ESTIMATION OF RETURNED BIOMASS AND NUTRIENTS IN OIL PALM PLANTATION IN ONE LIFE CYCLE

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ABSTRACT

Oil palm plantations development is still being a concern related to global trade and environment issues such as terrestrial carbon issue. The existing estimation of oil palm carbon absorption was only focused on standing biomass. Carbon which is derived from harvested biomass (FFB) and returned biomass through pruning has not much been studied in terms of oil palm carbon absorption. Besides C, returned biomass also contained essential nutrients such as N, P and K. The objectives of this research were to study the potency of biomass, carbon and nutrients (N, P and K) returned in one life cycle of oil palm. The result shows that the potency of returned biomass in one life cycle was 96.21 - 138.42 tons dry matter ha^{-1} or equivalent to 194.51 - 279.85 tons CO_2 ha^{-1}. While returned nutrient was 1.49 - 2.15 tons N ha^{-1} 147.61 - 212.36 kg P ha^{-1} and 1.32 - 1.89 tons K ha^{-1}.

Keywords**:** frond, nutrient, oil palm, pruning, returned biomass

1. INTRODUCTION

Oil palm was a plantation crops widely developed in Indonesia. The area of oil palm plantations (OPP) is increasing very rapidly. In Indonesia, the area of oil palm plantations has been reaches 11.30 million ha in 2015 with an average productivity rate of 15 - 20 tons of FFB/ha $year^{-1}$. The export value of CPO (crude palm oil) and PKO (Palm Kernel Oil) has reaches 18 billion US$ annually within the last five years (Directorate General of Estate Crops of Indonesia, 2015). Oil palm biomass has been widely studied as an alternative raw materials for the production of biofuel, pulp, paper, and biomass-based chemicals (Abdul-Khalil et al., 2010; Lammens et al., 2012; Rashid et al., 2012; Suhaily et al., 2012; Chin et al., 2013; Hassan et al., 2013; Singh et al., 2013; Sung et al., 2013).

The expansion of OPP is still being a concern related to affect the reduction of tropical forest area. Land used changes of a forest into oil palm plantation was not an entirely established from primary forest. Because in practice, most of converted forest was secondary forest and dominated by shrub or bush. As the results of Rehmaan et al. (2015) research in Riau and West Kalimantan indicated that only 0.94 % (29 thousand ha) of the total areas were converted into OPP derived from primary peat forests and 21.55 % (0.67 million ha) converted from secondary peat forests in the 1980 - 2013 period. Besides being developed in mineral soil, 2.30 million ha of peatlands has been developed into OPP (Miettinen et al., 2012: Sabiham and Sukarman, 2012; Gunarso et al., 2013). However, OPP development in peatlands was raises some debate related to environmental issues of carbon (C) emissions, global warming, and biodiversity.

Hooijer et al. (2012) was estimated that the average C loss due to OPP development in peatlands with drainage systems ranged from 73 - 78 tons CO_2 ha^{-1} $year^{-1}$. The carbon losses was based on measurement of peat subsidence which considered as organic carbon losses. This approach was inaccurate, since subsidence is a function of peat compaction and consolidation, erosion, and decomposition. The contribution of carbon losses from subsidence process was the smallest factor compared to others. Several other studies have mentioned that total emissions of OPP on peatlands around 19.20 - 55.00 ton CO_2 ha^{-1} $year^{-1}$ (Germer et al., 2007; Fargione et al., 2008; Reijnders et al., 2008; Wicke et al., 2008; Murdiyarso et al., 2010; Koh et al., 2011). Hirano et al. (2007) reported that CO_2 emissions measurements from tropical peatland was varies greatly depending on time and area, and greatly affect the CO_2 emissions measurement results.

CO_2 emissions can be offset by planting crops that has high capacity to absorb C such as oil palm (Henson et al., 2012). The accuracy of determine the C absorption by plants is very important. In the case of oil palm, the method of estimating plant biomass has been developed rapidly. Oil palm was absorbs CO_2 from the air and converts it into biomass through the photosynthesis process. The biomass of oil palm will be distributed into the growth of stalk, fronds and fruit forming. The largest biomass accumulation was obtained by standing biomass, which is widely used as the basis for estimating the carbon absorption of oil palm. In addition, there are still some other biomasses from harvested biomass in the form of fresh fruit bunches (FFB) and biomass from frond pruning which returned to the field.

In oil palm cultivation activities, pruning of oil palm fronds has becomes a necessity that should be regularly done in facilitating the maintenance and harvesting activities. Gromikora et al. (2014) stated that the pruning of oil palm frond increased the yield of FFB. Frond pruning will be stacked on soil which then used as mulch, an inhibitor of weed growth and source of soil organic matter. Besides being a source of organic matter, in the decomposition process, oil palm fronds waste will release essential nutrients which needed by oil palm such as N, P, and K. Nutrients which released from frond biomass can be a source of nutrients other than soil and fertilizer.

Oil palm which planted on peatlands has high nutrient requirements that depend heavily on fertilizer inputs. This was because peat has a low fertility rate which not able to sufficient the plant nutrient needs. Firmansyah (2006) suggested that oil palm which planted in peatlands required 250 kg of urea ha^{-1}, 275 kg SP-36 ha^{-1}, and 235 kg MOP ha^{-1}. Returned oil palm biomass can be a solution to reduce the fertilizer requirement. According to Singh et al. (1999), oil palm empty fruit bunches (EFB) has the potential to reduce the fertilizer use of 7 kg of urea, 19.3 kg of MOP, and 2.8 kg of rock phosphate per 1 ton of EFB. However, the data which related to the fertilizer potential substituted by frond pruning has not been widely published. A number of fertilizers that can be substituted by the nutrients returned through the frond pruning depends on how much the number of frond returned.

Research that related to returned biomass and nutrient has not much been studied. Thus, the objectives of this research were to study the potency of biomass, carbon and nutrient (N, P and K) returned to the soil in one life cycle of oil palm.

2. METHOD

2.1. Research Site

The research was conducted on August 2014 - June 2016 in the OPP area of PT Kimia Tirta Utama (KTU), Siak, Riau, Indonesia. Analysis of plant samples was conducted at the Laboratory of Soil and Land Resources Department, Faculty of Agriculture, Bogor Agricultural University (IPB).

2.2. Material and Tools

Materials and tools used are plant block map based on age, oil palm frond, observation form, notebook, stationery, digital analytical balance scale, plastic bag, knife, label paper, clinometer, and GPS.

2.3. Procedure of research

Research activities were divided into two steps: 1), observation and sampling of oil palm biomass (pruned fronds), and 2). analysis of C, N, P and K contents of plant samples. The observation, measurement, and sampling of oil palm biomass were carried out on blocks of oil palm plant at the age of 4 - 25 years old. Observation, measurement of length and weight of frond and sampling was done on 15th, 30th, and 45th planting lines in each planting block, the observation was performed on 10 trees sample of each planting line. Observations included the number of fronds, the number of pruned fronds, the weights and length of pruned frond. Fresh biomass samples was dried at 70° C to obtain dry biomass weight. Organic C-content of the samples were calculated used dry ashing method, nitrogen content used Kjedhal’s method, phosphorus and potassium used wet digestion method.

2.4. Data analysis

Analysis results of plant samples such as length, dry weight, C, N, P, and K contents were analyzed descriptively. The potency of returned oil palm biomass was calculated based on the dry weight, number of pruned fronds in one year and oil palm population per hectare. The data of returned biomass at each plant age was used as the basis for estimating the potency of returned biomass in one life cycle (25 years). The determination of the amount of returned nutrient was based on the amount of returned biomass multiplied by the contents of C, N, P, and K of the plant samples.

3. RESULT AND DISCUSSION

3.1. Frond characteristic

Observations and sampling of returned palm oil biomass were carried out on 28 planting blocks with 13 varieties of plant age, with each of 30 sample trees on each planting block. Frond sample from pruning activities was taken in each plant sample then observed. To represent the age of plants that are not represented in the field, then a line equation that approximates the shape of the oil palm growth curve was made. The analysis results of length and dry weight of frond from palm oil pruning are shown in Figure 1.

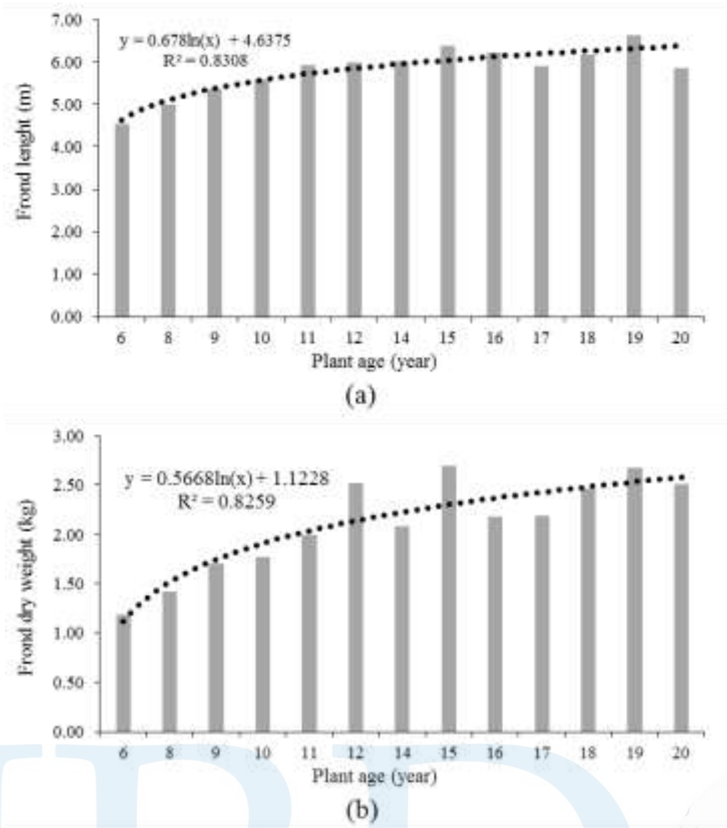

Figure 1. Length (a) and dry weight (b) of pruned frond based on the age of oil palm

The average dry weight of one pruned frond was 2.15 - 3.10 kg, while the lowest weight was 1.59 kg at 4 year old and the highest was 3.21 kg at 25 year old. The average gravimetric water content of the pruned frond was 130.15% for the leaf and 248.40% for the ford frond stalk. The fresh weight of pruned frond was 5.92 - 10.04 kg per frond (4.74 - 7.65 kg for frond stalk and 1.18 - 2.39 kg for leaves). This result was bigger than the result of Yulianti's research (2009) which stated that the fresh weight of one frond was 1.5 kg (1.25 kg for frond stalk and 0.25 kg for leaves). This was might be influenced by the growth of oil palm which determined by the carrying capacity of peatlands in support the growth of oil palm.

The length and weight of the pruned frond was increased with the age of palm oil grows. This was an accumulation of the photosynthesis result of plants that are converted into a biomass, in the form of trunk, frond, leave, and fruit. The increase of length and weight of oil palm was increased rapidly until 10 years of plant age, whereas at above 10 years ages, the increase of length and weight of the frond tend to decrease as the growth curve of the plant. It was caused by the oil palm growth at the ages above 8 years has slacked. Oil palm plants at 10 years old was entered the maximal generative period, where plant growth began to slow down along with the maximum yield of the oil palm fruit (Turner and Gillbanks, 2003; Risza, 2010).

3.2. Potential of returned biomass

Pruning was done regularly 4 to 6 times a year. Each pruning process has returned 2 - 4 frond to the field with maintained the amount of frond, 48 - 56 fronds on the young oil palm and 40 - 48 fronds on the mature oil palm, in order to maintain the productivity of palm oil (Pardamean, 2017). The potency of returned biomass total by pruned fronds was calculated based on the dry weight of the fronds multiplied by the average amount of pruned frond per year, and the number of oil palm population in one hectare. The assumption of pruned frond total in one year was ± 16 fronds (8 - 24 fronds per year), and the population of oil palms in one hectare with a 9 x 9 m spacing was 133 plants. The potential of returned palm oil biomass is shown in Table 1.

Table 1. Total of Returned Biomass, C, N, P and K based on oil palm ages

Oil Palm Ages (year)	Total of				
	Returned Biomass (tons ha^{-1} $year^{-1}$)	Returned C (tons ha^{-1} $year^{-1}$)	Returned N (kg ha^{-1} $year^{-1}$)	Returned P (kg ha^{-1} $year^{-1}$)	Returned K (kg ha^{-1} $year^{-1}$)
4	3.38	1.87	52.44	5.19	46.31
5	3.80	2.10	58.96	5.84	52.07
6	4.15	2.29	64.29	6.36	56.78
7	4.44	2.45	68.79	6.81	60.75
8	4.69	2.59	72.70	7.19	64.20
9	4.91	2.71	76.14	7.54	67.24
10	5.11	2.82	79.22	7.84	69.96
11	5.29	2.92	82.00	8.12	72.42
12	5.45	3.01	84.55	8.37	74.66
13	5.60	3.09	86.89	8.60	76.73
14	5.74	3.17	89.05	8.81	78.64
15	5.87	3.24	91.07	9.01	80.42
16	6.00	3.31	92.95	9.20	82.09
17	6.11	3.37	94.73	9.38	83.65
18	6.22	3.43	96.40	9.54	85.13
19	6.32	3.49	97.98	9.70	86.52

20	6.42	3.54	99.47	9.85	87.85
21	6.51	3.59	100.90	9.99	89.11
22	6.60	3.64	102.26	10.12	90.31
23	6.68	3.68	103.56	10.25	91.45
24	6.76	3.73	104.80	10.37	92.55
25	6.84	3.77	106.00	10.49	93.61

The potency of returned biomass from the pruning process has increased with the age increased of oil palm. The average of returned biomass from pruned frond was 4.58 - 6.59 tons of dry matter ha^{-1} $year^{-1}$, where the lowest was 3.38 tons dry matter ha^{-1} $year^{-1}$ at 4 year old and the highest of 6.84 tons ha^{-1} $year^{-1}$ at 25 year old. Aljuboori (2013) reported that the returned biomass of pruned frond in Sabah and Sarawak has reached 10.15 - 10.17 tons dry matter ha^{-1} $year^{-1}$. This result was still less than the returned oil palm biomass potency in Malaysia. The potency of total of returned biomass to 25 years would reach 96.21 - 138.42 tons dry matter ha^{-1} of returned pruned frond.

The activities of harvesting and returning biomass of oil palm was done as long as the oil palm still productive, and ends when the oil palm plantation was cut down and replanted. After replanting process, the cycle of oil palm biomass production will be repeated. The dynamic biomass production of oil palm does not occur in forest systems, where when forest has achieved a climactic growth, its biomass production tends to decrease. Oil palm has absorbs CO_2 from the air and converts it into biomass through photosynthesis, the resulting biomass then distributed into the growth of trunk, frond, and fruit formation. The largest accumulation of biomass was obtained by trunk, while the second was harvested biomass and returned biomass of pruned frond was the smallest biomass accumulation respectively.

The amount of returned C from returned biomass was greater along with increasing age of oil palm. The average amount of returned C was 2.53 - 3.64 tons C ha^{-1} $year^{-1}$ or equivalent to 9.26 - 13.33 tons CO_2 ha^{-1} $year^{-1}$. Accumulated to 25 years, the potency of returned C to soil reached 53.06 - 76.34 tons C/ha or equivalent to 194.56 - 279.92 tons of CO_2 ha^{-1}.

Table 2. Estimation of surface biomass based on land uses

Land Use	Surface biomass (ton dry matter ha^{-1})
Dense swamp Forest[a]	464.59
medium swamp Forest[a]	335.39
Primary peat forests[b]	249
Secondary peat forests[b]	172
Shrubs[b]	30
Oil palm plantation[c]	99
Oil palm plantation[d]	195.21 - 237.41
Oil palm plantation[e]	316.63 - 486.16

[a] : Forest in climactic condition Source: Maulana (2010); [b] : Forest in climactic condition Source Ur Rehman *et al.* (2015); [c] : standing biomass Source : Ur Rehman *et al.* (2015); [d] : standing biomass + returned biomass potential; [e] : standing biomass Ur Rehman *et al.* (2015) + the potential of returned and harvested biomasses.

Table 2 shows that oil palm plantation has the same capability as forests to absorb C. This can be seen from the total amount of total oil palm biomass (standing biomass, returned biomass and harvested biomass) tends to be similar to medium swamp forest biomass and larger than primary peat forest biomass. Tarigan and Sipayung (2011) and Henson et al. (2012) has mentioned that the superiority of OPP than forests was the ability to absorb C that higher than forests. In primary forest that has grown and reached climactic conditions, the plant growth was relatively small where photosynthesis rate was proportional to the rate of respiration. While in OPP, until the 25 year old the production still occur so that still absorb C to produce biomass.

3.3. Potential of returned nutrients

Based on Table 1, which shows that returned biomass was greater along with increasing age of oil palm plants. The average of returned nutrient was 71.02 - 102.18 kg N ha^{-1} $year^{-1}$, 7.03 - 10.11 kg P ha^{-1} $year^{-1}$, and 62.72 - 90.23 kg K ha^{-1} $year^{-1}$. The biomass of pruned frond was able to contribute the nutrients that equivalent to 32.67 - 47.00 kg urea ha^{-1} $year^{-1}$, 42.44 - 61.07 kg SP36 ha^{-1} $year^{-1}$, and 28.85 - 41.51 kg MOP ha^{-1} $year^{-1}$. The fertilizer requirement for oil palm in peatlands was 250 kg urea ha^{-1}, 275 kg SP36 ha^{-1}, and 235 kg MOP ha^{-1} per year (Firmansyah, 2006). The returned biomass of pruned frond potentially reduced 61.76 - 88.85 % urea, 16.28 - 23.43 % SP36, and 53.84 - 77.47 % MOP, or on average, it potentially reduces 53.06% of the annual fertilizer requirement of oil palm. This returned nutrient potential has not yet included other oil palm biomass. Another oil palm biomass that known could contribute nutrients from returned biomass is empty fruit bunch (EFB). According to Singh et al. (1999), EFB of oil palm has the potential to reduce the fertilizer requirement by 19.3 kg MOP, 2.8 rock phosphate, and 7 kg urea per 1 ton of EFB. Accumulated to 25 years, the returned nutrients are 1.49 - 2.15 tons N ha^{-1}, 147.61 - 212.36 kg P ha^{-1}, and 1.32 - 1.89 tons K ha^{-1}.

4. CONCLUSION

The potency of returned biomass from pruned frond of oil palm in one life cycle was 96.21 - 138.42 tons dry matter ha^{-1} or equivalent to 194.56 - 279.92 ton CO_2 ha^{-1}, while the potency of nutrients returned to the soil were 1.49 - 2.15 tons N ha^{-1}, 147.61 - 212.36 ton P ha^{-1}, and 1.32 - 1.89 tons K ha^{-1}. The returned biomass of pruned frond was potentially reduces 53.06 % of annual fertilizer requirement.

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