An investigation of age and yield of fresh fruit bunches of oil palm based on ALOS PALSAR 2

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Abstract. The objective on this study is to investigate age and yield of FFB of oil palms based on ALOS PALSAR 2. Study areas in oil palm plantations areas of Jerantut, Pahang Malaysia. Methodology consists of collecting of ALOS PALSAR 2 and tabular data on the study area, processing of ALOS PALSAR 2 including of converting digital numbers to normalized radar cross sections (NRCS), topography correction and filtering, making of regions of interest according to areas of age and yield of FFB of oil palms and making of relationship analysis between backscatter value of HH, HV and age and yield of FFB of oil palm. The results have showed relationship between HH, HV and age of oil palm which $R^2$ of 0.63 for HH and 0.42 for HV that indicated increasing of age of oil palm as increasing of HH and HV value. Also relationship between HH, HV and yield of FFB of oil palm which $R^2$ of 0.26 for HH and 0.15 for HV, that indicated increasing of yield of FFB as decreasing of HH and HV value.

1. Introduction

Oil palm is the most productive oil seed and is becoming an increasingly important agriculture in the world which is around 85% of the crude oil originates come from Malaysia and Indonesia [1]. High yield and low production costs of palm oil are the reasons driving commercial plantation companies to cultivate oil palm trees on a large scale [2]. Since the 1990s, palm plantations are in expansion in humid tropical areas, and land under oil palms increased to 12.6 million hectares in 2010 with annual palm oil production exceeding 32 million tons suggests that global demand for palm oil will be about 62–63 million tons in 2015 [3]. In the case of Malaysia, first oil palm plantations established in 1917, the oil palm area has expanded continuously, and recent increases in the demand for food, chemicals and biofuels have led to a surge in land conversion rates [4,5,6,7]. Oil palm plantations in Malaysia covered approximately 5.08 million ha in 2012, an increase of 1.6 per cents against 5.00 million hectares recorded in 2011 [4,8]. The state of Sabah is the largest producer of oil palm in Malaysia, with 1.44 million ha of oil palm plantations or 28.4 per cent of the total oil palm planted area in Malaysia, followed by Sarawak with 1.08 million ha (21.2 per cent) [4,8]. On the oil palms cultivation needs humid equatorial conditions to thrive, and conditions in Southeast Asia are ideal [9]. Seasonal droughts at higher tropical latitudes greatly reduce yields [10]. Also age of the oil palms is one of the important factors influencing the production of fruit bunches [11,12]. According to [11,13] age data on oil palm have the potential to be used in precision farming. Organization or management of zones based on such data is effective for maximization of palm oil yield, which is one of the most important variables...
affecting profit [11]. According to [11] collecting age data on oil palm trees is time consuming and costly, especially on a large or regional scale.

Remote sensing has been widely proven to be essential in monitoring and mapping highly threatened on land use land cover including forest and plantation area. Although sensors in the optical range of the electromagnetic spectrum have received the greatest attention but optical remote sensing is the degradation of the imagery through haze which is a very common phenomenon in Malaysia and other countries in South East Asia [12]. The launch of the Japanese Space Exploration Agency’s (JAXA) Advanced Land Observing Satellite (ALOS) Phased Arrayed L-band SAR (PALSAR) represented a milestone in the global observation, characterization, mapping and monitoring of land use land cover including forest and plantation area largely, because these provide more information on the three dimensional structure and biomass of woody vegetation. As data can be days or night regardless of weather conditions, land use land cover including forest and plantation area can be observed more frequently, even in regions with prevalent cloud cover. 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. If we consider an oil palm as crops this is very interesting. It would help to derive certain patterns for different growth stages of the oil palm. This is very relevant information for optimized and sustainable oil palm plantation management [16].

On wholes our study is to investigate utilizing ALOS PALSAR 2 for oil palm plantation management including mapping, estimating of biomass and yield producing but now just started on the preliminary study. On this paper we focus to investigate age and yield of fruit fresh bunches (FFB) of oil palms based on ALOS PALSAR 2. Study areas in oil palm plantations areas of Jerantut, Pahang Malaysia.

2. Methodology
Methodology consists collecting of ALOS PALSAR 2 and tabular data on the study area, processing of ALOS PALSAR 2 including of converting digital numbers to normalize radar cross sections, topography correction and filtering, making of regions of interest in according to areas of age and yield of FFB of oil palms and making of relationships analysis between backscatter value of HH, HV and age and yield of FFB of oil palm. Generally the methodology on this study can be seen on figure 1.

2.1 Data collection
We used ALOS PALSAR 2 (Figure 2) that was launched on May 24, 2014. ALOS PALSAR L-band with 1.2 GHz center frequency and 14 or 28 MHz bandwidths and dual polarization HH (horizontal transmitting and horizontal receiving) and HV (horizontal transmitting and vertical receiving) developed by Japan Aerospace Exploration Agency (JAXA). We collected ALOS PALSAR 2 Fine Beam Double
Polarization (FBD) product level 1.5 that was acquired on February 28, 2015. FBD product level 1.5 has spatial resolution of 10 meters and swath of 70 km which multi-look data on slant range from map projection amplitude data with range and azimuth compressed. For this study we also collected tabular data about age and yield of fruit fresh bunches (FFB) on the study area. Age and yield of FFB based on each block. We collect age and yield of FFB with totally on 12 blocks in study area but for this case we have limitation because we collect age of oil palm majority on 11 to 21 years old.
2.2 Pre processing
Preprocessing focuses converting of digital number (DN) value of HH (DN_{HH}) and HV (DN_{HV}) to a normalized radar cross section (NRCS) in decibel (dB), (i.e., \( \sigma^o_{HH} \) and \( \sigma^o_{HV} \)) by the following equations [17]:

\[
\sigma^o_{HH} = 10 \times \log_{10}(DN^2_{HH}) - CF \tag{1}
\]

\[
\sigma^o_{HV} = 10 \times \log_{10}(DN^2_{HV}) - CF \tag{2}
\]

Where, \( \sigma^o \) is backscattering coefficient and CF is the calibration factor. The CF is dependent on the processing date, in this study CF is equal to -83.0 both for HH and HV.

For reducing multiplicative speckle noise and topography effect on ALOS PALSAR 2 imaging we used frost enhancement filtering [18] with windows size 5x5 and orthorectification. Since lack of detail topography data, on this study we used Shuttle Radar Topography Mission (SRTM) data for processing of orthorectification.

2.3 Region of interest (ROI) and relationships analysis
We create ROI on ALOS PALSAR 2 with considering of age and yield of FFB region. We have totally 12 of ROI. Each ROI has information of age and yield of FFB of oil palm. On ALOS PALSAR 2 imaging data contain response from characteristics of oil palm. Backscattering response of oil palm area depends on structure and density of oil palm. All oil palm stand and even for that matter various structure and density have different backscattering and texture pattern in various wavelengths. Thus the relationships between age and yield of FFB and remotely sensed data are unique. For analyzing these relationships, Pearson’s correlation coefficient is used. If the coefficient is close to 1, it means there is a strong relationship between them. In this study, the first variable is age, yield of FFB and HH, HV value derived from ALOS PALSAR 2. The coefficient of determination (\( R^2 \)) is indication of the regression model. The \( R^2 \) value will show the percentage of variation as the regression models variables.

3. Result and discussion
On this study we have some variables such as age, yield of FFB of oil palms derived from field surveys and ancillary data and HH, HV value derived from ALOS PALSAR 2. We integrate each other to know regression models and coefficient determination. Based on regression models and coefficient determination we can get information about relationships both each other.

Firstly we investigate relationship between age and yield of FFB on the study area. We collect information of age and yield of FFB from 12 blocks in study areas. The limitation on this study area is variety of age of oil palms majority from 11 to 21 years old. Scatter plot between age and yield of FFB can be seen on figure (3). Based on figure 3 has indicated that increasing of age of oil palm as decreasing of yield of FFB. On this case we use linear analysis because we start from 11 to 21 years old. According to [11,12] commonly oil palm trees have an economical life pan up to 25 years old which begin at the time a tree reaches maturity at about 3 years, with production reaching a peak between 6 and 10 years [11, 13]. Yield reach a peak at around 10 years and decrease after that [11,17].
Secondly we investigate relationship between age and HH, HV derived from ALOS PALSAR 2 on the study area. Relationship between HH, HV and age of oil palm can be seen on figure 4. Based on figure 4 relationship between HH, HV and age of oil palms is moderate, the coefficient of determination ($R^2$) is 0.63 for HH and 0.42 for HV. Figure 4 can be indicated increasing of age of oil palms as increasing of HH and HV value. We hypothesized oil palms growing up that cause higher of trunks, more leafs, more branches and larger of canopy. The condition will add more double and volume backscattering value that overall will add HH and HV backscattering value. According to [11] height of oil palms has strong correlation with age, the coefficient of determination values is 0.90 and canopy of oil palm has strong correlation with age that larger of canopy as older of oil palm, the coefficient of determination value is 0.88 [18] also higher of HH and HV value indicated of higher of above ground biomass of oil palm [19].

Thirdly we investigate relationship between yield of FFB and HH, HV derived from ALOS PALSAR 2 on the study area. Relationship between HH, HV and yield of FFB of oil palm can be seen of figure 5. Based on figure 5 relationship between HH, HV and yield of FFB of oil palms are not strong. The coefficient of determination ($R^2$) is 0.26 for HH and 0.15 for HV, that was indicated increasing of yield as decreasing of HH and HV value. For this case we also use yield of FFB derived from age of oil palms.
from 11 to 21 years old. We believe if use more yield of FFB derived from variety of age of oil palms will get more better results. Our hypothesized of age has significant correlation with HH, HV derived from ALOS PALSAR and also age has significant correlation with FFB of oil palm because of that HH, HV has significant correlation with FFB of oil palm. However backscatter values derived from ALOS PALSAR depend on wavelengths, polarization, incident angle and temporal data, environment (e.g. moisture, landscape) [20, 21] and structure of oil palm (e.g. size, geometry and orientation of leaves, trunks, branches, and aerials or stilt roots) [22, 23].

4. Conclusion
The study has showed an investigation of age and yield of FFB of oil palms based on ALOS PALSAR 2. Based on age of oil palms from 11 to 21 years old we found increasing of age of oil palms as decreasing of yield of FFB. Also we found relationship between HH, HV derived from ALOS PALSAR 2 and age of oil palm is moderate. $R^2$ is 0.63 for HH and 0.42 for HV that be indicated increasing of age of oil palm as increasing of HH and HV value. We hypothesized oil palms growing up that cause higher of trunks, more leafs, more branches and larger of canopy. The condition will add more double and volume backscattering value that overall will add HH and HV backscattering value. Finally we found relationship between HH, HV derived from ALOS PALSAR 2 and yield of FFB derived from age of oil palm from 11 to 21 years old is not strong, $R^2$ of 0.26 for HH and 0.15 for HV that has indicated increasing of yield as decreasing of HH and HV value. We believe utilization of ALOS PALSAR 2 is promising for monitoring and management of oil palm plantation, for future works we will collect more ALOS PALSAR and samples of oil palm for mapping and creating a model to estimate biomass, age and FFB in regional area also considering effect of rainfall and topography on oil palm management.

Conflict of interest
The author declare that there is no conflict of interests regarding the publication of this paper.

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