO_2 emissions for one season due to land preparation and land arrangement (B); U1 = without raised beds, U2 = using raised beds, A1 = slash and burn, A2 = slash followed by composting the weeds, A3 = slash and make the weeds as mulches, and A4 = slash followed by composting the weeds and accompanied by plastic mulch.

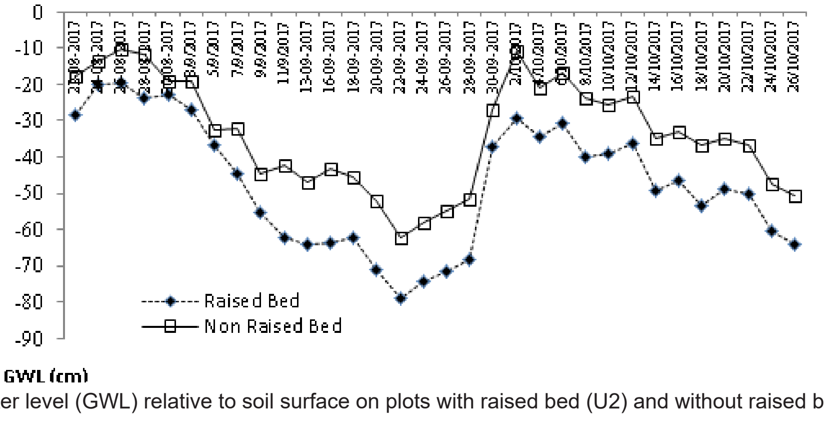

Fig. 6. Groundwater level (GWL) relative to soil surface on plots with raised bed (U2) and without raised bed (U1) treatment.

drier, Eh increased and finally resulted in high carbon emissions. Oxidative condition increases the activity of microbial decomposer on peat materials. Raised bed construction caused GWL to decrease by 2–10 cm compared to without raised beds (Figure 4). However, CO_2 emissions were not only influenced by water levels, but also by the ameliorant application (Susilawati et al. 2016) (Susilawati 2015) . In addition, the result of linear regression analysis also showed that CO_2 emissions have a strong correlation with pH and other macronutrient content (Marwanto et al. 2013). Furthermore, the most closely correlated relationship based on the sequence of regression coefficients from the largest CO_2 emissions was Ca (R^2 = 0.96), followed by P (R^2 = 0.90), pH (R^2 = 0.89), Na (R^2 = 0.85), K (R^2 = 0.74), and the last was Mg (R^2 = 0.73). In contrast, application of soil ameliorant with high polyvalent cation suppressed the carbon emissions. This ameliorant reduces GHG emissions through the complexation of organic acids, especially easily degraded compounds that make a stable condition. Coconut shell biochar was capable to reduce of both CO_2 and N_2O emissions on maize cultivation in tropical peatlands (Maftu'ah et al. 2016).

Effect of pH, Eh, Groundwater Level and Soil Water Content on CO_2 Emissions

The regression analysis results of pH, Eh and GWL to the amount of CO_2 emissions are shown in Figure 7. Groundwater levels greatly affected the amount of CO_2 emissions on peatland (Figure 7).

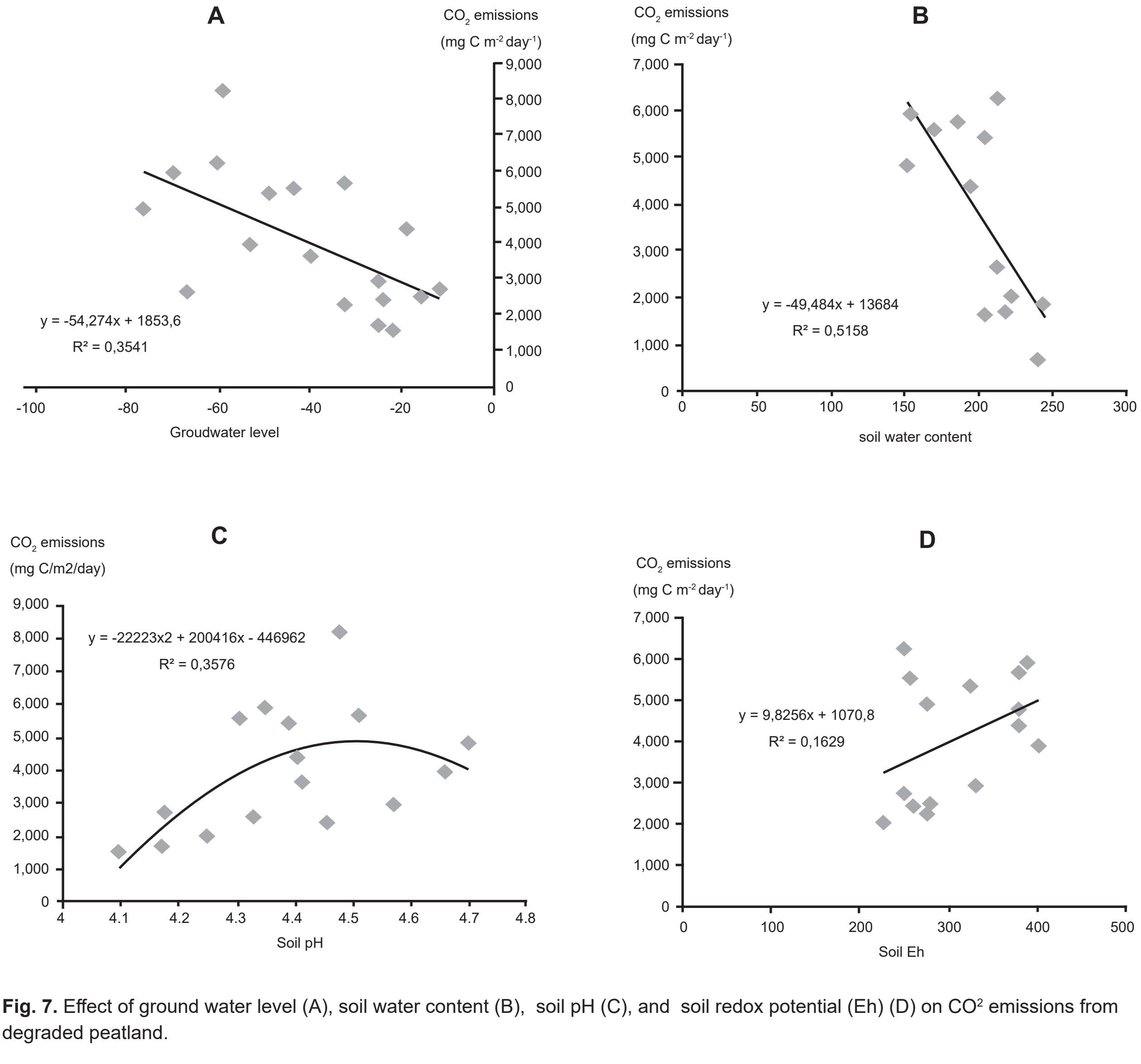

Fig. 7. Effect of ground water level (A), soil water content (B), soil pH (C), and soil redox potential (Eh) (D) on CO^2 emissions from degraded peatland.

There was a negative correlation between GWL and CO_2 emissions. The deeper the groundwater level (the farther from the surface), the higher the CO_2 emissions. This finding was in line with soil CO_2 emissions from a rubber plantation in Central Kalimantan (Wakhid et al. 2017). Decreasing GWL by 10 cm from the soil surface increased CO_2 emissions by 542 mg m^{-2} day^{-1}. This value is smaller when compared to peatland in Jambi, where a 10 cm drop in the GWL increased CO_2 emissions by 50% from 109.1 to 162.4 mg C m^{-2} day^{-1} or 2618.4 to 3897.6 mg C m^{-2} day^{-1} (Furukawa et al. 2005).

Water content was negatively correlated with the amount of CO_2 emissions (Figure 7) The increase in soil water content of 10% reduced CO_2 emissions by 494 mg m^{-2} day^{-1}. While Eh and soil pH were in contrast affected the CO_2 emissions. Great positive value of Eh indicates that the soil is in high oxidative conditions, resulting in great CO_2 emissions. Wet-dry conditions also greatly affect soil carbon transformation (Fierer and Schimel 2002). Moreover, aerobic conditions increase the diversity soil microorganisms (Fierer et al. 2003). Soil temperatures, soil moisture content, and dry wet cycles affect soil organic decomposition (Fierer and Schimel 2002; Howard and Howard 1993). The presence of oxygen accelerated the mineralization of organic materials, resulting in the increase in CO_2 emissions. In addition, the rate of organic matter decomposition is also influenced by temperature, humidity and nutrient content (Minkkinen et al. 2007).

The effect of soil pH on CO_2 emissions was a quadratic relationship, where CO_2 emissions rise to some extent (about 4.5) and then decrease with the increase in soil pH. (Hirano et al. 2007) Hirano et al. (2007) reported that CO_2 emissions from tropical peat are highly varied depending on time and place, when the land was converted (related to humification level), nutrient status, and variation during the measurement.

Plant Growth

Plant height was not affected by the type of land preparation and arrangement (Figure 8a). However, the raised bed treatment produced a better plant performance compared with without raised bed. The treatment that provides the best plant height was the raised beds and weed composted + plastic mulch (U2A4).

The largest chilli size is observed on treatment without raised beds with slash followed by composting (U2A3), but not significantly different from all treatments except U1A1, U1A3 and U1A4. The highest number of fruits was showed by the U1A1 treatment, but it was not significantly different from all treatments except U1A2 and U1A4. The fruit size of the raised bed treatment was better than that without raised beds (Fig 8b).

Land management using raised beds gave a better effect than that without raised beds on the chilli growth and yields. Making raised beds could reduce nutrient leaching along with the flow of surface water, increase soil compaction so that the roots become more robust, and protect the land from flooding.

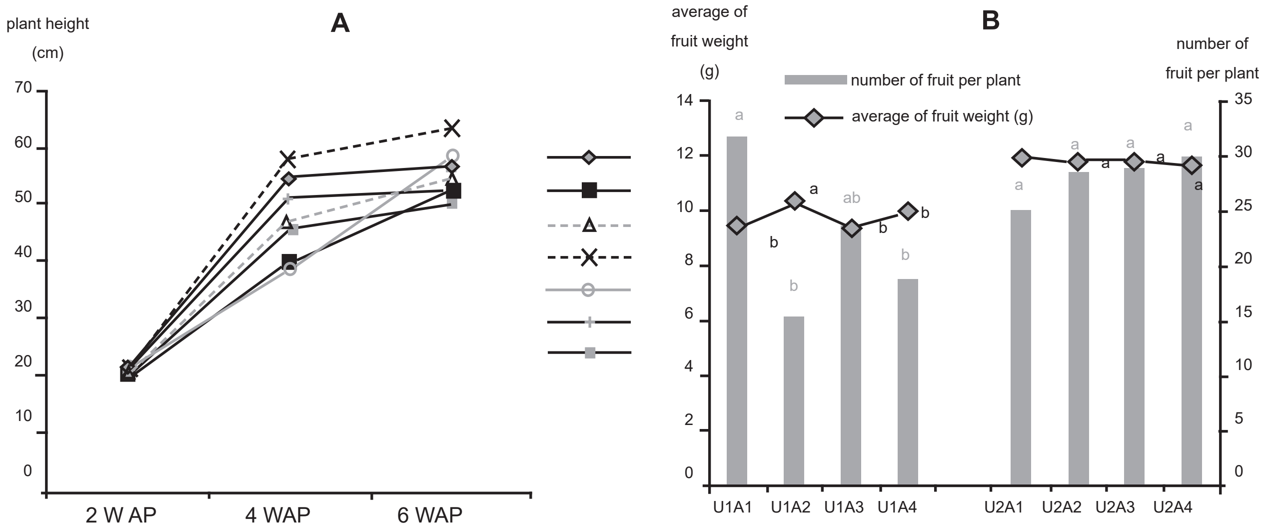

Fig 8. Effect of land preparation and arrangement on plant height (A), average fruit weight and number of fruit per plant (B) of chilli cultivated in degraded peatland.

CONCLUSION

Land clearing increased CO_2 emissions on degraded peatland from 3260 mg C m^{-2} day^{-1} to 11,500 mg C m^{-2} day^{-1}, and then decrease to 7500 mg C m^{-2} day^{-1} (35%) after soil compaction by raised bed system. Land preparation by slash and burn system increased CO_2 emissions up to four times higher during one planting season of red chili compared to land preparation by slashing weeds followed by composting. Groundwater level (GWL), pH and soil moisture affected CO_2 emissions. The decrease in GWL by 10 cm from the soil surface increased CO_2 emissions by 542 mg m^{-2} day^{-1}. An increase in soil water content of 10% reduced emissions by 494 mg m^{-2} day^{-1}.

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