International Journal of Religion
2024
Volume: 5| Number 11 | pp.2635 – 2643
ISSN: 2633-352X (Print) | ISSN: 2633-3538 (Online)
ijor.co.uk
DOI: https://doi.org/10.61707/2zas6p56

Mitigating Carbon Emissions of Community Palm Plantations on Peatland

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Abstract

Increasing smallholder oil palm plantation activities on peatlands has become a challenge in achieving carbon emission reduction targets.The contradiction between the value of carbon emissions released and the carbon absorption capacity of oil palm plants needs to be known. This research the aim is to determine the value of lost emissions and the capacity to absorb carbon due to smallholder oil palm plantation activities on peatlands. So it can be a consideration in formulating carbon emission mitigation efforts in smallholder oil palm plantations on peatlands. The research was carried out descriptively using a spatial approach and field surveys on smallholder oil palm plantations on peatlands in Riau Province. Spatial analysis was carried out to determine the value of emissions lost due to changes in land cover. A field survey was carried out to measure absorption and emission values in several age classes of smallholder oil palm plantations. The research results found that carbon emissions from smallholder oil palm plantations on peatlands have increased every year along with the rate of additional opening of new plantations. The largest carbon emissions occur in the immature plant age class. As the age of oil palm plants increases, the value of peatland carbon emissions tends to decrease, while the value of carbon absorption increases. Mitigation to reduce carbon emissions that can be done is regulating the density of oil palm plants and implementing Legume Cover Crop on immature plants.

Keywords: Carbon emissions; Palm oil plantations; Peatland; Smallholder plantations.

INTRODUCTION

The excessive increase in carbon emissions combined with the ongoing loss of vegetation cover has increased the amount of greenhouse gas emissions. The increasing accumulation of greenhouse gases in the atmosphere triggers the impact of increasingly rapid global warming. Global warming can have further impacts on humans and the environment. Several research results have revealed the impacts of global warming, including climate change anomalies, loss of biodiversity, increased flood disasters, drought disasters, land fires, and potential human health problems (Habibullah et al., 2021; Shahzad et al., 2015) . More extreme impacts of global warming on humans and the environment must be prevented through efforts to reduce carbon emissions.

The peat ecosystem is a type of wetland formed from the accumulation of decaying organic material over thousands of years which is a living habitat for a diversity of flora and fauna.The existence of extensive peatlands and the diversity of flora on them should have the ability to absorb emissions and store large carbon reserves. However, due to the conversion of peatlands for various types of oil palm activities, this has caused an increase in carbon emissions. The opening of oil palm plantations on peatlands is still happening today, especially smallholder oil palm plantations.

The rate of addition of smallholder oil palm plantations is due to a direct increase in economic value for the community. The research results of Syahza et al. (2019) the economic benefits of oil palm plantations are more profitable than other plantation commodities. Palm oil commodities have a positive impact on welfare (Syahza et al., 2018) and provide employment and business opportunities for the community (Sari et al., 2019). This increase in economic value makes the increase in the area of smallholder oil palm plantations on peatlands difficult to control.

Naturally, the carbon storage content in peatlands is relatively stable, but if natural conditions are disturbed, such as changes in land cover due to the opening of oil palm plantations, this will trigger an acceleration of

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the peat decomposition process and become flammable (Dohong et al. 2017). Carbon stored in peatlands will be emitted as greenhouse gases, including in the form of CO2. The large carbon storage content in peatlands causes the emissions released to be very large.Many research results reveal that oil palm plantation activities on peatlands are considered to have had a negative impact on environmental conditions such as biodiversity degradation, fires and increased greenhouse gas emissions (Suwondo et al., 2011; Austin et al., 2017). However, oil palm plants are classified as green plants with a productive age of more than 25 years. Oil palm plants also absorb CO2 through photosynthesis and processingC-sequestrationwhich is converted into carbon stock. The carbon absorption ability of oil palm plants will contribute to reducing carbon emissions in the air (Thenkabail et al., 2011). The amount of ability of oil palm plants to absorb carbon in formCO2 can be seen based onthe amount of carbon stock storedon plants.

The contradiction between the value of carbon emissions released and the carbon absorption capacity of oil palm plants needs to be well understood. Mitigation researchCarbon emissions from smallholder oil palm plantations on peatlands are needed to describe the value of lost emissions and the capacity for carbon absorption due to smallholder oil palm plantation activities on peatlands. This will be a new alternative perspective in supporting low carbon development and mitigation plans to reduce carbon emissions in the peatland sector due to smallholder oil palm plantations.

MATERIALS AND METHODS

The research was carried out using an exploratory descriptive approach with the aim of knowing the value of carbon emissions and the carbon absorption capacity of smallholder oil palm plants on peatlands. So it becomes a basis for consideration in mitigation efforts to reduce carbon emissions in the peatland sector due to smallholder oil palm plantations. The research was conducted on People's Palm Oil Plantations on peatlands in Riau Province from August 2022 to August 2023.

The primary data collected were (1) emission values due to changes in peat land cover and peat decomposition in smallholder oil palm plantations; and (2) carbon absorption value from the ability of smallholder oil palm plants to absorb carbon. Data collection was carried out using spatial analysis and field surveys. Data types and data collection techniques are presented in Table 1.

Table 1. Types and Techniques of Data Collection

Indicator	Collected data	Data collection technique
Value of Carbon Emissions in the Peat Land Sector due to Community Oil Palm Plantations	▪ Land Cover 1990-2020 ▪ Peat Hydrological Unit	Spatial Analysis
	▪ Peatland CO2 emission values	Field measurement survey with a CO2 Gas Analyzer using a closed hood technique
Carbon Absorption Value of Smallholder Oil Palm Plantations on Peatlands	▪ Diameter of oil palm plants ▪ Height of oil palm plants ▪ Plant Age	Field measurement surveys and interviews

The calculation of the amount of CO2 emissions is carried out to find out how much CO2 emissions are produced from peatlands. The amount of CO2 emissions was obtained based on an overlay of data on the distribution of peatlands and the condition of plantation land cover in 1990-2020. Changes in land cover on peatlands have CO2 emission factors determined by the Ministry of Environment and Forestry and the IPCC (2006). This data is used to determine the amount of CO2 emissions, as well as analyze the ability of oil palm plantations to absorb CO2 emissions.

Data on peat emission levels in oil palm plantations was also measured using the closed chamber method using a CO2 Gas Analyzer and a closed hood. Determination of sampling locations was carried out using a purposive sampling technique by representing the age characteristics of oil palm plants on peatlands consisting of: (1) Immature Plants (TBM) with an age of 1 – 4 years; (2) Producing plants aged 5 – 20 years; with a total sampling location of 9 stations.

Data analysis was carried out using several techniques consisting of spatial analysis techniques and descriptive analysis. Spatial analysis was carried out to obtain a characteristic mapping of the condition of the area and distribution of oil palm plantations on peatlands in the period 1990-2020. Spatial analysis was carried out using a Geographic Information System (GIS) in the form of ArcGIS. Descriptive analysis was carried out to describe the level of emissions and carbon absorption capacity of smallholder oil palm plantations on peatlands.

Emission level analysis was carried out using 2 approaches, namely a land cover change-based approach and a peatland emission measurement approach. The results of the analysis of emission values will be compared with the carbon absorption capacity of oil palm plantations based on differences in plant age and changes in land cover in 1990-2020. Activity data is data regarding the amount of activity related to the amount of carbon emissions released. Emission-producing activity data for the land sector is changes in land cover on oil palm plantations. Meanwhile, the emission factor (FE) is a coefficient that shows the amount of emissions per unit of activity. The emission factors used are the default emission factors (IPCC 2006) which have been developed by the Ministry of Environment and Forestry and Bapenas in determining the Indonesian Emission Factors Data Base (Agus et al., 2013). The emission factor for calculating CO2 emissions on land is calculated based on a comparison of changes in land cover classes and potential carbon stock values.

The calculation of carbon absorption capacity is carried out based on measuring the biomass value of coconut plants using a non-destructive method using the allometric equation. According to Haruni et al. (2012), the allometric equation model is in the form of W =0.0976 H + 0.0706orW = 0.00238 D2.3385 H0.9411, where W is biomass weight (kg), D is diameter at breast height (cm), and H is plant height (m). Carbon reserves are calculated using a plant biomass coefficient approach of 0.50 (IPCC, 2006; Forestry Research and Development Agency, 2010). After obtaining the value of stored carbon reserves (carbon stock), CO2 absorption was then analyzed as 3.67 of the value of carbon reserves (IPCC, 2006; Thenkabail et al., 2011).

The findings of carbon emission and carbon absorption values in smallholder oil palm plantations on peatlands will be analyzed further descriptively. This is needed to getbasic considerations and formulating mitigation efforts that need to be carried out to reduce carbon emissions in the peatland sector due to smallholder oil palm plantations.

RESULTS AND DISCUSSION

Analysis of carbon emission levels is calculated based on an approach to changes in the value of carbon reserves lost due to changes in land cover to oil palm plantations and the results of measuring carbon emissions on peatlands.

Analysis of Carbon Emissions from Smallholder Palm Oil Plantations on Peatlands Based on Land Cover Changes

The results of the spatial analysis found that there had been an increase in the area of oil palm plantations from 316,452.03 ha in 1990 to 1,897,194.43 ha in 2020. This transfer of function occurred in many types of land cover. This causes a decrease in the total value of carbon reserves due to the use of oil palm plantations in Riau Province. The total value of carbon reserves lost was 87,112,243.5 tons or 45.9 tons C/Ha. When compared with the duration of land cover used during 1990-2020, the rate of increase in CO2 emissions due to the conversion of peat land is 5.62 tonnes of CO2/ha/year. The results of the analysis of changes in carbon stocks based on land cover are presented in Table 2.

Table 2. Carbon Emission Values based on Changes in Peat Land Cover

d Cover Types	Extent of Change Land Cover Becomes Plantation Year 1990-2020 (Ha)	Total Changes in Carbon Stocks Year 1990-2020 (Ton C)	lark Changes in Carbon tocks ear 990-2020 Tons C/ha)
Primary Swamp Forest	31.74	7,390.2	.0
Secondary Swamp Forest	7,092.41	,012,501.6	[illegible]
Secondary Dryland Forest	16.71	9,151.7	.0
Secondary Mangrove Forest	34.57	,770.5	[illegible]
Plantation Forest	3.32	8.3	

d Cover Types	Extent of Change Land Cover Becomes Plantation Year 1990-2020 (Ha)	Total Changes in Carbon Stocks Year 1990-2020 (Ton C)	Mark Changes in Carbon Stocks Year 1990-2020 (Tons C/ha)
Open field	5.25	423.3	
Settlement	38	73.8	
Plantation	452.03		
Mining	72	52.3	
Dryland farming	00.88	5,546.8	
Mixed Dry Land Agriculture	23.27	4,367.9	
Swamp	72	72.9	
Ricefield	752.21	3,884.6	
Thicket	28.96	555.6	
Swamp Thicket	195.21	0,442.0	
Pond	72	52.3	
Waterbody	5.51	237.2	
Amount	**7,194.43**	**12,243.5**	**0**
CO2 emissions from the conversion of peatlands to oil palm plantations (ton CO2/ha/year)			

The decrease in the value of carbon reserves is due to the presence of forested land cover types such as primary swamp forests, secondary swamp forests, secondary dry land forests, primary mangrove forests, secondary mangrove forests and plantation forests that have been converted into plantations. Clearing land for plantations will cause the loss of vegetation and change to oil palm.

The loss of forest vegetation causes a decrease in the value of carbon stocks (Tacconi & Muttaqin, 2019). The emission factor for the value of carbon stocks in forested land cover is greater than in oil palm plantations. So the conversion of forests into plantations causes a reduction in the value of carbon reserves. The value of lost carbon stocks is the value of emissions released due to changes in land cover.

Changing the function of land cover can also provide an increase in carbon stocks. This happens if the type of non-forest land cover becomes plantations. The types of non-forest land cover include open land, settlements, plantations, mining, dry land agriculture, mixed dry land agriculture, swamps, rice fields, thickets, swamp thickets, ponds and water bodies. Land use for oil palm plantations causes an increase in oil palm vegetation types on non-forest land cover. So the emission factor for the value of carbon stocks in oil palm plantations is greater than in non-forest areas (IPCC, 2006). Each oil palm vegetation has a carbon reserve value that continues to increase as it grows.

The value of carbon stocks differs according to the condition of land cover and vegetation above it. Factors that determine the value of soil surface carbon stocks are the quantity, quality and distribution of biomass above it. Biomass is influenced by the type, amount and age of vegetation. The loss of vegetation above the ground surface will determine the magnitude of the loss of carbon stock values (Situmorang et al., 2016). The loss of vegetation land cover followed by the replacement of new vegetation types in an area will result in differences in the values of carbon release and absorption. The carbon lost is the value of the emissions released. Meanwhile, the addition of carbon value is the capacity to absorb carbon emissions.

Analysis Of Peatland Carbon Emissions In Palm Oil Plantations Based On Field Measurement Results

The emission value of oil palm plantations on peatlands is also seen through measuring CO2 values. The results of measuring CO2 values show that the average value of CO2 emissions in peatlands ranges from 16.36 – 41.27 tons of CO2/ha/year. This value is relevant to several previous research results which revealed that the value of CO2 emissions in oil palm plantations on peatlands ranges from 18-66 tons/ha/year. The research results of Agus et al. (2010), revealed that CO2 emissions from oil palm plantations in non-rhizosphere areas range from 18-24 tonnes/ha/year, while in rhizosphere areas range from 29-39 tonnes/ha/year. Non-rhizosphere CO2 emissions are a reflection of the value of CO2 released from the peat decomposition process. According to Putri et al. (2016) revealed that non-rhizosphere CO2 emissions in oil palm plantations can be measured in the middle part between oil palm plants. The minimum distance of the measurement point is 4.5 meters from the plant stem. The decomposition value ranges from 21.90 - 56.06 tonnes/ha/year.

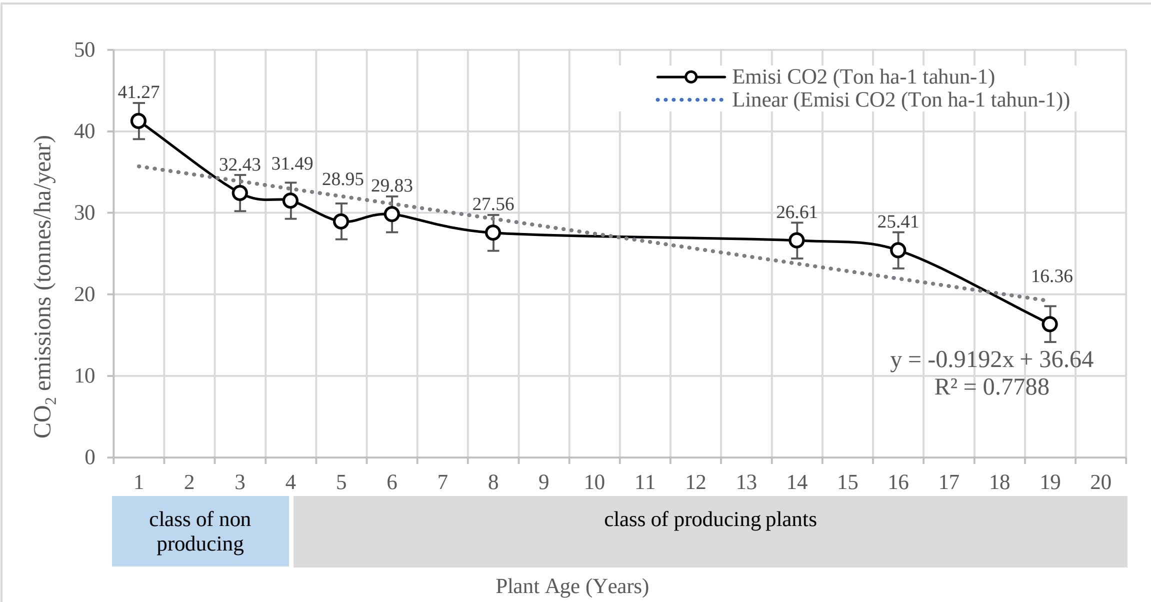

Figure 1. Peatland CO2 Emission Value based on the Age of People's Oil Palm Plants

The value of CO2 emissions from peatlands in smallholder oil palm plantations is different at each measurement location. The difference in these values can be viewed based on the age of the oil palm plant. The CO2 emission value decreases as the plant ages. The highest overall emission values are at TBM locations for oil palm plantations on peatlands. The research results revealed that the high emission value in TBM was caused by the condition of the land being open due to land clearing. Open land does not have peatland vegetation cover. So the peat decomposition process will occur more quickly. This is proven by the smaller CO2 emission values in the Producing Plants class. Produce crops have experienced additional land cover through the fronds and leaves of oil palm plants. According to Yudistina et al. (2017), along with increasing age, oil palm plants will experience vegetative growth which is characterized by an increase in plant diameter and height as well as an increase in the number and length of fronds. The fronds in the mature plant age class are longer than those in the immature plant age class.

The carbon emission value is related to the age of the oil palm plant. As the age of oil palm plants increases, peatland carbon emission values tend to show lower values. The use of peat land for oil palm plantations can affect the value of emissions released. Several research results reveal that carbon emission values can be influenced by changes in land cover in an area. According to Dewa et al. (2019) the reduction of forest vegetation to non-forest such as plantations triggers the loss of carbon absorption capacity and stored carbon reserves, thereby increasing carbon emissions. Changes in peatland cover also trigger the peat decomposition process and release carbon. According to Wakhid (2018), the change in forest land cover to oil palm causes an acceleration of the peat decomposition process. The decomposition process is one of the mechanisms for releasing peat carbon emissions. According to Ouyang et al., (2022) the process of releasing carbon in peatlands can occur from plant root respiration, peat decomposition, or carbon dissolved in water.

Various research results reveal that carbon emissions in peatlands can be caused by various factors, including the biophysical conditions of the peat such as peat depth, peat maturity, groundwater level (TMAT) and land cover conditions. Each of these factors contributes to the rate of peat decomposition and carbon emissions. The characteristics of peat in an area can produce various dynamic patterns of the relationship between decomposition rates and carbon emissions. Wakhid's research results (2018) found that the main factor influencing peat decomposition is TMA, where every year the average TMA decreases by 0.1 m can result in additional peat decomposition of 154 gr C/m2/year. According to Ayushita et al., (2021), the higher the pH, the greater the CO2 emissions produced, where peat pH can influence the emission value by 91.41%. The level of peat maturity can influence the value of CO2 emissions, where peat with a fibric maturity level has the highest average CO2 emissions compared to hemic and sapric maturity levels. Peat with a sapric maturity level has an effect on reducing the value of CO2 emissions in peatlands.

Analysis Of Carbon Uptake Of People's Palm Oil Plantations On Peatlands

Analysis of carbon uptake levels is measured to determine the ability of oil palm plants to reduce CO2 emissions. Carbon uptake analysis is calculated based on the presence and growth of oil palm plants. Results of analysis of CO2 absorption valuesOil palm plants on peat land are presented in Table 3.

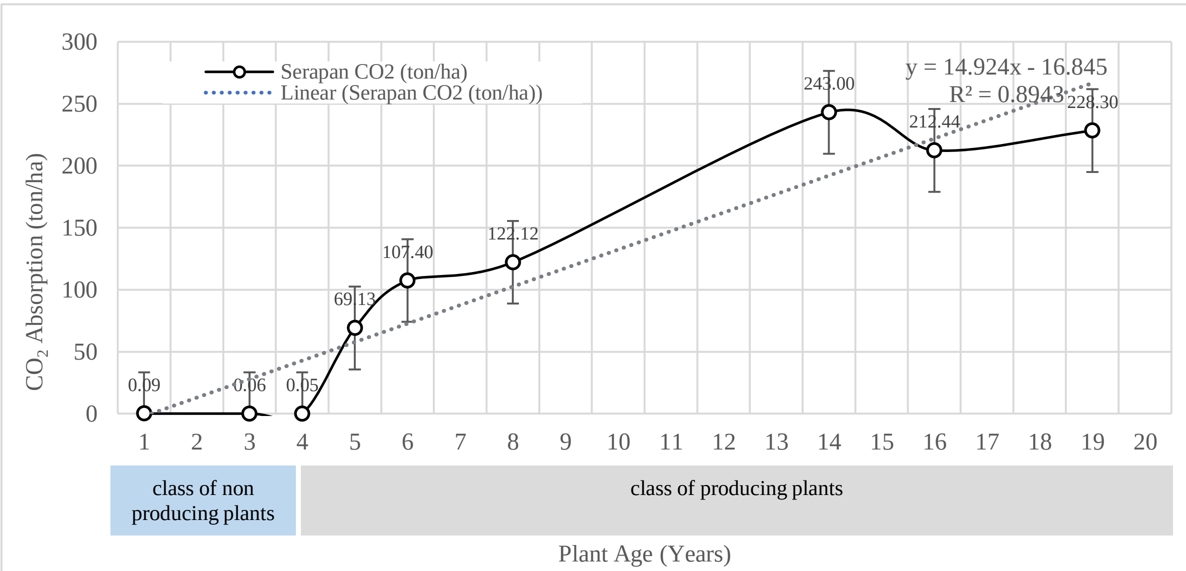

Figure 2. CO2 Uptake of Oil Palm Plants on Peatlands based on Plant Age

CO2 uptake values show a tendency to increase with increasing plant age. However, there are fluctuations in CO2 uptake values that occur specifically, such as when the plant is 16 years old, it decreases and increases again at the age of 19 years, as shown in Figure 15. These fluctuations are caused by variations in the distribution of plantations and peatlands at the research location. CO2 uptake measured at representative plant ages is distributed in various different plantation locations, so they have varying peatland characteristics and oil palm plant growth rates.

The older the plant, the greater the accumulation of carbon uptake. The large accumulation of carbon uptake will increase the value of carbon reserves stored in plants. Oil palm plants have the ability to absorb CO2. Henson's research results in Afandi et al. (2017) revealed that in the process of photosynthesis (assimilation) oil palm absorbs around 161 tonnes of CO2/ha. According to Hairiah and Rahayu (2007) carbon reserves in a land use system are influenced by the type and amount of vegetation. Each type of plant has a different carbon uptake capacity.

Factors that influence the carbon uptake capacity of each plant are the morphology, anatomy and physiology of a plant type. Based on the number, species that have high density values will have higher biomass compared to land that has species with low density values. Other factors that influence the carbon absorption capacity of oil palm plantations on peatlands are the type of seeds, biophysical conditions of the land and management patterns of oil palm plantations such as maintenance techniques and water management in peatlands. According to Ashraf et al. (2017) maintenance and fertilization activities can affect the growth and biomass of oil palm plants. Meanwhile, according to Veloo et al. (2015) factors that influence plant growth are the biophysical characteristics of the land.

The immature plant (TBM) class has lower carbon reserve and uptake values compared to the mature plant class. The increase in the value of carbon reserves in each plant age class is caused by plant growth, thereby increasing the value of plant biomass. The higher the value of plant biomass, the higher the value of carbon reserves. The increase in plant biomass is in line with plant growth and development which is influenced by the ability to absorb carbon (CO2) and photosynthesis. According to Rachdian et al. (2018), a significant increase in carbon stocks occurred in the age class 5 years to >10 years. This is because in this age class oil palm plants experience optimal growth and development. Meanwhile, according to Sabiham (2013), carbon reserves have increased significantly at around the age of 10 years. Biomass will increase until a certain age by increasing the diameter and height of the plant, and then the increase in biomass will decrease until it finally stops and dies.

Plant growth can be influenced by various factors, including the physical and chemical conditions of the land. Coastal peat and transitional peat are generally classified as more fertile than inland peat. This is because the source of nutrients in inland peat only comes from rainwater, whereas in coastal and transitional peat it is still influenced by tidal fluctuations in river and sea water. Tidal water fluctuations will carry and leave nutrients in the peat layer so that it has a higher accumulation of nutrients. Nutrients are needed for plant growth. According to Radjagukguk (1997) peat in Indonesia is generally classified as mesotrophic and oligotrophic. Eutrophic peat is found in coastal areas and along river routes. Eutrophic peat has a high level of fertility. The level of fertility is determined by the mineral content. According to Wahyunto et al. (2004) Peat in the coastal region of Sumatra is relatively more fertile compared to peat in Kalimantan.

Mitigation Of Reducing Carbon Emissions In The Peat Land Sector On Palm Oil Plantations

The research results found an important factor as a source of carbon emissions from smallholder oil palm plantation activities on peatlands, namely the function of peatlands for opening oil palm plantations. The largest source of emissions occurs in the Immature Plant phase with an age of 0 – 4 years. There are 3 alternative interventions that can influence the mitigation scenario for reducing carbon emissions. The intervention consists of a moratorium policy on stopping the opening of oil palm plantations on peatlands, regulating oil palm planting patterns, and implementing Legume Cover Crop (LCC) on immature plants.

A moratorium is a government policy regarding delaying and stopping the granting of permits for opening new land. The moratorium on stopping the granting of permits for new land clearing is also applied to oil palm plantations. According to Isnan (2018), the peat land moratorium policy can be used as a strategic step to reduce the rate of carbon emissions due to peat land clearing. This moratorium implementation scenario was adopted for smallholder oil palm plantations on peatlands. The scenarios developed consist of: (1) baseline scenario (no effort), if the moratorium is not implemented (0%), so that peatlands can still be converted into land use; (2) fair scenario, if the moratorium policy can only be implemented on 50% of the total peat land currently available; and (3) an ambitious scenario, if the moratorium policy can be applied to all peatlands (100%) or there are no new peatland clearing activities for oil palm plantations.

Alternative planting patterns are carried out by regulating the number of plant densities. Every oil palm plant has the ability to absorb carbon. The greater the number of plants, the greater the carbon absorption capacity. Planting pattern scenarios were developed based on oil palm planting distances consisting of: (1) baseline scenario (without effort), if the number of plants is 145 trees/hectare, namely with a planting distance of 9 meters with a five-eye pattern; (2) fair scenario, if the number of plants is 180 trees/hectare, namely with a planting distance of 8 meters with a five-eye pattern; and (3) an ambitious scenario, if the number of plants is 200 trees/hectare, namely with a planting distance of 7 meters in a square pattern.

Alternative application of Legume Cover Crop (LCC) in the Immature Plant age class. LCC is a legume or nut plant that is planted in plantation areas with the aim of covering open soil surfaces. LCC planting generally functions to prevent damage and improve the physical and chemical properties of the soil. According to Pramuhadi et al. (2020) planting LCC in oil palm plantations can suppress weed growth, reduce erosion by rain, and reduce evaporation from peatlands. LCC planted on the surface of peat soil also plays a role in absorbing and storing carbon, thereby reducing emissions from peat decomposition (Ahmad, 2018).

According to the IPCC, land planted with grass has the capacity to store carbon of 4 tons C/ha or the ability to absorb CO2 of 14.68 tons CO2/ha. Even though it is relatively small, LCC can reduce carbon emissions in oil palm plantations during the immature plant phase.

Implementation of the low-carbon smallholder oil palm plantation program can be realized through multi-stakeholder collaboration between government and non-government elements. Each party has a different role but strengthens each other and becomes one unit in supporting the mitigation target of reducing carbon emissions in the peatland sector on smallholder oil palm plantations in Riau Province. According to Wardhani et al. (2021) sustainable management of oil palm plantations can be realized through multi-stakeholder collaboration consisting of the government and business actors. According to Darmawan et al. (2021) the target of achieving carbon emission reduction is a shared responsibility and therefore requires public commitment and participation consisting of the bureaucracy, private sector and community support.

CONCLUSION

The research results found that carbon emissions from smallholder oil palm plantations on peatlands have increased every year along with the rate of additional opening of new plantations. The largest carbon emissions occur in the immature plant age class. As the age of oil palm plants increases, the value of peatland carbon emissions tends to decrease, while the value of carbon absorption increases. Reducing emissions and increasing carbon uptake is influenced by land cover conditions in oil palm plantations. During the immature plant period, the land cover becomes open, resulting in greater carbon emissions released during peat decomposition. As the age of the plant increases, land cover has increased due to the growth of oil palm plants. Based on the complexity of these conditions, mitigation efforts to reduce carbon emissions can be carried out through a moratorium policy on stopping the opening of new oil palm plantations, regulating the density of oil palm plants and implementing Legume Cover Crop on immature plants. Implementation of the low-carbon smallholder oil palm plantation program can be realized through multi-stakeholder collaboration between government and non-government elements. Each party has a different role but strengthens each other and becomes one unit in supporting the mitigation target of reducing carbon emissions in the peatland sector on smallholder oil palm plantations in Riau Province.

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