IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 13, Issue 8 Ser. II (August 2020), PP 26-31
www.iosrjournals.org

Water Deficit and Carbon Absorption of Oil Palm Plants (*Elaeisguineensis*Jacq)

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Abstract: *The expention of oil palm plantations needs to pay attention to the suitability of land consisting of aspects of location, physical and chemical characteristics of the soil and also agro-climate. Carbon absorption is influenced by the quantity of water hence the process of photosynthesis can form biomass optimally. This study aims to measure carbon (CO_2) absorption of 10-year-old oil palm plants. Above ground Biomass is done by non-destructive measurement (estimation) method and Button-ground biomass using gravimetric method. Water balance is processed from rainfall data to calculate the water deficit value. Rambutan Estate have an average water deficit of 324 mm/year (heavy category), the total biomass is 82,938 tons/ha and CO_2 absorption is 140 tons/ha. In the Bah BirungUlu Estate, the value of rainfall exceeds evaporation, water deficit is very low, biomass is formed as much as 107,220 tons/ha, 29% higher with CO2 absorption as much as 181.1 tons/ha.*

Keywords*: Palm oil, water deficit, above ground biomass, button ground biomass, carbon absorption.*

Date of Submission: 07-08-2020 Date of Acceptance: 21-08-2020

I. Introduction

Palm oil is a plantation crop that plays an important role as a source of income, employment, fulfillment of domestic cooking oil consumption and a mainstay of non-oil and gas exports for Indonesia. According to the Ditjenbun [1], the expansion area of oil palm cultivation continues to increase and in 2016 the area was ± 11.6 million ha.

Land suitability class is a quantitative method of evaluating the elements that affect the growth and productivity of oil palm plants which includes location, soil physical and chemical properties and agro-climate conditions [2]; [3]. Planting oil palm on suitable land is expected to be able to achieve an economic life cycle of 25-30 years. The important influential climate element is rainfall which includes the amount of rainfall, its distribution and the balance value to calculate the balance or whether there is a water deficit.

Global warming is one of the important environmental issues of concern because of the increasing pollution caused by several causes including, the industrialization that is growing rapidly, increasing population, declining land coverage due to various human needs including food needs and deforestation due to replacement with various kinds of plants including oil palm plants. One of the greenhouse gases is CO_2 (carbon dioxide) which is in the atmosphere and is part of the most important carbon cycle on earth.

Photosynthesis is a synthesis of carbohydrates derived from CO_2 and H_2O by green plants with the active role of light and photosynthetic pigments. The availability of water, light and pigments plays an important role in the photosynthesis process [4].

This study aims to calculate CO_2 absorption by oil palm plants in relation to the water balance that occurs in oil palm plantations.

II. Material And Methods

1. Research Location

The study was conducted in 2 locations of oil palm plantations, which are:

a. Rambutan Estate - PTPNIII located in SerdangBedagai Regency at coordinates 99^o4-99^o20 East longitude; 3^o20^I- 3^026 North latitude; altitude 18-27 m above sea level with Red-Yellow Podsolic soil types or TypicTropudult soil type, S2 land suitability class with climate type according to Schmidt & Ferguson is type C (rather wet) and BS according to Koppen.

b. Bah BirungUlu Estate - PTPN IV located in Simalungun Regency, coordinate point 98^032^I-99^035^I East longitude; 2^036^I-3^018^I North latitude; altitude of 660-1100 m above sea level, podsolic soil type with sandy texture (Psammenticpaleudults), S3 land suitability class with climate type according to Schmidt and Ferguson is Type A (very wet) and AF according to Koppen.

This research was conducted in April-June 2018.

2. Tools and Materials

The material used is the variety DxP oil palm plants planted in 2008 in the 2 observed Estates, button-ground biomass material and other supporting materials.

The tools used were the meter, scissors, machetes, ropes, stakes, scales, rain gauge, and other assistive devices.

3. Research Design and Stages

The study used descriptive design, explains and compares the value of water balance and CO_2 absorption by oil palm plants.

The stages of research conducted were:

a. Water balance

The data source used is derived from records made from rain gauge and the balance calculated using the Lysimeter method with the following description;

- CH (Rainfall; mm/month)
- HH (Number of rainy days/months)
- PE (Evaporation; if the number of HH > 10, then PE = 120 mm, and if HH < 10 then PE = 150 mm)
- CP (Initial reserves; a maximum value of 200 mm)
- KA (Water balance, that is (CP + CH) -PE)
- CA (Final backup; if the KA value > 200; then CA is 200 and if KA < 200 then CA = KA)
- DA (Water deficit; if the CA value is negative then the value is the Water Deficit value)

b. Above Ground Biomass (AGB)

Measurements were made using a non-destructive method through estimation based on the height of oil palm plant stems according to the allometric formula [5] in the following manner;

- Determining a sample plot measuring 20 x 60 m (1200 m^2 with an estimated 18 plants); with 3 replications..
- Measuring stem/plant height from ground level to midrib/leaf number 17. Phyllotaxy formula for palm oil leaves is 3/8 and leaf identification number 17 is guided by LPP [6].
- The Allometric Models used were:

BAP = 0.0706 + 0.0976 H (H is plant height). The observational data was converted to an area of 1 ha (10,000 m^2)

c. Button Ground Biomass (BGB)

The button-ground biomass plant is collected (destructively) from 6 sub-plots size 1 m x 1 m in large plots. The button-ground plant is collected, cleaned hence the attached soil is removed, weighed wet weight, dried by oven at a temperature of 70-80^{o}C for 24 hours and weighed dry weight after drying.

$$\text{Total BTB} = \frac{\text{Sub sample dry weight}}{\text{Sub sample wet weight}} \text{ X Total Wet Weight}$$

(Sub-sample for oven heat is ± 100gr). Observation data is converted into an area of 1 ha (10,000 m^2)

d. Carbon Absorption

Calculation of carbon stocks and absorption is calculated as follows:

- Total of biomass = AGB + BGB (Ton/ha)
- Potential Carbon Stocks = (BAP + BTB) x 0.46 (Ton/ha)
- CO_2 absorption = C x 3.67 (Ton/ha)

III. Result and Discussion

1. Rain Distribution and Water Balance

The pattern of monthly/average rainfall distribution (2013-2017) from 2 research locations can be seen in Figure 1.

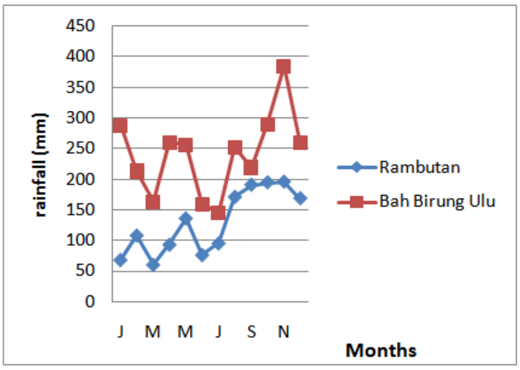


Figure 1: Rainfall Distribution Pattern

The pattern of rainfall in 2 locations was almost the same, but in Bah BirungUlu the amount of rainfall was > 2000 mm, presented in Table 1.

Table 1. Summary of Water Balance

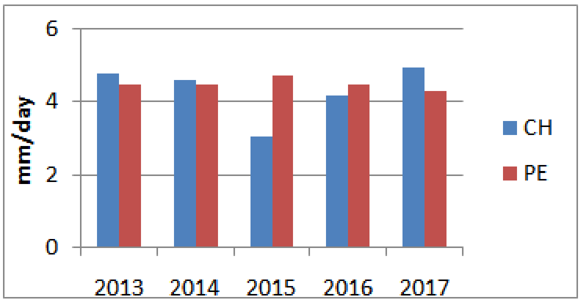
Location/Year	Rainy day		Rainfall (mm)		Evaporation (mm)		Drainage		Water deficit	
	HH	%	Year	Day	Year	Day	BL	mm	BL	mm
1. Rambutan Estate										
2013	140	39	1728	4.79	1620	4.5	3	296	5	378
2014	132	37	1661	4.61	1620	4.5	2	364	4	364
2015	105	29	1104	3.07	1710	4.75	0	0	10	525
2016	128	36	1513	4.2	1620	4.5	1	4	4	251
2017	150	42	1790	4.97	1560	4.33	4	269	3	100
Average	131	36	1559	4.33	1628	4.52	2	187	5.2	324
2. Bah BirungUlu Estate										
2013	122	34	2475	6.87	1520	4.25	10	1895	0	0
2014	97	27	1969	5.47	1620	4.5	4	443	3	169
2015	141	39	2505	6.96	1620	4.5	5	785	0	0
2016	141	39	2216	6.15	1530	4.25	7	805	0	0
2017	166	46	3307	9.19	1500	4.17	11	1808	0	0
Average	133	37	2494	6.93	1560	4.33	5.4	1148	0.6	34

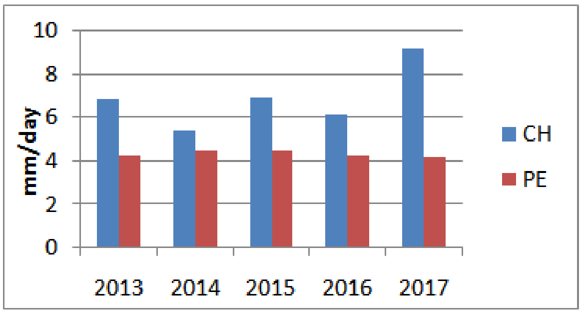
Information: HH (Rainy Day), BL (Month in 1 year)

Harahap and Darmosarkoro [7], argued that oil palm plants are known as plants that grow rapidly and needs to be sufficient and sustainable water supply throughout the year. Ideal conditions to achieve the growth requirements are in areas that have rainfall of 1750-2250 mm/year with the number of rainy days is 100-150 days/year and the number of dry months (rainfall < 60 mm/month) maximum is 2 months in 1 year. The research area of Rambutan Estate has less than optimum rainfall and the Bah BirungUlu Estate has more than enough rainfall. According to Adiwiganda et al., [8] and Lubis [3], in the grouping or zoning of rainfall the Rambutan Estates are included in the rather dry climate zone (1250-1750 mm) with S2 land suitability class (quite suitable) and the Bah BirungUlu Estate included in the wet zone (2250-2750 mm) with S3 land suitability class (not suitable) because it has a severely limiting factor that is lack of solar radiation just about < 5 hours/day (8 hours for normal condition).

The value of water balance is influenced by evaporation that occurs. Oil palm plantations are planted using an equilateral triangle system with a distance of 9.4 m, the number of trees is 130/ha. The age of the plants in this study is 10 years, including the category of adult plants with canopy conditions that have overlapped to each other [9]. With this condition, it is expected that evaporation from the soil can be reduced by canopy cover or by the presence of a cover crop planted that is Mucunabracteata.

The calculation of water balance is should be done by considering soil infiltration, evapotranspiration and surface runoff [10]. Comparison of the average daily rainfall and evaporation in Rambutan Estates there was a deficit of 4.33 mm to 4.52 mm and the lowest condition occurred in 2015 data, which was the average rainfall per day of 3.07 mm and evaporation was 4.75 mm. In the Bah BirungUlu Estate, there is always a surplus and the highest surplus value occured in 2017 with an average rainfall of 9.19 mm per day and an average evaporation per day is 4.17 mm (Figure 2).





a. Rambutan Estate b. Bah BirungUlu Estate

Descriptions: CH (Rainfall), PE (Evaporation)

Figure 2. Comparison of Daily Rainfall and Evaporation.

Murtilaksono et al., [10], suggested that the ideal development of oil palm plantations is in areas with an average rainfall of 5-6 mm/day while Widodo [11], suggested that in the process of growing, oil palm plants need water equivalent of 4.10-4.65 mm/day. Corley and Tinker [2], reported that the evapotranspiration of oil palm plants in the immature plant phase (age 1-3 years) is 4-5 mm/day; adult plants (8-13 years) can reach 6-7 mm/day and in old age (>20 years) decreases again, that is 4-5 mm/day.

The occurrence of water excess as happened in the Bah BirungUlu Estate then the water is went out as a drainage water. Based to the standards applied in the PTPN IV, it was made a conservation building that is a continuous terrace with the direction of cutting the slope hence it is expected to reduce the speed of water flow that can have an impact on soil erosion. Prevention of biological erosion is also done by planting cover crops of *Mucunabracteata* (Wahyuni, 2019)[9].

In Rambutan Estate, water deficits occured every year and the highest value occurred in 2015 of 525 mm, including the very high deficit category. The water deficit affects the physiological conditions of oil palm plants, there are the abnormal fruit maturity; frond fracture and affect the formation of the sex of the flower [12]. Corley and Tinker [2] suggested that a water deficit > 400 mm can result in a decrease in the production of 38.6%. In Bah BirungUlu Estate, the water deficit in 2014 amounted to 169 mm included in the very low category and it is not expected to have an impact on the growth and productivity of oil palm plants.

Widodo and Dasanto [11], also reported that in extreme agro-climate conditions oil palm cultivation indicated a decrease in river water debit. The absence of cover crops can cause run-offs 10 times more than in land with good cover crops. Observation of Taufiq*et al*., [13] in the sub-watershed of the Landak, Kapuas watershed, the oil palm plantations in the area affected in the reduction of river debit by 30-40%.

Research conducted by Pasaribu*et al* [14] reported that interception in oil palm stands was 21.23% of rainfall; the evapotranspiration value was 68.23-125.63 mm/month. It was also stated that the water consumption of oil palm plants were less than the water consumption of coconut palms and forest plants such as pine, acacia, sengon, rubber and teak.

2. Above Ground Biomass (AGB) and Button-Ground Biomass (BGB)

The observations results of biomass measurements (AGB and BGB) were presented in Table 2.

Table 2. Average BAP and BTB measurements

Location	Stem		BAP (ton)		BTB (ton)		Total
	Height (m)	/ Year	/ Plot	/ ha	/ Plot	/ ha	(Ton/ha)
1. Rambutan Estate	4.84	0.48	9.771	81.425	0.00092	1.533	82.938
2. Bah BirungUlu	6.49	0.65	12.67	105.57	0.00099	1.65	107.22
Index B/A (%)	134	135	130	130	108	108	129

Note: AGB (Above Ground Biomass), BGB (Button Ground Biomass).

The growth of oil palm plant stems in Bah BirungUlu is 34% higher than in Rambutan Estate with a surplus of water, the stems can grow faster.

Above Ground Biomass (AGB) formed in Bah BirungUlu is 105,570 tons/ha or 812 kg/tree. In one palm tree there are generally 56 fronds with a weight of about 9 kg one (total 504 kg), hence from the data it is estimated that the weight of oil palm stem is 308 kg. The average above ground biomass in the Rambutan Estate is 81.425 tons/ha or 637 kg/tree.

Jain (1993) also stated that in the process of photosynthesis the role of nutrients such as Mg needs to be considered hence leaf chlorophyll density can be increased. The observation results of button-ground biomass plant consisted of several types of weeds, that are *Ottochloanodusa*, *Ageratum conyzoides*, *Dactycocteniumaegyptium* (starlings), *Brachiariadecumbers* and*Axonopuscompressus*.

The weeds are controlled with chemical herbicides 4 times / year. Thus the results of weighing the amount of plant biomass are only small. The total button-ground biomass formed in the Bah BirungUlu Estate is 29% higher than the button-ground biomass in the Rambutan Estate. The availability of water that is quite good in Bah BirungUlu resulted more biomass.

According to Susanto*et al* [15], plant health also influences the rate of photosynthesis. Leaf rust caused by algae *Cephaleurosvirescenses* has an impact on the rate of photosynthesis, which is from mild to severe disease down 42.48%, from 15.15 to 8.92. mmolCO_2 m-^{2}S^{-1}. It was also stated that its need environmental sanitation by cutting the fronds/old leaves hence the condition of the plantation area such as in Bah BirungUlu is not too humid.

Hatfield and Dold [16] argued that in the condition of global climate change, efforts are needed to improve water use efficiency hence the photosynthesis process can increase the amount of biomass. Compbell*et* *al* [17], emphasized the importance of sustainability aspects in agriculture with global climate change conditions that occur hence land degradation does not occur too quickly.

3. Carbon Absorption

Biomass that is formed in the root, stem, leaf, and fruit tissue can be interpreted as Carbon (C) which has been converted to $C_6H_{12}O$. The results of observations of carbon stocks and CO_2 absorption are shown in Figure 3.

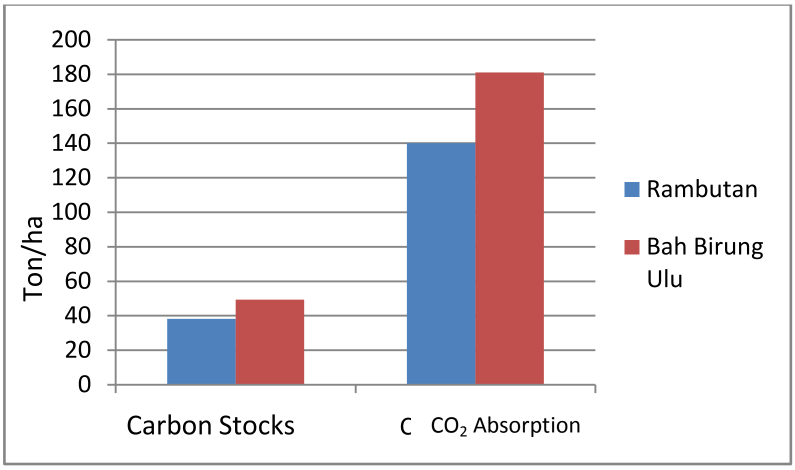


Figure 3. Carbon Stocks and Absorbed CO_2 in the Rambutan and Bah BirungUlu Estates

Carbon (C) stocks in oil palm plants in Rambutan Estate was 38,151 tons/ha compared to carbon stocks in Bah BirungUlu, which was 49,321 tons/ha, with carbon absorption of 140 tons/ha and 181 tons/ha, respectively.

In comparison, the ability of secondary forests to absorb CO_2 is 102.31 tons/ha; primary forests is 129.15 tons/ha and acacia forests (*Acacia mangium Wild*) is 115.29 tons/ha [5]. Based on this graph, on less ideal rainfall conditions, oil palm plants in Rambutan plantations are still able to absorb CO_2 quite well; the value exceeds the absorption of CO_2 in primary forests and acacia forests.

Sutarta*et al* [18] suggested that the application of good agricultural techniques could reduce CO_2 emissions on peatlands from 48-52 tons/ha/year to 28-38 tons CO_2/ha/year. Furthermore, CO_2 that is still emitted will be absorbed through photosynthesis to produce 20-24 tons of FFB/ha/year. Yulianto [19] obtained the measurements results of CO_2 absorption of oil palm plants at the age of 6-10 years was 1169 tons/ha and at the age of 11-15 years was 241.8 tons/ha.

Wahyuni*et al* [20] repored that cultivation systems affect carbon stocks. In mature plants (15-20 years) carbon stocks in farmer's plantations are 61.53 tons/ha and in state plantations that are better done are 93.42 tons/ha; increased by 52%. Good agricultural techniques can optimize the absorption of CO_2.

IV. Conclusion

The average rainfall at Rambutan Estate is 1559 mm/year or 4.33 mm/day, evaporation of 4.52 mm/day, there is a heavy water deficit category with an average of 324 mm/year. In Bah BirungUlu Estate, the average rainfall is 2494 mm/year (6.95 mm/day), evaporation of 4.33 mm/day, water deficit only occurred in 2014, including as a low category.

The total biomass of oil palms in the Rambutan Estate is 82,938tons/ha and in the Bah BirungUlu Estate is 107,220 tons/ha (29% more), CO2 absorbed in the Rambutan Estate is 140 tons/ha and in the Bah BirungUlu Estate is 181.1 tons/ha.

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MardianaWahyuni. "Water Deficit and Carbon Absorption of Oil Palm Plants (ElaeisguineensisJacq)." *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS),* 13(8), 2020, pp. 26-31.