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The Estimation of Carbon Stocks on Palm Oil Plant (*Elaeis guineensis* Jacq) in Smallholder and State Plantation in Indonesia

Mardiana Wahyuni[a*], Aulia Juanda Djaingsastro[b], Marshal Arifin S.[c]

[a,b,c]*Plantation, STIPER Agrobisnis Perkebunan (STIPAP), Medan, Indonesia Jl. Williem Iskandar Medan 20000 Sumatera Utara, Indonesia*

[a]*Email: mardiana.wahyuni59@yahoo.co.id,* [b]*Email: aulia_juanda@yahoo.com,* [c]*Email: marshal_arifinsinaga@gmail.com*

Abstract

Palm oil plantations have a very important role for the Indonesian economy. The area of palm oil plantation in 2014 is 10.9 million Ha consisting of Smallholdings 4.55 Million Ha (41.55%), State Plantation (Plantation owned by the government) 0.75 Million Ha (6.85%) and Private Plantation 5.66 Million Ha (51.62%). Plantation land generally comes from deforestation and peat land use. As the results, it's faced with the potential to damage the environment, increasing of global temperature (global warming) due to the increasing of CO_2 emissions (Greenhouse Gas). The understanding that the development of palm oil plantations can still contribute positively is done by the measurement of carbon estimation that can be stocks in a stand (Above Ground Biomass). This research aimed to provide data or information about stocks carbon of palm oil plantation in smallholdings and state plantations. The research was conducted from May to July 2016 in Karang Gading Village for Smallholder Plantations and at Perkebunan Nusantara III Inc. (PTPN III) Sei Putih Estate, Galang Deli Serdang, Sumatera Utara. The research method is mainly guided by [8] carbon measurement. The research results showed that the most biomass found was in old plants that is 153.950 Ton Ha^{-1} in Smallholder Plantations and 220.713 Ton Ha^{-1} in PTPN III (143%). Carbon stocks in adult plants at Smallholder Plantation is 61.533 Ton Ha^{-1} and in PTPN III is 93.417 Ton Ha^{-1} (152%). The highest CO_2 total absorption in old plants at PTPN III is 372.608 Ton Ha^{-1} with environmental service value as much as 1702.82 USD.

Keywords: Above Ground Biomass; Carbon; Carbon dioxide; Elaeis guineensis Jacq.

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* Corresponding author.

1. Introduction

1.1. Palm Oil Plantation

Palm oil plantations have a very important role for the Indonesian economy. The area of palm oil plantation in 2014 is 10.9 million Ha consisting of Smallholdings 4.55 Million Ha (41.55%), State Plantation (Plantation owned by the government) 0.75 Million Ha (6.85%) and Private Plantation 5.66 Million Ha (51.62%) [5]. The use and change of land especially deforestation and peat land use in tropical areas have a significant impact on one of greenhouse gases emission (CO_2) which causing global warming. Global climate changes occur due to the disruption of the energy balance between the earth and the atmosphere. The balance is affected by the increase of Carbon Dioxide (CO_2), Methane (CH_4) and Nitrogen Oxide (N_2O) known as greenhouse gas (GHG) [8].

1.2. Carbon Absorption

In photosynthesis, palm oil will absorb CO_2 from the air and release O2 [4]. This process will continue throughout its growth and development. Palm oil plant in 1 cycle is economically cultivated for 25 years. In the process of photosynthesis palm oil absorbs about 161 Ton CO_2 Hectares^{-1} Year^{-1}. When subtracted by the absorbed CO_2 in the respiration process then as a net palm oil absorbs CO_2 of 64.5 Ton CO2 Hectares^{-1} Year^{-1} [9]. The net uptake of CO_2 from palm oil exceeds the ability of tropical rain forests that are equivalent to absorbing 42.4 tons of CO_2 Hectares^{-1} Year^{-1}. Palm oil is able to absorb more than 80 tons of C Ha^{-1}. The amount is achieved after the plants are aged 10-15 years. In general the average absorption is 60.4 Ton Ha^{-1} or 2.44 Ton C Ha^{-1} Year^{-1} is equivalent to 8.95 Ton CO_2 ha^{-1} Year^{-1} [11]. The understanding that the development of palm oil plantations can still contribute positively is done by the measurement of carbon estimation that can be stored in a stand (Above Ground Biomass) on smallholder plantations and/or large plantation companies. This research aimed to provide data/information on Carbon stocks in palm oil plantations at Deli Serdang as one of the center production of palm oil in Sumatera Utara-Indonesia

2. Materials and Methods

2.1. Place and time of research

The research was conducted from May to July 2016. Samples measurement for smallholder plantations is done in Karang Gading Village Labuhan Deli, Deli Serdang District. Karang Gading Village is a coastal village with 1500 ha of palm oil area consists of 800 ha smallholder plantations and 700 ha of private plantations. Observation for State Plantations is done in block F15 and H15 Afdeling III Sei Putih Estate, Perkebunan Nusantara III Inc. Kecamatan Galang, Deli Serdang. This research is specifically done on mineral soil with good climatic conditions, in the field of S2 (good / suitable land)

2.2. Tools and materials

The tools used in this research are Global Position System (GPS), compass, meter, plastic strap, machetes,

scales, oven and other small tools. The materials used are the plant/stand of palm oil and lower plants i.e. a mixture of legume cover crops and weeds that are on plantation land.

2.3. Research methods

The research design used in this research was descriptive design by measuring Non Destructive for Stacked Biomass and measuring Destructive for Below Ground Biomass (Above Ground Level). The research's observation was adjusted to the age group/phase of palm oil i.e. Young Plants (3-8 years), Adolescents (9-14 years), Adult Plants (15-20 years), and Old Plant (>20 years). Smallholder Plantation has all of group age and in PTPN III only has 2 group age i.e. adult and old plants.

2.4. Research Stage

The research stages with the determination of the sample are as follows [7]:

a. Biomass estimation of palm oil plantation

- The plot is made with a size of 20 m x 60 m (1,200 m2) with 2 times replication and is selected at the representative spot.
- The area is measured, stacked with bamboo and rope mounted.
- Measuring the height of palm oil stands contained in the plot is on Frond No.17. Data used to measure Above Ground Biomass for palm oil crops with the following formula [8].

AGB = 0.0706 + 0.0976 H (Ton $Tree^{-1}$)

AGB = Above Ground Biomass

H = Stand Height (m)

Observation data is converted to an area of 1 Ha (10000 m^2)

- Bottom plant sampling is taken from 6 points each of 1m x 1m = 1m^2 from inside a large plot with 2 times replication (12 m^2 total). Bottom plants taken are herbs, legume cover crops, grasses in the quadrant. From the sample obtained, 100g is dried by the oven 80^o for 2 x 24 hours.

$$\text{Total Dry Weight} = \frac{\text{Subsample Dry Weight}}{\text{Subsample Gross weight}} \text{x Total Gross weight}$$

b. Measurement of Carbon Storage Potential

Carbon Storage Potential (Ton Ha^{-1}) = (Above Ground Biomass + Below Ground Biomass) x 0.46. Biomass observation data used is data that has been converted to 1 ha (10.000 m^2)

c. CO_2 Measurement

Calculated based on conversion number i.e. $CO_2 = C \times 3.67$

d. Environmental Services Value

The carbon price used is 5.8 USD Ton^{-1} CO_2 which is reduced by the transaction costs (administrative, monitoring and verification process) as much as 1.23 USD so that the Environmental Services Value is 4.57 USD ton^{-1} CO_2 [1] [3].

3. Result and Discussion

3.1. The Cultivation of Smallholder Plantation and State Plantation

The cultivation of smallholder plantations generally uses illegitim planting materials / seedlings. Smallholder farmers generally do not prioritize the seeds due to the lack of information about productivity, lack of funding and lack of access to obtain original seeds. Fertilization is very minimal and not scheduled. Density per hectare is 150 trees (Planting distance 8.8 m equilateral triangle). The management of the state plantations uses seeds from Pusat Penelitian Kelapa Sawit Medan (Palm Oil Research Center in Medan), the density is 130 trees/hectare and the dose of fertilizer in the yielding plant phase was [10]:

Table 1: Dose of Fertilization in Large State Plantations

Semester	Urea	TSP	KCL	Kieserit	Total
I	1,00	0,50	0,75	0,50	2,75
II	1,00	0,75	0,75	0,75	3,25
Total/years	2,00	1,25	1,50	1,25	6,00

Description: Dose Kg $tree^{-1}$.

3.2. Above Ground Biomass

Above Ground Biomass observation results are:

The average height of palm oil plantation in PTPN III is 43-112% higher than that of plantation in Smallholder. Above Ground Biomass of palm oil palm trees in each age class continues to increase with the most biomass present in older plants i.e. 148.950 Ton Ha^{-1} in Smallholder and 212,983 Ton Ha^{-1} in PTPN III.

The growth of palm oil plant is influenced by several factors, namely land condition, soil fertility, management (type of plant, fertilization, pest control) and other factors. The better the management system, the more biomass production increases. The increase in palm oil biomass in state plantations is 43-53% higher than in smallholder

plantations. The greater the biomass then the carbon stock/CO2 fixation potential also increases [12].

Table 2: Above Ground Biomass Observation Results.

Phase	Age (years)	Smallholder			PTPN III		
		stand height average (m)	Biomass Sample (Ton)	Biomass (Ton Ha^{-1})	stand height average (m)	Biomass Sample (Ton)	Biomass (Ton Ha^{-1})
Young	3-8	1,01	7,098	29,574	*	*	*
Adolescent	9-14	3,33	15,440	64,333	*	*	*
Adult	15-20	5,35	30,857	128,487	11,36	47,173	196,550
Index (%)		(100)	(100)	(100)	(212)	(153)	(153)
Old	>20	8,67	35,748	148,950	12,40	51,116	212,983
Index (%)		(100)	(100)	(100)	(143)	(143)	(143)

Description: 2.400 m² Sample, *No Observation, Smallholder Plantation is as control with 100% index.

3.3. Below Ground Biomass

The below ground biomass are consist of shrubs that are less than 5 cm in stem diameter, creeping plants, grasses or weeds. On a smallholder plantation consists of *Ageratum conycoides, Asystasia intrusa, Mimosa pudica,* and *Melastoma afines.* In state plantations routinely carried out weed control, existing weeds are *Micania micranta* and *Asystasia intrusa*.

Table 3: Below Ground Biomass Observation Results.

Phase	age (year)	Smallholder		PTPN III	
		Sample (ton)	Ton Ha^{-1}	Sample(ton)	Ton Ha^{-1}
Young	3- 8	0,004392	3,660	*	*
Adolescent	9-14	0,005040	4,200	*	*
Adult	15-20	0,006336	5,280	0,007836	6,530
Index(%)			(100)		(123)
Olde	>20	0,006000	5,000	0,009276	7,730
Index(%)			(100)		(154)

Description: Sample=12m^2, *No Observation, Smallholder Plantation is as control with 100% index.

The results of below ground biomass observations are not always increasing at every age of the plant. The below ground biomass found in the state plantations is 23% more in adult plants and 54% in older plant. The difference is influenced by the penetration of sunlight to the base of an ecosystem, as the affect is the types of plants/vegetation below can live properly. The fertilization in PTPN is also stimulated the growth of below ground plants.

3.4. Carbon Storage Potential

The observed results of carbon storage potential are:

Table 4: Observations of Stored Carbon

Phase	Age (Year)	Smallholder				PTPN III			
		Above Ground Biomass	Below Ground Biomass	Total	C	Above Ground Biomass	Below Ground Biomass	Total	C
Young	3- 8	29,547	3,660	33,207	15,275	*	*	*	*
Adolescent	9-14	64,333	4,200	68,533	31,525	*	*	*	*
Adult	15-20	128,487	5,280	133,767	61,533	196,550	6,530	203,080	93,417
Index (%)				(100)	(100)			(152)	(152)
Old	>20	148,950	5,000	53,950	70,817	212,983	7,730	220,713	101,528
Index (%)				(100)	(100)			(143)	(143)

Description: C = (AGB + BGB) x 0,46(Ton ha^{-1})

Carbon stocks showed an increasing from young to old age groups. The observation in PTPN showed an increasing at 52% and 43% in the age group of adult and old. Palm oil plants are able to store >80 Ton C Ha^{-1} after 10-15 years old with the average of 2.44 Ton C Ha^{-1} $Year^{-1}$ or 8,95 Ton CO_2 Ha^{-1} $Year^{-1}$ [11]. In smallholding plantation the amount of C stocks in adult plants is 61.533 Ton which means 77% compared to standard 80 Ton C Ha^{-1} [11]. The unavailability of carbon stocks in biomass is caused by some factors such as low quality seedlings and low plant maintenance.

Adult plants which cultivated in PTPN III are able to store C for 93.417 Ton (17% above standard/80 Ton C). 14-15 years old palm oil plant (adult) has storage C value for 68.85 Ton Ha^{-1} [12]. The observation value in this research is at a reasonable level. The highest of carbon stocks potential is in 11-15 years palm oil plant, i.e. 69.32 Ton Ha^{-1} [17].

The carbon stocks potential of the agro-forestry system is based on the assumption that tree components can determine the carbon uptake in the atmosphere significantly through the rate of growth and productivity. The ecosystem's complexity will affect the speed time of carbon cycle which through of its component. Total

potential of stored stocks in old rubber plants (*Hevea brasiliensis* Muell) (21-25 years) reported by Djaingsastro [6] is 36.35 Ton Ha^{-1} in smallholder plantation and 42-98 Ton Ha^{-1} in PTPN III [6].

Above and below surface of old palm oil plant carbon stocks is 60 – 100 Ton Ha^{-1} [16]. Thus the observational data of the research are within the range. Carbon stocks value in primary forest is 214. 234 Ton Ha^{-1}, swamp forest 109.540 Ton Ha^{-1} [15]. Thus a well-managed palm oil plantation capable of storing C for 101.528 Ton Ha^{-1} equal to C stocks in swamp forest.

3.5. Environment Service Value

CO_2 uptake and Environment Service Value Calculation are listed in Table 5.

Table 5: CO_2 uptake and Environment Service

Phase	Age (Year)	Perkebunan Rakyat			PTPN III		
		C Storage	CO_2 Uptake	Total Environment (USD)	C Storage	CO_2 Uptake	Total Environment (USD)
Young	3- 8	15,275	56,059	256,190	*	*	*
Adolescent	9-14	31,525	115,697	528,730	*	*	*
Adult	15-20	61,533	225,826	1.032,020	93,417	342,840	1.566,780
Old	>20	70,817	259,898	1187,73	101,528	372,608	1.702,820

Description: CO_2 = C x 3.67 (C and CO_2 in Ton Ha^{-1}) : Environment Service = Ton C x USD 4.57

Assuming using the exchange rate of 13.000 IDR in 2016 then the value of environmental services of adult plants in smallholder plantations is 13.416.260 IDR and 20.368.140 IDR in PTPN III.

The development of palm oil plantations that poses many challenges at home and abroad; especially America and Europe as the cause of deforestation, turns out to show their ability to absorb CO_2, resulting in high biomass equal to swamp forest's C stocks.

With a good management system, palm oil crops have contributed to the environment in reducing greenhouse gas emissions which causing global warming.

4. Conclusion

- Most biomass is found in old plants that is 153.950 Ton Ha^{-1} in smallholder plantation and 220.713 Ton Ha^{-1} in state plantations with 43% difference.
- Carbon stocks in smallholder plantations in adult plants is 61.533 Ton Ha^{-1} and PTPN III is 93.417 Ton

Ha^{-1}, the highest total CO_2 uptake is found in old plants cultivated in state plantation (PTPN III) which is 372. 608 Ton Ha^{-1} with a 52% difference.

- Palm Oil Plantations provide an environmental service with the highest value from old plants in PTPN III as much as 1702.82 USD.
- The development of oil palm plantations is expected to provide economic benefits while maintaining the environment. It is advisable to apply good agriculture practices so that oil palm plants can keep carbon stocks well enough and able to reduce greenhouse gas emissions.

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