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Oil Palm Plantation Monitoring from Satellite Image

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Abstract. Malaysia is one of the largest palm oil producers in the world. To meet the production, its plantation needs to be monitored accordingly. Manual monitoring is no longer feasible due to energy, cost and time consumption. Remote sensing technology such as satellite images can be utilized for palm oil monitoring as they are cost effective, time and energy saving, and able to enhance the possibility of classifying the vegetation through spectral and texture analyses. Due to its impact towards Malaysia economy, an effective monitoring of palm oil plantation can be done by using satellite image to maintain the sustainability of palm oil in Malaysia. This project utilized the computation of Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI) to determine the plant health. Relationship of NDVI and SAVI with respect to temperature and precipitation is studied based on the data obtained from Malaysian Meteorology Department. By using regression model technique, the relationship of the plant health based on NDVI analysis, nitrogen content based on SAVI analysis and temperature is found out to be highly correlated while plant health and precipitation is found out to be no or low correlated. The results can be utilized by the plantation operators, especially independent smallholders in monitoring the health status of the palm oil trees to ensure high productivity.

1. Introduction

Palm oil and palm kernel oil are among the most consumed vegetable oil in the world [1], where their production has recorded to reach 75.17 million tonnes in 2017 from the plantation area of 19.04 million hectares worldwide. Malaysia alone has its planted area of 5.81 million hectares, where more than 3 million hectares of the area are managed by the smallholders [2]. To meet demands and production, a lot of land has been converted to palm oil plantations, which could bring towards endangers biodiversity and degrades the environment [3]. Thus, there is a need to increase oil yield with lesser new plantations establishment [4]. To achieve this, help is needed to monitor the plantation, as manual monitoring is no longer feasible due to its costing and energy consuming [1].

Remote sensing has benefited a lot of areas including agriculture as to improve farming practices [5], such as for tree detection and counting [6], habitat monitoring in mapping pest and disease [7] and nutrient detection [8], where satellite images are among the favoured source of data. Satellite images provide a huge amount of information about our earth's surface. It is beneficial for researchers especially to get more information on inaccessible areas. Apart from that, satellite-based research has a lot of advantages such as cost effective, time saving in obtaining data without having to go to the site, as well as having the possibility of classifying the vegetation through spectral and texture analyses [9].

Hence, this project will utilize publicly available satellite data to monitor palm oil plantation, in terms of the plants' condition to ensure good productivity. Researchers in [10][11] have shown that oil palm yields higher productivity under high temperature of around 29°C to 33°C maximum. Features



like nitrogen content and soil moisture are also playing important parameters that could determine the condition of oil palm, and all these can be determined by applying suitable indexes from images data. As nutrient deficiency could affect the growth of the tree, thus, these features can be utilized to indicate good condition of trees to ensure good productivity. Researchers in [12] utilized UAV data to collect the images, but there is a need to hire a UAV to collect the data and this may lead to additional cost. Furthermore, UAV is not sufficient to cover a large scale area of plantation due to its short flying time.

This paper is separated into several sections – Section 1 on the introduction, where some background on palm oil and the importance to monitor their plantations are highlighted. Methodology is highlighted in Section 2 covering data collection and processing, while results are discussed in Section 3 and finished with a conclusion in Section 4.

2. Methodology

2.1 Area of Interest and Data Collection

As this project is purely educational, a suitable oil palm plantation is chosen randomly where the data is obtained from a free-source public domain. Kamuning Estate is chosen to be the testing palm oil plantation for this project which is located at Sungai Siput, Perak, with 37,241 hectares. The satellite image representing the plantation is obtained from Landsat-8 image data through the United States Geological Survey (USGS) website [13]. Landsat-8 satellite data has been chosen due to its high resolution and consist of more wavebands compared to the other Landsat satellite.

2.2 Data Processing

The image is being processed using a geographic information system (GIS) software called ArcMAP 10.5 of ArcGIS. The satellite image obtained is having 11 bands stored in 11 files, hence it must be stacked into 1 image file in order to obtain the result based on the band requirements. However, only 9 bands are selected as Band 10 and 11 are more suitable for land surface temperature study since they contain data from the thermal infrared sensor. As the data covers neighbouring area as well, validation of the correct area needs to be done. Thus, upon checking the area of interest in Google Earth Pro, the same place is determined in the ArcMAP software manually for further processing. For more detailed analysis, a subset image was created to focus on the specific area of interest with lesser smaller size compared to the original image. Next, classification is done through training and testing to determine the entity exists in the subset image. For example, to train data containing water, multiple polygonal shapes is drawn on the image of water to represent the area. Similar processes are done to other classes of entities like road, soil, urban area, oil palm plantation, cloud and hill. Training of sample is carried out by comparing the image from Google Earth. An accuracy assessment is carried out to determine whether the classification has being done correctly using confusion matrix, with a minimum requirement for the classification to be more than 80% in order to have a success results.

To further analyse the image in monitoring the plants' condition, Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI) were used. NDVI can be used to separate the background with respect to the tree image in [1], and furthermore, as healthy vegetation absorbs most of the visible light and reflects most of the near infrared (NIR), they will have higher NDVI values [14][15]. Meanwhile, SAVI is a vegetation index used to restrain the influence of soil on the vegetation data which is proposed to increase the sensitivity to chlorophyll concentration [16]. Both NDVI and SAVI can be calculated using Equation (1) and (2), where L is the soil adjustment factor:

$$NDVI = \frac{\text{Near Infrared Band} - \text{Red Band}}{\text{Near Infrared Band} + \text{Red Band}} \quad (1)$$

$$SAVI = \frac{\text{Near Infrared Band} - \text{RedBand}}{\text{Near Infrared Band} - \text{Red Band} + L} (1 + L) \quad (2)$$

For the purpose of finding the best correlation factor in determining the condition of oil palm trees, regression model were developed for NDVI, SAVI, precipitation and temperature data. Temperature and rainfall data were collected from the Malaysian Meteorology Department of the same time when the satellite data is obtained.

3. Results and Discussion

Figure 1 shows the classification results obtained from the ArcMAP software in segmenting the image into classes of entity exist in the image. A reference map from Google Earth (Figure 2) is used to check the results. It can be seen here that the image has been classified into 7 classes which is water, road, soil, urban area, oil palm plantation, cloud and hill.

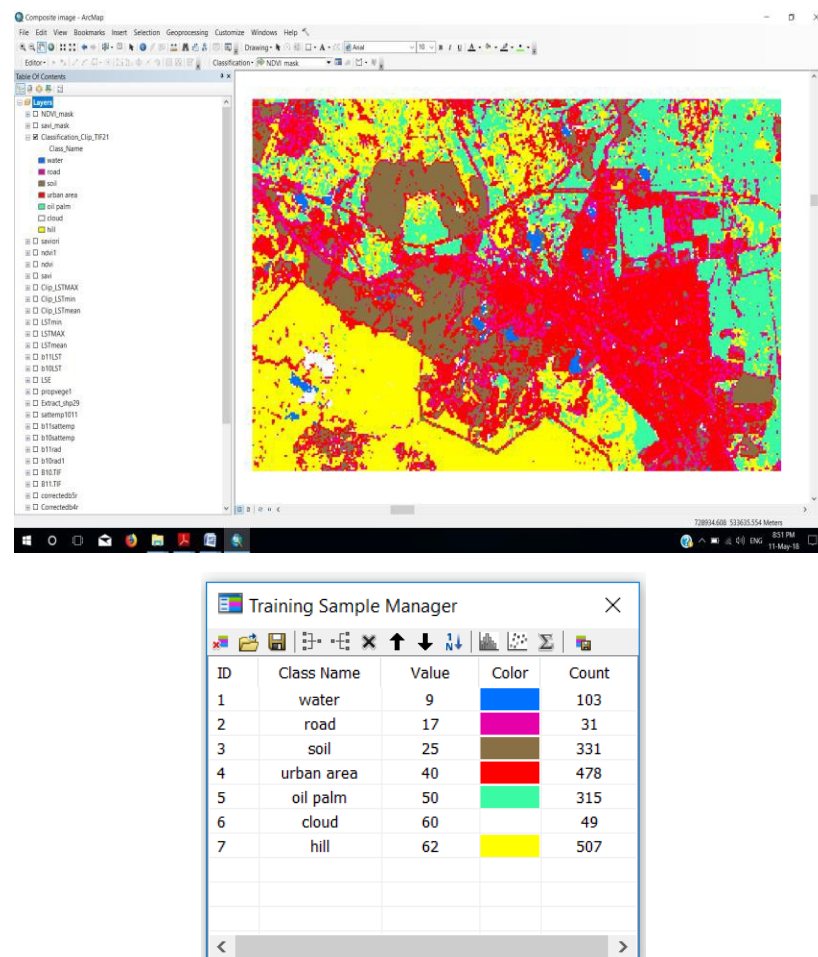


Figure 1: Result of supervised classification on Kamuning estate

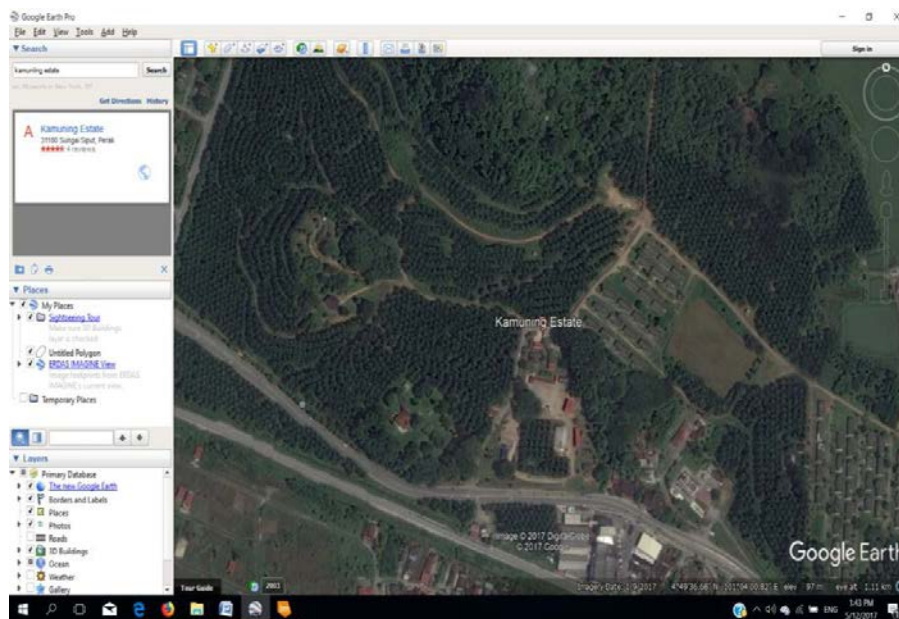


Figure 2: Google Earth image of Kamuning estate

Next, the calculations of the vegetation indices were done. Figure 3 shows the mapping of the plantation with respect to the NDVI distribution and Figure 4 is for SAVI. It can be seen that the healthy vegetation is range between 0.45 and 0.57. Healthy vegetation shows higher NVDI values due to the light is absorbed and reflected by the plants at the leaves. However, soil and urban area show low values of NDVI as both do not produce chlorophyll and no absorption of light and reflectance or infrared band.

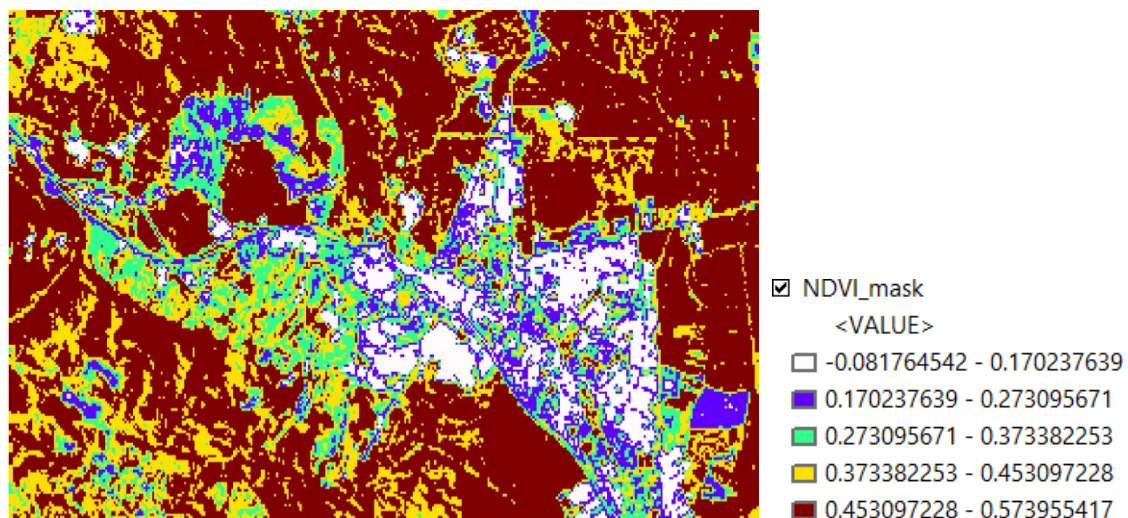


Figure 3: Results of NDVI

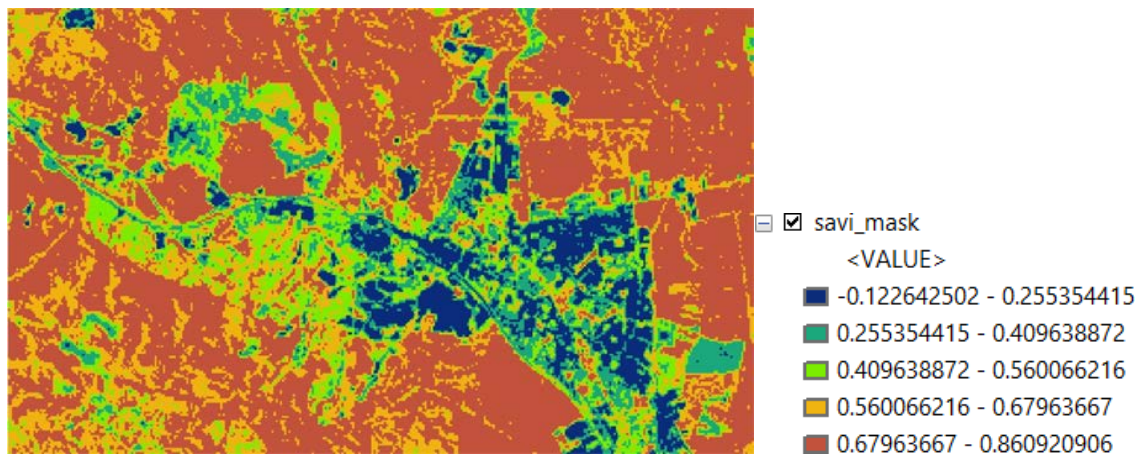


Figure 4: Results of SAVI

SAVI can be used to determine nitrogen content in a plant. Figure 4 shows the distribution of colour based on the values for SAVI. The higher the SAVI value, the more nitrogen contains in the plant vegetation. Based on the results obtained, dark brown area shows the high nitrogen contains from range value of 0.68 to 0.86.

Regression model is used to study the relationship between NDVI and temperature, NDVI and SAVI as well as NDVI and precipitation. Figure 5 shows the relationship between NDVI and the maximum temperature recorded. The coefficient determination, R^2 in this model is 0.8711 and correlation, $r = 0.9333$ which show strong relationship between these two variables. The temperature data obtained during this time is between 29°C to 34°C (obtained from Malaysian Meteorological Department) which could indicates that there are sufficient sunlight for the oil palm to carry out photosynthesis [17], which is why the NDVI is highly correlated with the temperature.

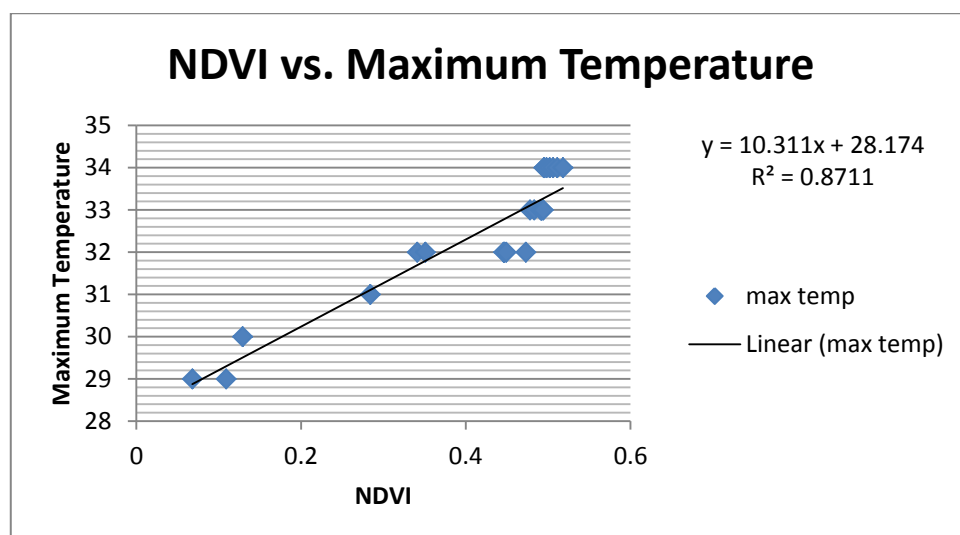


Figure 5: Correlation between NDVI and temperature

Meanwhile, Figure 6 shows the correlation between NDVI and SAVI. From here, the coefficient determination, R^2 in this regression model is 0.9953. The correlation calculated is equal to 0.997 where it shows strong correlation between NDVI and SAVI since it is close to 1. This means that the relationship between NDVI and SAVI are strong. i.e. the plant health depends on the nitrogen content. The higher the SAVI means higher in nitrogen content where it will leads towards higher in NDVI value where it shows healthy plants.

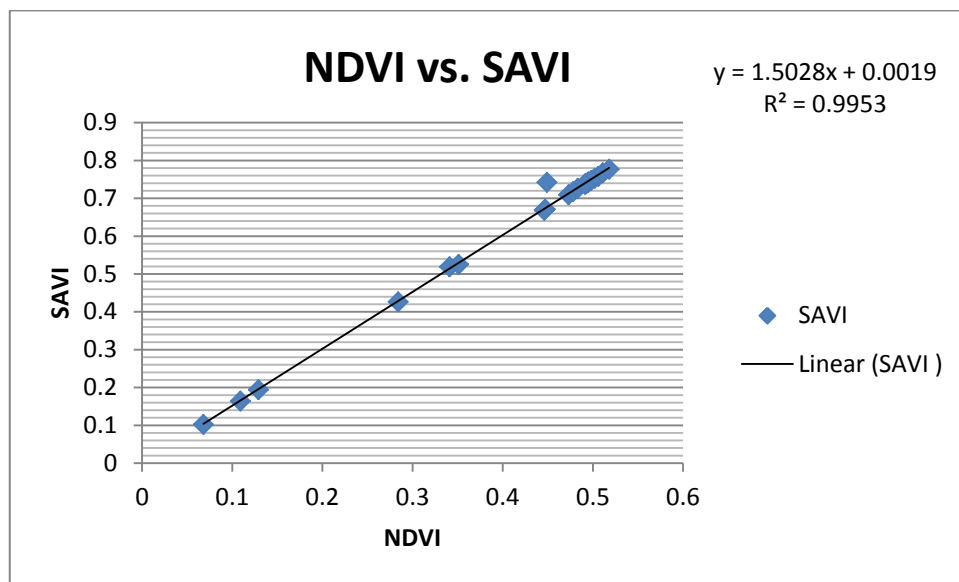


Figure 6: Correlation between NDVI and SAVI

Figure 7 shows the correlation between NDVI and precipitation. From here, the coefficient determination, R^2 in this regression model is 0.0218 and the correlation calculated is equal to 0.148 where it shows weak correlation. Although the average of rainfall receive in March is 8.2 mm, but it does not have much impact on the palm oil growth. The plantation has been took care well by the workers since climate started to change to hot and dry in March to June. Suitable amount of water has been applied on the plantation to maintain the condition of plantation. Besides that, continuous of rainfall may affect the growth of palm oil. Thus, palm oil plantation may not depends on the precipitation.

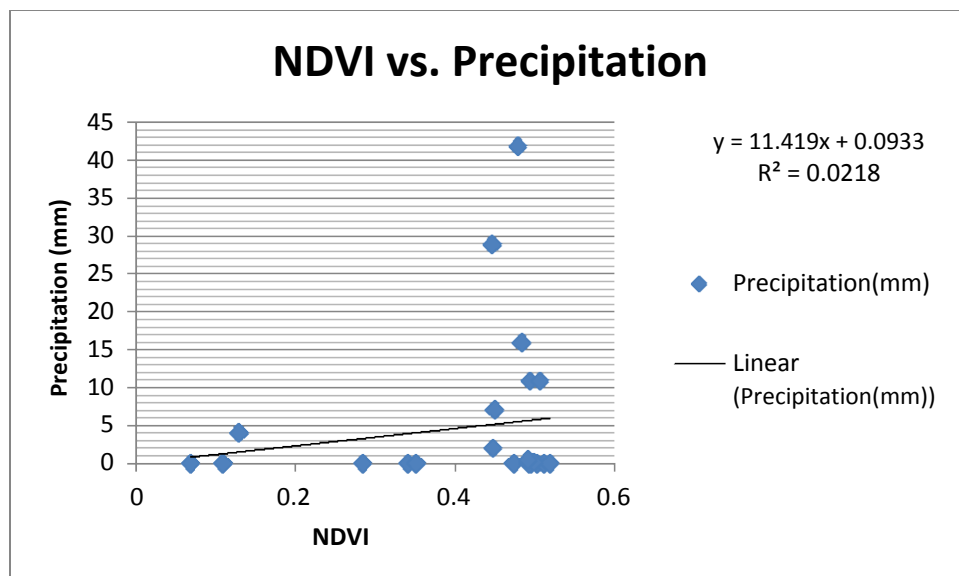


Figure 7: Correlation between NDVI and precipitation

4. Conclusion

This project has shown the capability of satellite image for environmental monitoring in agricultural, especially in oil palm plantation. From the results, it can be seen that NDVI, an index that can be used to determine the health condition of a plant, is having strong correlations with SAVI and temperature, but not with precipitation. Thus, it can be concluded that the image obtained from the satellite can be used for plantation monitoring with appropriate analysis. Further tests especially with suitable laboratory experiments can be done to investigate further the results of this project.

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