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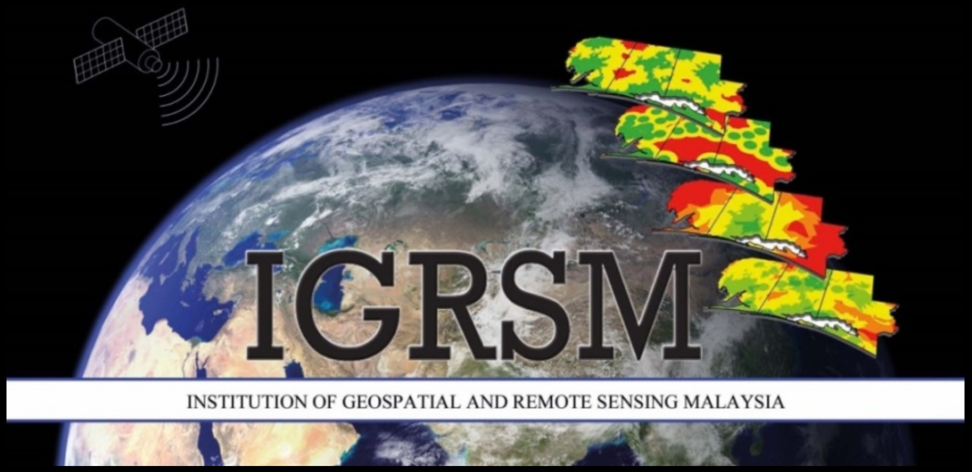

AN INVESTIGATION OF AGE AND YIELD OF FRESH FRUIT BUNCHES OF OIL PALMS BASED ON ALOS PALSAR 2

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ABSTRACT

The objective on this study is to investigate the age and yield of fresh fruit bunches (FFB) of oil palms based on ALOS PALSAR 2. The study area is oil palm plantations areas of Jerantut, Pahang Malaysia. The methodology consists collecting of ALOS PALSAR 2 and inventory 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, creating regions of interest according to areas of age and yield of FFB of oil palms, and performing relationships analysis between backscattering of HH, HV, and age and yield of FFB of oil palm. The results showed the relationship between HH, HV and age of oil palm, with R^2 of 0.63 for HH and 0.42 for HV, which indicated increasing age of oil palm causing increasing backscattering value of HH and HV. In addition, there was a relationship between HH, HV and yield of FFB of oil palm, with R^2 of 0.26 for HH and 0.15 for HV, that has indicated increasing of yield of FFB as decreasing of backscattering value of HH and HV.

Keywords: *Tree plantation; L band; coefficients of correlation and determination.*

1. INTRODUCTION

Oil palm is the most productive oil seed and is becoming an increasingly important agriculture in the world, with approximately 85% of the crude oil originating from Malaysia and Indonesia (Mc Donald *et al*., 2013). 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 (Wahid *et al*., 2005). Since the 1990s, oil palm plantations have been in expansion in humid tropical areas, and land under oil palms increased to 12.6 mil. ha in 2010 with annual palm oil production exceeding 32 mil. tons, suggesting that global demand for palm oil will be about 62–63 mil. tons in 2015 (Aholoukpè *et al*., 2013). In the case of Malaysia, the first oil palm plantations were established in 1917. The oil palm areas has expanded continuously, and recent increases in the demand for food, chemicals and biofuels have led to a surge in land conversion rates (Basri *et al*., 2005; Corley *et al*., 2009; Danielsen *et al*., 2009; Kho *et al*., 2015). Oil palm plantations in Malaysia covered approximately 5.08 mil. ha in 2012, an increase of 1.6% from 5 mil. ha recorded in 2011 (Malaysian Palm Oil Board, 2012; Kho *et al*., 2015). The state of Sabah is the largest producer of oil palm in Malaysia, with 1.44 mil. ha of oil palm plantations or 28.4% of the total oil palm planted area in Malaysia, followed by Sarawak with 1.08 mil. ha (21.2%) (Malaysian Palm Oil Board, 2012; Kho *et al*., 2015). Oil palms cultivation requires humid equatorial conditions to thrive, and the conditions in Southeast Asia are ideal (Sheil *et al*., 2009). Seasonal droughts at higher tropical latitudes greatly reduce yields (Basiron, 2007). In addition, the age of the oil palms is one of the important factors influencing the production of fruit bunches (Van Gelder, 2004; Tan *et al*., 2013). According to (Mc Morrow, 2001; Tan *et al*., 2013), the age data of 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. However, collecting age data on oil palm trees is time consuming and costly, especially on a large or regional scale (Tan *et al*., 2013).

Remote sensing has been widely proven to be essential in monitoring and mapping land use and land cover (LULC), including forest and plantation area. Although sensors in the optical range of the electromagnetic spectrum have received the greatest attention, optical remote sensing suffers from degradation of imagery through haze, which is a very common phenomenon in Malaysia and other countries in South East Asia (Van Gelder, 2004). 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 LULC, including forest and plantation area largely, because these provide more information on the 3D structure and biomass of woody vegetation. As data can be obtained in day or night regardless of weather conditions, LULC including forest and plantation area can be observed more frequently, even in regions with prevalent cloud cover. ALOS-PALSAR penetrates through 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 (Lucas *et al*., 2007). Longer L-band (e.g., 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 (Tsomon *et al*., 2002; Lucas *et al*., 2004). 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, trunk and ground surface. Using fully polarimetric, SAR it is possible to derive a relationship between backscatter, texture and crop status. This 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 (Christine *et al*., 2014).

Our study, which is aimed at utilizing ALOS PALSAR 2 for oil palm plantation management including mapping, estimation of biomass and yield production, has just been started and is in the preliminary study. In this paper, we focus on investigating the age and yield of fruit fresh bunches (FFB) of oil palms based on ALOS PALSAR 2. The study area is the oil palm plantations areas in Jerantut, Pahang Malaysia.

2. MATERIALS AND METHODOLOGY

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

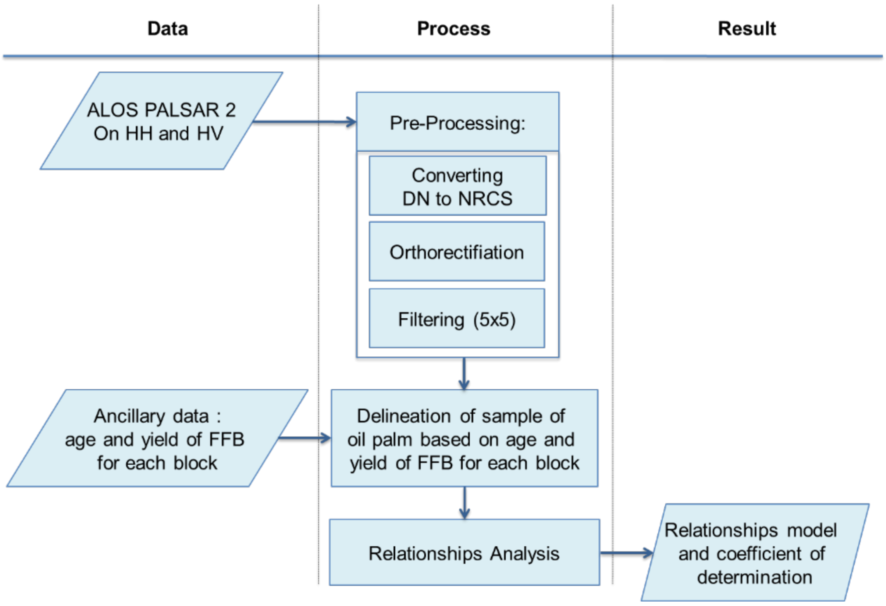


Figure 1: Methodology of this study.

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), was developed by the Japan Aerospace Exploration Agency (JAXA).

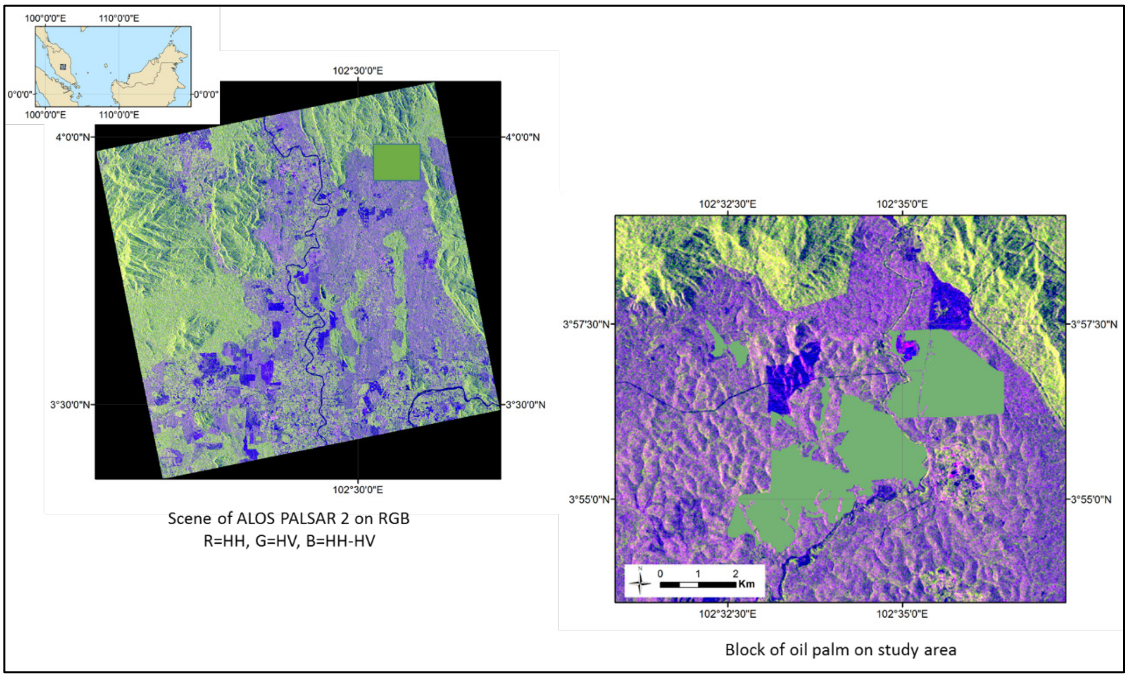


Figure 2: Data used for the study area.

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 m 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 field data about age and yield of fruit fresh bunches (FFB) in the study area, which was based on each block. We collected the age and yield of FFB with totally on 12 blocks in the study area, but for this case, we had limitation because we collected age of oil palm with majority of 11 to 21 years old.

2.2 Preprocessing

Preprocessing focuses on converting of the digital number (DN) values of HH (DN_{HH}) and HV (DN_{HV}) to a normalized radar cross section (NRCS) in decibel (dB), (i.e., $\sigma°_{HH}$ and $\sigma°_{HV}$) using the following equations (Shimada *et al*., 2009):

$$\sigma°_{HH} = 10 \text{ x } \log_{10}(DN^2_{HH}) - CF \quad (1)$$
$$\sigma°_{HV} = 10 \text{ x } \log_{10}(DN^2_{Hv}) - CF \quad (2)$$

where $\sigma°$ 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 topographic effect on ALOS PALSAR 2 imaging, we used frost enhancement filtering (Shimada *et al*., 2010) with windows size 5x5 and orthorectification. Due to lack of detailed topographic data, for this study, we used Shuttle Radar Topography Mission (SRTM) data for processing of orthorectification.

2.3 Region of Interest (ROI) and Relationships Analysis

We created ROI for the ALOS PALSAR 2 data by considering of the age and yield of the FFB regions. We have totally 12 ROIs. Each ROI has information on age and yield of FFB of oil palm. The ALOS PALSAR 2 data contains response from the characteristics of oil palm. Backscattering response of oil palm area depends on structure and density of oil palm. All oil palm stands, and even for that matter various structure and density have different backscattering and texture patterns 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 (r) is used. The value of r is such that $-1 \leq r \leq +1$. The + and – signs are used for positive linear correlations and negative linear correlations respectively. If the correlation coefficient (r) is close to 1, it means there is a strong relationship between them. In addition, we calculate the coefficient determination (R^2), which is a number that indicates the proportion of the variance in the dependent variable that is predictable from the independent variable. The coefficient of determination is such that $0 \leq R^2 \leq 1$, and denotes the strength of the linear association between x and y. In this study, the variables are age and yield of FFB, and HH and HV value derived from ALOS PALSAR 2.

3. RESULTS AND DISCUSSION

For this study, we had some variables such as age and yield of FFB of oil palms derived from field surveys and ancillary data, and HH, HV values derived from ALOS PALSAR 2. We integrated each other to determine the coefficient correlations and determination. Based on regression models and coefficient of determination, we obtained information on the relationships between each other.

Firstly, we investigated the relationship between age and yield of FFB in the study area. We collected information of age and yield of FFB from the 12 blocks in study areas. The limitation of this study area is the age of oil palms has majority from 11 to 21 years old. The coefficients of correlation and determination between age and yield of FFB are r = -0.48 and R^2 = 0.23 respectively. The scatter plot between age and yield of FFB can be seen on Figure 3, indicates increasing of age of oil palm with decreasing of yield of FFB. In this case, we used linear analysis because we started from 11 to 21 years old. Based on linear analysis for age and yield on 11 to 21 years old, the values of coefficients correlation and determination are not strong. According to Van Gelder (2004) and Tan *et al*., (2013), oil palm trees commonly have an economical life span up to 25 years old, which begin at the time a tree reaches maturity at about 3 years, with production reaching peak between 6 and 10 years (Mc Morrow, 2001; Tan *et al*., 2013), and decreases after that (Chemura, 2012; Tan *et al*., 2013).

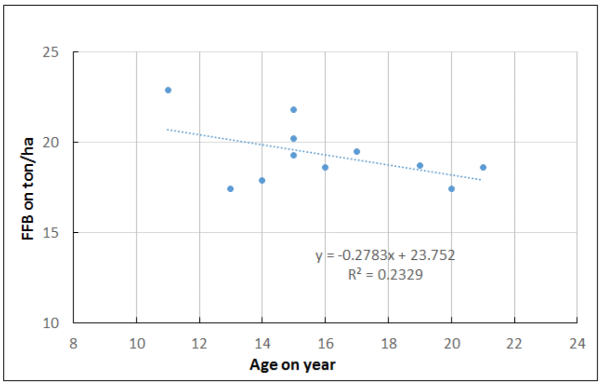
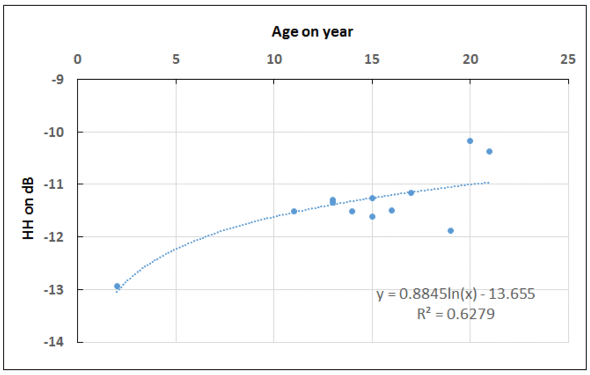


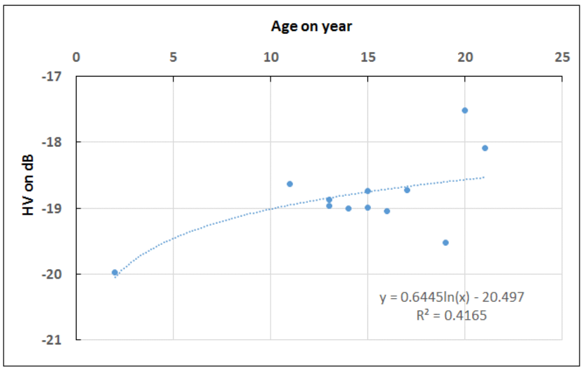
Figure 3: Relationship between age and yield of FFB of oil palm based on 11 to 21 years old oil palm trees.

Secondly, we investigate relationship between age of FFB, and HH and HV derived from ALOS PALSAR 2 for the study area. For this relationship (Figure 4), we used logarithmic trend line because the rate of change in data increased quickly. The relationship between HH, HV and age of oil palms is moderate, with the coefficient of determination (R^2) being 0.63 for HH and 0.42 for HV. Figure 4 indicates increasing of age of oil palms with increasing HH and HV values. We hypothesized oil palms growing that causes higher of trunks, more leafs and branches, and larger canopy. This condition will increase the overall volume of backscattering values, which increases the HH and HV values. According to Tan *et al*., (2013), the height of oil palms has strong correlation with age, the coefficient of determination being 0.90, while according to Chemura (2012), the canopy of oil palm has strong correlation with the coefficient of determination value being 0.88. Furthermore, Vena *et al*. (2012) reported that higher HH and HV values indicate higher above ground biomass of oil palms.

Thirdly, we investigate the relationship between yield of FFB, and HH and HV derived from ALOS PALSAR 2 for the study area. Based on Figure 5, the linear relationships between HH and HV, and yield of FFB are not strong. The coefficient correlation (r) is -0.52 for HH and -0.38 for HV. The coefficient of determination (R^2) is 0.26 for HH and 0.15 for HV. It is observed that yield increases with decreasing values of HH and HV.

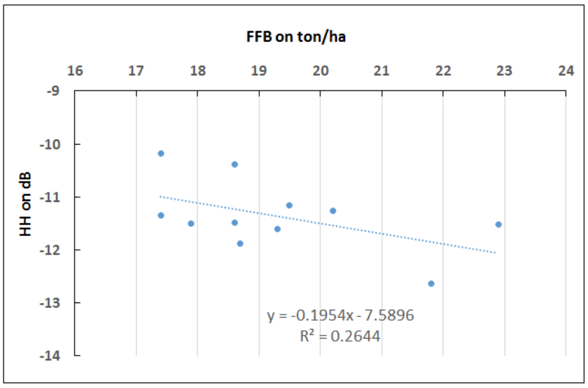


(a)

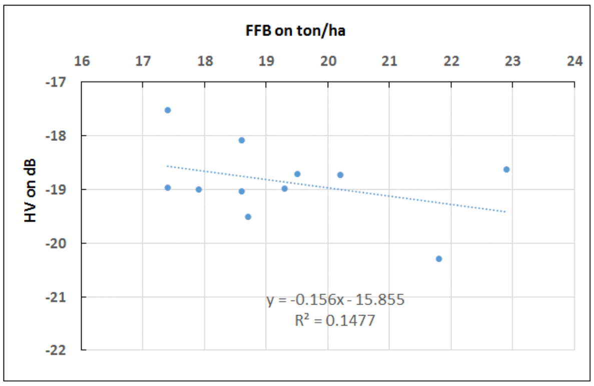


(b)

Figure 4: Relationships between (a) backscattering of HH and age of oil palms, and (b) backscattering of HV and age of oil palms.



(a)



(b)

Figure 5: Relationships between (a) backscattering of HH and yield of FFB, and (b) backscattering of HV and yield of FFB. The FFB was derived from oil palms of 11 to 21 years old.

For this case, we also use the yield of FFB derived from age of oil palms from 11 to 21 years old. We believe if we used more yield of FFB derived from a larger variety of age of oil palms, we will get better results. Our hypothesized age has significant correlation with HH and HV derived from ALOS PALSAR, and age also has significant correlation with FFB of oil palms because of that HH and HV has significant correlation with FFB of oil palms. However backscatter values derived from ALOS PALSAR depend on wavelengths, polarization, incident angle, temporal data and environment (e.g., moisture, landscape) (Lucas *et al*., 2010; Darmawan *et al*., 2015) and structure of oil palm (e.g. size, geometry and orientation of leaves, trunks, branches, and aerials or stilt roots) (Morel *et al*., 2011; Darmawan *et al*., 2014).

4. CONCLUSION

This study has reported on 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 increase of age of oil palms with decreasing yield of FFB. We also found that the relationship between backscattering of HH and HV derived from ALOS PALSAR 2, and age of oil palm is moderate. The coefficient determination (R^2) is 0.63 for HH and 0.42 for HV. Increasing of age of oil palm is observed for increasing of backscattering values of HH and HV. We hypothesized that oil palms growing results in higher trunks, more leafs and branches, and larger canopy. This condition increases the volume of overall backscattering values, which increases the values of HH and HV. In addition, we found that the relationship between HH and HV, and yield of FFB derived from age of oil palm from 11 to 21 years old is not strong, with R^2 of 0.26 for HH and 0.15 for HV. Increasing yield is observed for decreasing backscattering values of HH and HV. We believe that utilization of ALOS PALSAR 2 is promising for monitoring and management of oil palm plantations. For future works, we will collect more ALOS PALSAR 2 and samples of oil palm for mapping and creating a model to estimate biomass, age and FFB in regional areas, while also considering the effect of weather conditions 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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