A PRELIMINARY STUDY OF MONITORING KENAF *(HIBISCUS CANNABINUS L.)* GROWING STAGES USING MULTI-TEMPORAL RADARSAT-2 QUAD-POL SAR IMAGES

Faizu Hassan[1], Nurul Aina Abdul Aziz[1] and Mohd. Zaim Mohd Nor[2]

[1]Malaysian Remote Sensing Agency (MRSA)
No 13, Jalan Tun Ismail, 50480, Kuala Lumpur, Malaysia, faizu@remotesensing.gov.my, aina@remotesensing.gov.my
[2]National and Tobacco Board
B66, Jalan IM 3/10 BIM Point, Bandar Indera Mahkota, 25200 Kuantan, Pahang, zaim@lktn.gov.my

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ABSTRACT: Kenaf (*Hibiscus Cannabinus L.*) is a source of raw material for fiber-based industries and paper production in Malaysia. Normally, matured kenaf can grow up to 4.3 meters in four months and produce yields from 12 tons fibers per hectare. Based on the current management practice, kenaf plant is cultivated by stages which resulting of multi-aged plots for the same growing area. Information of kenaf growing stages is essential for a well-planned harvesting and post-harvest activities. The aim of this study is to determine kenaf growing stages by using RADARSAT-2 multi-temporal and multi-polarized images. Four multi-temporal RADARSAT-2 C-band quad-polarized SAR images were acquired for a complete cycle of life span. Ground truthing were conducted during image acquisition to correlate between backscatter value and selected growing stages parameters i.e height and age of the crops. The result of regression analysis (r^2) of growing stages using multi-polarization HV, VH, HH and VV are 0.85, 0.68, 0.55 and 0.31, respectively. This study shows that HV is the best polarization that able to indicate kenaf growing stages.

1. INTRODUCTION

Kenaf research in Malaysia was initiated in early 2000 with adaptability, identification of suitable cultivars and agricultural usage, agronomical management and inputs, end product and cost productions (Aminah et al., 2006; Ashori, 2006). There are only a few references regarding the monitoring aspects of growth especially using remote sensing data. Since information on productivity and growth monitoring are very few and has not been explored in detail, this study was designated to explain the technique of monitoring growing stages using satellite images. Most studies of satellite imagery for crop monitoring have focused on the use of optical imagery using the reflectance of visible and NIR radiation to map characteristics over large areas. However, in this study, longer microwave is chosen due its ability to pass through the atmosphere and clouds with negligible attenuation, thus allowing frequent measurements over the short growing season of crops.

The RADARSAT-2 satellite system with C-band offers all of these specifications. RADARSAT-2 imagery is used for determining crop and soil condition, including monitoring crop growing stages for a well-planned harvesting and post-harvest activities. According to Ferrazzoli et al., 1999, different polarizations may be most sensitive to crop development at different crop stages whereby radar signal tends to increase quickly with increasing crop height (biomass) until a threshold height which depends on crop type, radar polarization, and beam incidence angle after which the signal slightly increases. This paper describes the analysis of the sensitivity of multi-temporal and multi-polarization RADARSAT-2 with regards to kenaf growing stages. The objectives of this study is to investigate: (1) temporal backscatter behavior of kenaf; (2) correlation between multi-polarization backscatter with growth parameter; and (3) mapping kenaf growing stages using backscatter response.

2. MATERIALS AND METHOD

2.1 Study Area And Image Acquisition

A planting area in Tanjung Putus, Kuantan, Pahang known as Kenaf Integrated Park (KIP) located at approximately on 3◦49'20” N and 103◦12'46” E in the south east Malaysia was selected as a study area. Six (6) plots were selected as a study site known as plot A, B, C D, E and F with area of 5.3, 2.1, 1.4, 5.4, 2.4 and 4.4 hectares respectively. Figure 1(a) shows location of study site.

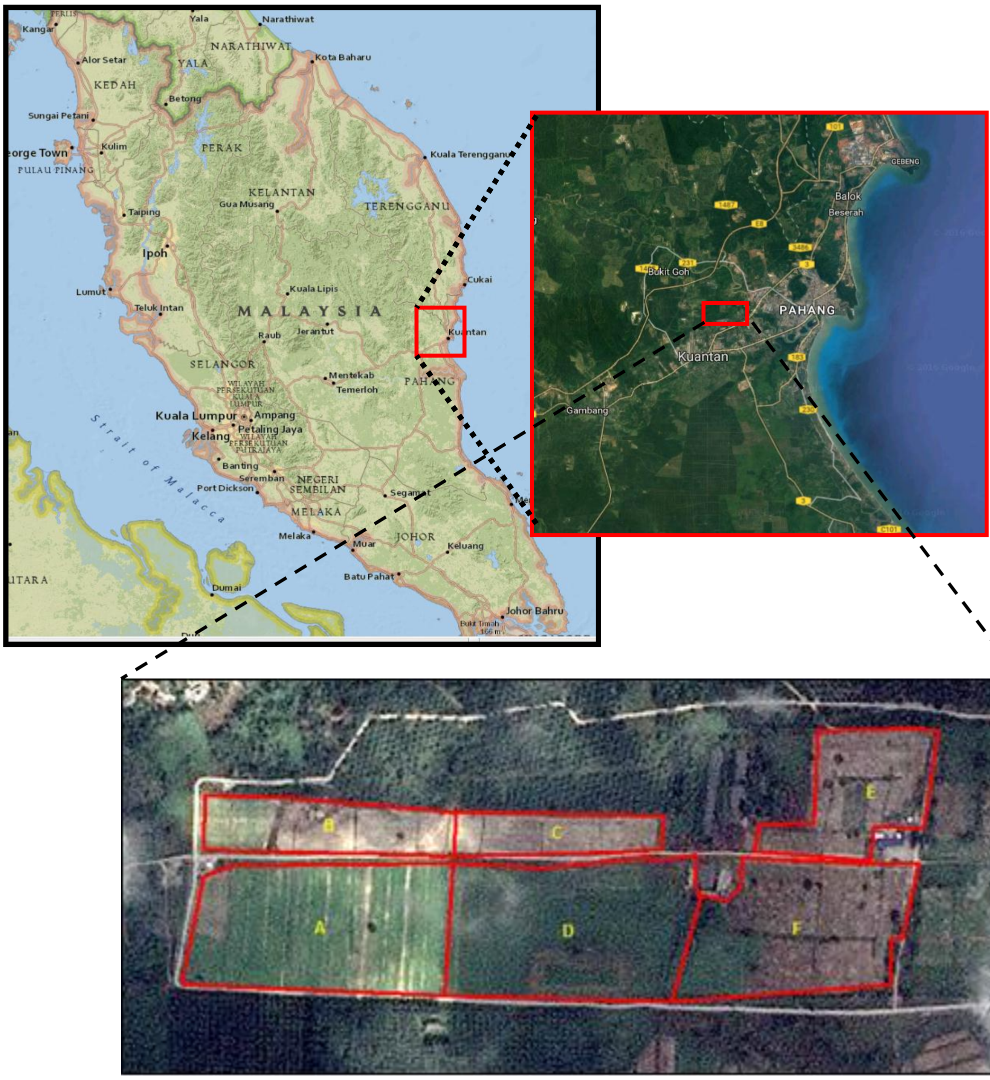


Figure 1(a) Location of study site at Tanjung Putus, Kuantan, Pahang

Kenaf is an annual irrigated crop with five major growth periods in the life cycle namely sowing, germinating, tillering, generative and matured. In this study, the earliest planting date is in early of December 2015, and the latest is in end of February 2016. The RADARSAT-2 images used in this study were acquired from January 2016 till April 2016. All of the plots were used for backscatter correlation analysis.

2.2 Satellite Remote Sensing And Ground Measurements

The SAR data used in this study were multi-polarized RADARSAT-2 image acquired in fine-beam mode (FQ26) with the characteristics as shown in Table 1. The RADARSAT-2 images were acquired every 24 days revisit time to ensure same image geometry.

Table 1: Characteristics of the SAR Image

Sensor RADARSAT-2	
Frequency GHz (band)	5.40 (C)
Wavelength	5.6 cm
Polarization	HH/HV/VH/VV
Acquisition mode	Fine Quad-Pol
Level processing	Single Look Complex (SLC)
Data type (n looks)	Polarimetric (1)
Nominal resolution	11 m × 9 m
Pixel spacing	4.73 (range) and 4.98 (azimuth)
Orbit of acquisition	Descending
Incidence angle	23^o to 41^o
Acquisition date	February 10, March 5, March 29 and April 15 in 2016

The PCI Geomatica software was used to convert SLC product to sigma naught (σ^o) in dB unit based on the radiometric parameters for each data set. The kernel 3 x 3 of enhanced Lee filter was used to reduce speckle noise inherent in the SAR images and all images were geo-referenced using National Grid. The ground based measurements which are average height and age parameters were used to correlate with σ^o. The SPOT-6 image dated 10 February 2016 was used to delineate plots boundary and overlaid with RADARSAT-2 images as shown in Figure 1 (a) and 1 (b). The σ^o for each plots were then extracted from the multi-temporal RADARSAT-2 images.

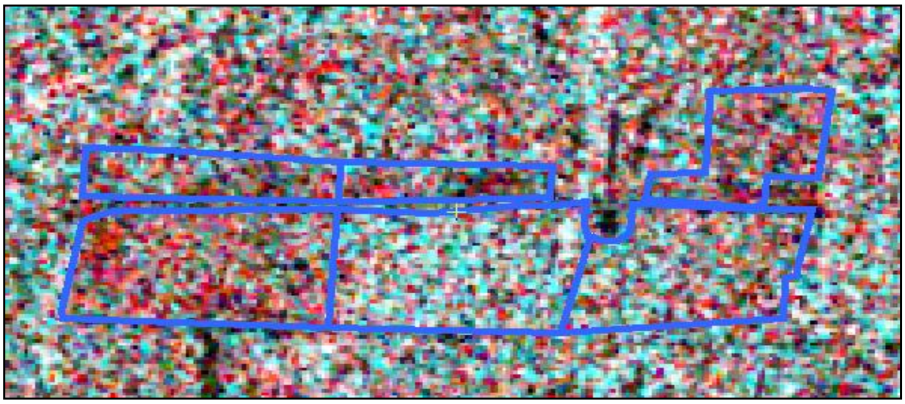


Figure 1(b): RGB band combination of RADARSAT-2 Quad pole image

2.3 Regression Analysis for Evaluating Image Growth Stage with Backscatter

Using the mean backscatter for each site and date, statistical comparisons development were conducted using Pearson correlation and simple linear regression as well as step-wise regression. Analysis of the two factors Pearson correlations and simple linear regressions was first conducted to determine those backscatter best suited to independently estimate height of the tree. The correlation coefficient (r^2) between σ^o value over a given time period for each plot is calculated to determine correlation between σ^o and height of kenaf plant. According to Height of the tree was used as the dependent variable. Then, the HV value will be used for generating backscatter reference value that represents kenaf height and finally to produce kenaf growing stages map.

3. RESULTS AND DISCUSSION

3.1 Temporal Backscatter Behavior and Height of Kenaf

Understanding the backscattering behavior of kenaf tree over its life cycle and its relationships with kenag growth-related parameters is pre-requisite for developing effective methods to correlate and map the kenaf plantation area. The average backscatter value of plot on each acquisition date of RADARSAT-2 is measured by plant age. Pattern of backscatter value of all four multi-polarization HV, VH, HH and VV with day after planting are shown in Figure 2. The graph shows a general trend of increasing of HV as the time increased while HH, VV and VH value shows the decreasing of value in the middle stages of growth. The plant height from planting to harvested divided by the classes using number of days in the growing season or known as day after planting (e.g. 0-30, 30-61, 61-90, 9, and 91-120). HV and VH of value is almost in the same range which is between (-19 to -14) while co-polarization value of HH and VV range is slightly lower which is between (-14 to -10). The general trend of all polarization seem increasing but the most consistant shown by HV with clear distiction value between each growth stages.

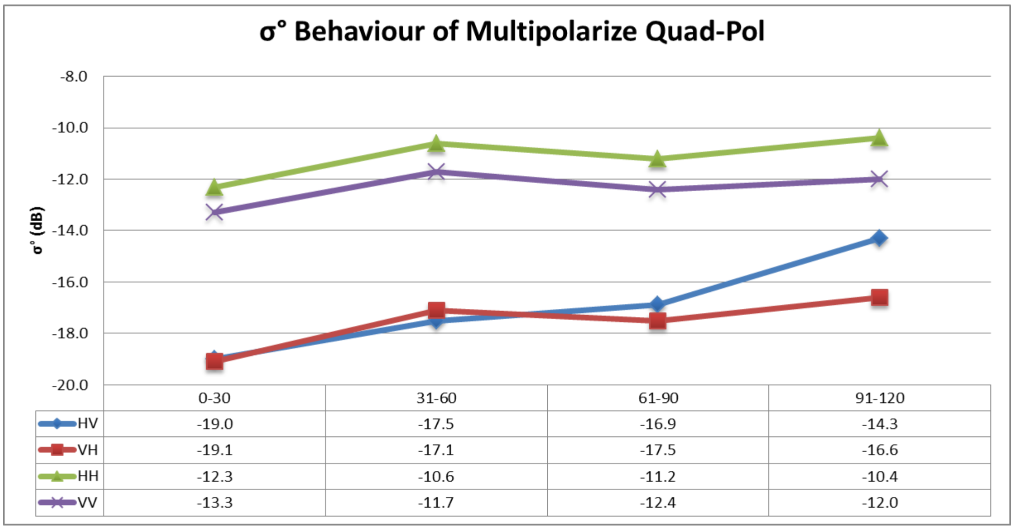


Figure 2: σ° value of HH, HV, VH, VV and day after planting

As plant elements emerge and begin to develop, both the co-polarized and cross-polarized backscatter intensities tend to increase. The increase in co-polarized backscatter is due to a combination of single bounce backscatter directly off leaves or stems, etc. and soil-vegetation double-bounce backscatter, whereas the cross-polarized backscatter is amplified by volume scattering influenced by the crop canopy. Both McNairn et al., 2011 and Skriver et al., 2012 observed that co-polarized phase differences aid in revealing the dominant scattering mechanism for various crop types and growth stages. Specifically, the phase difference observed in these studies is likely due to the delay resulting from the phase in the vegetation canopy for V polarization being different from that of H polarization. It has also been shown that polarization responses and decompositions may provide additional information on crop type and growth stage development.

Table 2: Average values of height and ages by month

Date Imagery	Age(days)	Height (Mean)
10-Feb-16	0-30	0.5
5-Mar-16	31-60	1.3
29-Mar-16	61-90	2.3
15-Apr-16	91-120	2.8

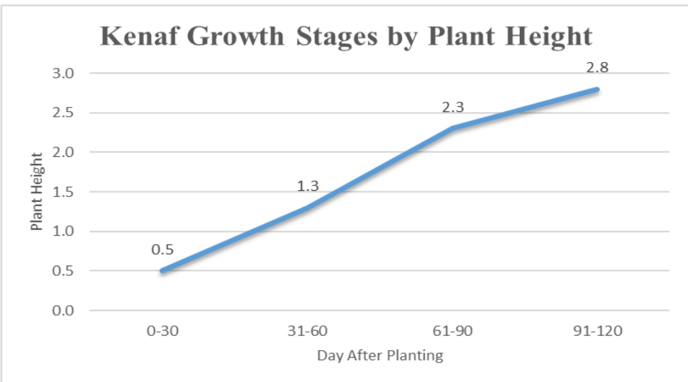


Figure 3: Graph of kenaf growth stages by plant height

Ground measurement data clearly shows that several parameters remained unchanged as the crop grew (i.e., row spacing), while others showed significant temporal changes like plant water content, leaf length, biomass and soil content (Shao.Y,et al., 2001). Regarding to age parameter, it has higher correlation with height of kenaf tree with r^2= 0.95 based on kenaf Growth Simulation Model produced by Alexopoulou. E, 2013 for kenaf plant in Greece. Thus, only height of the tree has been selected for correlation analysis in this paper, since they demonstrated distinct changes over a kenaf growth cycle and provides a significant contribution to backscatter values. Starting from transplanting period the average height of the kenaf stem increase about 0.8 meter and about 1.0 meter and reach it peak growth during matured period at average 2.8 meter with more slower rate compare to second to third month (31-60 to 61-90) with the increasing of 1.0 meter as shown in Figure 3. Kenaf growing stages at study area previously can reach until 3.0 meter - 3.5 meter but due to dry season and less precipitation, the growth of the crop at the end season 120-150 is stunted and no obvious changes in height is observed. Our results are in accordance with Knowles C.K. et al, 1999, where kenaf growth rates are different in every stage of kenaf growth.

3.2 Correlate SAR Backscatter Value to Above Ground Height

Based on the correlation graph, the relationship between SAR σ^o and height of tree is strong for HV polarization with r^2= 0.86 (Figure 4 (a)) followed by VH with r^2= 0.68 (Figure 4 (b)), HH and VV with r^2= 0.55 (Figure 4 (c)) and 0.31 (Figure 4(d)) respectively. The simulated SAR attributes for co-polarization (HH) and cross polarization (HV) were plotted as a function of simulated kenaf hydrological condition related to soil moisture and ground roughness. In this study, the date of planting is different by plot, thus the ground roughness is obviously seen with the different range from plot with growing kenaf tree height.

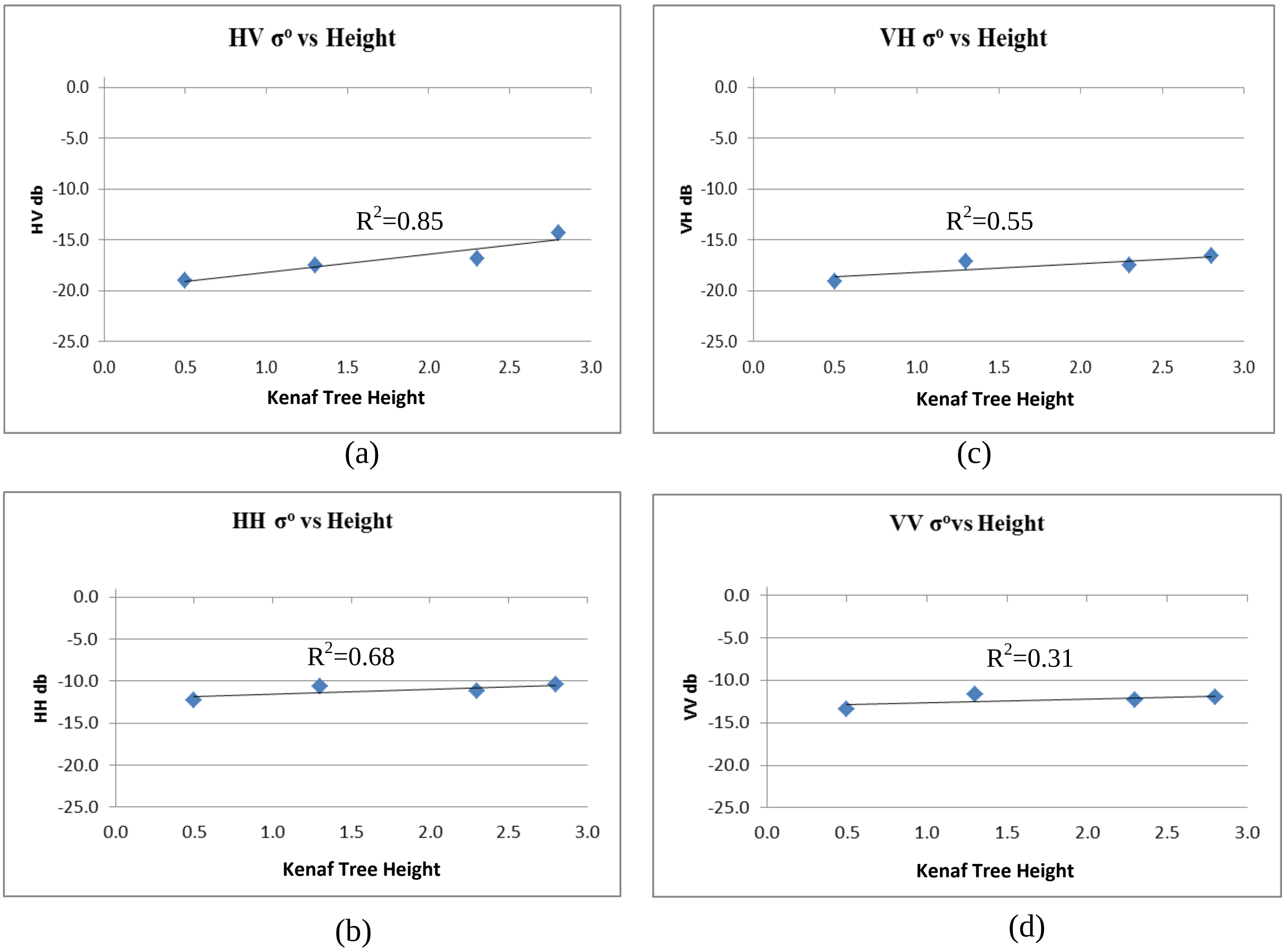


Figure 4 Regression of (a) HV b) VH (c) HH (d) VV

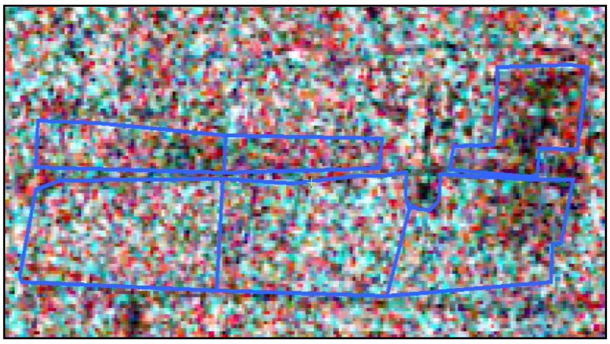
Results shows that cross-polarized HV was more sensitive than other polarization to the changes in vegetation structure associated with crop seasonal growth and harvest. Due to high correlation value between HV σ^o and plant height, average of HV σ^o value is extracted by plot and has been classified based on the imagery date which also represent the age of plant as shown in Table 3.

Table 3: Average values of backscattering coefficient per plot of HV polarization

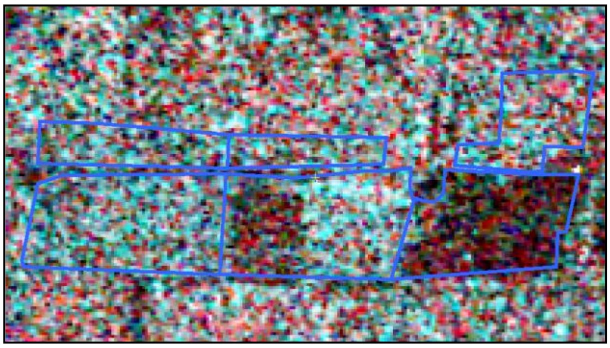
ate Imagery	Plot A		Plot B		Plot C		Plot D		Plot E	
	dB	Age	dB	Age	dB	Age	dB	Age	dB	Age
10-Feb-16	-19.57	0-30	-21.2	*	-20.22	*	-22.12	*	-20.55	*
5-Mar-16	-17.16	31-60	-19.12	0-30	-19.87	*	-19.93	*	-19.88	*
29-Mar-16	-16.96	61-90	-17.58	31-60	-18.66	0-30	-18.50	0-30	-18.06	0-30
15-Apr-16	-14.30	91-120	-16.67	61-90	-17.21	31-60	-17.14	31-60	-17.32	31-60

* Nil

In addition to HV σ^o value, the RGB composition for the quad pol images is observed. By selecting HH in red band, HV in green band and VH in blue band, the RADARSAT-2 quad pol image can be displayed to see the variation of backscatter value. Based on Figure 5(a) and Figure 5(b), the differences between each plot can be generally observed. HH band is represent by reddish colour and HV represent by greenish colour while VH represents. the bluish colour Plot with this three colors shows the plot is planted and the composition of RGB produce cyan colour that shows the different stages of growth. Basically red colour shows the young plant while high concentration of cyan color is represent matured plant. The darker color show bare soil means unplanted or harvested plot since the backscatter value is very low.



(a)



(b)

Figure 5: Quad pole band combination in RGB dated (a) 10 February 2016 (b) 15 April 2016

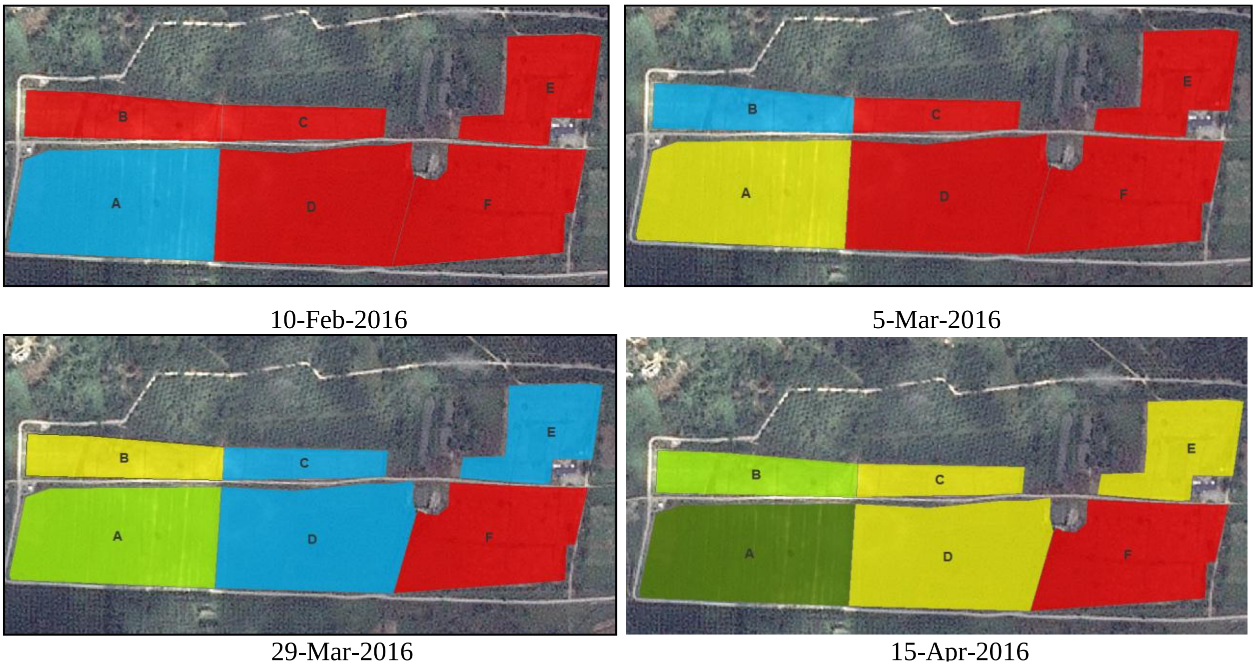
Based on the data tabulated in Table 3 and layer combination chosen in RGB composition above, the reference value for monitoring kenaf growth stages by its height can be simplify as in Table 4. This range can be used as a reference for mapping kenaf growing stages by plot that is important for monitoring of multi-age plot like in study area. The mapping step will be discussed in following section.

Table 4: HV σ^o Range Based On Kenaf Growth Stages

Mean of Height	**Range of HV**	**Mean of HV**	**Age**
0.5	-18 to -20	-18.6	0-30
1.3	-16 to -18	-17.5	31-60
2.3	-16 to -15	-16.9	61-90
2.8	-15 to -14	-14.3	91-120
(No crop)	-20 to -22	-20.5	N/A

3.3 Mapping Kenaf Growing Stages

The backscattering behavior of kenaf HV σ^o show a relatively larger variation of temporal radar response over the whole life cycle than that of the other major ground types as in Table 4, which suggests that the difference of the variation can be used as a classifier. Date of planting is recorded to validate the age of the crop with the backscatter value. The backscatter value is extracted by plot and HV value of each plot is calculate as mean of HV. The plot is label with different colour according to their age. Mapping result is more suitable in age of the plant to represent the growth instead of height due to harvesting activity that usually arranged by period of planting that complete in four months.



Stage of Kenaf Growth February to April 2016					
Legend	(red)	(blue)	(yellow)	(light green)	(dark green)
Age (days)	Unplanted	0-30	30-60	60-90	90-120
Average Height (m)	N/A	0.5	1.3	2.3	2.8

Figure 6: Mapping of kenaf growth stages by plot

The results in Figure 6 imply that important radar data acquisition time for kenaf monitoring is at the end of the seedling period and mature period in February and April 2016, respectively. The data set of the four dates can give the significant difference of radar response and resulting significant map results. Based on the map produced, only five from total of six plots are planted but in different planting date. Only Plot A complete the full cycle of the growth stages until 120 days while the rest of the plot only complete half cycle due to certain obstacle especially the effect of El-Nino that cause less precipitation in study area during the growing season. Plot C, D and E planting date is same which is started in March while Plot F are not planted for this season. Plot F can be used as control plot for no crop sample. In future, to improve the accuracy of mapping crop field is to find proper data acquisition dates to maximize the temporal variation of other land cover types with the crop to be distinguished and avoid other important parameter i.e, water supply to effect the plant growth.

4. CONCLUSION

This paper showed preliminary results obtained from analysis using RADARSAT-2 quad-pol images for monitoring kenaf growing stages in Tanjung Putus, Kuantan, Pahang in January to April 2016. Regression analysis between temporal variation of multi-polarize HV, VH, HH and VV of RADARSAT-2 shows that HV σ^o has achieved the best correlation, r^2=0.86 with kenaf growth. The σ^o range can be applied to produce map of kenaf growing stages for other area. More data set of kenaf σ^o value during growing season need to be collected in order to increase the accuracy of the map. As a conclusion, the results shows that C-band SAR data appear a very promising alternative to optical remote sensing data in developing an operational system for monitoring kenaf crop growth in cloudy and rainy areas. In the future, applications of RADARSAT-2 using HV cross polarization data could be utilized for yield prediction study.

5. REFERENCE

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