Application of Remote Sensing In The Investigation of Maturity Age Of Palm Oil Trees In Pasir Puteh, Kelantan

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ABSTRACT

The determination of oil palm age is essential for the plantation industry as it influences the growth and yield production of the plantation. The aim of this study is to identify the maturity age of oil palm trees using remote sensing technique. Satellite image, SPOT 7 with 6 meter resolution is used in this research study. Ground data is collected to know the height, age and production of the oil palm plantation. Satellite image data is obtained from Malaysian Remote sensing Agency (MRSA) while the ground data is acquired from Malaysian Palm Oil Board (MPOB). The processing is carried out via Erdas Imagine and ArcGIS software. The pixel value for three different ages of oil palm trees, 1 year, 2 year and 5 year are observed to analyze the pixel value for different tree ages. Then, the spectral reflectance of the trees are observed for each of the age. Vegetation indices of NDVI and SAVI are carried out to observe the health of the plantation. Next, the regression model between age and palm oil growth is modeled. The regression shows the relationship of the age and growth. The final result is the map showing the healthy level of oil palm trees using Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI).

Keywords: oil palm, remote sensing, pixel value, vegetation indices, regression model

1. Introduction

Elaeis guineensis or known as oil palm is a tree species originated from Africa, was brought to Malaysia during British colonization. The oil palm plantation is harvested in many countries including Malaysia. Nowadays, Malaysia is known as the second largest country in exportation of palm oil products (Basiron, 2007). The global production of oil palm has increased for the last three decades as palm oil production used are widely used for food resources and biofuel (Corley, 2009). The age of oil palm has become one of the biggest factors which influence its productivity. The age of oil palm is essential to be identified in order to know the productivity, net primary production (NPP) of the fruits which is influenced by the age (Tan et al, 2013).

This study applies the usage of remote sensing in the determination of oil palm age. The study is beneficial as it offers advantages in term of cost effectiveness and time saving. Remote sensing technique is useful especially when involving a vast area. Compared to ground data, remote sensing offers a simpler way of age detection using satellite image. The study could help Malaysian Palm Oil Board (MPOB) in managing the plantation. For instance, the research on application of remote sensing in detection of oil palm trees have been conducted by various researchers. Thus, this similar study could be used in the study area to show how beneficial is remote sensing technique in determining oil palm ages.

The collection of data include remote sensing imagery data and ground data obtained from the oil palm study area. The Imagery data is obtained from Malaysian Remote sensing Agency (MRSA) while the ground data is obtained from Malaysian Palm Oil Board (MPOB). Several process were conducted to identify the age of plantation. The processing were conducted via Erdas Imagine and ArcGIS software. The analysis of the digital number or pixel value was carried out in Erdas Imagine software.

1.1 Research Background

Oil palm production has become our country’s largest exportation. The determination the age of oil palm tree is important as to help in managing the plantation. Malaysian Palm Oil Board (MPOB), an agency that manages the oil palm plantation determines the ages of the trees via conventional method known as field data. In this study, remote sensing technique is applied to identify the age of the oil palm plantation. The relationship between the ages of the trees with their height is investigated. Table 1 below shows the review from various researches regarding determination of the age of oil palm via remote sensing technique.
There are previous researches that applied the use of remote sensing technique for the determination of oil palm age using various satellite data. The aim of the researches is similar, which is to apply remote sensing technique in the identification of oil palm age. Siti Aishah Mansor and Md.Latifur Rahman (2012), and Chemura, van Duren and van Leeuwen (2015) are several from a number of researchers that had applied remote sensing technique in their research study for oil palm age determination. The two researches also collected ground truth data as part of the research. The researchers all used the same software which is Erdas Imagine with difference in data analysis.

There are some advantages and disadvantages of the previous journals. Through the review of the journals, various imagery data were used which include Landsat, ALOS PALSAR, SPOT and also Worldview image. However, the journals do not really explain the data processing part and the purposes they were carried out. This has caused some difficulties in understanding the study. Analysis of the results obtained also has unclear explanation. This has added to difficulty in understanding the outcome of the study as the result and analysis are the crucial part of the study.

Even though the previous researches have applied various remote sensing software and techniques in processing the data, there are still some disadvantages of their research. The relationship between age and the height does not properly explained.

### Table 1 Previous researches

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<tr>
<th>Authors</th>
<th>Title</th>
<th>Objective</th>
<th>Method</th>
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| (Darmawan, Takeuchi, Haryati, Najib, & Na, 2016) | An investigation of age and yield of fresh fruit bunches of oil palm based on ALOS PALSAR 2 | To investigate the age and the yield of fresh fruit bunches of oil palms using ALOS PALSAR 2 | -Conversion of the digital numbers to normalize radar cross section  
-Topography correction and image filtering  
-Analysis of relationship of backscatter value of horizontal transmitting and receiving (HH), horizontal transmitting and vertical receiving (HV), age and productivity of oil palm. | Analyse the application of the remote sensing in investigation of oil palm age based on pixel value, analysis of healthy level based on Normalized Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI) and the relationship of age and growth of the plantation. |
| (Chemura, van Duren, & van Leeuwen, 2015)    | Determination of the age of oil palm from crown projection area detected from WorldView-2 multispectral remote sensing data: The case of Ejisu-Juaben district, Ghana | To develop an approach of remote sensing data in determination of palm oil age | -Determination of relationship of age and crown projection of oil palm area  
-Classification of object based image analysis.  
-Combination of crown projection areas with field regression model. |                                                                                               |
| (Vadivelu, Ahmad, & Choo, 2014)              | Remote sensing techniques for oil palm age classification using Landsat-5 TM satellite | To investigate relationship of spectral measurements with age of the oil palm plantation | -Classification of land cover and oil palm age  
-Calculation of the accuracy using confusion matrix. |                                                                                               |
| (Ishak & Hudzari, 2010)                      | Image based modeling for oil palm fruit maturity prediction           | To develop an image database of oil palm fruit bunches for different stage of fruits age. | -Analysis of hue pixel value of fruits  
-Correlation analysis of reliability of fruits properties with the percentage of mesocarp oil content |                                                                                               |
| (Siti Aishah Mansor & Md.Latifur Rahman, 2012) | Remote Sensing Technique For Estimating the Age of Oil Palm Using High Resolution Image | To identify the use of high resolution remote sensing data in classification of oil palm age. | -Vegetation indices in Erdas Imagine 2014  
-Classification of images  
-Accuracy assessment |                                                                                               |
1.2 Aim and objectives

The aim of this study is to identify the maturity age of palm oil trees in Pasir Puteh, Kelantan using remote sensing technique. The objectives of the study are as below:

a) To identify the age of oil palm trees based on pixel values, Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI).

b) To compare the healthy level of different oil palm ages between Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI)

c) To compare the relationship between age and tree growth of oil palm trees

2. Literature Review

There are many features on the surface of the earth and the reflectance of each of the features are different. The properties of the features are identified by measuring the incident energy that are reflected from the features. As radiation reach the surface target, the radiation are absorbed, transmitted and reflected. The spectrum of the reflectance is known as the plot of the fraction of reflected radiation. The spectral resolution is important for the identification of the features. Spectral characteristics of vegetation for different ages differ as it depends on the physical structure of vegetation. The physical structure include leaf crown density, canopy cover and also land cover. The leaves of the plantation contains chlorophyll and this compound absorbs radiation in red and blue wavelengths and reflect back the green wavelength. The healthy vegetation will act as diffuse reflector for near infrared wavelength. Mature oil palm has bigger leaves, thus, making the canopy distance closer. This has contributed to low spectral reflectance of visible wavelength and high reflectance of near infrared (NIR). The value of the mature trees are higher as it is less affected by the soil. Soil gives a high reflectance at the red wavelength and near infrared. The other factors that influence the spectral reflectance of vegetation include interaction of radiation with vegetation canopy and soil effect from the study area (Ibrahim et al, 2000). For the study of oil palm plantation, the spectral reflectance are greatly influenced by the density of planting, harvesting and also the topographic illumination effects (McMorrow, 1995).

Vegetation Index is defined as the spectral transformation for the two or more bands that are carried out to enhance the vegetation properties. Remote sensing has been applied since 1960s and the measurement of the vegetation cover the leaf area index, chlorophyll content and also green biomass that are observed throughout photosynthesis. Vegetation indices is basically the indicator that are used to measure the greenness or healthy level of vegetation for the features in satellite image. With vegetation indices, the healthiness of the plantation can be figured out. There are various vegetation indices that can be used depending on the types of satellite image. There are many vegetation indices available like Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Indices (SAVI) and Triangulation Vegetation Index (TVI). NDVI is the most commonly used vegetation index indicator that are used. NDVI provided a method to estimate the net primary production for biome types. NDVI measures the value from +1.0 to -1.0. Low NDVI value that less than 0.1 describe barren and sandy land while 0.6 to 0.9 value describe the dense vegetation. The formula of NDVI is as below:

\[
NDVI = \frac{\text{NIR} - \text{red}}{\text{NIR} + \text{red}}
\]

Another vegetation index is Soil Adjusted Vegetation Index (SAVI). SAVI introduce a soil calibration factor, L in the equation of NDVI. It minimize the influence of the soil from spectral interactions. The 0.5 value of L minimize the brightness of the soil and eliminates the calibration of other types of soils. The formula to calculate SAVI is as below:

\[
SAVI = \frac{(1 + L) (\text{NIR} - \text{red})}{\text{NIR} + \text{red} + L}
\]

3. Methodology

SPOT 7 image with resolution of 6 meter acquired on date 5 April 2016 was obtained from Malaysian Remote Sensing Agency (MRSA). The image was reprojected in Erdas Imagine 2014 software with projection was set as RSO projection and Kertau as datum. Ground data for the growth of the trees were obtained from Malaysian Palm Oil Board (MPOB). Imagery data was processed in Erdas Imagine. Basemap of Pasir Puteh and the imagery image were overlaid and then subsetted for the study area. Spectral profile for 30 samples with three different ages were carried out to learn the profile for the samples. Region of interest (ROI) were drawn for three different ages, 1 year, 2 year and 5 year to
observe the pixels of different oil palm trees. Vegetation indices were carried out to identify the healthiness of plantation. The relationship between height and age of palm oil trees were modelled in Excel with linear regression model. In order to achieve the aim of this study, subset, georeferencing, spectral profile, region of interest were conducted. Fig. 1 below shows the flow chart of methodology.

![Flow chart of methodology](image)

**Fig. 1 Flow chart of methodology**
Fig. 2 below shows the study area of the project. The study area is in Pasir Puteh, a district located in Kelantan and shares boundaries with Terengganu. The coordinate is 5.50 North and 102.24 East. Pasir Puteh is selected for the research project as to support the state government in harvesting and managing the oil palm plantation.

Fig. 2 Pasir Puteh study area (Source: Google Earth, 2015)

3.1 Data Acquisition

Imagery data or satellite data is the main data in the project. The imagery data of Pasir Puteh is obtained from MRSA. The image was taken on 5 April 2016 with resolution of 6 meter. Field data or ground data was obtained from site investigation. Before field data collection were conducted, imagery data was observed to ensure that the field data conducted is within the satellite image obtained. Oil palm trees were measured to obtain information regarding the age, height, diameter of trunk and also crop production. There are 30 samples of trees for age 1, 2 and 5 with 10 sample points of each age. The measurements of the trees were carried out using a measuring tape. The coordinate of the trees were collected for the purpose of marking the location of the study area in the satellite image.

3.2 Pre-processing

Pre-processing is the first step carried out upon receiving a remotely sensed data. Pre-processing is carried out to correct any distortion that may occur on the image due to the imaging system and imaging conditions. The pre-processing that was carried out involved subset, haze reduction and rescale.

3.3.1 Subset

The satellite image can cover a vast area. Not the whole part of the image will be used in the processing. Thus, the area of the interest can be subset from the satellite image. Several ways can be done to subset the image which include subset by coordinate, subset by inquire box and the last one is to subset by boundary or AOI. For this project, the subset was carried out by the boundary (AOI). The basemap of Pasir Puteh and the satellite image were overlaid in Erdas software. Area of Interest (AOI) of the study area was created and then used during subset of the image. Fig. 3 shows the image before and after subset were done.
3.3.2 Haze reduction

Haze reduction is one of the methods in the radiometric enhancement that was carried out to enhance the image presentation. The process helps in eliminating the appearance of the haze in the image. After subset was carried out, the image seems to be foggy and unclear. To remove the haze, haze reduction was carried out. Fig. 4 above shows the image before and after haze reduction.

3.3.3 Rescale

Rescale is a technique under radiometric correction. Rescale is a method where the raster image is resized by specific x and y factors. The image used in the project was rescaled from 16 bit to 8 bit. Rescale enables user to minimize the digital number or pixels of the image. Thus, after the rescaling, the digital number becomes much smaller than before the rescale process.

3.4 Image Processing

3.4.1 Geo-referenced

There were times when the satellite image data did not properly aligned with the other data that the user has. To use all the data in the same work, the data need to be geo-referenced to map coordinate system. Geo-referenced needed to be carried out in this project as satellite data and the field data (coordinate) of the samples did not aligned. Root mean square (RMSE) error calculated the error of the geo-referenced process. The error shall be less than the pixel size. Figure 3.5 below shows how the image changes after the geo-referenced process.
3.4.2 Spectral signature

Spectral signature normally is carried out to observe the signature of features in an image. In this project, the signature of the three different oil palm ages were observed. The statistics data for the signature were observed and analyzed. The signature plot of the oil palm was observed as well. Spectral signature was carried out in Erdas via ‘Signature editor’.

3.4.3 Spectral profile

Spectral profile is a tool in Erdas Imagine software that provides the graphical depiction of object’s at the recorded band. The spectral profile for the features on the image are different. All the spectral profile of 30 samples were observed. The graphical representation of the profiles are different as they travel through all the four bands though they are from the same age. When observing the profile, zooming is used to ensure that correct features are picked.

![Fig. 6 Zooming the samples for spectral profile](image)

3.4.4 Digital number analysis

Digital number or pixel number of the samples were observed throughout this project. Different pixel values represent different features in the image. As rescale was carried out, the value of the digital number has changed to the smaller value. Digital number of all the pixels can be analyzed after spectral profile of the samples are carried out. The value could been seen from the tabular data of the spectral profiles.

3.4.5 Vegetation indices

Vegetation indices are derived from the satellite image and normally are used for vegetation monitoring, drought studies and agriculture activities. Vegetation indices are used for measuring the healthiness of the plantation. There are several vegetation indices available to be used which are Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Indices (SAVI), Triangulation Vegetation Index (TVI) and RATIO. NDVI and SAVI are the two vegetation indices that were used for this study. They were calculated in Erdas imagine software. The healthiness of the plantation were compared using these two indices. Satellite sensor measures the feature of the earth with various bands. Vegetation indices are generated through some of the bands. NDVI for example, used only red and near infrared bands since the energy reflected in the bands are related to vegetation cover on the surface. The healthy vegetation will absorb more visible light and reflected a large amount of near infrared wavelength. Meanwhile, unhealthy vegetation reflects more visible light and absorb a little amount of near infrared wavelength. The range of calculation of NDVI is from -1 to +1. 0 value represent no vegetation detected. High value (0.8-0.9) shows that the density of the green leaves on that surface is high. SAVI is the other vegetation index that available for use. It is developed as an improvement to NDVI. This is because that NDVI is known to be quite unstable. SAVI utilize the use of red and near infrared wavelength. SAVI minimize the influence of soil brightness. SAVI value is higher than NDVI as SAVI is more sensitive to the vegetation.

3.4.6 Regression model

Regression model is the statistical model that are used to show the relationship of the variables. The model has many techniques for the modeling and analysis of several variables. Common technique used to show the regression model are linear regression and ordinary least squares. Regression analysis are normally used for the prediction. The analysis could been carried out using excel. R² generated shows the strength of the relationship. Closer the value to 1, stronger the relationship is. In this research paper, regression model is used to show the relationship between age of oil palm trees and the height of the trees.
4. Findings

Erdas Imagine software is used in the identification of oil palm age. Every different age of oil palm has different spectral characteristics. The spectral of each sample are analyzed. Final map which shows the value of the vegetation indices for NDVI and SAVI is produced.

4.1 Identification of oil palm trees age based on pixel value, NDVI and SAVI

4.1.1 Different age plot

Oil palm area for three different ages, age 1, 2 and 5 are marked in Erdas Imagine software to see the difference in the signature plot of the trees. The results are shown in the Fig. 7, Fig. 8 and Fig. 9 above. The signature plot for each of the ages are different. For age 1 oil palm, the plot increases as it goes pass layer 1 to layer 4. There is a steady increase from layer 1 to layer 3 and rapidly increase from layer 3 to layer 4. Meanwhile, the signature plot for age 2 oil palm trees shows a rapid rise from layer 1 to layer 2 and slightly fall from layer 2 to layer 3. The plot then shows a rapid rise as it passes layer 3 to layer 4. The signature plot for age 5 can be seen in Fig. 9. From the figure, it can been concluded that the plot only shows a rise as it go through all the four layers. The plot shows a steady rise from layer 1 to layer 3 and a rapid rise for layer 3 to layer 4. The layers used indicate the visible band (spectral) of blue (layer 1), green (layer 2) and red (layer 3) including infrared (layer 4).

![Signature plot for age 1](image1)

Fig. 7 Signature plot for age 1

![Signature plot for age 2](image2)

Fig. 8 Signature plot for age 2
4.2 Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI)

Fig. 10 and Fig. 11 below shows the result of Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI) of the study area. The two vegetation index are carried out to analyze the healthy level of the oil palm plantation. The result above shows the result of SAVI is clearer for SAVI compared to NDVI.
Table 2 below shows the result of Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI) values for all thirty samples of three oil palm trees. Samples 1 to 10 are the samples for age 1 oil palm trees, the point 11 to 20 are age 2 samples and the samples of age 5 cover from number 21 to 30. Going through all the three ages, the result shows increase of values for the older trees. The value for SAVI is higher than NDVI for all the samples. Based on the conversation with Mr. Caswira, an officer from Malaysian Palm Oil Board (MPOB) agency on 23 March 2017, the growth of the oil palm trees can be influenced by several factors like water supply during the early stage of plantation and the species type of the oil palm harvested. These factors could influence the plantation’s growth and health. Some of the sample points of age 1 are from different species and this explains how the growth of age 1 trees appears to be higher than age 2 plantation. In the early stage of plantation, the water supply of most of the samples of age 2 are inadequate and this has caused the slow phase in growth.

**Table 2. Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI) values**

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Normalized Difference Vegetation Index (NDVI) value

Fig. 12 Normalized Difference Vegetation Index (NDVI) value
Fig. 13 Soil Adjusted Vegetation Index (SAVI) value

Fig. 14 Map of Normalized Difference Vegetation Index (NDVI) of oil palm plantation in Pasir Puteh, Kelantan
4.3 Relationship of age and growth of oil palm trees

The relationship between age of the oil palm trees and the height are shown in the Fig. 16 below. There are 30 samples and they are used for linear regression model. The height are varies for the samples even they are from the same age. The regression analysis, whereby the $R^2$, correlation is 0.8528. The result shows a strong relationship between age and height of the oil palm trees.

5. Conclusions

In conclusion, the determination of oil palm trees are important to the plantation industry. The main reason of using remote sensing in the identification of oil palm trees is to utilize an easier way of age determination. This is beneficial as it could help in reducing the cost for ground data collection as well as time consuming. The aim of this research is to identify the maturity age of oil palm trees. Several steps were carried out in Erdas software to detect the age of the trees. In addition, ArcGIS software also was used to produce the final map. The results of this study are produced to answer all the objectives of the study. Through the processing of the data, there are various techniques in Erdas that could help in analyzing the age of the trees. Furthermore, the results of this present study was conducted based on the research objectives. Ground data is collected and used in the accuracy assessment. This study will expose
people more to the application of remote sensing and how it helps in solving problems and help the plantation industry.

References


