Potential of PALSAR SCANSAR data for oil palm plantation in growth monitoring and mapping

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Abstract. The main objective of this study is to analyze the potential use of L-band radar data with 100 meter spatial resolution for age estimation of oil palm. Age of oil palm are very important parameter to be investigated, because age and condition of oil palm are the main factors for yield forecasting, biomass estimation, replanting plan, fertilization plan, etc. As sensitive to roughness and moisture, the variations of oil palm backscatter that received by SAR satellite caused by the differences of oil palm age. This condition give possibility to investigate the relation between backscatter and age. Four radar images were acquired using the Scanning synthetic aperture radar /Advanced Land Observing Satellite (ScanSAR/ALOS)-2 sensor over the oil palm plantation in Tandun Riau, July 2016, 2017, 2018 and 2019. The information about ages from very young up to mature were gathered from oil palm plantation of PTP N V in Tandun. The growth model equation was built to describes the development of backscatter of oil palm from young age to mature age. Method to get growth model is regression analysis. The growth model that has been obtained is logarithmic equation with R² around 0,90 for HH SAR polarization. Growth model then can be used for age estimation and produce oil palm map based on it’s age that can be used for yield estimation, as well as for oil palm’s condition monitoring including it’s health.

1. Introduction

Oil palm, or what is known in Latin as Elaeis, is one of the most popular commodity types in plantation businesses, not only in Indonesia, but also in the world. This is indicated by the trend of clearing land for oil palm plantations. Palm oil is the world’s second most widely consumed edible oil [1]. In Indonesia, which is one of the major oil palm commodity producing countries, it grows a lot in Sumatra, Java, Kalimantan and Sulawesi. Oil palm trees have a shape similar to palm trees, with trunks that can reach 24 meters high. As a type of plantation that is developed and widely cultivated in Indonesia, oil palm has much benefits.

As the largest producer, good management in oil palm plantation is very important, such as detecting unhealthy plants, fertilization plan, irrigation management. Therefore the information about oil palm or condition of their growth is needed. Age information is a good indicator for yield prediction as it influences the quality and quantity of the fresh fruit bunches [2]. Besides it is an important piece of information to complete the allometric equation for the estimation of biomass [2], [3]. This further indicates the carbon stock of oil palm and its environmental effects [3], [4]. Besides, age information is important to precision agriculture, to detect the growth anomalies among oil palms to plan good management practices and optimize resource management [3], [5]. All in all, accurate information on tree age is important for scientific and practical reasons, for it determines the
productivity of a tree. Since Indonesian of Oil Palm Research Institute (IOPRI or PPSK) in Medan Indonesia has analyzed data of production of fresh bunch fruit in ton per hectare in 3 land suitability level as figure 1 [6] [7], this gives possibility to do preliminary forecasting of oil palm production.

![Figure 1. Oil Palm Production in Indonesia based on Land Suitability level](image)

Remote Sensing has significant potential to aid oil palm monitoring and detection efforts. It also provides a cost-effective method to these purposes and at the same time provides site-specific assessments of management practices and growth performance of the palms. Some aspects of oil palm monitoring have been studied. Within the domain of land cover classification, previous studies show that oil palm can be mapped, for instance, have reported that oil palm plantation in some South East Asian countries can be observed by coarse-scale MODIS [8]. Satellites data including Landsat Thematic Mapper and SPOT have been successfully used to identify oil palm areas and to map the oil palm even based on their ages [9], [10]. Research by LAPAN on oil palm plantation in Lampung Sumatera Indonesia showed that the regression coefficient between Landsat spectral band and oil palm age is 69%. Band 5 of Landsat, IRI (Infra Red index), and MIRI (Middle Infra Red Index) of Landsat give the biggest correlation with oil palm age [11]. Research by LAPAN also showed that the growth of oil palm can be explained by NDVI of SPOT6 with determination coefficient around 87% [12].

ALOS (Advanced Land Observation Satellite) is one of satellite that has SAR sensor. The post-ALOS program of JAXA has the goal to continue the ALOS (nicknamed Daichi) data utilization consisting of ALOS-2 (SAR satellite) and ALOS-3 (optical satellite) in accordance with Japan's new space program. In 2010, ALOS has been operated for more than four years since January 2006 to accomplish four mission goals, including: cartography, regional observations, disaster monitoring, and resource surveys. ALOS-2 will continue the L-band SAR observations of the ALOS PALSAR (Phased Array L-band Synthetic Aperture Radar) and will expand data utilization by enhancing its performance [13].

ALOS-PALSAR penetrates through the foliage and interact primarily with the woody components of vegetation. Horizontally transmitted waves are either depolarized through volume scattering by branches in the canopy, with a proportion of vertically polarized microwaves returning to the sensor, or penetrate through the canopy and interact with the trunks, returning primarily through double bounce scattering as a horizontally polarized wave [13]. Longer L-band (e.g. L-band 15-20 cm) microwaves have a greater likelihood of penetrating the foliage and small branches at the upper canopies of the forest, and interacting with woody trunks and larger branch components as well as the underlying surface [14,15]. It has been proven that radar is sensitive to the structure of the canopy. The
received backscatter intensity represented in the image is a composition of interactions with the crown, the trunk and the ground surface. Using fully polarimetric SAR it is possible to derive a relationship between backscatter, texture and crop status [16]. The studies of ALOS PALSAR with fine resolution for detection of oil palm has been conducted by several researcher. Combination of ALOS PALSAR and MODIS data can distinguish oil palm, rubber and forest by using ISODATA and K-Means Classification [17]; combination with ALOS AVNIR also can detect small holder oil palm by using texture analysis. [18]. The successful in distinguishing of oil palm from other land use give further challenge, that is oil palm’s age estimation.. Some researches about correlation between crown diameter, Leaf area index, height and stem’s diameter of plants with age proved there is strong relation between age and parameters and very strong correlation between height and age of oil palm [19]

The difference appearance of oil palm from young to mature age can be indicated by the increasing of it’s height and frond’s length. Correlation between length of palms fronds with age also high. These condition will give difference backscatter that recorded by SAR sensor. The correlation of age and backscatter of oil palm has been analyzed by using regression analysis, and give good correlation [19]. Between 2006 and 2011 the ALOS PALSAR acquired an impressive archive of ScanSAR data which are potentially suited also for land surface monitoring including vegetation. The advantage of ScanSAR is the ability to achieve wideseath coverage required for short repeat intervals with moderate increase of system complexity. ScanSAR successively illuminates parallel overlapping swaths with a burst of radar pulses. A sketch of the PALSAR acquisition modes is shown in Figure 2 [13]

| SCANSAR Mode          | Parameters                  |
|-----------------------|-----------------------------|
| Frequency             | 1270 MHz (L-band)           |
| Channel wide          | 24/14                       |
| Polarization          | HH or VV                    |
| Spatial Resolution    | 100 m                       |
| Coverage wide         | 250-350 km                  |
| Incident Angle        | 14 – 43 degree              |
| NE Sigma 0            | -25 DB                      |

This study has objective to investigate the potential of ALOS SCANSAR with middle resolution to monitor the growth of oil palm and map the oil palm distribution based on it’s age.
2. Methodology

2.1. Study Area
The Study Area of this study is District Tandun, Riau, with the focus area of oil palm plantation that belongs to PTP N 5, located in area around 1.220 – 0.517 North Latitude and 100.204 – 100.97 East Longitude.

2.2 Data
The ALOS SCANSAR data that used in this study has 2 polarizations: HH and HV. We used data of ALOS data July 2016, 2017, 2018 and 2019 that obtained from JAXA Japan. One image of data 2019 with RGB combination is shown in figure 3. This data cover most of Riau Province area, and has clipped by vector of oil palm that obtained from Coordinating Ministry for Economic Affairs of the Republic of Indonesia.

Field survey and secondary data collection was conducted in PTP N V Tandun areas. Figure 3 shows ALOS image of that area with vector of oil palm blocks. This vector has detail information about block and planting year as in figure 4. The planting years are in this area are : 1991, 1993, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2012, and 2015.
Meanwhile figure 5 is the information about oil palm block and year of planting.

The planting years are in this area are: 1991, 1993, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2012, and 2015.

2.3. Flow Chart
For this study the works that shown in dash square in flow chart was done in other projects under coordination of Coordinating Ministry for Economic Affairs of the Republic of Indonesia, three authors were involved in this works. Analysis data to get the relation between age and SAR backscatter of oil palm is regression analysis. The result of this analysis can be called as growth model because explain the development value of back scatter of oil palm year by year. The data processing for this study followed this flow chart (figure 6).
Figure 6. Flow Chart of Study

3. Result dan Discussion

Figure 7 is pictures of oil palm condition that gathered from field that describes the condition of oil palm with 6, 10, 12 and 13 years

![Condition of oil palm at several ages in PTPN V](image)

Figure 7. Condition of oil palm at several ages in PTPN V

Regression analysis to investigate the relation between age and backscatter of oil palm are shown in Figure 6. Left figure is result of regression analysis for HH polarization, and right figure is result for HV polarization. Regression Models for both polarization as the results of regression analysis are

\[ y = 3.2578 \ln(x) - 20.99 \] with \( R^2 = 0.7626 \) for HV polarization

And \[ y = 3.6472 \ln(x) - 16.925 \] with \( R^2 = 0.908 \) for HH polarization

Where \( y \) = back scatter of oil palm by ALOS SCANSAR, and \( x \) = age of oil palm

...and the graphics of each models are in figure 8.
Figure 8. Regression analysis between age and backscatter of oil palms

Models also describe the growth of healthy palm because training sample for regression analysis were taken from healthy oil palm from young age to mature age. The health oil palm will scatter energy by following logarithmic function during their growth. Back scatter increase rapidly from age 1 to around 15 years old then slowly after 15 years old.

Logarithmic model also confirmed by study result that conducted in Malaysia [14] and HH polarization give better $R^2$ than HV polarization. The rapid increasing of back scatter when oil palm still young until around 15 years old is caused by the growth of trunk’s height, length of fronds, more leaves and more branches [20]. Meanwhile after age 15 there is no more addition even become less fronds length.

Due to this model was built from healthy oil palm, therefore the difference of backscatter that resulted at certain age can be made as indicator of oil palm problem, particularly health problem. Several diseases such as Ganodhema reported cause the broken of palm’s fronds [14-5]

As describing of relation between age and backscatter of oil palm, model with biggest $R^2$ can be used to estimate age from backscatter. It means whenever we want estimate the age in certain area in Tandun district, we can use that model. The equation of regression model where age as dependent variable is:

$$y = 85.36e^{0.249x}, \quad R^2 = 0.908$$

Spatial information as result of age estimation by using equation 3 is shown in figure 9. Figure 9 explain about the distribution of oil palm based on it’s age in Tandun District Riau that generated from ALOS SCANSAR data. Ages in this area was classified into 7 class, where each class has range of age 5 years, and each class was represented with different color. The lowest age is dark green color and the highest age is red color. From this image, we can see that the age of oil palm in Tandung Riau is dominated by age from 5 years old to 20 years old. In this area also there are oil palm with age >25 years old.

This spatial information can be used to predict yield production as shown by figure 1, also to know the location and area of oil palm that must be replanted due to it’s age, as well as to monitor the condition of oil palm if data that used is time series data. Growth model is also can be used to monitor the health of oil palm by comparing the growth model of health oil palm and the value of backscatters of oil palm that monitored.
Figure 9. Spatial information of oil palm distribution based on age.

4. Conclusion
This study found that ALOS ScanSAR with 100 m resolution can be used for investigating the age of oil palm. Relationship between HH, HV derived from PALSAR SCANSAR and age of oil palm is very strong, with determination coefficient of model $R^2$ is 0.91 for HH and 0.71 Model can be used to estimate age of oil palm in the area that has same or similar condition. The information about age give possibility to predict oil palm yield production, and to investigate oil palm that must be replanted and to know the anomaly condition due to it’s health.

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