

A Study of Carbon Dioxide Emission in Different Types of Peatland Use in Kalimantan

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ABSTRACT

Study of carbon dioxide emissions in different types of peatlands use in Central and West Kalimantan has been conducted in January-June 2006 and January-April 2007. The study represents 4 types of land use in Central Kalimantan as treatment: 5 years for chinese cabbage, 10 years for chinese cabbage, 5 years for sweet corns, and 10 years for sweet corns. As for the treatments in West Kalimantan, they include corn field, *Aloe vera* field, oil palm plantation, and rubber plantation. Carbon dioxide was measured using infrared gas analysis (model EGM-4, PP systems, Hitchin, UK). In Central Kalimantan, the highest CO₂ is emitted from sweet corn plants (arable land for 10 years) by 0.79 g CO₂/m²/hour, chinese cabbage plants (for 5 years) by 0.73 g CO₂/m²/hour, chinese cabbage plants (for 10 years) by 0.67 g CO₂/m²/hour and, the least, sweet corn plants (for 5 years) by 0.41 g CO₂/m²/hour. The highest CO₂ emission from West Kalimantan is released from rubber plants at 1.22 g CO₂/m²/hour, followed by palm oil plants by 0.96 g CO₂/m²/hour, *Aloe vera* plants by 0.68 g CO₂/m²/hour and corn plants by 0.35 g CO₂/m²/hour. Groundwater table depth are the most important factors among other factors that influence CO₂ emissions. Groundwater table depth indicated a positive correlation with CO₂ emissions in all types of peatlands use. C-organic production of sweet corn plants at 11.66 t C/ha/year is higher than that of chinese cabbage plants at 1.64 t C/ha/year. Corn plants produce organic-C was 11.66 t C/ha/year, equivalent to the amount of loss of C through CO₂ emissions by 11.29 t C/ha/year.

Keywords: peat, types of land use, carbon, CO₂ emission

INTRODUCTION

Ecological functions of tropical peatlands are to store carbon, to balance the carbon composition, to pin nutrient-trapping sediments, and to stabilize the microclimate (Page *et al.*, 2004; Rieley, 1992 and Rieley *et al.*, 2008). Peat land conversion to agriculture will disrupt the ecological functions of peatlands. This happens due to the reclamation of peatlands to agricultural land that includes the creation of drainage to remove excess water in order to decrease water table depth. Syarkowi (2007) noted that the sweet corn and chinese cabbage plants are two most profitable commodities for farmers in Kalamangan.

The decrease in the depth of groundwater table resulted in changes in the conditions of peat on the top layer, from anaerobic to aerobic condition. In this aerobic condition oxidation of carbon occurs to generate carbon dioxide released into the atmosphere. CO₂ emission released into the atmosphere impacts not only global warming, due to its very large contribution, but also threatens the existence of peatlands as the carbon storehouses.

Utilization of peatlands for agriculture purposes affects the environmental changes. Environmental factors such as the depth of groundwater table, temperature, humidity and peatland pH affect the magnitude of emitted CO₂ released by peatlands (Jauhiainen *et al.*, 2005; Hooijer *et al.*, 2006; Agus *et al.*, 2010; Jauhiainen and Hooijer., 2012).

Plant biomass productions in peatlands are still relatively low, and therefore no balance was found between the ability of plants to produce carbon and the carbon loss through CO₂ emissions. This condition is made worse by the fact that nearly all the biomass produced, especially by annual crops, were transported out so that almost no biomass restored in the soil. The impact will not only on peat loss due to subsidence, but also the emitted CO₂ itself as one source of greenhouse gas.

The research aims (1) to determine the amount of CO₂ emitted by various types of peatlands use, (2) to determine the correlation between environmental factors as well as other factors and the amount of CO₂ emitted by different types of peatlands use, and (3) to determine the ability of various types of peatlands

use in producing carbon to substitute the carbon lost through CO₂ emissions. The results of this study are expected to be useful to understand the magnitude of peat loss through CO₂ emissions from various types of land use, and to maintain a balance between the release of carbon through CO₂ emissions and carbon sequestration by plants.

Peatlands constitute an accumulation of soil organic matter in the form of stems, twigs, leaves, and roots as the raw material in waterlogged conditions (Andriess, 1988). Accumulation of organic matter occurs when the production of organic matter is higher than the decomposed organic matter. This occurs in a condition that is not optimal for the decomposition process (Collins and Kuehl, 2001).

Ecologically, peatlands serve, among others, as a storehouse of carbon. In case of ecological function disturbance, peatlands have a huge potential to release CO₂ into the atmosphere. Peat swamp forests conversion into agricultural land is one source of CO₂ emissions (Hooijer *et al.*, 2006). According to Kawahigashi and Sumida (2006), fertilizer applied in high dose will accelerate decomposition.

Emitted gases contributing to the greenhouse effect include carbon dioxide (48%), freon (26%), ozone (10%), methane (8%), nitrous oxide (6%), and other gases (2%) (Pirkko, 1990). Meanwhile, according to the IPCC report (2001), carbon dioxide, methane and nitrous oxide contributed very significantly to the global warming by 60%, 20% and 6%, respectively.

The results of a study by Jauhiainen *et al.* (2008) demonstrated that CO₂ emissions from drained peatland forests or secondary forests amount to approximately 0.84 g CO₂/m²/hour. The results differ only slightly from those of Melling (2005) indicating that secondary forest in Sarawak emitted 0.89 g CO₂/m²/hour. Carbon dioxide emitted by undrained peat swamp ranges from 0.40 to 0.50 g CO₂/m²/hour (Inubushi *et al.*, 2003; Jauhiainen *et al.*, 2005).

Recovered forest after deforestation emits 0.30 - 0.32 g CO₂/m²/hour, higher than the CO₂ emitted by abandoned agricultural land that amount to 0.22 g CO₂/m²/hour (Jauhiainen *et al.*, 2004), yet even lower than the emissions by oil palm land and sago land at 0.65 g CO₂/m²/hour and 0.46 g CO₂/m²/hour, respectively (Melling, 2005). Hatano *et al.* (2004) showed that the CO₂ emitted by Kalamangan vegetable farms ranged

from 0.23 to 1.02 g CO₂/m²/hour. Highest CO₂ emission was released by *Acacia* plantations in Riau at 1.07 g CO₂/m²/hour with groundwater table depth of 0.80 m (Jauhiainen and Hooijer, 2012).

Carbon dioxide emission from the soil is the result of respiration process, which means a process of decomposition of organic molecules into energy, water and CO₂ in cells. The emitted carbon dioxide can be derived from the results of the root respiration, microbial respiration in the rhizosphere, respiration and decomposition of litters and organisms, or respiration of soil organic matter oxidation (Luo and Zhou, 2006; Moyano *et al.*, 2010).

Environmental factors such as the depth of groundwater table, temperature, humidity and pH greatly influence the magnitude CO₂ emitted by peatlands (Jauhiainen *et al.*, 2001; Hooijer *et al.*, 2006; Strack, 2008; Agus *et al.*, 2010). Different types of peatland use have resulted in environmental changes such as groundwater table depth, soil and air temperatures. Differences in agricultural cultivation and treatment due to different types of land use have resulted in differences in the physical, chemical and biological properties of the soil. Environmental differences and differences in physical, chemical and biological properties of peatland are assumed to correlate with the amount of CO₂ emitted by peatlands.

Carbon emissions and sequestration in peatlands take place simultaneously, but the magnitude of both boils down to the ecological condition and human intervention. Thus, one strategy that can be done to reduce the amount of CO₂ emitted by the peatlands is by setting the proper water table depth, according to the depth of groundwater level optimal for plants. On the other hand, to offset the amount of CO₂ released by peatlands, selection of plant species potential to generate carbon is an equally important strategy.

Improper management of peatlands resulted in carbon loss from the peatlands due to increased release of carbon dioxide into the atmosphere. Thus, the study of carbon dioxide emissions from various types of peatland use is very important.

Ecological functions of tropical peatlands are to store carbon, to balance the carbon composition, to pin nutrient-trapping sediments, and to stabilize the microclimate. Peatland conversion to agriculture will disrupt the ecological functions of peatlands, which increased the release of CO₂ from the soil. The release of CO₂ is influenced by biotic and abiotic factors. In tropical peatlands, release of CO₂ is influenced by the depth of the groundwater table (Hirano *et al.*, 2007).

Decreased depth resulted in changes in the condition of the peat upper layer, from anaerobic conditions to aerobic conditions. In aerobic conditions, oxidation of carbon occurred to yield carbon dioxide released into the atmosphere (Lou and Zhou, 2006). Conversion of peat swamp forest is a source of CO₂ emissions (Hooijer *et al.*, 2006). Fertilizing with a high dose will accelerate decomposition (Kawahigashi and Sumida, 2006).

The carbon dioxide can be derived from the process of root respiration, rhizosphere respiration, respiration from litter decomposition or soil organic matter oxidation (Luo and Zhou., 2006; Moyano *et al.*, 2010). Factors that affect the amount of respiration are substrate availability, temperature, soil moisture, availability of oxygen, nitrogen, soil pH and the interaction between these factors (Luo and Zhou, 2006; Reddy and Delaune, 2008).

Different types of peatlands use lead to environmental changes such as groundwater table depth, soil and air temperatures. Differences in agricultural cultivation and in treatment due to different types of land use resulted in differences in the physical, chemical and biological properties of peat. Differences in ecology and in the physical, chemical and biological properties of peat are assumed to correlate with differences in the amount of CO₂ emitted.

Carbon emissions and sequestration in peatland take place simultaneously, but the amount of each depends on the ecological condition and human intervention. In the natural forest conditions that are generally water saturated, carbon sequestration last shorter than the decomposition, resulting in the growth of peat. In contrast, on the land managed for agricultural purposes, carbon decomposition occurs faster than carbon sequestration, resulting in peat subsidence.

To preserve the peat means to keep the balance between CO₂ emissions from peatlands and carbon sequestration by plants. One strategy to maintain the balance is by controlling the depth

of the groundwater table because it is a factor that most significantly affects the amount of CO₂ emissions. On the other hand, the plants cultivated on peatlands should have a high potential for carbon emission, and it is necessary to make sure that the sequestered carbons are not entirely transported out of the soil. In reality, the biomass in most horticultural crops cultivated on peatlands transported out and thus it left only in a small fraction in the soil.

MATERIALS AND METHODS

The study was conducted in two provinces: Central Kalimantan and West Kalimantan, within two years of the study period from January to June 2006 and January to April 2007. In Central Kalimantan, the research was conducted in the Village of Kalampangan, Sabangau District, Palangka Raya City. In Kalampangan research, 4 types of peatlands use that serve as treatments constitute a combination of duration of managed land and crop species. The four types of land use are: (1) 5 years for chinesis cabbage, (2) 10 years for chinesis cabbage, (3) 5 years for sweet corns, and (4) 10 years for sweet corns. Each type of land use is represented by three farmers' fields.

The research in West Kalimantan covers 4 types of land use, each at a different location. The four types of land use are: (1) corn field in Rasau Jaya, (2) *Aloe vera* field in Siantan Hulu, (3) oil palm plantation in Sungai Ambawang and (4) rubber plantation in Sungai Ambawang. The corn field, *Aloe vera* field and rubber plantation each represented by 3 farmers' land, while the oil palm plantation is represented by 3 blocks of field.

Aspects observed include CO₂ emissions, soil, and biomass production. The method used to measure CO₂ emission from peatlands by using infrared gas analysis (model EGM-4, PP systems, Hitchin, UK). Along with the measurement of CO₂ emissions, the depth of groundwater table, air temperature and soil temperature at depths of 10, 20, 30 and 40 cm were also measured.

The soil measurement aspects include analysis of bulk density, organic matter content, C-organic content, total bacteria, pH (H₂O), the content of N, P, K, Ca, Mg, Cu and Zn-total. Peat sampling was conducted using a special drill, *Edjerkamp*. Peat examples of all types of land use in each replication were taken from three depths: 0-15cm, 15-45cm and 45-100 cm.

Plant biomass production only occurs on chinese cabbage field and sweet corn field in Central Kalimantan. Chinese cabbage plants biomass include the roots, stems and leaves, while the corn plants biomass include roots, stems, leaves and corn skins.

RESULTS AND DISCUSSION

Characteristics of Peat

Bulk density of peat in 4 types of land use in Central Kalimantan ranged from 0.13 to 0.15 g/cm³, similar to that in 4 types of peatland use in West Kalimantan that ranged from 0.13 to 0.16 g/cm³. Based on the degree of decomposition, both peat derived from Central Kalimantan and West Kalimantan belongs in suborde Hemist.

Different types of land use resulted in differences in the pH of peat and this happens at all levels of peat depth. Such differences also lead to differences in the pH of peat and in all types of land use. This difference occurs in both the peat from Central Kalimantan and from West Kalimantan.

On the research in Central Kalimantan, the peat samples were from the depths of 0-15 cm, 15-45 cm and 45-100 cm with pH (H₂O) values ranged from 3.30 to 3.50, 3.23 to 3.37 and 3.00 to 3.20, respectively. As for the research in West Kalimantan, peat samples were taken from the depths of 0-15 cm, 15-45 cm and 45-100 cm with pH (H₂O) values ranged from 3.23 to 3.83, 3.20 to 3.87 and 2.87 to 3.57, respectively. Both in Central Kalimantan and West Kalimantan, pH (H₂O) values decreased with the peat depth.

In the four types of peatlands use in Central Kalimantan macro nutrients like N, P, K, Ca and Mg-total were found in different amount, except for N-total at a depth of 45-100 cm and P-total at a depth of 0-15 cm. This was also the case for peatlands in West Kalimantan, where in four types of peatlands use nutrients N, P, K, Ca and Mg-total were found in different amount, except for N-total at a depth of 45-100 cm. In general, the content of N, P, K, Ca and Mg-total decreased with depth of the peat.

The peat originating from Central Kalimantan contains nutrients of Cutotal on the four types of land use that were not significantly different, except at a depth of 15-45 cm. Similarly, the nutrient content of Zn-total shows no significant differences in the four types of peatland use, except at a depth of 0-15 cm. The peat derived from West Kalimantan contains

nutrients of Cu and Zn-total that were significantly different among the types of peatland use, especially at a depth of 0-15 cm and 15-45 cm, but not significantly different at a depth of 45-100 cm.

On all types of peatland use in Central Kalimantan, the peat depth factor causes differences in the content of Cu-total. The Content of Zn-total indicates also the difference between the levels of peat depth on all types of land use, except for the chinese cabbage (for 5 years). In West Kalimantan, peat depth factor affects the total content of Cu-total of *Aloe vera* field and oil palm plantation. In addition, peat depth was also affect the the Zn-total content on *Aloe vera* field, rubber plantation and corn fields.

Both research in Central Kalimantan and West Kalimantan, on all levels of peat depth, indicate that the C-organic content was not significantly different among the types of land use. Based on the factors of peat depth in research conducted in Central Kalimantan, C-organic content was significantly different between the depths of peat and this occurs in all types of land use. The content of C-organic at a depth of 0-15 cm was lower than the C-organic content at a depth of 15-45 cm and 45-100 cm.

The peat from West Kalimantan contains C-organic that was also significantly different between the depths of peat and this occurs in all types of land use except for oil palm plantation. The content of C-organic at a depth of 0-15 cm lower than the organic C content at a depth of 15-45 cm and 45-100 cm.

More intensive management on top layer of peat and followed by the application of fertilizers and ameliorant materials are expected to result in decomposition of the peat layer more quickly than the lower layers of peat, so that the organic C content in the upper layers is lower.

The number of bacteria was significantly different among the types of land use, and these differences were found both in Central Kalimantan and West Kalimantan. In Central Kalimantan, it seems that the duration of land management affects the number of bacteria. Land managed for 10 years contain the number of bacteria that ranged from 5.42 to 6.20 (Cfu/g x10⁵), higher than the number of bacteria on land that is managed for 5 years, which ranged from 2.36 to 3.46 (Cfu/g x 10⁵). In West Kalimantan, the highest number amounts to 4.50 bacteria (Cfu / g x 10⁵), which occurs on *Aloe vera* fields.

Carbon Dioxide Emissions and environmental factors

The measurement of CO₂ emission from the four types of peatland use in Central Kalimantan showed that the highest CO₂ emission was from sweet corn field (for 10 years) at 0.79 g CO₂/m²/hour, followed by chinese cabbage field (for 5 years) at 0.73 g CO₂/m²/hour. Chinese cabbage field (for 10 years) at 0.67 g CO₂/m²/hour and sweet corn field (5 years) at 0.41 g CO₂/m²/hour, each on the condition of the groundwater table depth of 46.11 cm, 39.06 cm, 42.94 cm and 24.10 cm, respectively.

In general, the four types of land use in Central Kalimantan release of CO₂ emissions in relatively equal amounts. This might be due to the fact that the four types of land were located in one area, so that environmental factors such as the depth of groundwater table, temperature and degree of decomposition are relatively similar. Also, both chinese cabbage and sweet corn plants share the same root system, that is, the short fibrous roots. With almost similar environmental conditions and similar root systems, the released amounts of CO₂ are differing only slightly.

The amounts of CO₂ emitted by the four types of land use in Central Kalimantan were not too much differ from those of Hatano *et al.* (2004), which suggests that Kalamangan peatlands with groundwater depth ranges from 61-77 cm, emit the CO₂ at 0.23 to 1.02 g CO₂/m²/hour. However, it is much higher when compared to the results of the study by Jauhiainen *et al.* (2004) indicating that abandoned agricultural land releases of 0.22 g CO₂/m²/hour emissions.

The high CO₂ emissions by chinese cabbage field and sweet corn field might be due to the relatively fertile peatlands with applied fertilizer, ameliorant and crop residues, when compared to open and abandoned land. Sri Nuryani *et al.* (2009) indicated that some of abandoned peatlands in Berengbengel underwent changes from hydrophilic to hydrophobic in nature. Hydrophilic peat emits CO₂ in higher amount than that of the hydrophobic peat.

Results obtained from CO₂ emission measurement in the 4 types of land use in West Kalimantan showed that the highest emissions are from the rubber plantation at 1.22 g CO₂/m²/hour, followed by oil palm plantation at 0.96 g CO₂/m²/hour, *Aloe vera* field at 0.68 g CO₂/m²/hour and corn field at 0.35 g CO₂/m²/hour, with the condition of the groundwater table depths of 77.92

cm, 64.11 cm, 53.74 cm and 21.84 cm, respectively.

Differences in plant species in each type of land use or different growing environments result in differences in physiology, especially in the root system. Rubber, oil palm, *Aloe vera* and corn plants have different morphology and root system. In terms of morphology, rubber and oil palm trees have leaves in large numbers and wide canopy of leaves, thus affecting the micro-environmental conditions, especially temperature around the plants and soil temperature. In terms of rooting, rubber and oil palm trees have thicker and longer root, so that the radius of root distribution was also increasingly farther compared to that of *Aloe vera* and corn plants.

In West Kalimantan, the CO₂ emissions from rubber plantation amount to 1.22 g CO₂/m²/hour on the water table depth of 77.9 cm, higher than the CO₂ emissions from oil palm plantation at 0.96 g CO₂/m²/hour on water table depth of 64.1 cm. These results contradict the predictions by Agus and Subiksa (2008) who noted that the CO₂ emissions from rubber plantation was only about 0.42 g CO₂/m²/hour assuming that the water table depth is about 20 cm and is lower than CO₂ emissions from oil palm plantation. Oil palm plantation emits CO₂ at 0.96 g CO₂/m²/hour, higher than the results of Melling (2005) on oil palm plantation in Sarawak emitting 0.69 g CO₂/m²/hour.

Depth of groundwater level shows a consistent effect on CO₂ emissions. The lower the depth of the groundwater table, the higher the amount of CO₂ emission. CO₂ emission rate shows a linear relationship with the groundwater table depth (Jauhiainen *et al.*, 2005; Hooijer *et al.*, 2006; Agus *et al.*, 2010; Jauhiainen and Hooijer., 2012). On tropical peat, water table depth plays more significant role compared to the temperature in controlling CO₂ emissions. It is also supported by Hirano *et al.* (2009), noting that the hydrology is one of the abiotic factors that are important in controlling the balance of carbon in tropical peat due to smaller variations in soil temperature and the air temperature in the tropics compared to that of subtropical peat.

The groundwater table depth in Central Kalimantan ranges from 24.1 to 46.1 cm, and the water table depth in West Kalimantan ranges from 21.8 to 77.9 cm. Groundwater depth ranges, both in Central Kalimantan and West Kalimantan, are still within the normal range. According Hooijer *et al.* (2006), the optimal groundwater table depth

for peatlands cultivated with annual plants is about 33 cm and the groundwater table depth for plantations is about 95 cm. And according to Morrison *et al.* (2012), the optimal groundwater table depth for plantation crops ranges from 60 to 80 cm.

CO₂ emissions from rubber plantation and palm oil field are higher than those of corn and *Aloe vera* fields. The high CO₂ emissions from the rubber plantation and oil palm fields might be attributed, largely, to the roots and rhizosphere respirations. Such expectation is associated with the correlation between air and soil temperature and CO₂ emissions. Air and soil temperature decreased, while CO₂ emissions increased. This applies also to the correlation between the content of organic matter and CO₂ emissions, where the higher the organic matter content, the higher the CO₂ emitted. It is most likely that CO₂ emissions from rubber and oil palm plantations were not entirely derived from oxidation of soil organic matter and litter decomposition. According to Hirano *et al.* (2009), CO₂ emission from root respiration is inseparable from the emissions caused by decomposition. Root respiration magnitude range varies widely from 10 to 90% of total soil respiration. However, on average, they amount to almost 50% of total soil respiration (Hanson *et al.*, 2000 in Luo and Zhou, 2006). According to Moyano *et al.* (2010), emission of CO₂ from root respiration may be greater in number than that of decomposition of soil organic matter.

Carbon sequestration by plants

CO₂ emissions and carbon sequestration in peatland take place simultaneously, but the amount of each depends on the ecological condition and human intervention. The effect of plant species on the ability of plants to sequester carbon can be seen from the very large difference between sweet corn and chinese cabbage plants, where the former may generate C at 9.02 to 14.30 t of C/ha/year, comprising of stems (46.00%), leaves (24.65%), corn skins (16.85%) and roots (12.5%). Chinese cabbage plant can only generate C at 1.48 to 1.80 t of C/ha/year, consisting of leaves (82.98%), trunks (9.75%) and roots (7.27%).

During the plant growth carbon sequestration will occur, the amount of which determined by the amount of biomass. Both in chinese cabbage and sweet corns, their roots contribute insignificantly to the amount of biomass. Page *et al.* (2004) noted that, while the roots contribute insignificantly to the total

biomass, they play critical role in accumulating peats because of very slow decomposition of roots. Plant leaves have a high enough contribution to biomass production, but due to the fast decomposition of leaf tissue, it available only in a small amount in peat accumulation (Verwer *et al.*, 2008).

Chinese cabbage plants have a huge gap between the amount of CO₂ emissions, i.e, an average of 16.69 t of C/ha/year and the ability of the plants to tie C, which is an average of 1.64 t of C/ha/year. The average emission from corn fields is 14.29 t of C/ha/year, and the ability to tie up carbon is 11.66 t of C/ha/year. The results of this study are far greater than those of Agus and Subiksa (2008) which reported that the average amount of carbon stored in the biomass of corn plants ranged from 1 to 3 t of C/ha/year. The ability of corn plants to generate C was lower than the C loss from peatlands. However, corn plants have a great potential to generate C and to maintain a balance between the C loss and the generated C as compared to chinese cabbage.

Both oil palm and rubber plantation indicate a large gap between CO₂ emissions from each land and the ability of plants to sequester C. CO₂ emission from oil palm field is at 23.05 t C/ha/year, while the ability of oil palm sequester carbon is only at 2.44 ton C/ha/year (Rogi, 2002; Agus and Subiksa, 2008). In rubber plantation, CO₂ emissions amount to 29.15 t C/ha/year, while its ability to sequester C is only at 2.56 t C/ha/year (Agus and Subiksa, 2008). Both rubber and oil palm plantation generate lower C than *Acacia* plantations which is able to generate C at 6.38 t C/ha/year, and is higher than the C generated by peat swamp forest, which is at 5.52 t C/ha/year (Djajakirana *et al.*, 2012).

CONCLUSION

1. Carbon dioxide (CO₂) emissions

CO₂ emissions obtained in this study are not merely generated by peat decomposition process, but also contributed by plant root respiration. Land use type, both the cultivated commodities and the cultivating duration, found to emit CO₂ with varied values, despite the fact that in 2006, in Central Kalimantan, the four types of land use indicated no significant differences in terms of CO₂ emission.

Based on average CO₂ emissions measured in 2006 and 2007 in Central Kalimantan, the highest emissions are those from

sweet corn field (arable land for 10 years), followed by chinese cabbage field (for 5 years), chinese cabbage field (for 10 years) and sweet corn field (for 5 years) by 0,79, 0,73, 0,67 and 0,43 g CO₂/m²/hour, respectively. In the four types of land use, CO₂ emission levels decline over time, from 0,56 – 0,82 g CO₂/m²/hour (2006) to 0,29 – 0,77 g CO₂/m²/hour (2007).

In West Kalimantan, of the average CO₂ emissions measured in 2006 and 2007, the highest being those released by rubber plantation at 1,22 g CO₂/m²/hour, followed by oil palm plantation at 0,97 g CO₂/m²/hour, *aloe vera* field at 0,68 of CO₂/m²/hour, and corn field at 0,35 g CO₂/m²/hour. Meanwhile, CO₂ emissions from the three types of land use (corn, *aloe vera*, and palm trees) increase, i.e. corn field from 0,30 g CO₂/m²/hour (2006) to 0,39 g CO₂/m²/hour (2007), *aloe vera* field from 0,64 g CO₂/m²/hour (2006) to 0,72 g CO₂/m²/hour (2007), oil palm plantation from 0,78 g CO₂/m²/hour (2006) to 1,15 g CO₂/m²/hour (2007). The emission from rubber plantation declined insignificantly from 1,26 g CO₂/m²/hour (2006) to 1,18 g CO₂/m²/hour (2007).

2. Peat characteristics that affect CO₂ emissions

In Central Kalimantan, the physical, chemical and biological properties of peat that affect and significantly correlated with the amount of CO₂ emitted from the types of land use are the cation-exchange capacity (CEC), groundwater level, pH of H₂O, K-total. As for those in West Kalimantan, they are cation-exchange capacity (CEC), groundwater level, pH of H₂O, soil temperature, and organic C. The increased CO₂ emission might be caused by the decreasing groundwater level, soil temperature, and increased pH of H₂O, CEC, K-total, and organic C content.

Variations in pH (H₂O) for two-years period in types of land use and depth of sampling were 3,07 – 3,43 (Central Kalimantan) and 3,22 – 3,87 (West Kalimantan). The groundwater levels in Central Kalimantan and West Kalimantan are 18,10 - 55,25 cm and 19,34 – 87,25cm, respectively. CEC values are higher on topsoil layer (0-15cm) and decreasing in sample depth of 45-100cm, which indicate the growth of microorganism that enable them to rapidly decompose organic matter in water unsaturated layer of peat. Variations in CEC values in all types of land use and depth of peat sample in Central Kalimantan and West Kalimantan are 159,33 – 253,92 cmol(+)/kg and 145,65 – 271,43 cmol(+)/kg, respectively. The varied average

values of the three macro elements that affect only the CO₂ emission in Central Kalimantan are K-total 69,88 – 106,34 mg/100g, Ca-total 20,88 – 28,49 g/kg, and Mg-total. As for the soil temperature and organic C that only affect the CO₂ emission in West Kalimantan, the variation in their values are 27,83 – 30,56 oC and organic C of 56,49 – 57,91%.

3. Plant Carbon sequestration

Plant C sequestration is greatly determined by the species and duration of cultivation. Average values of sequestered C in four types of land use in Central Kalimantan are 1,48 t of C/ha/year for chinese cabbage (5 years), 1,80 t of C/ha/year for chinese cabbage (10 years), 9,02 t of C/ha/year for sweet corn (5 years), and 14,30 t C/ha/year for sweet corn (10 years). Meanwhile, the carbon sequestered by corn plants studied in West Kalimantan amounts, in average, to 11,66 t C/ha/year. The secondary data (of previous research) indicates that oil palm plantations generate 2,44 t of C/ha/year, rubber plantations generate 2,56 t of C/ha/year, while the data for *aloe vera* field was not available. From CO₂ emission level in each type of land use, in terms of differences between CO₂ emission and plant carbon sequestration in four types of land use in Central Kalimantan, chinese cabbage (of arable land for 5 years) has the largest deficit rate at -12,24 t of C/ha/year, followed by chinese cabbage (for 10 years) at -10,84 t of C/ha/year, sweet corn (for 10 years) at -0,58 t of C/ha/year. In the sweet corn field by additional at 1,32 t of C/ha/year and. While no deficit in corn commodity was found in West Kalimantan, which remains at 3,45 t of C/ha/year, the highest deficit was found in rubber commodity at -26,59 t of C/ha/year, followed by palm plantation at -20,61 t C/ha/year.

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