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Estimating Aboveground Biomass of Oil Palm Trees by Using the Destructive Method

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Abstract Palm oil is one of the important commodities in Indonesia. Estimating the aboveground biomass of oil palms is one of the most important oil palm carbon studies. The objective of this study was to estimate the aboveground biomass of oil palm trees at plot scale for three age classes namely, class 1 (1 to 3 years), class 2 (4 to 10 years) and class 3 (11 to 20 years) in South Sulawesi, Indonesia using destructive method. The AGB for each age class: class 1, class 2, and class 3 they are 5.84 kg tree^{-}1, 173.17 kg tree^{-}1, 823.50 kg tree^{-1} respectively.

Keywords: *aboveground biomass, destructive method, oil palm*

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1. Introduction

Palm oil is one of the important commodities in Indonesia. Indonesia and Malaysia are the largest oil palm plantations countries in the world [1]. Oil palm occupies over 17 Mha and produces 267.55 Mt of palm oil globally [1]. World demand for palm oil products continues to increase from year to year, causing the expansion of oil palm plantations on a large scale, especially in Indonesia. In 2020, there will be 20 Mha of oil palm plantations in Indonesia and it's capable of producing 28 Mt of crude palm oil (CPO). The high demand for palm oil has triggered the conversion of forests to oil palm plantations. Land use conversion will change the carbon stocks of the land. Therefore, there has been considerable interest in studying the carbon sequestration and emissions of oil palms. Estimating the aboveground biomass of oil palms is one of the most important oil palm carbon studies. Estimates of biomass give a direct measurement of carbon sequestration in oil palm and help to quantify the anthropogenic impacts on climate change and to validate carbon model. Aboveground biomass of an oil palm tree includes the components, namely, stem, fronds, leaflets, fruit bunches, and flowers. Biomass estimation can be done by (i) harvesting methods/destructive sampling, by oven and dried the components at 105°C and (ii) indirect estimation methods/non-destructive sampling using allometric equations [2,3,4].

2. Methodology

2.1. Study Area

The study area was located at the Province of South Sulawesi. The area of oil palm plantations in the province was 23,625 ha in 2012 and will continue increasing in coming years [5]. The study was conducted in an oil palm estate owned by PTPN XIV-Persero. It was located at 120°11' E -120°19' E and 3°47' S - 3°52' S, which is in the Village District Ciromanie Keera Wajo in the Province of South Sulawesi, Indonesia. The species of oil palm tree is *Elaeisguineensis*.

2.2. Data Collection

The objective of this study was to estimate the aboveground biomass of oil palm trees at plot scale for three age classes namely, class 1 (1 to 3 years), class 2 (4 to 10 years) and class 3 (11 to 20 years) in South Sulawesi, Indonesia. Generally, oil palm plantationshavean economical lifespan up to 25 years. Age is one of the important factors influencing the production of fruit bunches and primary productivity [6]. The age of oil palm can be discriminated into stages, namely (i) young- 1 to 3 years old, (ii) intermediate- 4 to 10 years, (iii) productive- 11 to 20 years [7].

2.3. Data Analysis

A field work was conducted in May 2013. We harvested 3 trees for each age class (total of 9 trees). These harvested trees were separated into components, namely, stem, frond, leaflets, fruit bunches and flowers. These components were used for determining the wood density and volume, and the dry weight of the components to determine biomass, and the dry weight of the components to determine biomass.

2.3.1. Felled down Tree Process

Before felling the trees, the *dbh* of the trees were measured. After the felling process (Figure 1 (a), the total *h* and the *h* without rachis of tree were measured. The components of oil palm tree were separated into fronds, leaflets, fruit bunches, flower, and stem (Figure 1 (b)). Then, a hanging scale was used to get the fresh weight of stems, fronds, leaflets, fruit bunches and flowers. The samples were then stored in plastic bags [8]. The samples were sent to the nearby laboratory quickly to prevent the samples from decay.

Figure 1. (a) The felling process, (b) the components of tree (leaflets, flowers, fruit bunches and fronds), and (c) cutting the felled stems into slices in pie shape

2.3.2. Estimating Volume by Newton's Formula

With regard to the felled stem, it was further cut into 3 slices at the lower, middle and upper parts which is a destructive method (Figure 1 (c)). Each of the slices is 10 cm thick in pie shape. These slices were used to calculate the volume and dry weight of the trees. The volume of each slice was calculated using Newton's formula [9] (Eq (1)).

$$V = \left(\frac{B + 4M + S}{6}\right)L \qquad (1)$$

where:

V= volume of stem (m^3)
B= base/lower of the stem basal area (m^2)
M= middle of the stem basal area (m^2)
S= upper of the basal area (m^2)
L = length of stem (m)

2.3.3. Estimating Volume by Newton's formula

After estimating the volume, each of the 3 slices were further cut into 8 small cubes with 5 cm × 5 cm × 5 cm. In total we obtained 24 cubes for each tree. These cubes were measured for their fresh weight using a digital scale (accuracy 0.01 g).

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2.3.4. Determining Dry Weight

The cubes were put into a desiccator for around 30 minutes to reach room temperature before they were put in an oven. The cubes were kept in the oven at 105°C± 3°C for 48 hours until reach a constant weight [10,11,12,13].

2.3.5. Determining Wood Density

The wood density ρ, which is an important parameter to calculate biomass was calculated using Eq (2) [14]. It was calculated as dry oven weight divided by wet volume.

$$\rho = \text{dry weight} / \text{wet volume} \qquad (2)$$

where

ρ is wood density (kg m^{-3}), dry weight was determined by the samples after oven process while wet volume is the fresh volume samples before oven drying process. For each age class, we averaged wood density from 3 trees.

2.3.6. Estimating Total Biomass

With the volume and wood density information, we calculated the biomass of stem using Eq (3).

$$B = \rho \times V \qquad (3)$$

where,

B= biomass of stem (kg)
ρ= wood density (kg m^{-3})
V= volume (m^3)

3. Result

3.1. Wood Density

The average ρ of class 1, class 2 and class 3 are 0.11 g cm^{-3}, 0.24 g cm^{-3} and 0.16 g cm^{-3} respectively (Figure 2). The wood density obtained in this study was compared with the wood density obtained by [14]. The results of ρ *[14]* for class 1, class 2 and class 3 are 0.11 g cm^{-3}, 0.14 g cm^{-3} and 0.22 g cm^{-3} respectively. This study and Corley and Tinkers obtained the same value (0.11 g cm^{-3}) for class 1. The difference in class 3 is small (0.06 g cm^{-3}). However, a large difference (0.11 g cm^{-3} difference) is noticed in class 2. Wood density values as obtained by Corley and Tinker shows an increase linearly with the age of oil palm trees in Malaysia. This is in contrast to the result obtained in this study where higher wood density was obtained in class 2 compared to class 3.

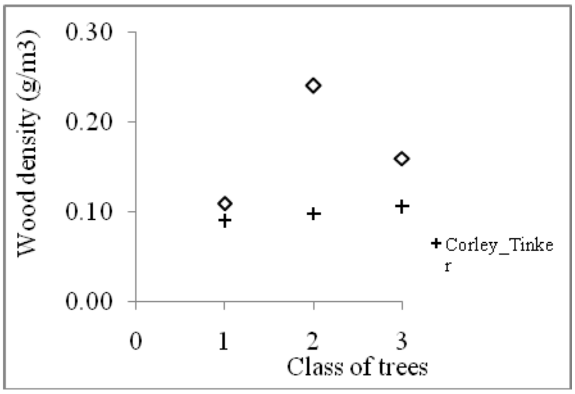

Figure 2. Wood density as a function of age of oil palm trees

It can be explained that ρ is affected by many factor not only by age. It can be explained that ρ is affected by many factor not only by age. Wood is a collection of cells. Each cell consists of cell walls and cell cavities. Cell cavity is empty space being cell wall contains lignin, cellulose and hemicellulose. This cell wall is wood mass. Thus wood which is composed of thick-walled cells will have a higher density wood [15]. Even though the plants of same species growing in different places, they would have different speed of growth. The plants that grow faster generally have a thinner cell wall and a lower wood density. Plants of the same species that grow slower typically have a thicker cell wall and a higher wood density. This is what happened in class 2 with ground tree growing areas included in the category *S3* that have higher wood density.

3.2. Aboveground Biomass of Oil Palm Trees

Aboveground biomass of class 3 (823.50 kg $tree^{-1}$) is higher than class 1 (5.84 kg $tree^{-1}$) and class 2 (173.17 kg $tree^{-1}$) (Table 1). The results showed that the biomass is the highest in class 3 (11 to 20 years). This is consistent with previous studies, biomass content increases with age [16,17,18].

Table 1. Aboveground biomass of oil palms

Class	Aboveground Biomass (kg $tree^{-1}$)
1	5.84
2	173.17
3	823.50

4. Conclusion

The aboveground biomass this study was estimated using destructive method. The AGB for each age class: class 1, class 2, and class 3 they are 5.84 kg tree-1, 173.17 kg tree-1, 823.50 kg $tree^{-1}$ respectively. The AGB is sum of stem biomass, fronds biomass, leaflets biomass, fruit bunches biomass, and flowers biomass of oil palm tree.

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