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Journal of Experimental Biology and Agricultural Sciences, February - 2023; Volume – 11(1) page 199 – 208

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Journal of Experimental Biology and Agricultural Sciences

http://www.jebas.org

ISSN No. 2320 – 8694

Estimation of Carbon pool in various agricultural crops in peatlands of West and Central Kalimantan, Indonesia

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Received – January 12, 2023; Revision – January 28, 2023; Accepted – February 26, 2023
Available Online – February 28, 2023

DOI: http://dx.doi.org/10.18006/2023.11(1).199.208

KEYWORDS

Carbon fixation

Land uses

Tropical peatlands

Indonesia

ABSTRACT

Tropical peat is an important natural ecosystem, and its natural state plays an important role in climate regulation. These peatlands globally provide vital environmental benefits, especially in case of their enormous carbon storage potential. Peat land also functions as a source of livelihood for the community, especially for agricultural activities, and this will lead to the potential loss of carbon stock in peatlands. This study examines plants' potential to create Carbon to offset carbon dioxide emissions and different land use types. The study focused on Central and West Kalimantan, Indonesia. Peat soil samples were collected from various types of land from 0-15, 15-45, and 45-100 cm depth and analyzed for physical and chemical parameters. The cylinder chamber method with infrared gas analysis model EGM-4 was used to measure CO_2 emissions. Plant carbon sequestration was measured in a 6.25 m^2 plot in the study sites of Central Kalimantan. The study showed that type of commodity and period of management affect the carbon content in peat with different land uses, and it is affected by soil bulk density, organic matter content, and CO_2 emission. In the case of study crops, oil palm, rubber, corn, and mustard emit the highest CO_2. Further, corn crop has the highest potential to fix carbon dioxide and produces more Carbon per hectare than the Carbon emitted from corn-planted under peatland conditions. The study indicated that the type of commodity and the time of its management affected the carbon content in peat with different land uses, and carbon content got the change with soil bulk density and soil organic matter content.

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Peer review under responsibility of Journal of Experimental Biology and Agricultural Sciences.

Production and Hosting by Horizon Publisher India [HPI] (http://www.horizonpublisherindia.in/).

1 Introduction

Worldwide, the peatlands reached up to 400 million ha; about 350 million ha of this is subtropical, and the rest is tropical (Strack et al. 2008; Page et al. 2011). In addition, according to Maltby and Proctor (1996), approximately 31–46 Mha of peatland (or 10–12% of the total peatlands) are found in tropical countries such as Southeast Asia, South America, Africa, Central America, the Caribbean region, Mainland Asia, Australia and Pacific regions (Rieley and Page 2016). According to Anda et al. (2021), peat area in Indonesia reaches 13.43 million ha, and it is mainly spread over Sumatra (5.5 million ha), Kalimantan (4.54 million ha), Papua (3.01 million ha), and several other areas. Further, in West Kalimantan, the recorded peat area was about 1.55 million ha, consisting of 1.02 million ha of less than 3 m depth and 0.53 million ha with a depth of > 3 m. While in Central Kalimantan, the peat area reaches 2.55 million ha, consisting of 1.86 million peat with a depth of < 3 m and 0.69 million ha of peat with a depth of > 3 m (Anda et al. 2021).

In total recorded Indonesian peatland, peat forest covers 12.31 million ha, including 2.34 million ha of conservation forest, 1.02 million ha of protection forest, and 8.95 million ha of production forest (Wahyunto et al. 2010). Peat land available for the plantations is 1.42 million ha, for agriculture 1.23 million ha, and 4.66 million hectares for other uses (Bappenas 2010). About 3.74 million acres (25.1%) of Indonesia's peatland have been degraded or overrun with plants (Wahyunto and Dariah 2014).

Tropical peats are vital in biodiversity, climate regulation, and human health (Joosten 2015; Wildayana 2017). In their natural state, peatlands provide globally important environmental services, primarily related to climate change due to their enormous Carbon (C) storage capacity (Page et al. 2011). This peatland also regulates water flow (water storage, filtration, and water resources), protect against natural stresses (prevention of erosion and flooding), provides macro-climate stability, helps in recreation and education, and is also a source of natural resources and biodiverse. Other ecological functions of peatland are sediment retention, nutrient detention, and microclimate stability (Maltby 1997; Rieley et al. 2008). In Central Kalimantan, peatlands are used to plant horticultural and food crops.

Further, Kalampangan Village of Central Kalimantan is a center for peat-grown vegetables. Sjarkowi (2005) found that sweet corn, green mustard, tomatoes, and long beans were the most suitable plants among Kalampangan farmers. The peatlands of West Kalimantan is ideal for producing food crops, horticulture crops, rubber, and oil palm. The Slamet River area in Siantan Hilir is a production center for horticultural crops, while the Siantan Hulu area is a production center for aloe vera plants. Plantation crops such as rubber and oil palm are the major crops of the Ambawang river area of Mempawah.

The construction of drainage facilities to reduce the depth of the groundwater table is an essential requirement in the utilization of peat land into agricultural land. The decrease in the depth of the groundwater table also results in changes in the upper peat conditions from anaerobic to aerobic conditions. Under aerobic circumstances, oxidation of Carbon occurs, which produces CO_2 and releases it into the atmosphere. This release of Carbon dioxide from the soil is also the result of the respiration process, namely the decomposing of organic molecules into energy, water, and CO_2 in cells. Further, this CO_2 release process results from root respiration, microbial respiration in the rhizosphere, respiration from the decomposition of litter and organisms, and soil organic matter oxidation (Luo and Zhou 2010; Moyano et al. 2009). Environmental factors such as the depth of the groundwater table, temperature, humidity, and pH of peat soil significantly influence the amount of CO_2 emissions released from peatland (Jauhiainen et al. 2001; Hooijer et al. 2006; Strack et al. 2008; Agus et al. 2010). If Carbon is released through carbon dioxide emissions in large quantities and lasts for a long time, then this, in addition to threatening the existence of the peat function as a carbon repository, is also a source of greenhouse gases whose contribution reaches 48% (Pirkko and Nyronen 1990).

Various agricultural production systems and uses of peatland also affect the groundwater level, soil's physical, chemical, and biological qualities, and air temperature, which can be affected the peatlands' CO_2 emissions. Information related to the CO_2 emissions from peatland comes from the forests, open land (Jauhiainen et al. 2005), and agricultural land (Hatano et al. 2004) of the Kalimantan region, while the information regarding the CO_2 emissions from peatlands utilized for oil palm, rubber, biennial aloe vera, and seasonal corn and mustard greens production in the central Kalimantan and west Kalimantan have not been estimated in any previous study.

Various biological and abiotic factors also affect the CO_2 emissions from peatlands. Among the various studied abiotic factors, the depth of the groundwater table is one of the most influential abiotic factors that remarkably affect CO_2 emissions. Decreased groundwater table depth also correlates with increased peatland CO_2 emissions (Hooijer et al. 2006; Fahmuddin and Subiksa 2008; Jauhiainen et al. 2012). Each type of plant requires a specific depth of groundwater table for its normal growth and development (Fahmuddin and Subiksa 2008; Morrison and Page 2012). Therefore, different types of plants in the same peatland have differences in CO_2 emissions, and it is related to their need for groundwater depth.

Peatlands emit and store Carbon simultaneously, but the final amounts of carbon emission depend on various natural conditions and human intervention. Changing the depth of the groundwater table to the optimal depth of plants can minimize the emissions of

CO_2 from peatlands. Selecting plant species that can produce Carbon to offset peatland CO_2 emissions is also crucial. Selecting plants that can create Carbon will preserve a balance between CO_2 emissions and carbon sequestration. In peatland areas, the carbon-producing potential of some plants is still unknown. Therefore, this study aimed to evaluate the plants' potential to create Carbon to offset CO_2 emissions. Further, this study also intends to assess the effect of various types of peat land uses on the amount of CO_2 emissions and sequencing Carbon to replace Carbon lost through CO_2 emissions.

2 Materials and Method

2.1 Study area and Design

The current study was carried out in the peatland area of Central Kalimantan and West Kalimantan, Indonesia. The research was conducted in the Central Kalimantan region in the Kalampangan Village, Sebangau District, located 20 km southeast of Palangka Raya Municipality (Figure 1a). Since 1980, Kalampangan Village has been a transmigration center for horticulture crops. Land use in Kalampangan village is determined by the duration (period) of managed agricultural land and plant type. The land management of Kalampangan village is separated into two categories, i.e., freshly managed land (land maintained for five years or less) and long-managed land (land managed for ten years). Green mustard (*Brassica campestris*) and sweet corn (*Zea mays*) are the major crops frequently grown in both land groups. As per the crop duration, study area land uses are divided into four categories, i.e., mustard greens cultivation in 5-year-managed land, mustard greens in 10-year-managed land, sweet corn in 5-year-managed land, and sweet corn in 10-year-managed land.

In West Kalimantan, various annual, perennial, and plantation crops have been selected for this study. Corn (*Zea mays*) was chosen to symbolize annual crops, while oil palm (*Elaeis guineensis*) and rubber (*Hevea brasiliensis*) represented perennial crops. Major corn farms are in Rasau Jaya, aloe vera fields in Siantan Hulu, and oil palm and rubber fields in the Ambawang river area (Figure 1b). The four types of crops which determined the land use in the study area are corn, aloe vera, oil palm, and rubber.

2.2 Peat-sampling

Undisturbed peat samples were obtained from 30 to 40 cm depths. The undisturbed peat samples were collected using a metal ring of 5 cm in height and diameter. In contrast, the customized Eijkelkamp peat drill was used for the collection of disturbed samples collections. Peat samples from all land use types were obtained from 0-15, 15-45, and 45-100 cm depth in each replication. In the case of mustard greens and corn crops, peat sampling was carried out between the plants, while in the case of aloe vera cultivation, peat sampling was carried out between plant spacing in rows. The peat sampling was carried out 1.5 m from the plant trunk in oil palm and rubber cultivating the land. Peat samples for total bacterial analysis were taken from a 10-20 cm depth.

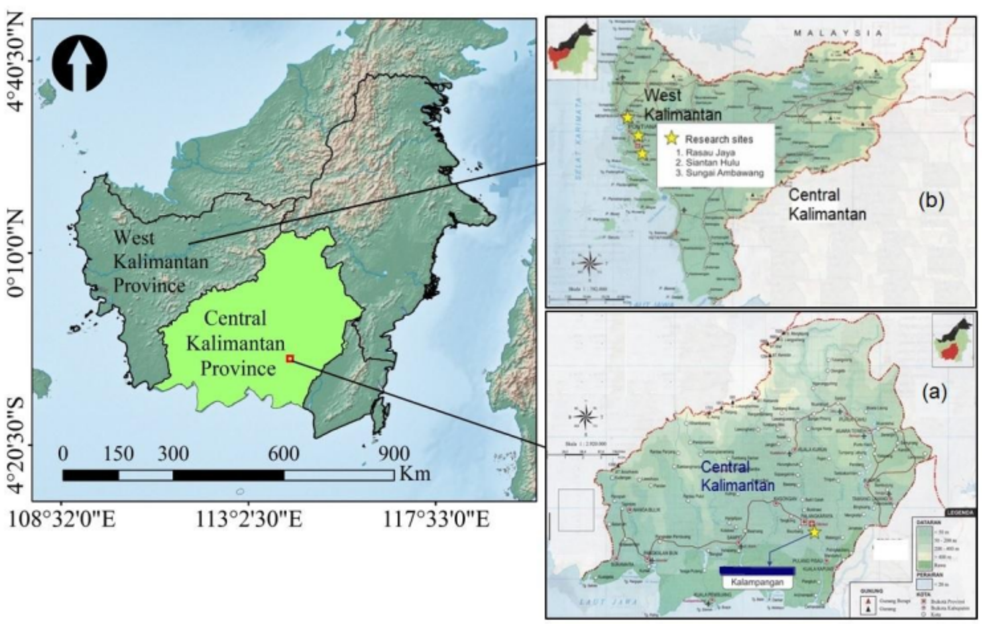

Figure 1 geographical location of the study areas

2.3 Plant-sequestered carbon

Carbon sequestration by plants is limited by the Carbon produced by the plants and does not consider the Carbon that comes from land cover. Observation of plant carbon fixation and biomass production was computed for each farmer in 5 plots of 2.5 m × 2.5 m or 6.25 m2 representing each land use type.

For mustard and corn biomass estimation, the complete plant was uprooted, kept in a paper bag, and incubated in a hot air oven at 60°C for 48 hours, or until its weight stabilized. Dry biomass can estimate organic matter, and organic Carbon is extracted from the total organic matter.

2.4 Estimation of CO_2 Emission

The infrared gas analysis method measured peatland CO_2 emissions (model EGM-4, P.P. system, Hitchin, U.K.). The CO_2 analyzer recorded the CO_2 emissions from the ground from the first second to the 81st second at three sites per replication (Jauhiainen et al. 2001). The CO_2 estimation chamber is set 50 cm away from the rows of mustard greens plants to measure CO_2 emissions. While the distance between the chamber sites and the mustard plant stem is around 10 cm. In corn fields, the chamber is set between rows of corn 60 cm apart, and the distance of the chamber is 15 cm from the corn stem. In such close planting rows, it is impossible to avoid the chamber wall being beyond the root radius, even though the roots of plants grown in peat do not extend too far from the planting hole. In *Aloe vera* fields, the planting distance is 80 cm x 100 cm, and the chamber is positioned between planting rows, so it is believed that the chamber is still inside the root radius. In oil palm and rubber fields, the chamber is placed at a distance of 1.5 m from the stem of the plant, and it is estimated that the chamber is within the radius of root spread because the oil palm and rubber fields used in this study are ten years old, so the roots of the rubber plant have spread far from plant stems.

CO_2 emissions recorded at 81 seconds are CO_2 emissions released by peatlands with units of g $CO_2/m^2/hr$. Measured CO_2 emission data are validated by looking magnitude of r^2 from the regression between time and CO_2 concentration in the atmosphere. The data is considered valid if the value of r^2 is at least 0.98. Along with the CO_2 emissions measurement, the groundwater table depth, air temperature, and soil temperature were also recorded at 10, 20, 30, and 40 cm depth. Conversion CO_2 emissions from units of g $CO_2/m^2/hr$ from measurement to units of ton $CO_2/m^2/y$, as follow:

$$CO_2 \text{ emission (ton } CO_2/m^2/y) = g\ CO_2/m^2/hr \times 24\ hr \times 365\ days$$

The conversion results only provide a rough idea, likely higher than the actual annual emission value. This is because the measurement of CO_2 emissions is only carried out for a short duration, so it cannot represent the rainy and dry seasons, which are closely related to the depth of the groundwater table. In addition, in the current study, the measurements were only carried out during the day, when the temperature was higher than at night.

2.5 Analysis of Peat Properties in the Laboratory

Peat soil analysis was conducted at the Soil Science Laboratory, Faculty of Agriculture, Gadjah Mada University, Indonesia. The analytical method depends on the parameters analyzed, and standard methods were used for peat analysis (Table 1).

Table 1 Peat soil analysis method

Parameter	Method
Water content (% weight)	Collected soil dried in an oven at 80°C for 24 hr*
Bulk density (gr/cm^3)	Ring Sample**
Carbon	Based on bulk density, percentage of organic matter content, and percentage of C-organic; Accounted for 58% of the total plant organic matter
Percentage of peat organic matter	Air-dried peat was dried in a kiln at 80°C for 24 hr, then burned in a 600°C muffle furnace for 4 hr. The percentage of organic matter is calculated from the percentage of ash content.
Percentage of C-organic	Calculated 58% of peat organic matter percentage
Total plant organic matter	Calculated 98% of dry plant weight
C-organic plant	Calculated 58% of total plant organic matter

*Water content was determined by drying, and peat was placed in an oven at 80°C for 24 hours. The calculation results are expressed in percent (%), namely as follows:

$$WC = ((WC\ wet\ soil - WC\ oven\ dry\ soil) / WC\ oven\ dry\ soil) \times 100\% \qquad (WC=water\ content)$$

**peat bulk density was measured by calculating the volume of soil contained in the metal ring under wet and dry conditions, namely after being heated in a heating oven at 105°C for 24 hours. Peat volume values are determined in dry unit weight and are expressed in units of weight per volume of peat (g/cm3).

Table 2 Average content of organic matter and organic Carbon (C-organic) in peat soil of various land use

Land use type	Content of organic matter	C-organic of Peat Soil	
	(%)	(%)	(ton C/ha/m)
Central Kalimantan			
Mustard green, land 5 yrs	98.68	57.23	782.19
Mustard green, land 10 yrs	98.01	56.85	876.38
Corn, land 5 yrs	98.65	57.22	810.06
Corn, land 10 yrs	98.19	56.95	817.82
West Kalimantan			
Corn	98.51	57.13	802.13
Aloe vera	98.06	56.87	929.89
Palm oil	98.80	57.30	820.85
Rubber	99.09	57.47	748.82

2.6 Data analysis

To find out the differences in the characteristics of peat based on the type of land use, depth of the peat, and the differences in the amount of CO_2 emissions released, the data were analyzed using variance fingerprints and then Duncan's test. Meanwhile, to compare the amount of CO_2 emissions by various types of land use during the study period of the first year with the second year, the data were analyzed using the t-test.

3 Results

3.1 Carbon Content

The content of organic matter and organic Carbon (C-organic) in peat soil from various types of peat land use in Central Kalimantan and West Kalimantan is presented in Table 2.

Table 2 shows that the average organic matter in Central Kalimantan peat soil was 98.01–98.65%, while it was reported to be 98.06–99.09% in West Kalimantan. According to Andriesse (1988), the high proportion of organic matter indicates the differences in bulk density of peat between the types of land use. It depends on the nature or condition of the peat material, including its maturity, compression, and peat soil water content. Based on bulk density, the percentage of organic matter content and the percentage of C-organic content was calculated and recorded 782.19 to 876.19-ton C/ha/m C-organic content in the peat soil samples collected from the Central Kalimantan, while a minor variation was reported in the peat soil samples collected from the West Kalimantan, where it was recorded 748.82 to 929.89-ton C/ha/m (Table 2).

3.2 CO_2 Emissions

The land use type also affects the rate of CO_2 emissions. Based on the analysis of variance in CO_2 emissions by four types of peat land uses in Central Kalimantan, the study's results revealed a significant difference in the second year of study, and a reduction was reported in the rate of CO_2 emission. The results of the average value of CO_2 emissions by the different types of land use in Central and West Kalimantan are presented in Table 3.

Based on the average CO_2 emissions in the first year, the highest CO_2 emissions value of 0.81g $CO_2/m^2/hr$ was recorded from the sweet corn (10 years of land use) in Central Kalimantan. The lowest emission of 0.56g $CO_2/m^2/hr$ was recorded from sweet corn (5 years of land use) in the same region. Further, a significant difference was reported in the ten years of land use for mustard greens and corn than in the five years of land use of sweet corn CO_2 emissions value (Table 3). In the case of the second year CO_2 emission rate, a sharp decline was recorded in all four land uses and two crop types. In mustard greens (10 years of land), the average CO_2 emissions value was recorded 0.82g $CO_2/m^2/hr$ in the first year, while it dropped to 0.52 $CO_2/m^2/hr$ in the second year. Similarly, 0.56g $CO_2/m^2/hr$ in the first year for the sweet corn (5 years land) was reported, and it fell to 0.29g $CO_2/m^2/hr$ in the second year.

The analysis of variance shows that CO_2 emissions from all four forms of peatland use in West Kalimantan differ significantly in both years of investigation. The average value of CO_2 emissions showed that rubber plantations showed 1.26g $CO_2/m^2/hr$ CO_2 emissions in the first year of the study, significantly higher than oil palm, aloe vera, and corn fields. Like the first year, in the second

Table 3 Average CO_2 Emissions in four land types of Central and West Kalimantan Peatland

Land use Types	CO_2 Emission (g $CO_2/m^2/hr$)		
	Y1	Y2	Average
Central Kalimantan			
Mustard green, land 5 yrs	0.74 ± 0.11^{b}	0.72 ± 0.11^{b}	0.73 ± 0.07
Mustard green, land 10 yrs	0.82 ± 0.05^{b}	0.52 ± 0.08^{c}	0.67 ± 0.08
Corn, land 5 yrs	0.56 ± 0.03^{c}	0.29 ± 0.06^{d}	0.43 ± 0.07
Corn, land 10 yrs	0.81 ± 0.04^{b}	0.77 ± 0.04^{b}	0.79 ± 0.03
West Kalimantan			
Corn	0.30 ± 0.03^{d}	0.39 ± 0.01^{d}	0.35 ± 0.02
Aloe vera	0.64 ± 0.09^{bc}	0.72 ± 0.04^{b}	0.68 ± 0.05
Palm oil	0.78 ± 0.08^{b}	1.15 ± 0.18^{a}	0.97 ± 0.12
Rubber	1.26 ± 0.16^{a}	1.18 ± 0.04^{a}	1.22 ± 0.07

The mean followed by the same letter in the same column is not significantly different based on Duncan's test (p =5%*) compared to Year 1 and Year 2 average emissions

Table 4 Total C emissions and emissions from the decomposition of conversion results in four types of peat land use in Central and West Kalimantan

Landuse types	C emission (ton C/ha/yrs)				
	Y 1		Y 2		Average emission from decomposition
	Total Emission	Emission from decomposition	Total Emission	Emission from decomposition	
Central Kalimantan					
Mustard green, land 5 yrs	17.68±2.64	13.97±2.09	17.06±2.61	13.48±2.06	13.72±1.66
Mustard green, land 10 yrs	19.59±1.33	15.48±1.05	12.42±0.76	9.81±0.60	12.64±0.44
Corn, land 5 yrs	12.66±1.04	10.00±0.82	6.83±1.38	5.40±1.09	7.70±0.14
Corn, land 10 yrs	19.35±1.09	15.29±0.86	18.32±0.90	14.47±0.71	14.88±0.30
West Kalimantan					
Corn	7.17±0.83	5.66±0.65	9.25±0.16	7.31±0.13	6.49±0.33
Aloe vera	15.29±2.22	12.08±1.75	17.20±0.90	13.59±0.71	12.83±0.71
Palm oil	18.63±1.95	14.72±1.54	27.47±4.47	21.70±3.53	18.21±2.09
Rubber	30.10±4.66	23.78±3.68	28.19±0.99	22.27±0.79	23.02±1.48

year also, rubber plantations had the highest CO_2 emission (1.18g $CO_2/m^2/hr$), which was immediately followed by the oil palm plantations (1.15g $CO_2/m^2/hr$). In contrast, the Aloe vera and corn fields had significantly lower CO_2 emissions than the rubber plantations (Table 3). In contrast to the Central Kalimantan, all tested crops except rubber have higher CO_2 emissions in the second year in the West Kalimantan, but in t-test, it is not statistically different. Results presented in Table 4 convert the total CO_2 emissions from g $CO_2/m^2/hr$ to ton C/ha/yr and conversion of emissions from decomposition. Mustard green and corn plants with more prolonged use produce more significant CO_2 emissions and emissions resulting from decomposition.

In Central Kalimantan, ten years of land use show the highest total emission and lowest decomposition for both crops in the first year of study. In the second year, all crops and land uses except for five-year uses of corn have similar emissions, and average decomposition was recorded. In West Kalimantan, the highest total emission and decomposition were recorded from the rubber plants, while the lowest was reported from the corn crops for both years.

3.3 Plant-sequestered carbon

Production of plant biomass shows the ability of plants to sequester Carbon stored in the form of biomass. Dry plant biomass and C-

Table 5 Dry biomass production and C-organic production obtained from four types of peatland use in Central Kalimantan

Land use types	Dry biomass production			C-organic production		
	(ton/ha/y)					
	Y1	Y2	Average	Y1	Y2	Average
Mustard green, land 5 yrs	2.72±0.09	2.48±0.10	2.60±0.08	1.55±0.05	1.41±0.06	1.48±0.05
Mustard green, land 10 yrs	3.34±0.06	2.98±0.05	3.16±0.09	1.90±0.04	1.69±0.03	1.80±0.05
Corn, land 5 yrs	16.72±0.17	15.03±0.03	15.87±0.39	9.50±0.10	8.54±0.02	9.02±0.22
Corn, land 10 yrs	26.35±0.03	23.95±0.12	25.15±0.54	14.98±0.02	13.61±0.07	14.30±0.31

Table 6 CO_2 emissions from decomposition, C fixing by plants, and the difference between C emissions and C fixing in four types of peat land use in Central and West Kalimantan

Land use types	CO_2 emissions from decomposition (ton C/ha/y)	C fixing by plants (ton C/ha/y)	Difference between C emission and C-fixing (ton C/ha/y)
Central Kalimantan			
Mustard green, land 5 yrs	13.72±1.66	1.48±0.04	-12.24±1.69
Mustard green, land 10 yrs	12.64±0.23	1.80±0.12	-10.84±0.32
Corn, land 5 yrs	7.70±0.14	9.02±0.04	1.32±0.17
Corn, land 10 yrs	14.88±0.30	14.30±0.04	-0.58±0.33
West Kalimantan			
Corn	6.49±0.23	11.66*	5.17
Aloe vera	12.83±0.71	Nd	nd
Palm oil	18.21±2.09	2.44**	-15.77
Rubber	23.02±1.48	2.56***	-20.46

Here nd = no data and references * Average C mooring in Central Kalimantan, **Reference value as per Rogi (2002), and *** Reference value as per Fahmuddin and Subiksa (2008)

organic production obtained from all four types of peat land use were only measured in Central Kalimantan during the first and second-year research periods and are presented in Table 5.

In dry biomass and C-organic production, the highest dry biomass production and C-organic production were recorded from the five and ten years of land uses for the corn crop for both years (Table 5). Table 5 shows that corn crop for ten years of land uses shows the highest dry biomass production and C-organic production, and it was recorded at 26.35±0.03 ton/ha/y and 14.98±0.02 ton/ha/y respectively, for the first year, while 23.95±0.12 ton/ha/y and 13.61±0.07 ton/ha/y, respectively for the second year. The land followed its uses for the five years for corn crops; other crops showed at par results and no significant difference. In corn, other part biomass was recorded at 46.34% for the stem, 24.74% for leaves, 16.74% for cornhusk, and 12.18% for root.

Table 6 shows the difference between C released by peatlands through CO_2 emissions and Carbon fixed by plants through photosynthesis and stored in plant biomass in four types of peat land use in Central Kalimantan by excluding organic C from land cover. Among the four types of land uses, the highest CO_2 emissions from decomposition (14.88±0.30 ton C/ha/y) and C fixation by plants (14.30±0.04 ton C/ha/y) were recorded from the ten years of the land uses corn crop, and the difference between these two was recorded -0.58±0.33 ton C/ha/y. In contrast to ten years of the land uses, five years of land uses for corn crops have shown the lowest value of CO_2 emissions from decomposition (7.70±0.14 ton C/ha/y) and C fixation by plants (9.02±0.04 ton C/ha/y), and the differences were recorded as 1.32±0.17 ton C/ha/y. In the case of Mustard green, no significant difference was recorded between both types of land use and study years (Table 6).

Using secondary data for C fixation by plants, the difference between the amount of C released by peat lands and the ability of plants to produce Carbon in four types of crops in West Kalimantan have been presented in Table 6. Based on research data and existing reference information on the C fixation, the difference between C emissions and C fixation of the four crops or land types in West Kalimantan was evaluated, and the highest CO_2 emission (23.02±1.48 ton C/ha/y) was recorded from the rubber plantation while lowest (6.49±0.23 ton C/ha/y) was reported from the corn plant. In contrast, the highest C fixation (11.66 ton C/ha/y) was recorded in the corn crop, while the lowest was in the palm oil plantation (Table 6).

4 Discussion

4.1 Carbon Content

The level of the carbon content depends on the duration of the land uses; in Central Kalimantan, there is a tendency for the more prolonged the land is used, the more C-organic content increases. In Central Kalimantan and West Kalimantan, the difference in C-organic contained in various types of peat land uses seems to be influenced by the kind of commodity and the time it has been managed. The results of this study agree with the findings of Devi et al. (2019), who found that the maturity level of peat soil is strongly related to the length of time the peatland has been used, and the degree of maturity of the peat is related to bulk density. Similar types of findings have been reported by Adji (2017). Further, the value of total C-organic estimated in this study for both Central Kalimantan peat and West Kalimantan peat was higher than the results reported by Page et al. (2002).

4.2 CO_2 Emissions

CO_2 emissions by mustard greens and corn fields in Central Kalimantan are lower than the results of Hatano et al. (2004), which claims that vegetable fields release CO_2 emissions in the range of 0.23 - 1.02g $CO_2/m^2/hr$, with a range of 0.61-0.75 m groundwater depth. This is more than the 0.22g $CO_2/m^2/hr$ released from unmanaged agricultural land (Jauhianien et al. 2004). The analysis of variance shows that CO_2 emissions from four forms of peatland use in West Kalimantan differ significantly in both years of investigation. The average value test showed that rubber plantations released 1.26g $CO_2/m^2/hr$ (110.38 ton CO_2/ha/yr) in the first year, and it was recorded as 1.18g $CO_2/m^2/hr$ (103.37 ton CO_2/ha/yr) in the second year. For rubber plantation, the results of this study show higher emissions than the research conducted by Jamaludin et al. (2020), which is 42.6 tons CO_2/ha/year, and Wakhid et al. (2017), which is 51.60 tons CO_2/ha/year. According to Kusin et al. (2015), using nitrogen fertilizers, especially in oil palm plants, may significantly contribute to greenhouse gas emissions and loss of carbon content. Therefore, applying nitrogen fertilizers is likely to increase C emissions from the conversion of rubber plantations to oil palm plantations. However, this seems slightly different at the study site, where emissions from rubber plantations are greater than from oil palm plantations.

The average CO_2 emissions from all land uses in the first year were not substantially different from the second year. In the second year also, the rubber plantations released the highest CO_2, followed by oil palm, aloe vera, and corn fields. These differences in the rate of CO_2 emissions might be due to the variations in water table depth, which was reported 24.33 and 19.33 cm for corn crops in the first and second year, respectively. In comparison, 87.25 cm and 68.59 cm were reported for rubber fields in the first and second years, respectively. These results agree with the findings of Evans et al. (2021), who stated that greenhouse gas emissions from peatlands drained for agriculture are strongly related to groundwater depth and that raising the groundwater table can be achieved without reducing productivity in land use. Halving the groundwater depth in drained agricultural peatlands could reduce emissions equivalent to more than 1 percent of global anthropogenic emissions. According to Luo and Zhou (2010), decreasing groundwater level will make the peat soil aerobic, increasing soil microorganism activity to decompose organic matter, producing CO_2 and harmful organic acids. Jauhiainen et al. (2001) also reported that CO_2 emissions from peatlands in West Kalimantan are strongly correlated with groundwater table depth.

In the current study, oil palm and rubber land produced more CO_2 emission for both years than Melling's (2005) study, which found that oil palms emitted 0.64g $CO_2/m^2/hr$, sago palms 0.49g $CO_2/m^2/hr$, and forests 0.92 g $CO_2/m^2/hr$. Similar results were also recorded by Fahmuddin and Subiksa (2008).

Accumulated emissions may be higher or lower than the annual emissions after conversion. It might be due to short-term emission measurements that do not reflect CO_2 emissions emitted during rainy or dry seasons and are directly tied to groundwater table depth. In addition, in this study, CO_2 emissions are measured only during the day, without considering temperature changes between day and night. Luo and Zhou (2010) state root respiration increases with temperature in response to temperature sensitivity. Root respiration increases exponentially with temperature, but biochemical reactions slow it because substrates like glucose, oxygen, and CO_2 cannot diffuse at high temperatures.

During the conversion of emissions from mustard greens, corn, and aloe vera, the period of no crop is ignored, so this is also one of the reasons for the significant error in the conversion. Likewise, emission measurements from oil palm and rubber fields that are ten years old have spreader root systems extensively. Hence, the measured CO_2 emissions are likely not only the result of peat decomposition but are also expected to originate from root respiration. With these limitations, presenting CO_2 emission data in units of g $CO_2/m^2/hr$ from instantaneous measurement results is considered the most appropriate because it is not conversion data.

4.3 Carbon-Fixation

Results related to the carbon fixation study showed significant variances in organic C produced by various crops; this variation is assumed to be driven by numerous factors, including population per unit (hectare), plant fertility, and corn species with varying traits or sizes of stems and leaves.

Using secondary data for C anchorage by plants, the difference between the amount of C released by peatlands and the ability of plants to produce Carbon in four types of peatland use in West Kalimantan is presented in Table 6. These results show that corn can provide a value of 5.17 tons of C/ha/yr, which means the level of emissions from corn fields can be overcome by metabolic processes in the plant, other than that corn plants do not require excessive drainage or merely require a depth of groundwater table not far from the soil surface.

According to Rogi (2002), oil palm can store more than 80 tons C/ha, but this amount is reached after 10-15 years of growth, so the average amount of Carbon held by oil palm plants is around 60.5 tons/ha equivalent to 2.44 ton C/ha/yr, assuming one oil palm production cycle of 25 years. The ability of rubber plants to sequester Carbon is not much different from oil palm plants. Fahmuddin and Subiksa (2008) found that rubber plants store 56.45 tons C/ha for 25 years or 2.26 tons C/ha/yr.

The ability of plants to produce biomass varies on the type of crop. Based on the metabolic mechanism, corn plants are C4 plants, and these plants can create higher biomass due to their high photosynthetic efficiency. Table 6 shows the difference between C released by peatlands through CO_2 emissions and C fixed by plants through photosynthesis and stored in plant biomass in four types of peat land uses in Central Kalimantan by excluding organic C from land cover.

Conclusion

Results of the study can be concluded that the type of commodity and period of management significantly affected the carbon content, soil bulk density, and organic matter content in peat with different land uses in Central and West Kalimantan. Further, among the studied crops, the highest CO_2 emissions were recorded from the perennial crops (oil palm and rubber), followed by seasonal crops (corn, mustard greens), and this CO_2 emission is positively and significantly associated with the depth of the groundwater table. Results of the study also suggested that plant biomass production is also associated with carbon dioxide fixation.

References

Adji, F. F. (2017). Dampak alih fungsi lahan terhadap sifat fisik tanah dan emisi karbon gambut transisi di Desa Kanamit Barat Kalimantan Tengah. *Pedontropika: Jurnal Ilmu Tanah dan Sumber Daya Lahan*, *3*(1), 79-88.

Agus, F., Ai Dariah, Wahyunto, Setyanto, P., I.G. Made Subiksa, Runtunuwu, E., Susanti, E., & Supriatna, W. (2010). Carbon budget and management strategies for conserving Carbon in peatland: case study in Kubu Raya and Pontianak districts, West Kalimantan, Indonesia. In *Proceeding of International Workshop on Evaluation and Sustainable Management of Soil Carbon Sequestration in Asian Countries*, pp. 28-29. Bogor, Indonesia: Indonesian Soil Research Institute.

Anda, M., Ritung, S., Suryani, E., Hikmat, M., Yatno, E., Mulyani, A., & Subandiono, R. E. (2021). Revisiting tropical peatlands in Indonesia: Semi-detailed mapping, extent and depth distribution assessment. *Geoderma*, *402*, 115235. https://doi.org/10.1016/j.geoderma.2021.115235.

Andriesse, J. P. (1988). *Nature and management of tropical peat soils*. No. 59. Food & Agriculture Org.

Bappenas. (2010). Rencana Aksi Nasional Penurunan Emisi Gas Rumah Kaca (GRK). Bappenas – Jakarta

Devi, S. A., Khairullah, K., & Alibasyah, M. R. (2019). Perubahan Beberapa Sifat Fisika Gambut Akibat Lamanya Penggunaan Lahan di Rawa Tripa. *Jurnal Ilmiah Mahasiswa Pertanian*, *4*(1), 714-723.

Evans, C. D., Peacock, M., Baird, A. J., Artz, R. R. E., et al. (2021). Overriding water table control on managed peatland greenhouse gas emissions. *Nature*, *593*(7860), 548-552.https://doi.org/10.1038/s41586-021-03523-1

Fahmuddin, A., & Subiksa, I. M. (2008). Lahan Gambut: Potensi untuk Pertanian dan Aspek Lingkungan. *Balai Penelitian Tanah dan World Agroforestry Centre (ICRAF)*, *3*.

Hatano, R., Tomoaki, M., Untung, D., Limin, S. H., & Syaiful, A. (2004). Impact of agriculture and wild fire on CO_2, CH_4 and N_2O emissions from tropical peat soil in Central Kalimantan, Indonesia. *Necessity of Establishment of Inventory on Carbon Cycling in Tropical Peatland Ecosystems for Sustainable Agroproduction and Environmental Conservation, Report number*, *13574012*, 11.

Hooijer, A., Silvius, M., Wösten, H., & Page, S. (2006). PEAT-CO2, *Assessment of CO2 emissions from drained peatlands in SE Asia, Delft Hydraulics report Q* 3943, pp. 36.

Jamaludin, G. E., & Anshari, G.Z. (2020). Emisi Karbon Dioksida (CO_2) dari Pertanian Skala Kecil di Lahan Gambut. *Jurnal Ilmu Lingkungan*, *18*(3), 582-588.

Jauhiainen, J., Heikkinen, J., Martikainen, P.J., & Vasander, H. (2001). CO_2 and CH_4 fluxes in pristine peat swamp forest and peatland converted to agriculture in Central Kalimantan, Indonesia. *International Peat Journal*, *11*, 43-49.

Jauhiainen, J., Hooijer, A., & Page, S. E. (2012). Carbon dioxide emissions from an Acacia plantation on peatland in Sumatra, Indonesia. *Biogeosciences*, *9*(2), 617-630. https://doi.org/10.5194/bg-9-617-2012.

Jauhiainen, J., Takahashi, H., Heikkinen, J. E., Martikainen, P. J., & Vasander, H. (2005). Carbon fluxes from a tropical peat swamp forest floor. *Global Change Biology*, *11*(10), 1788-1797. https://doi.org/10.1111/j.1365-2486.2005.001031.x.

Jauhiainen, J., Vasander, H., Adi Jaya, Inoue, T., Heikkinen, J., & Martikainen, P. (2004). "Carbon balance in managed tropical peat in Central Kalimantan, Indonesia." In *International Peat Congress* (pp. 653-659). International Peat Society, Canada.

Joosten, H. (2015). *Peatlands, climate change mitigation and biodiversity conservation: An issue brief on the importance of peatlands for carbon and biodiversity conservation and the role of drained peatlands as greenhouse gas emission hotspots*. Vol. 2015727, Nordic Council of Ministers.

Kusin, F. M., Akhir, N. I. M., Mohamat-Yusuff, F., & Awang, M. (2015). The impact of nitrogen fertilizer use on greenhouse gas emissions in an oil palm plantation associated with land use change. *Atmósfera*, *28*(4), 243-250.

Luo, Y., & Zhou, X. (2010). *Soil respiration and the environment*. Academic Press. DOI: https://doi.org/10.1016/B978-0-12-088782-8.X5000-1.

Maltby, E. (1997). Developing guidelines for the integrated management and sustainable utilisation of tropical lowland peatlands. In: J.O. Rieley, and S.E. Page. (eds.), *Biodiversity and Sustainability of Tropical Peatland* (pp. 9-18). Proceeding of the International Symposium on Tropical Peatlands, Palangka Raya, Indonesia. Samara Publisher, Cardigan, U.K.

Maltby, E., & Proctor, M. C. F. (1996). *Peatlands: their nature and role in the biosphere*. (No. NEI-FI-326).

Melling, L.J. (2005). *Greenhouse gas fluxes from tropical peatland of Sarawak, Malaysia*. PhD Dissertation submitted to the Soil Science Laboratory, Division of Environmental Resources, Graduate School of Agriculture, Hokkaido University, Japan.

Morrison, R., & Page, S.E. (2012). *Assessing the empirical basis of peat CO_2 emissions estimates from oil palm plantations on tropical peatland*. In: Peatlands in Balance. Proceeding of the 14th International Peat Congress, Stockholm, Sweden.

Moyano, F.E., Atkin, O.K., Bahn, M., Bruhn, D., Burton, A.J., Heinemeyer, A., Kutsch, W.L., & Wieser, G. (2009). Respiration from roots and the mycorrhizosphere.. In *Soil Carbon Dynamics: An Integrated Methodology* (pp. 127-156), Cambridge University Press.

Page, S. E., Rieley, J. O., & Banks, C. J. (2011). Global and regional importance of the tropical peatland carbon pool. *Global change biology*, *17*(2), 798-818.https://doi.org/10.1111/j.1365-2486.2010.02279.x.

Page, S. E., Siegert, F., Rieley, J. O., Boehm, H. D. V., Jaya, A., & Limin, S. (2002). The amount of Carbon released from peat and forest fires in Indonesia during 1997. *Nature*, *420*(6911), 61-65.

Pirkko, S., & Nyronen, T. (1990). *The carbon dioxide emissions and peat production*. In *International Conference on Peat Production and Use, Jiväskylä, Finland*, 1, 150-157.

Rieley, J. O., & Page, S.E. (2016). Tropical peatland of the world. In M. Osaki & N. Tsuji, (Eds.). *Tropical peatland ecosystems*, (pp. 3-32), Springer Japan. Tokyo.

Rieley, J. O., Wüst, R. A. J., Jauhiainen, J., Page, S. E., et al. (2008). Tropical peatlands: carbon stores, carbon gas emissions and contribution to climate change processes. In : Peatlands and climate change (pp. 148-181), International Peat Society, Canada.

Rogi, J. E. X. (2002). *Penyusunan model simulasi dinamika nitrogen pertanaman kelapa sawit (Elaeis guineensis, Jacq.) di unit Usaha Bekri Propinsi Lampung*." Disertasi. Institut Pertanian Bogor, Bogor.

Sjarkowi, H. F. (2005). *Is poverty eradication possible in the peatland areas of Kalimantan Tengah, Indonesia*. In *Proceedings of the International Symposium and Workshop on Tropical Peatland, Restoration and Wise Use of Tropical Peatland: Problems of Biodiversity, Fire, Poverty and Water Management, Palangka Raya*, pp. 20.

Strack, M., Waddington, J. M., Turetsky, M., Roulet, N. T., & Byrne, K. A. (2008). Northern peatlands, greenhouse gas exchange and climate change. In: M. Strack (ed.), *Peatlands and climate change* (pp. 44-69), International Peat Society, Vapaudenkatu 12, 40100 Jyväskylä, Finland

Wahyunto, & Ai Dariah. (2014). "Degradasi lahan di Indonesia: kondisi existing, karakteristik, dan penyeragaman definisi mendukung gerakan menuju satu peta. http://repository.pertanian.go.id/handle/123456789/2303.

Wahyunto, Dariah, A., & Fahmuddin, A. (2010). Distribution, Properties, and Carbon Stock of Indonesian Peatland. Proceedings of International Workshop on Evaluation and Sustainable Management of Soil Carbon Sequestration in Asian Countries, Bogor, Indonesia, September pp. 28-29.

Wakhid, N., Hirano, T., Okimoto, Y., Nurzakiah, S., & Nursyamsi, D. (2017). Soil carbon dioxide emissions from a rubber plantation on tropical peat. *Science of the total environment*, *581*, 857-865.

Wildayana, E. (2017). Challenging constraints of livelihoods for farmers on the South Sumatra Peatlands, Indonesia. *Bulgarian Journal of Agricultural Science*, *23*(6), 894-905.

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