Journal of Oil Palm Research Vol. 33 (2) June 2021 p. 267-277
DOI: https://doi.org/10.21894/jopr.2020.0114

THE DYNAMIC OF CARBON DIOXIDE (CO_2) EMISSION AND LAND COVERAGE ON INTERCROPPING SYSTEM ON OIL PALM REPLANTING AREA

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ABSTRACT

Oil palm replanting has faced environmental criticism as it is a source of carbon dioxide (CO_2) emission. The aim of this study was to determine the level of CO_2 emissions and the value of carbon stocks for oil palm smallholders replanting. The measurements were taken using the infrared gas analyser (IRGA) method for CO_2 emission. Non-destructive methods were used to measure carbon stocks for oil palm-stands while destructive methods were used for understorey and intercropped plants. This study shows that there was dynamic of CO_2 emission during the replanting averaging (t CO_2 ha^{-1} yr^{-1}) 28.5 for 28-year-old oil palm, 59.0 for bare land after land clearing, 47.0 for intercropped plants in the vegetative phase, 51.6 for intercropped plants in the generative phase and 42.9 for one-year-old oil palm. It was found that CO_2 emissions were reduced due to the conditions of land coverage and that the reduction in CO_2 emissions occurred not only because of the absorption of CO_2 by plants for photosynthesis but also due to being stored away, as much of the carbon stock (t C ha^{-1}) was found in corn (10.2), legume cover crops (7.6), soyabeans (3.5) and natural vegetation (2.8). In 28-year-old oil palm it was found to be at 74.7.

Keywords: carbon stocks, corn, intercropped, smallholders, soyabeans.

Received: 10 September 2019**; Accepted:** 7 September 2020**; Published online:** 28 December 2020.

INTRODUCTION

In 2018, the total oil palm plantation area in Indonesia was 14.3 million hectares, of which 5.8 million hectares belonged to smallholders (Direktorat Jenderal Perkebunan, 2017). Of the area held by smallholders, 2.7 million hectares require replanting as the plants are over 25 years old and unproductive. The significant increase in oil palm plantations in Indonesia has led to negative campaigns related to environmental issues, including deforestation, greenhouse gas (GHG) emissions, loss of biodiversity and forest and peatland fires.

The smallholders' oil palm replanting programme in Indonesia has the potential to generate a negative response from the international community due to the GHG emissions, especially carbon dioxide (CO_2) associated with the programme. Hence, information about the level of CO_2 emissions that will be generated during the oil palm replanting stage is needed.

Olivier *et al*. (2016) concluded that GHG emissions are a cause of global warming. Greenhouse gases include water vapour (H_2O),

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CO_2, nitrous oxide (N_2O), methane (CH_4), ozone (O_3) and chlorofluorocarbons (Zein and Chehayeb, 2015). Olivier *et al*. (2017) reported that most GHG emissions (about 72%) consist of CO_2, followed by CH_4 (19%), N_2O (6%) and fluorinated gases (3%). The agricultural sector plays a role in producing CO_2.

According to the Environmental Protection Agency (EPA) (2017), 9% of GHG emissions in 2017 resulted from agricultural activities. Henderson *et al*. (2018) found that several sectors contributed to the global greenhouse effect in 2010: 25% came from electricity and heat; 24% from agriculture, forestry and other land-use (AFOLU); 21% from industry; 14% from transportation; 6.4% from buildings; and 9.6% from other energy sources.

The formation of CO_2 occurs as a result of plant respiration, which includes root respiration and respiration of microorganisms. In photosynthesis, CO_2 is converted into organic matter with the help of sunlight. In turn, the dead organic matters are broken down into water vapour and CO_2, some of which is converted into C-organic in the soil. During the decomposition process, various products are released, including CO_2, energy, water, plant nutrients and resynthesised organic carbon compounds (Khatoon *et al*., 2017). It is possible to reduce CO_2 emissions by improving the absorption capacity of plants, that is by increasing photosynthetic efficiency. Increasing plant photosynthesis can be done by increasing the number of plants including by planting bareland. Therefore, an intercropping system is a promising option for improving efficiency and optimising land use (Li-li *et al.,* 2015).

Intercropping is a farming system whereby the main commodity is planted in the same area as a second crop either at the same time or at a different time (Poppy *et al*., 2017). This system has the advantages of optimising the use of light, water and nutrients; controlling weeds, pests and diseases; facilitating sustainable alternative agriculture (Sujayanand *et al*., 2016; Zarekar *et al*., 2018) and improving biomass yield and land-use efficiency (Jalal *et al*., 2017). Legume cover crops are common in oil palm replanting areas as they can maintain moisture in the soil during the early replanting period.

However, legume cover crops are not economically viable for farmers as they do not provide an income for farmers for at least three years while the oil palms are still in the immature stage. Corn and soyabeans are more viable secondary crops for oil palm smallholders as they can provide additional income for farmers in the early stages of replanting.

It is not yet known whether corn and soyabeans can reduce CO_2 emissions more effectively than legume cover crops. The aim of this study was to determine the level of CO_2 emissions and the value of carbon stocks at various stages of oil palm replanting on smallholders' land.

MATERIALS AND METHODS

Study Sites

The research was conducted on a smallholders' oil palm plantation at plasma PIR KUD Bina Usaha Baru, PT. Inti Indosawit Subur Ukui, Bukit Jaya Village, Ukui Subdistrict, Pelalawan District, Riau Province, Indonesia. The oil palms were planted in 1987 and 1988 (28 years old) and were due for replanting. The coordinate points were 00°09'35.2" SL and 103°06'23.5" EL, and the altitude was 44 m above sea level. The soil type was ultisol. The location is shown in *Figure 1*.

The CO_2 emissions were measured at five different stages of the replanting process: 1) before felling the 28-year-old palms (November 2016); 2) after land clearing (April 2017); 3) at the vegetative phase of the intercrops (September 2017); 4) at the generative phase of the intercrops (February 2018); and 5) when the replanted palms were approximately a year old (August 2018).

Measurements of CO_2 emissions at the vegetative and generative phases 45 and 75 days after planting (DAP), respectively-were taken for each planting season. Season 1 was from June 2017 to October 2017, season 2 from November 2017 to February 2018 and season 3 from March 2018 to July 2018.

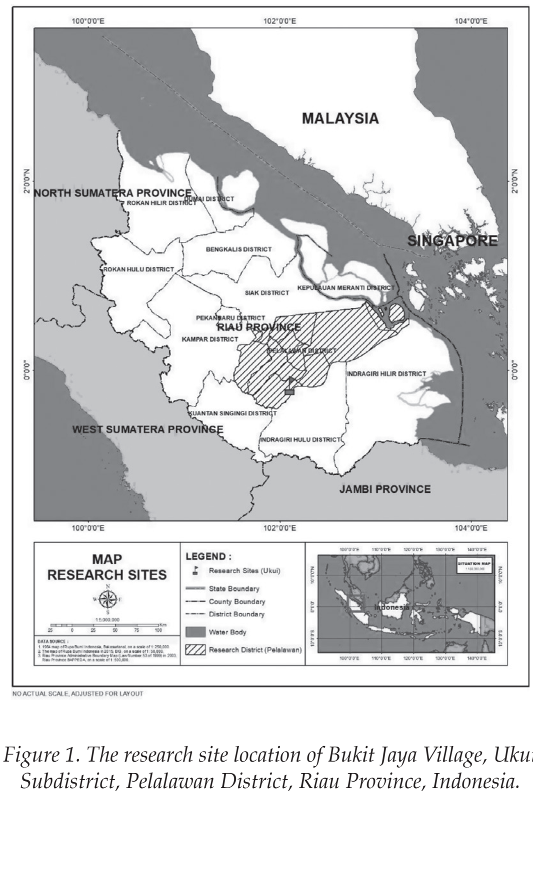


Figure 1. The research site location of Bukit Jaya Village, Ukui Subdistrict, Pelalawan District, Riau Province, Indonesia.

The carbon stocks of old oil palms and understorey vegetation biomass were measured in November 2016. The carbon stocks of the new oil palms planted with soyabeans were measured in May 2018 and those of the palms planted with corn in June 2018.

Materials and Equipment

The main crop was 28-year-old oil palm (*Elaeis guineensis* Jacq.) of the DxP Marihat variety, which was replaced with 12-month-old seedlings of the Topaz 3 variety. The intercropped plants were corn seed (*Zea mays* L.) of the BISI II variety, soyabean seeds [*Glycine max* (L.) Merrill] of Argomulyo variety, and legume cover crop seeds consisting of *Pueraria javanica*, *Calopogonium mucunoides* and *Centrosema pubescens*.

The young palms were planted in a triangular formation at a spacing of 9 m x 9 m x 9 m. The intercropped plants were grown at different planting distances: corn at 100 cm x 20 cm, soyabeans at 50 cm x 10 cm and legumes at 1 m x 1 m. For the natural vegetation treatment, the plants were allowed to grow freely. The distance between the intercropped plant row and the main crop row was 2 m. The harvesting ages of the soyabeans and corn were 85 DAP and 105 DAP, respectively.

An infrared gas analyser (IRGA) type LI-820, consisting of closed polyvinyl chloride (PVC) pipe chamber with a diameter of 25.5 cm and a height of 25 cm was used to measure CO_2 emissions. The IRGA was equipped with supporting tools, including a 12 V battery, a 12 V air pump, an air filter, a manometer, a data logger or laptop, a hose, an air flow meter, a fan, a thermometer, a machete and raffia. The carbon stocks of plant biomass were measured using a ruler, stationery (markers) and scales.

Measurement of CO_2 Emissions and Carbon Stocks

The sampling for measuring CO_2 emissions under 28-year-old oil palms before felling and after land clearing was carried out on three plots of 2 ha each. Each plot had five observation subplots, giving a total of 15 samples (*Figure 2*).

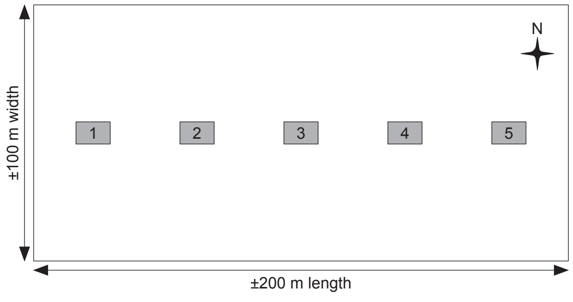


Figure 2. The infrared gas analyses (IRGA) placement for measurement of carbon dioxide (CO_2) emissions samples under 28-year-old oil palm and bare land in one plot.

The CO_2 emissions from the replanting area were measured using a split plot design. The main plot in this study was composed of land owned by three farmers (Farmer 1, Farmer 2 and Farmer 3), each of whom farmed 2 ha of land. The plot was divided into subplots for the intercrop plants (corn, soyabeans, legumes and natural vegetation) and repeated three times, giving 36 sample subplots.

The plant growth parameters were plant height and number of leaves for corn and plant height, number of branches and number of pods for soyabeans. Measurements were taken twice a month for each of the three planting seasons. The growth parameters for oil palms were plant height, length of fronds and number of fronds over an 11-month period.

The CO_2 emissions were measured using Husnain's method (Husnain *et al*., 2014). Following Madsen *et al*. (2009), the linear relationship between measurement time and CO_2 concentration was used to calculate CO_2 flux. The closed chamber was placed above the ground for the following five conditions: 1) under the stand canopy of the 28-year-old oil palms; 2) above the ground after land clearing (bare land); 3) under vegetative phase of intercropped plants; 4) under generative phase of intercropped plant; and 5) under young oil palm plant aged 15 months (*Figure 3*). Measurements of CO_2 emissions were taken during the periods of 7.00-12.00 am and 14.00-17.00 pm.

The observation parameters for CO_2 emissions were based on those proposed by Husnain *et al*. (2014) and consisted of the CO_2 emissions in ppm, plant lid height after installation of above-ground lid (cm), air pressure inside lid (kPa), soil temperature (°C), plant lid temperature (°C) and air temperature (°C).

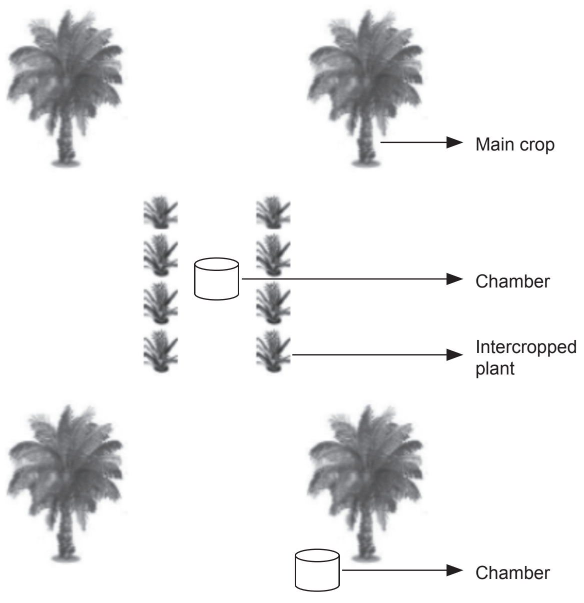


Figure 3. The location of chamber for measurement of carbon dioxide (CO_2) emissions.

A personal computer with an IRGA, the LI 820 CO_2 gas analyser, was used to calculate CO_2 emissions. Data were processed using Microsoft Excel 2013 software. Microsoft Excel was also used to calculate the linear regression equation between time (seconds) and the concentration of carbon in the lid. The Equation obtained was:

$$Y = ax + b \qquad \text{Equation (1)}$$

where Y is the concentration of CO_2 in the chamber, a is the regression coefficient of change in CO_2 concentration of time and b is the initial concentration of CO_2.

The CO_2 flux was calculated using the following Equation (Madsen *et al*., 2009):

$$Fc = \frac{\text{ph}}{\text{R}\tau} \text{ x } \frac{\partial C}{\partial t} \qquad \text{Equation (2)}$$

where Fc is the CO_2 flux (mol m^{-2} s^{-1}), h is the height of the chamber (cm), R is the ideal gas constant (8.314 Pa m^3 $°K^{-1}$ mol^{-1}), τ is the air temperature of the chamber (°K) and $\frac{\partial C}{\partial t}$ is the change of CO_2 concentration every changing time, linear equation slope of concentration with time (ppm s^{-1}). Field measurement of soil and air temperatures use degrees Celcius, but calculation of the equation is converted to degrees Kelvin.

The technique of observing and measuring carbon stocks was proposed by Hairiah *et al.* (2010). The carbon stocks of the 28-year-old oil palms were measured using a non-destructive method, which involved measuring the plant height from ground level to the lowest fruit bunches. Each of the three plots (2 ha) consisted of 256 plants (±11.7% of the population), of which 30 were sampled, giving a total of 90 samples (*Figure 4*).

A destructive method was used to measure the carbon stocks of understorey vegetation biomass. This involved taking out the plant samples. The size of the plot sample was 1 m x 1 m. The understorey was all vegetation with a stem diameter of <5 cm, which was netted in wooden frame 1 m x 1 m in size (*Figure 5*).

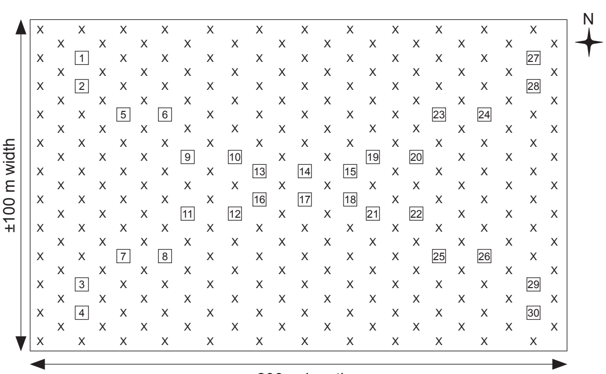


Figure 4. Sketch of stands height sample measurement at 28-year-old oil palms.

Figure 5. Understorey carbon stocks observation.

The carbon stocks of the intercropped plant (corn, soyabeans, legumes and natural vegetation) were observed for areas of 1 m x 1 m square. First, the plants were cut and weighed to obtain their wet weights. Then, 500 g of each sample was dried in an oven at 70°C for 48 hr to measure the dry weight of the biomass.

The dry weight (DW) of the oil palm biomass was calculated using the following Equation (Hairiah *et al*., 2010):

$$\text{DW} = (0.0976 \text{ x H}) + 0.0706 \qquad \text{Equation (3)}$$

where DW (t per palm) and H is the height of the plant (m).

The carbon stocks of the old oil palms were calculated using the following Equation:

$$\text{Plant carbon stock} = 0.46 \text{ x dry weight biomass} \qquad \text{Equation (4)}$$

The conversion rate of 0.46 showed that the average C content in biomass was around 46% (Hairiah *et al*., 2010).

RESULTS AND DISCUSSION

Environmental Conditions of Research Location

Air temperature and rainfall were the main climate elements to consider. The average temperature in the Pelalawan district while CO_2 emissions were being measured was 24°C-34°C. Rainfall from January to December 2017 ranged from 15-534 mm mth^{-1} with an average of 270 mm mth^{-1}. The average humidity was 80%-85%. The soil pH at the location was 4.1-4.7. Field observations showed that there were 20 species of natural vegetation under the dense canopy of 28-year-old oil palms, including ferns, weeds, *borreria*, *Cromolaena odorata*, *laportea* and *Heliotropium indicum*. There was no vegetation cover at all on the bare land (after land clearing).

CO_2 Emissions

The CO_2 emissions for various cropping conditions are presented in *Table 1*. *Table 1* shows the dynamic pattern of CO_2 emissions in the oil palm replanting area. The CO_2 emission in the 28-year-old oil palm area was 28.5±13.5 t CO_2 ha^{-1} yr^{-1}. It increased when the land was bare (59.0±49.4 t CO_2 ha^{-1} yr^{-1}) and then decreased in the vegetative phase of the intercropped plants (47.0±26.5 t CO_2 ha^{-1} yr^{-1}). The CO_2 emissions in the generative phase of the intercropped plants and in 1-year-old oil palm were 51.6±28.8 t CO_2 ha^{-1} yr^{-1} and 42.9±23.3 t CO_2 ha^{-1} yr^{-1}, respectively.

The lower CO_2 emissions from the oil palms at the age of 28 years (28.5±13.5 t CO_2 ha^{-1} yr^{-1}) compared to those from bare land (59.0±49.4 t CO_2 ha^{-1} yr^{-1}) was thought to be related to CO_2 uptake for the respiration of roots and microbes and the decomposition of organic materials. In the 28-year-old oil palm plantations, some of the released CO_2 would have been absorbed by the leaves for photosynthesis, so less would have been released into the air than from the bare land.

The level of CO_2 emissions decreased again (47.0±26.5 CO_2 t ha^{-1} yr^{-1}) after the land was covered by intercropped plants (vegetative phase) due to the consumption of CO_2 by the plants. In the generative phase, the amount of released CO_2 increased to 51.6±28.8 t CO_2 ha^{-1} yr^{-1} because the leaves of the intercropped plants had aged and were less efficient in carrying out photosynthesis. This meant that they absorbed less CO_2 than they did during the vegetative phase. According to Misbahuddin *et al*. (2018), soil respiration which produces CO_2 and causes it to be released into the air is determined by various factors, including temperature, soil moisture and soil pH (Pahlipi *et al.*, 2017).

After the new oil palms had grown (one year old) and needed CO_2 for photosynthesis, CO_2 emissions decreased to 42.9±23.3 t CO_2 ha^{-1} yr^{-1}. Cetin and Sevik (2016) found that plants absorb CO_2 throughout the day, which indicates that oil palm replanting activities do not increase CO_2 emissions in the air. The CO_2 emissions from the old oil palm were 28.5±13.5 t ha^{-1} yr^{-1}, which are lower than those reported in other studies (*Table 2*). The CO_2 emissions from 33-year-old oil palms at Rokan Hilir District Riau Province were 34.7 t CO_2 ha^{-1} yr^{-1} (Yahya *et al*., 2017) and those from a logged-over forest were 32.62 t CO_2 ha^{-1} yr^{-1} (Khasanah and Nordwijk, 2019). In terms of CO_2 emissions, the old oil palm ecosystem is similar to a secondary forest ecosystem.

With corn, soyabeans, legumes and other vegetation as intercrop plants, CO_2 emissions from the oil palm replanting area decreased. The reduced emissions were due to the absorption of CO_2 by leaves during photosynthesis in planting seasons one to three for soyabeans and corn. Growth of the intercropped plants in the oil palm replanting areas of the three farmers during the three seasons are presented in *Figures 6* and *7*.

TABLE 1. EMISSION OF CARBON DIOXIDE (CO_2) AT DIFFERENT PHASES OF REPLANTING

Plant conditions	Mean±STD CO_2 emissions ($t\ CO_2\ ha^{-1}\ yr^{-1}$)		
	Morning	Afternoon	Average
28-year-old oil palm	30.3±14.7	26.7±11.8	28.5±13.5
Bare land (after land clearing)	39.9±29.7	78.1±57.8	59.0±49.4
Vegetative phase intercropping plant	46.9±27.3	47.0±25.6	47.0±26.5
Generatitive phase intercropping plant	63.4±34.2	39.8±14.9	51.6±28.8
1-year-old oil palm	49.9±31.5	35.9±16.4	42.9±23.3

TABLE 2. EMISSION OF CARBON DIOXIDE (CO_2) AT VARIOUS LAND USES

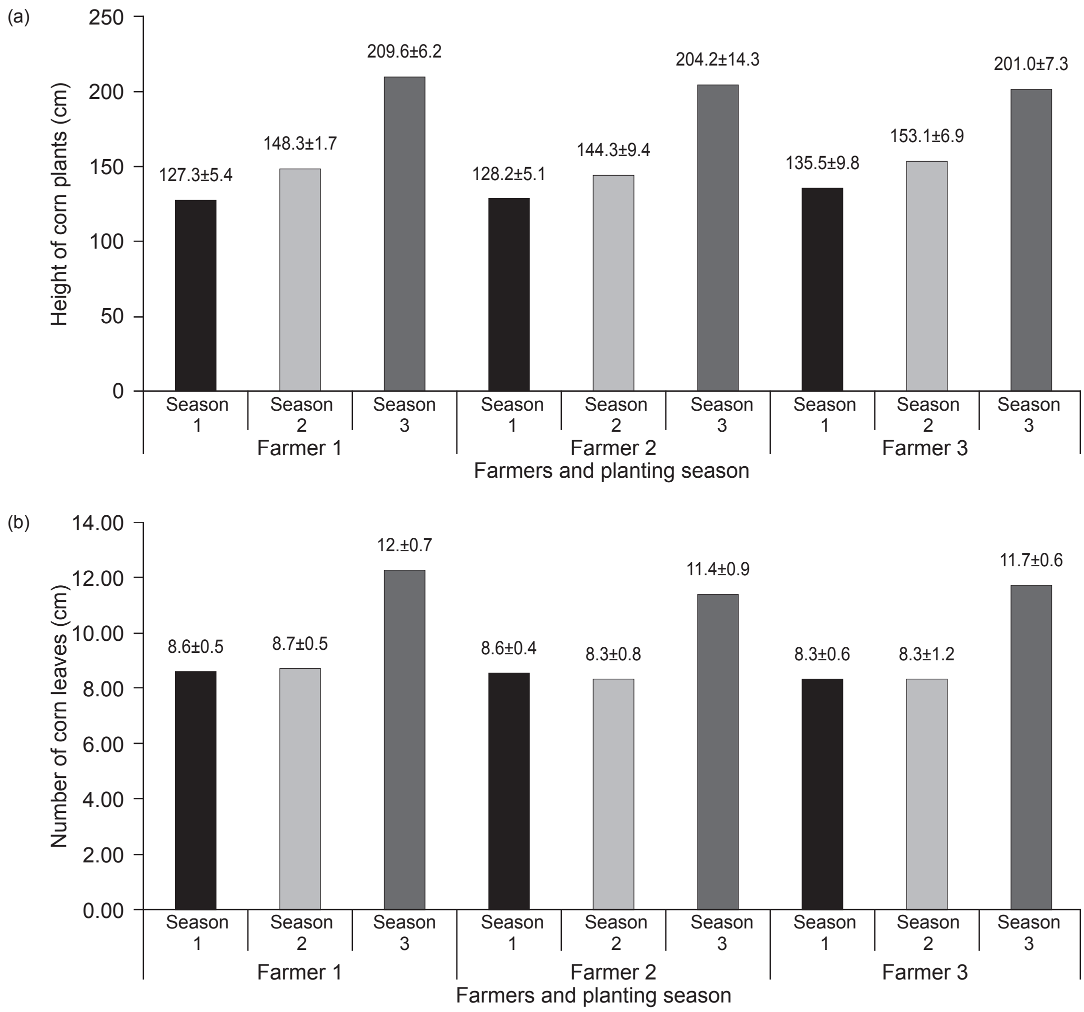
Land type	Vegetation	$t\ CO_2\ ha^{-1}\ yr^{-1}$	Source
Peatland in Sarawak, Malaysia	Oil palm eight years	22.07±0.8	Manning *et al*. (2019)
Peatland in Jambi, Indonesia	Oil palm one year	96.13	Khasanah and Noordwijk (2019)
	Rubber > 30 years	75.17	
	Logged-over forest	32.63	
	Betel nut and coffee > 20 years	71.00	
	Coconut and coffee > 40 years	85.00	
Peatlands in Kalimantan, Indonesia	Oil palm	84.10	Rumbang (2015)
	Corn	69.20	
	Rubber plant	106.87	
Mineral land in Rokan Hilir, Riau, Indonesia	Oil palm 33 years	34.70	Yahya *et al*. (2017)
Mineral land in Kampar, Riau, Indonesia	Shrubs	98.40	Misbahuddin *et al.* (2018)

The CO_2 emissions from the oil palm replanting area decreased as a result of intercropping. The CO_2 emissions during the vegetative and generative phases of the intercropped plants are presented in *Table 3*.

Table 3 shows that the CO_2 emissions from intercropped plants during the vegetative phase were significantly different. CO_2 emission from corn was the highest at 67.2±31.1 t CO_2 ha^{-1} yr^{-1}, followed by those from soyabeans, natural vegetation and legumes, at 48.7±20.7, 38.0±24.8 and 34.1±14.1 t CO_2 ha^{-1} yr^{-1}, respectively. The average emission from intercrop plants was 47.0±26.5 t CO_2 ha^{-1} yr^{-1}. The high levels of CO_2 emissions from corn can be attributed to the higher amount of inorganic fertiliser applied to corn than to soyabeans. Chemical fertiliser significantly increased CO_2 flux by 9% compared to solitary urea application (Salehi *et al*., 2017). The application of inorganic fertiliser over the long-term will increase the CO_2 flux (Dhadli and Brar, 2016).

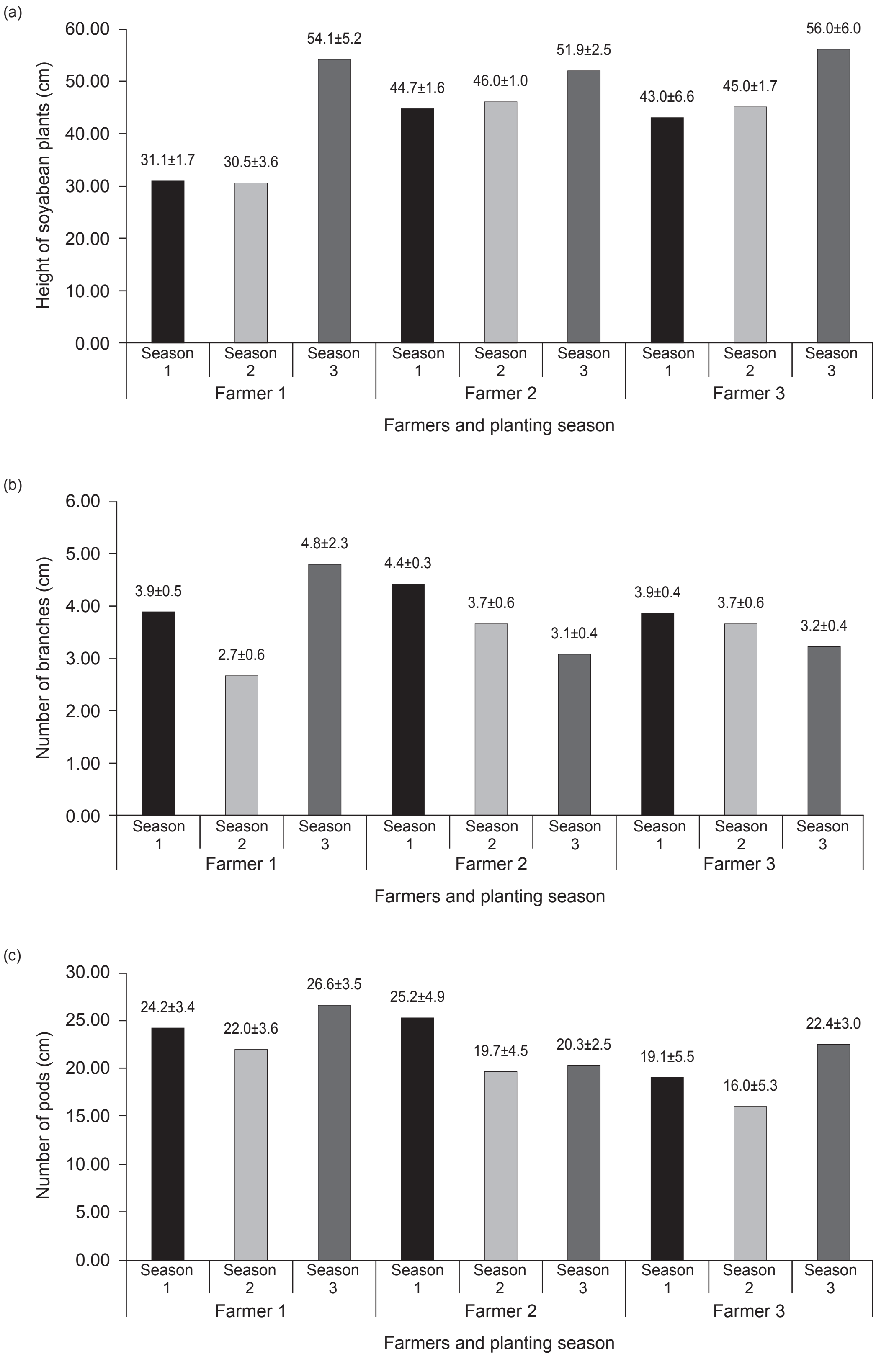
The CO_2 emissions from the various intercropped plants during the generative phase were not significantly different. The average CO_2 emission from intercropped plants during the generative phase was higher (51.6±28.8 t CO_2 ha^{-1} yr^{-1}) than that during the vegetative phase (47.0±26.5 t CO_2 ha^{-1} yr^{-1}). This may be caused by the fact that microbial activity was still high, but the ability of the plants to absorb CO_2 for the metabolic activities in leaves had decreased. This meant that the amount of CO_2 absorbed by the leaves was low, resulting in higher CO_2 emissions in the generative phase.

The CO_2 emissions in the morning were higher than during the day (*Table 3*). Saleh *et al*. (2017) attributed a higher concentration of CO_2 in the morning to microorganism activity and a layer in the atmosphere that traps CO_2 between sunset and sunrise.



Note: Season 1 – June 2017 to October 2017.
Season 2 – November 2017 to February 2018.
Season 3 – March 2018 to July 2018.

Figure 6. Growth of corns plants. (a) height of plants, (b) number of leaves. The all groups were analysed by Duncan's Multiple Range Test (DMRT) at the level of 5%. The numbers followed by the same lowercase letter was not significantly different according to the DMRT at the level of 5%.



Note: Season 1 – June 2017 to October 2017.
Season 2 – November 2017 to February 2018.
Season 3 – March 2018 to July 2018.

Figure 7. The growth of soyabeans plants. (a) height of plants, (b) number of branches, (c) number of pods. All groups were analysed by Duncan's Multiple Range Test (DMRT) at the level of 5%. The numbers followed by the same lowercase letter was not significantly different according to the DMRT at the level of 5%.

TABLE 3. CARBON DIOXIDE (CO_2) EMISSION DURING VEGETATIVE AND GENERATIVE PHASES OF INTERCROPPED PLANTS

Treatment (Intercropping plant)	Mean±STD CO_2 emissions of vegetative phase ($t\ CO_2\ ha^{-1}\ yr^{-1}$)			Mean±STD CO_2 emissions of generative phase ($t\ CO_2\ ha^{-1}\ yr^{-1}$)		
	Morning	Afternoon	Average	Morning	Afternoon	Average
Corn	67.2a±33.3	67.2a±29.7	67.2a±31.1	73.8a±46.1	37.9ab±19.2	55.9a±39.1
Soyabeans	50.1ab±21.7	47.2ab±20.5	48.7b±20.7	51.7a±18.5	39.1ab±13.8	45.4a±17.2
Natural vegetation	36.7b±24.5	39.2b±26.8	38.0bc±24.8	56.0a±24.0	34.5b±9.2	45.3a±20.9
Legume	33.9b±15.7	34.3±12.2	34.1c±14.1	72.0a±39.2	47.6a±14.1	59.8±31.4
Average	47.0±27.3	47.0±25.6	47.0±26.5	63.4±34.2	39.8±14.9	51.6±28.8

TABLE 4. LEVEL OF CARBON STOCKS IN VARIOUS CROPPING CONDITION

Plant conditions	Mean±STD carbon stocks ($t\ C\ ha^{-1}$)
28-year-old oil palm	74.7±4.8
Understorey of 28-year-old oil palm	0.7±0.4
Corn	10.2±2.6
Legume	7.6±0.8
Soyabeans	3.5±0.6
Natural vegetation	2.8±0.8
1-year-oil palm*	43.5±0.4
2-year-oil palm*	45.4±1.3

Source: * Singh *et al*. (2018).

The lower CO_2 emissions in plantations with intercropping compared to bare land correlated with the carbon stocks presented in *Table 4*. The carbon reserve in the 28-year-old oil palms was 74.7±4.8 t C ha^{-1}, while that in the understorey of the 28-year-old palms was at 0.7±0.4 t C ha^{-1}. Corn had the highest carbon stocks of the intercropped plants at 10.2±2.6 t C ha^{-1}, followed by legumes, soyabeans and natural vegetation at 7.6±0.8, 3.5±0.6 and 2.8±0.8 t C ha^{-1}, respectively.

For comparison, the carbon stock of young oil palms at Mizoram, Northeast India was at 43.5±0.4 t C ha^{-1} after one year and 45.4±1.3 t C ha^{-1} after two years (Singh *et al*., 2018). Carbon stocks of 5- to 6-year-old oil palms in Jambi and Riau were 10.7±0.4 t C ha^{-1} and 9.5±0.2 t C ha^{-1}, respectively, while those of 33-year-old oil palms in Riau were 75.8 t C ha^{-1} (Yahya, 2017). In Central Kalimantan, 7-year-old rubber plants had carbon stocks of 32.9±2.3 t C ha^{-1} (Susanti and Dariah, 2014). In Northeast Brazil, the carbon stocks of 25-year-old oil palms average at 40 t C ha^{-1} (Sanquetta *et al*., 2015), corn at 2.36 t C ha^{-1} (Ocampo and Oscar, 2016), soyabeans at 0.3 t C ha^{-1} (Nagy *et al*., 2017) and legumes at 14.6 t C ha^{-1} (Guan *et al*., 2016).

The vegetative growth of the oil palms over 11 months (August 2017 to June 2018) is presented in *Figure 8*.

Plant height, number of leaves and number of fronds indicate the carbon stocks of oil palm plants. *Figures 8a-c* shows that intercropping affected the vegetative growth of oil palms, although not significantly. The best plants in terms of plant height and length of fronds were found intercropped with legumes, while the highest number of fronds was found in palms intercropped with corn.

These results indicate that farmers should cultivate corn and soyabeans as intercrops during oil palm replanting. These plants reduce CO_2 emissions and increase carbon stocks in the replanting areas. In addition, the cultivation of corn and soyabeans is a source of additional income for smallholders.

CONCLUSION

The CO_2 emissions during the replanting of an oil palm area follow a dynamic pattern. The CO_2 emission from the area under the 28-year-old oil palm stands before the land clearing was 28.5±13.5 t $CO_2\ ha^{-1}\ yr^{-1}$. They were 59.0±49.4 t $CO_2\ ha^{-1}\ yr^{-1}$ from bare land, 47.0±26.5 t $CO_2\ ha^{-1}\ yr^{-1}$ in the vegetative phase of the intercropped plants, 51.6±28.8 t $CO_2\ ha^{-1}\ yr^{-1}$ in the generative phase of intercropped plants; and 42.9±23.3 t CO $ha^{-1}\ yr^{-1}$ when the new oil palms were a year old.

The carbon stocks of intercropped plants were 10.2±2.6 t C ha^{-1} in corn; 7.6±0.8 t C ha^{-1} in legumes; 3.5 ± 0.6 t C ha^{-1} in soyabeans and 2.8 ± 0.8 t C ha^{-1} in natural vegetation. The findings of this study show that oil palm replanting activities do not increase CO_2 emissions in the air but do increase carbon stocks.

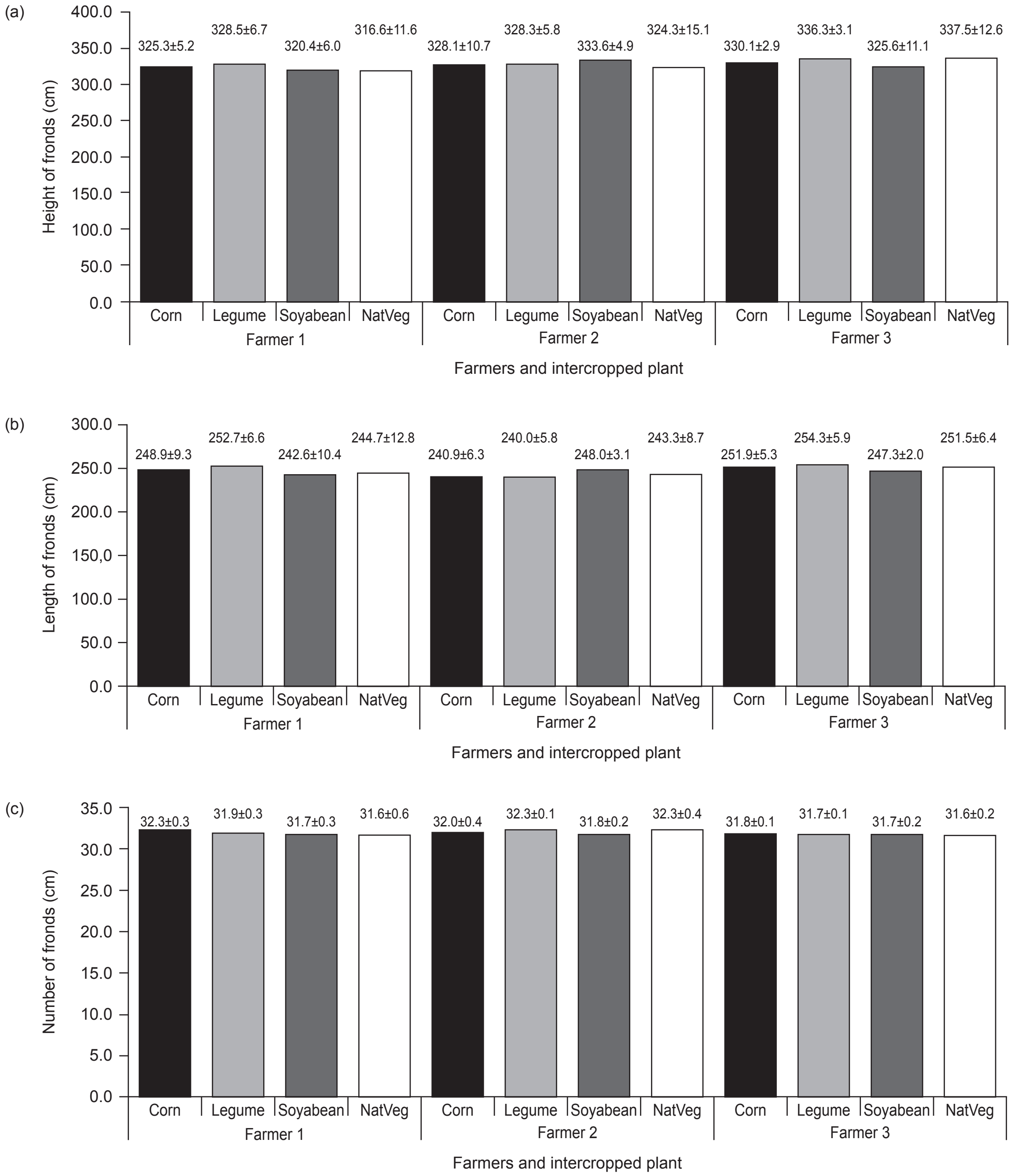


Figure 8. (a) Height of fronds, (b) length of fronds and (c) number of fronds of oil palm in different farmers' plantation and intercropping plants. All groups were analysed by Duncan's Multiple Range Test (DMRT) at the level of 5%. The numbers followed by the same lowercase letter was not significantly different according to the DMRT at the level of 5%.

ACKNOWLEDGEMENT

We acknowledge the Indonesian Oil Palm Estate Fund (BPDPKS) for the financial support, Sustainable Strategic Plantation Development Forum (FP2SB) and PT. Asian Agri for providing research facilitation. We thank to the researchers (Dr. Ir. Ida Nur Istina, M.Si as main contributor, Nurhayati, SP, MSi and Hery Widyanto, SP), enumerators, technicians and laboratory assistants of Riau Assessment Institute for Agricultural Technology (BPTP Riau) for the support in completing this research.

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