APPLICATION OF AIRSAR DATA TO OIL PALM TREE CHARACTERIZATION

Laili Nordin
Malaysian Centre For Remote Sensing (MACRES)
13 Tun Ismail Rd., Kuala Lumpur, MALAYSIA
E-mail: laili@macres.gov.my

KEY WORDS: AIRSAR, Oil Palm**,** multi-polarization, multi-frequencies, backscatter

ABSTRACT

The utilities of AIRSAR data for oil palm biomass inventory and mapping are investigated. The study is on oil palm plantations in Tapah, Malaysia. The work focuses on two main applications. First, retrieval of oil palm biomass by establishing empirical relationships between backscatter coefficient and conventional estimation of biomass based on model as well as ground data. Second, mapping oil palm plantation based on age using segmentation algorithms and classification. The results of estimation oil palm biomass from radar backscattering coefficient using AIRSAR data are encouraging. The backscattering coefficient from both L-and P-bands of horizontally transmitted and horizontally received (hh), vertically transmitted and vertically received, and horizontally transmitted and vertically received (hv) are linearly correlated (r=0.75) with oil palm biomass and age. This is in agreement with other studies using JERS-1 SAR on oil palm where backscattering coefficient of L-hh is linearly correlated with oil palm height.

The results also show good degree of agreement between the outputs of a region growing segmentation algorithm applied to de-speckling SAR images (using 5 x 5, 7 x 7, 9 x 9, and 11 x 11 windows of Frost, Lee and Gamma filters), and conventional classification using optical Landsat Thematic Mapper data and field checking. However, the results are very complex, variable and highly dispersed. Oil palm of ages 6, 7, 15 and 20 years can be discriminated in L-hh polarization and 25 years old in P-hh polarization, respectively, after de-speckling with the Gamma filter of 5 x 5 window. The oil palm of one and two years old are highly discriminated in L-hh polarization with the Frost Filter of 5 x 5 and 7 x 7 windows, respectively. Oil palm with an age of 25 years can be discriminated in P-hh polarization with the Lee filter of 5 x 5 window and the five years old oil palm can be discriminated in L-hv polarization with the Lee filter of 9 x 9 windows. Overall, the Gamma filter of 11 x 11 window discriminates oil palm age classes more effectively than the rest.

The main conclusion of this work is that the biomass and age of oil palm can be estimated, discriminated and mapped using AIRSAR images. Thus, the multi-polarization and multi-frequencies AIRSAR data can be useful in monitoring oil palm biomass production and distribution in Malaysia based on their ages.

1. AIRSAR DATA AND STUDY SITE

The study area is the oil palm plantations in Tapah Malaysia, some 150 Kilometer north of Kuala Lumpur, Malaysia as showed in Figure 1. The AIRSAR data was acquired by JPL on 3rd December 1996. The site was imaged in both nadir and narrow swath modes of about 12 km width and 60 km long. The site is mountainous on the northern portion of the swath and flat on the southern. The flat portion minimizing geometric distortions in the image.

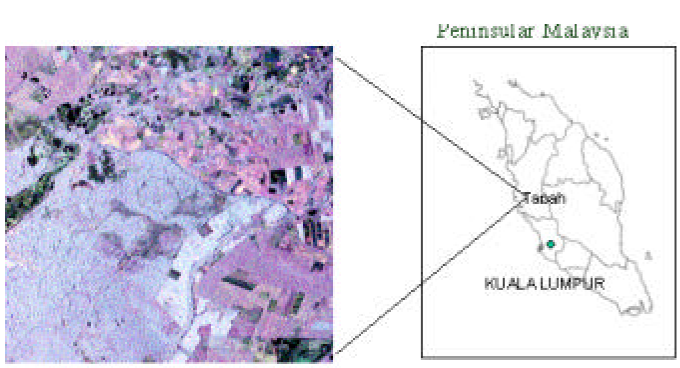


FIGURE 1 Location map of the study site at Tapah, Malaysia

The AIRSAR data was acquired, processed, and calibrated by NASA/JPL. The processed scene covered the whole strip of 60km. However, the scene used for this study is only 6 km x 6km corresponding to incidences angle between 20° and 55°. The image was smoothed using filters (Frost, Lee, Gamma and Local Sigma) with several window sizes (5 x 5, 7 x 7, 9 x 9 and 11 x 11) in order to reduce image speckle.The study site includes various ages of oil palm (1, 2, 5, 6, 7, 15, 17, 20 and 25 years old).

2. DATA ANALYSIS

2.1 Image interpretation

The segment of the AIRSAR data used in this study is shown in Figure 4, which shows polarization colour composite images of L-hh, L-hv and L-hv; P-hh, P-hv and P-vv. The difference in the backscatter between the various surface types is well pronounced at various polarizations of L- and P-band. The bright signature of rubber tree due to strong returns at all three polarizations is attributed corner reflection effect between stems branches. Oil palm, which scatter less strongly at L-hh and L-vv polarizations relative to cross-polarization, appear purplish and distinguishable from others. Natural forest and plantation forest are also identifiable on the imagery, although their signatures sometimes overlap. Roads at the middle of the imagery can also be well identified. However, the oil palm of various ages could not be well identified. It could be discriminated through further image processing. This study focuses on characterization of oil palm.

2.2 Signature Studies

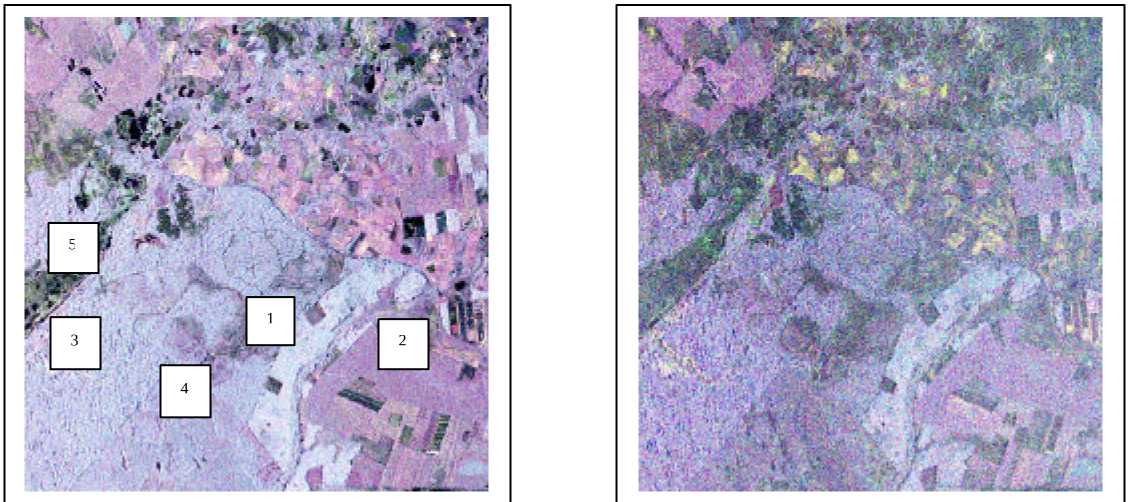
Image analysis was carried out to study various oil palm ages at the site. For each oil palm age, several training sites were identified based on field observation. The sites selected are homogeneous areas of 20 x 20 pixels or greater to reduce speckle-related fluctuation in the data and to generate reliable radar return statistics. In the analysis of the AIRSAR data, we have investigated the backscattering coefficient for each training site in both co- and cross polarizations of L- and P-bands: σ°_{HH}, σ°_{VV}, σ°_{cross} (mean of HV). Figure 5 shows the backscattering coefficient of various oil palm ages for each polarization and frequency as a function of oil palm ages. The curves represent the backscattering coefficient of the training site given by averaging the values of all pixels belonging to the site. The standard deviation is < 1.5dB for all ages of oil palm.

To reduce the effect of the incidence angle, the backscattering coefficient are normalized by a function F(θ) which represents the mean angular dependence for frequency and polarization. The normalized backscattering coefficient is defined as:

$$\sigma^{\circ}\nu = \frac{\sigma^{\circ}(\theta_t)}{F(\theta_t)} \qquad \text{Eq (1)}$$

Where $\sigma^{\circ}(\theta_t)$ is the backscattering coefficient at the incidence angle θ_t.

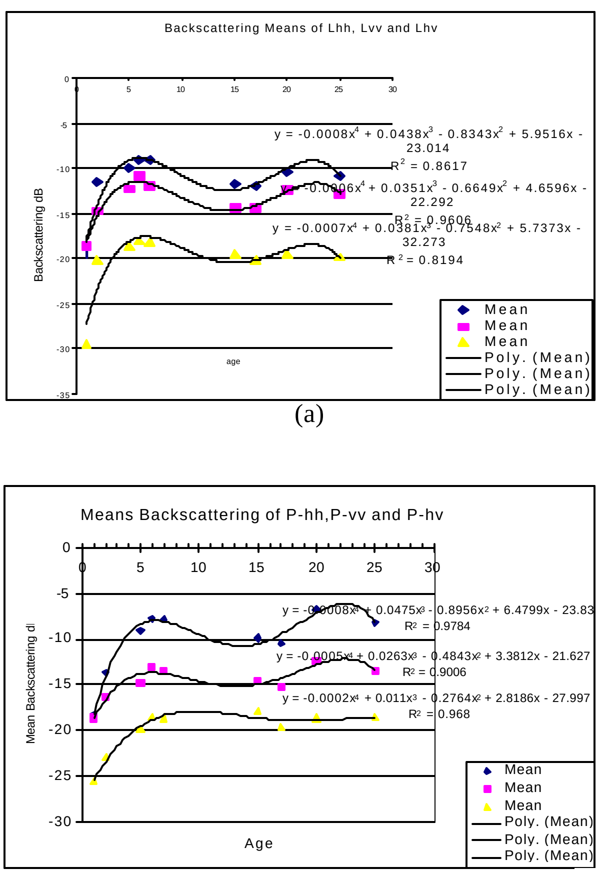
In linear units $\sigma^{\circ}(\theta_t)$ is given approximately by the relation $\beta \cos^{\alpha}\theta$ (Ulaby et al. 1982). Thus $F(\theta_t)$ is of the form $\cos^{\alpha}\theta$ and the normalized backscattering (β) is then by $\sigma^{\circ}(\theta_t)/\cos^{\alpha}\theta t$. The coefficient β is related to the target backscattering properties and α depending on the dominant scattering mechanism and sensor condition (Shi et al. 1994). It can be seen that a cosine-based curve will be represented by a straight line of slope α in a σ° (dB) verse 10log [cos (θ)] plot. The parameter α is computed for each surface for each surface type, each polarization and each frequency. Statistical analyses of normalized backscattering coefficient σ°_n at HH, VV and cross polarization of L- and P-band for various oil palm ages are shown in Figure 5. The author observed that the cross-polarization signature was lower than the HH and VV polarization of both L-and P-band The measurement show also that the backscattering coefficient at HH polarization of both L- and P-band are greater than those VV polarization due radar reaction with horizontal position of the oil palm fronds.



(a) (b)

N.B 1= Rubber Plantation, 2= Oil Palm Plantation, 3=Natural Forest, 4=Plantation Forest, and 5= Ex-tin mining

FIGURE 4 AIRSAR imagery (a) L-hh , L-vv and L-hv displayed in Red, Green and Blue (b) P-hh, P-vv and P-hv displayed in Red, Green and Blue



(b)

FIGURE 5 Mean Backscattering of (a) L-and (b) P-bands with hh, vv and hv Polarization from Oil Palm of

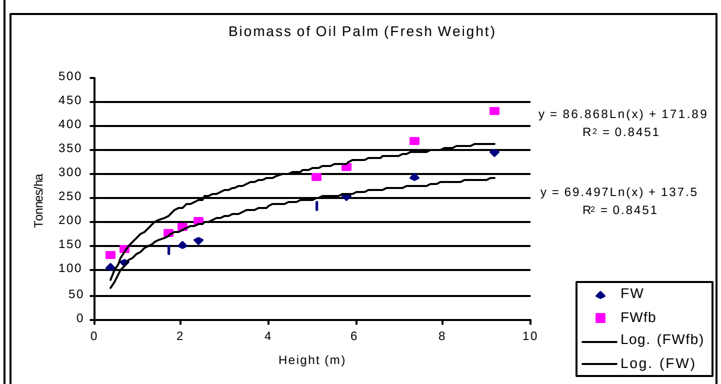


FIGURE 6 The Trend of Oil Palm Biomass Production Based on Height

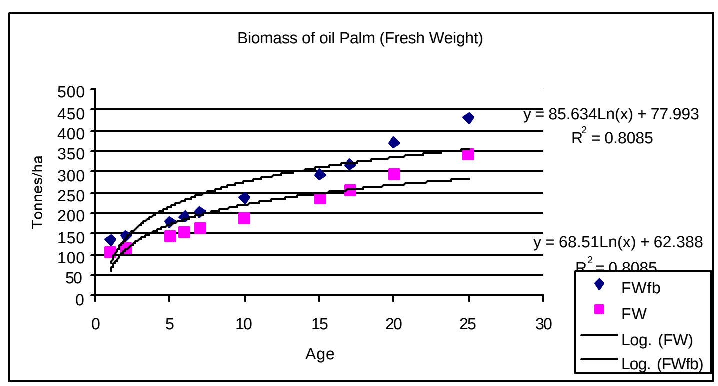


FIGURE 7 The Trend of Oil Palm Biomass Production Based on Age

2.3 Separability between Oil Palm Ages

The separability between the nine ages of oil palm has been studied for images of all polarizations and frequencies in order to identify the best configuration to discriminate different age of oil palm. The angular dependence of the backscattering coefficient was reduced by normalized the measured backscattering coefficients using equation (1). Oil palm age class separability matrix is computed using the separability measure, 'S' for nine classes. It is assumed that the nine classes are normally distributed with mean μ_i , μ_j and standard deviation σ_i and σ_j respectively. The separability measure 'S' for nine ages classes, I and j is defined as follows:

$$S = \frac{|\mu i - \mu j|}{\sigma i + \sigma_j} \qquad \text{Eq (2)}$$

The low 'S' values derived from the original images were significantly increased in the de-speckled images. However, there was an exception to this case with oil palm age class above five years old producing 'S' values of less than 0.5. The de-speckled images used the Frost, Lee and Local Sigma filters. This suggests the separability of all palm age classes. Age class separability also varied with polarization images. Superior separability values were observed for the L-vv polarization, especially using the Gamma filter. The highest separability obtained was between one and six year old oil palm with 'S'= 4.73. Separability among other ages classes (except between fifteen and seventeen years old oil palm) was also high, with 'S' values ranging from 0.75 to 4.33. Separation between fifteen and seventeen years old oil palm is observed in Gamma filtered using 11 x 11 window of L-hv and P-hv polarization images. The 'S' values were 1.06 and 1.08, respectively. Results showed that the Gamma filter was superior to the Lee, Frost and Local Sigma filters. The L-vv, L-hv and P-hv polarization images were better interpreted than in L-hh, P-hh, and P-vv for oil palm age classes.

2.4 Oil Palm Biomass Estimation

(a) SAR biomass Index

The above ground biomass of oil palm was calculated using Biomass Index (BMI) developed by Pope *et. al.,* (1994). The index was developed for forestry application. Since, oil palm is also one of the forestry components, it was used for oil palm. The biomass model was defined as follows:

$$BMI = \frac{\bar{\sigma}^{\circ}vv + \bar{\sigma}^{\circ}hh}{2} \qquad \text{Eq (3)}$$

The vertical penetration of microwaves into vegetation components was different and was quite relative to wavelengths such as the L- and P-band. Thus, in general, L-band indices apply to characteristics of the canopy for forest and branches and thicker secondary branches. Thus, this is assumed to be equivalent to oil palm fronds and the upper part of the oil palm trunk. P-band indices apply to thick primary branches, trunks and forest soil, and it is assumed closely equivalent to oil palm trunks and oil palm soil surfaces. In this study the biomass estimation for oil palm was defined as follows:

$$BMI = \frac{\bar{\sigma}^{\circ}L\text{-}vv + \bar{\sigma}^{\circ}L\text{-}hh}{2} + \frac{\bar{\sigma}^{\circ}P\text{-}vv + \bar{\sigma}^{\circ}P\text{-}hh}{2} \qquad \text{Eq. (4)}$$

(b) Empirical Biomass Model for Oil Palm

The results of the oil palm biomass index derived from BMI model was verified with biomass obtained from Empirical Biomass Model developed by Hassan (1994) which has very high accuracy (99%). The models are defined as follows:

$FW = 725 + 197 \times Ht = \text{ton matter palm}^{-1}$ Eq (5)
$FWfb = 906.25 + 246.25 \times Ht = \text{ton matter palm}^{-1}$ Eq (6)

where,

FW = fresh weight
Fb = with frond base
Ht = height

In this equation, height of oil palm parameter is the key parameter for estimation of oil palm biomass. The biomass of the oil palm increases with age and height as illustrated in Figure 6 and illustrated in Figure 7.

The results of biomass Index derived from BMI using equation (3) was plotted against the biomass results

derived the empirical model.

A detailed evaluation of different regression model was not undertaken. However, an inversion model yielded higher correlation coefficients as compared to linear and algorithmic relationship as shown in Table 4 and Figure 8. The correlation between the biomass indices (derived from radar backscatter coefficient) and oil palm biomass model is consistently positive. The correlation coefficients ranged from 0.30131 to 0.99933 (at p=0.05). The strength of the correlation varied with oil palm phenological growth and biophysical parameters.

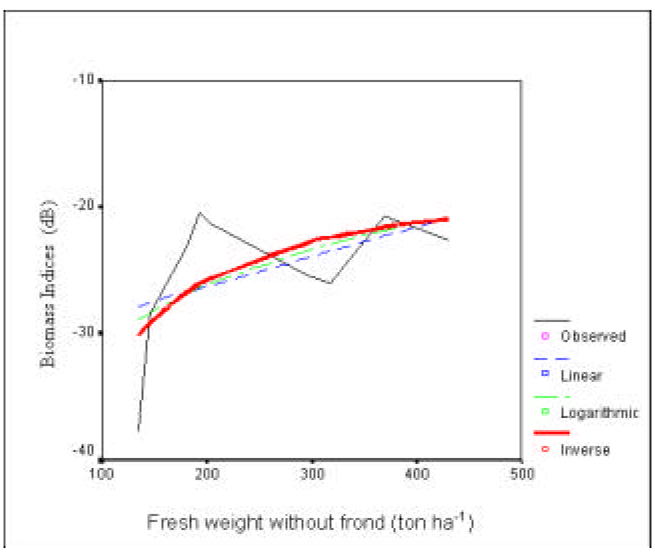


FIGURE 8 Correlation between Indices Derived from Radar Backscattering and Biomass Derived from Empirical data with the Oil Palm Biomass Model

2.5 Segmentation and Classification of AIRSAR data for Oil Palm Ages Mapping

A portion of the original AIRSAR data (6km x 6 km) was used for segmentation and classification to generate oil palm ages map. Before segmentation and classification analysis, the data was filtered four filter algorithms ((Frost, Lee, Gamma and Local Sigma) with various window sizes (5 x 5, 7 x 7, 9 x9 and 11 x 11) in order to reduce image noise within homogeneous categories. The results shows that the L-hh polarization with Lee filter of window sizes 5x5 and 9x9, is the best mean retention for oil palm of ages five, six, 20, and 25 years. A Local Sigma filter with window sizes 5x5, 9x9 and 11x11 shows the best mean retention for oil palm of ages one, two, and 17 years, respectively. A Gamma filter with window sizes of 5x5 and 9x9, shows the best mean retention for oil palm of ages of five and seven years, respectively. However, in terms of reduction in standard deviation, the Local Sigma filter performs the best for most ages of oil palm (2,5,6,7,15,20 and 25 years) except for the Frost filter which performs best for one-year old oil palm. This suggests that the Local Sigma filter (various window sizes) performs higher noise reduction compared to the other filters (Frost, Lee and Gamma). However, this observation is not similar with other SAR polarization and frequencies. The imagery of L-hv polarization, filtered using Lee Filter generate the best mean retention image of a number of oil palm ages (1, 5, 6, 7, 17, 20, and 25 years old), but not for oil palm of age two and 15 years, which work well with Gamma filters and Local Sigma filters, respectively. In terms of reduction in the standard deviation, the Local Sigma (window size 5x5), Lee (window size 5x5) and Frost filters (window size 7x7) perform best. This suggests that a number of filters are required to perform noise reduction. The L-vv polarization works well with only two filters, the Gamma and Lee. The Gamma filter with window sizes of 5x5 and 7x7, shows the best mean retention for oil palm of ages of two, five, seven and 15 years. The Lee filter with window size of 5x5 shows the best mean retention for oil palm of ages of one, six, 20, and 25 years. However, in terms of reduction in standard deviation, the Local Sigma filter performs the best for all oil palm ages, except for one year old oil palm which works well with the filter.

In P-band (low frequency), the Gamma and Lee filters show the best mean retention and the Local Sigma filter perform best reduction in standard deviation. The Lee filter with window sizes of 5x5 and 7x7 shows the best mean retention for oil palm of ages of one, five, six, seven, 15, 20, and 25 years. A Gamma filter with window size of 5x5 shows the best retention of oil palm age of two and 17 years. However, in terms of reduction in standard deviation the Local Sigma filter (5x5 and 9x9) perform the best.

In the P-hv polarization image the Lee filter of window sizes 7x7 and 11x11 shows the best mean retention for oil palm of ages of six, seven, 15, and 25 years; and the Gamma filter with window sizes 5x5 shows the best mean retention for oil palm ages of two, five, and 17 years. And in the P-vv polarization image, the Gamma filter with window sizes of 5x5 and 11x11 shows the best mean retention for oil palm of age two, five, seven, 15, and 20 years. The Lee filter with window sizes 5x5 and 11x11 shows the best mean retention for oil palm of ages of six, 17, and 25 years. However, in terms of reduction in standard deviation, the Local Sigma filter (5x5) performs the best. This suggests that the Local Sigma Filter (5x5) performs a higher reduction of noise compared to other filters. However, the most significant improvement was observed in the case of the Gamma filter, notably with the 11x11 window size. The filter shows the highest improvement while the Frost filter performs better than the Lee filter. The trend was similar for three polarizations (hh, hv and vv) of the L-band and P-band images. Segmentation processing using was applied to the de-speckle images using software developed by Institute for Space Research (INPE) Brazil. And the processing was followed by supervised classification. The accuracy of the results was analyzed using confusion matrix with accuracy of 74 percent. The age map is illustrated in Figure 9. The AIRSAR data L-hh, L-vv and P-hh polarization were used in the supervised classification as they represent the highest Separability values.

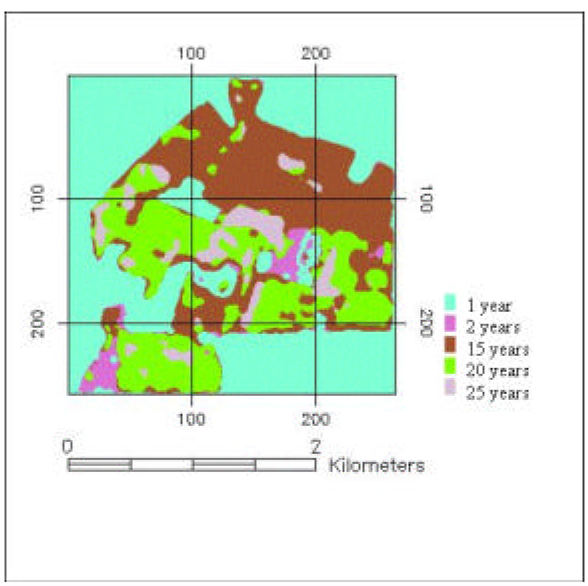


FIGURE 9 Oil Palm Based on Segmentation and Classification of AIRSAR Image of L-hh, L-vv and P-hh

3. CONCLUSION AND FUTURE WORK

The availability of AIRSAR data has given scientist the opportunity to use multi-polarization and multi-frequency microwave imageries of the earth surface for various applications. This study investigated the use of AIRSAR data for oil palm biomass estimation, age classification and age class mapping.

The biomass of oil palm was calculated by using the oil palm biomass model. Oil palm tree height measured from field was an input parameter into the model. The results show that the oil palm biomass increases with age with high accuracy of r = 0.85. The results also show that at an age of 25 years, oil palm produces 344.28 ton/ha of fresh weight biomass, which has no frond, and 430.35 tonnes/ha of fresh weight with fronds. Both fresh weight biomass is equivalent to 68.85 ton/ha and 86.0 ton/ha. This result is then used to correlate oil palm biomass that is estimated using AIRSAR data. Both results show an increasing trend of oil palm biomass production and AIRSAR biomass indices with age.

Based on the separability analysis, a process segmentation and subsequently classification of the images was carried out. The overall classification accuracy for oil palm separability analysis is as follows: One year (73 %), two years old(99 %),Fifteen years old (96 %) Twenty years oil (63 %) and Twenty-five years old (82 %).

Future research will be focus on the effects of the backscattering on undulating grounds, other ages of oil palm, the moisture, soil type and plantation management. Radar application also should be experimented in other areas where having of four months of dry season, topsoil and high total rainfall. The results could help in understanding the influence of radar on other variables important to the oil palm industry.

4. ACKNOWLEDGEMENT

The author would like to thank Mr. Nasaruddin Mahmood, Director of Malaysian Centre for Remote Sensing (MACRES) for continuous support and NASA/JPL for their effort in the planning and execution of the polarimetric AIRSAR flight used in this study.

5. REFERENCES

Corley, R.H.V. 1973. Oil palm physiology: In advances in oil palm cultivation (ed.R.L.. Wastie & D.A. Earp). Pp. 37-51, Kuala Lumpur: Incorporated Soceity of Planters.

Harun, K. 1998. *Oil Palm Biomass Estimation*. Thesis Ph.D on Biomass estimation. PORIM.

Shi, J. Dozier, J., and Rott, H., 1994, Snow mapping an Alpine regions with Synthetic Aperture Radar. *IEEE Transaction on Geosciance and remote Sensing,* **32,** 152-158**.**

Ulaby, F.T., Moore, R.K., and Fung, A.K., 1982. *Microwave Remote Sensing, Active and Passive, 2, Radar Remote Sensing and Surface Scattering and Emission Theory* (NewYork: Addision-Wesley)