Estimation the Amount of Oil Palm Trees Production Using Remote Sensing Technique

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Abstract. Currently, fossil fuels were used as the main source of power supply to generate energy including electricity. Depletion in the amount of fossil fuels has been causing the increasing price of crude petroleum and the demand for alternative energy which is renewable and environment-friendly and it is defined from vegetable oils such palm oil, rapeseed and soybean. Indonesia known as the big palm oil producer which is the largest agricultural industry with total harvested oil palm area which is estimated grew until 8.9 million ha in 2015. On the other hand, lack of information about the age of oil palm trees and changes also their spatial distribution is mainly problem for energy planning. This research conducted to estimate fresh fruit bunch (FFB) of oil palm and their distribution using remote sensing technique. Cimulang oil palm plantation was choose as study area. First step, estimated the age of oil palm trees based on their canopy density as the result from Landsat 8 OLI analysis and classified into five class. From this result, we correlated oil palm age with their average FFB production per six months and classified into seed (0-3 years, 0kg), young (4-8 years, 68.77kg), teen (9-14 years, 109.08kg), and mature (14-25 years, 73.91kg). The result from satellite image analysis shows if Cimulang plantation area consist of teen old oil palm trees that it is covers around 81.5% of that area, followed by mature oil palm trees with 18.5% or corresponding to 100 hectares and have total production of FFB every six months around 7,974,787.24 kg.

Keywords: Remote sensing, GIS, Oil palm, FFB

1. Introduction
Currently, most countries are trying to find alternative energy resources which is renewable and environment-friendly to reducing their depending on fossil fuels such as petroleum, natural gas and coal as the main source to generate electricity. One of renewable energy that can be converted into electricity is biomass. Biomass energy or bio energy is the largest source of domestic renewable energy in Indonesia. Renewable energy such as biodiesel has the potential to replace petroleum-derived transportation fuel in the future. Biodiesel is defined as the mono-alkyl esters of long-chain fatty acids derived from vegetable oils such palm oil, rapeseed and soybean [1]. The energy output of oil palm is almost three times higher compared to soybean and rapeseed oil [2]. Moreover, another products are also produced from oil palm such as empty fruit bunch (EFB) fibers, shells, fronds, and trunk.
Palm oil is the largest agricultural industry in Indonesia. It means the potential sources for renewable energy especially from oil palm was abundant. Information about oil palm trees production and their spatial distribution very useful in organization or management of oil palm plantation and one of important variables affecting profit. On the other hand, lack of information about the amount of oil palm production and changes also their spatial distribution is mainly problem for energy planning. According to [3], collecting production data of oil palm trees especially on a large area or regional scale is time consuming and high costly. Remote sensing provides an effective and efficient approach for oil palm monitoring including the amount of oil palm production.

Our study, which is aimed at utilizing optical remote sensing data for oil palm plantation management including mapping, estimation of fruit bunch production and energy potential for electricity, has just been started and is in the preliminary study. In this paper, we focus on the amount of oil palm production based on the age of oil palm trees with Landsat 8 OLI. The study area is the oil palm plantations areas in Cimulang, Bogor Indonesia.

2. Methodology

This research was conducted in two steps that are satellite image analysis using forest canopy density (FCD) formula to know relationships between canopy density with the age of oil palm trees, and the next step is estimate the amount of oil palm trees production. Generally, the methodology on this study can be seen on Figure 1.

2.1. Forest Canopy Density (FCD)

In this research, the age of oil palm trees is predicted using remote sensing technique based on canopy density of oil palm trees. Forest canopy density (FCD) utilized as essential method to estimate stand age. This model involves bio-spectral phenomenon modelling and analysis utilizing data derived from four indices that are Advanced Vegetation Index (AVI); Bare Soil Index (BSI); Shadow Index (SI); and Thermal Index (TI). The result of four indices integration in this modelling is percentage of canopy density in each pixel. Zero percent is no vegetation and 100 percent is very high density.

Advanced Vegetation Index (AVI) was used to measure green vegetation. In remote sensing field, healthy vegetation characterize by high absorption and low reflectance in visible region. AVI has been calculated using equation 1.

\[ AVI = (B5 - B4) / (B5 * (1 - B4)) \]  

(1)
Similar with AVI, BI is normalized indices that used to separating vegetation and their background. This indices have opposite result with AVI because this is used to detected soil, it means near infrared wavelength will have low reflectance due to absorption by soil moisture. BSI has been calculated using equation 2.

\[
BSI = \frac{(B6 + B4) - (B5 + B2)}{(B6 + B4) + (B5 + B2)} + 100 \times 100
\]  

(2)

Canopy density also can detected by shadow characteristics that derived from spectral information and thermal information of the forest shadow. In remote sensing, shadow characteristics are defined by shadow index (SI) as spectral information because crown arrangement of oil palm trees will have shadow pattern that it affecting spectral responses. SI has been calculated using equation 3.

\[
SI = \left(\left(1 - B2\right) \times \left(1 - B3\right) \times \left(1 - B4\right)\right)^{1/3}
\]  

(3)

Thermal Index (TI) is used to check the black or shadow is real shadow not black soil. Land surface that was closed by shadow will have low temperature because leaf surface blocks and absorbs energy from the sun. TI has been calculated using equation 4 and 5.

\[
L_1 = M_1 * Q_{calc} + A_1
\]  

(4)

\[
T = K_2 / \ln\left(\frac{K_1}{L_1} + 1\right)
\]  

(5)

FCD value was shown as percentage of canopy density. Integrated from four indices was used to calculated this model. AVI and BSI wan integrated and have result as vegetation density (VD). Processing method is using principal component analysis which is AVI and BSI have high negative correlation. Higher AVI value will have low value in BSI because canopy density or vegetation cover was high and no bare soil or open surface at there. After that, VD will set in the percentage scaling from zero percent to a hundred percent point.

Another calculation is scaled shadow index (SSI) that derived from integration of SI and TI. In areas where the SSI value is zero low, this corresponds with oil palm plantation that have the lowest shadow value or minimum canopy density, opposite with areas where the SSI value is 100 that have the high canopy density. VD and SSI will integrated to achieve FCD value with equation 6.

\[
FCD = (VD \times SSI + 1)^{1/2} - 1
\]  

(6)

2.2. The Age of Oil Palm Tree

Forest canopy density (FCD) was used to estimate oil palm trees age with assumption if older trees will have higher percentage of canopy density. The class number of stands age divided into 4 class, according to oil palm classification from Plantation Education Agency of Indonesia. Correlation between oil palm trees age and canopy density was shown in Table 1.

| No | Class | Stands Age | % Canopy Density |
|----|-------|------------|-----------------|
| 1  | Seed  | 0 - 3      | < 10            |
| 2  | Young | 3 - 8      | 10 - 40         |
| 3  | Teen  | 9-14       | 41 - 80         |
| 4  | Mature| 15 - 25    | > 80            |

Source: Plantation Education Agency, 2013 with modification
Secondary data such as planting pattern was used to achieve trees density in every hectares. In this research we use assumption if planting pattern in research area using triangle pattern with 9 m distance between stands. According to Plantation Education Agency (2013), planting pattern with 9 m distance between stands and distance between rows is 7.8 m, in every hectares will have 143 trees.

Correlation of FFB production with stands age will show in Table 2. Average bunches or FFB in this table using 6 months because oil palm trees will harvest every 6 months. From this spatial data, overlay with oil palm trees stands age and FFB production for each trees will achieved the amount of FFB in every stands age in every hectares.

| No | Class  | Stands Age | Average Bunch/trees (kg/6 months) |
|----|--------|------------|----------------------------------|
| 1  | Seed   | 0 - 3      | 0                                |
| 2  | Young  | 4 - 8      | 68.77                            |
| 3  | Teen   | 9-14       | 109.08                           |
| 4  | Mature | 15 - 25    | 73.91                            |

Source: Plantation Education Agency, 2013 with modification

3. Result and Discussion

3.1. Forest Canopy Density Model

Canopy density of oil palm trees in Cimulang plantation shows similar variation between 54%-93% with average density as 75%. Crops pattern and time of planting in this area that relatively same, indicated by similar variation of their canopy density. Furthermore, it is important to do other research in different area as a part to check the accuracy assessment for forest canopy density model to estimate the age of oil palm trees that have been used.

3.2. Oil Palm Trees Age

Forest canopy density was used to estimate the age of oil palm trees with assumption older trees will have higher percentage of canopy density but using non linear assumption. Satellite image analysis shows the results for Cimulang area covers with FCD value ranges from 49.00 – 93.98 for each pixel.
These results were used to estimate oil palm trees age and from that value and based on Table 1, this area consist of two class of oil palm trees age that are teen with canopy density 41–80% and mature with canopy density more than 80%.

![Figure 3](image1.png)

**Figure 3.** Correlation of Canopy Density with the Age of Oil Palm Trees

The result from satellite image analysis shows in Cimulang plantation teen old oil palm trees covers around 81.5% of that area, followed by mature oil palm trees with 18.5% or corresponding to 100 hectares. In this area we cannot found seed or young oil palm trees and it is means no new plantation in this area. Based on Table 2 about correlation of FFB production with the age of oil palm trees, we can calculate if Cimulang area have total production of FFB every six months around 7,974,787.24 kg.

![Figure 4](image2.png)

**Figure 4.** Class of oil palm trees age
In this research, we have assumption if some variable was equal for all area such as soil type, planting pattern, type of fertilizer, and another plantation management, because all of this variable have big correlation with canopy. Other plantation management have big correlation with canopy density is pruning tree branches. Many plantations have this policy to keep the amount of sunlight in that plantation and it will make the dense of oil palm trees canopy will different compare with natural oil palm trees.

The result in this paper is preliminary result, and in the future, field survey will be conducted as verification process for interpretation result. The age of oil palm trees is very important part for FFB production. The class number of stands age divided into 4 class and consist of seed, young, teen, and mature. From table 2, we can see if almost all of this class have small range of age difference such as seed class from 0 – 3 years old, young class from 4-8 years old, and teen from 9 – 14 years old. But this condition is different for mature class where this class have large range of age from 15 – 25 years old, this condition was happened because in this class was difficult or have problem to distinguish the mature (15-20 years) and old stands age (more than 20 years old). Characteristic from oil palm trees after 20 years old is different, the length of canopy or steam leaves increases is equal with growing phases, but the direction is different which steam leaves will grow with smaller angle and tend to lead downwards. Detailing the stands age class will make estimation of FFB production using remote sensing more accurate. Multi-temporal analysis can be used for detailing the stands age class and to know remote sensing capability to estimate the age of oil palm trees age and their production.

4. Conclusions
Forest canopy density can be used to estimate the age of oil palm trees with assumption older trees will have higher percentage of canopy density. Result from this research shows this method only can divide 4 class and consist of seed, young, teen, and mature caused by difficult to distinguish the mature (15-20 years) and old stands age (more than 20 years old). This problem was happened because characteristic from oil palm trees after 20 years old have steam leaves growing with smaller angle and tend to lead downwards. Multi-temporal satellite image analysis of oil palm plantation area will be very useful for monitoring and detailing information of oil palm trees age particularly to distinguish the mature (15-20 years) and old stands age (more than 20 years old).

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