Integrating Remote Sensing and GIS Techniques for Accurate Mapping and Analysis of Oil Palm Plantation Distribution in Kelantan: A Case Study

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Abstract. The research conducted in Kelantan focused on analysing the distribution of oil palm plantations using remote sensing data and ArcGIS, a Geographic Information System (GIS) platform. The demand for accurate and up-to-date information on oil palm plantations has been increasing due to advancements in technology and the need for effective management of the environment. The study aimed to compare the distribution of oil palm plantations in 2016 and 2021 by using vegetation analysis techniques such as Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and Soil-Adjusted Vegetation Index (SAVI). Remote sensing data from Landsat 8, specifically Bands 5, 4, and 2, were utilized to derive these vegetation indices. Ground-truthing data, obtained through GPS coordinates, were employed to increase the accuracy of the analysis. The expansion of oil palm plantations and non-oil palm areas was assessed using the Supervised Classification Maximum Likelihood method. The distribution data of oil palm plantations is highly sought after by oil palm plantation companies and serves public and private purposes, contributing to environmental monitoring and promoting sustainable practices.

1 Introduction

Development of remote sensing technology in mapping methods driving into another level of Earth surface discovery. Remote sensing can be used in any type of case by using certain systems especially on surfing the geography of Earth using Geographic Information System (GIS). This system allows to create, manage, analyse, and map all types of data on Earth's surface. The benefits of this technology are help humans to be more knowledgeable about Earth's behaviour for example in recognizing the species of vegetation in a certain area [1].

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GIS is a system contributed by remote sensing technology as a system that helps to analyse and show geographically referenced information using raw data on the Earth's surface [2]. GIS) has been upgraded year by year is now has the capabilities to use either through the online platform or offline platform. This kind of development help human to applicate GIS in daily life or business. Performing this system should be able to assess vegetation in certain areas to discover new knowledge that can be used in Earth surface study [3]. Malaysian oil palm plantations have increased for many years. It is also categorized as a commodity plantation that triggered the economy throughout the year until now. As evidence, there are so many oil palm trees grow internally or by a large organisation in every area of Malaysia today [4]. This oil palm plantation can be use in several ways, such as in consume food products, as an energy source and many more [5].

In this study, oil palm plantations in Kelantan as the module to achieve target on application of remote sensing and GIS in studying the distribution for 2012, 2017 and 2022. Applying this remote sensing and GIS should be used the EVI, NDVI and SAVI method to assess the vegetation indices and releasing the data analysis of oil palm plantation in Kelantan.

2 Materials and Methods

2.1 ArcGIS

ArcGIS has been chosen as a main software for this study. It is because the characteristics of this software, allow user to be editor, create new data and generate geospatial data. In this study, integration between remote sensing and GIS especially using the ArcGIS software that integrated satellite image or GPS data to analysis [6] This study also used ArcGIS to examine the spatial patterns, the interaction between data and analyse data and trend of data including the distribution of certain vegetation for example the oil palm plantation [7].

2.2 GPS

Global positioning System (GPS) as tool that used to detect actual coordinates which is the location of specific data far more accurately [8]. In this research, by using GPS, data coordinate of oil palm plantation acquired at certain area. This information assumes as the important data that shows this study using accuracy data which is using ground through process.

2.3 USGS EarthExplorer

The data will be derived from USGS EarthExplorer. The USGS is the biggest civilian mapping and earth science organisation in the country. It gathers, monitors, examines, and offers scientific knowledge of the situations, challenges, and concerns relating to natural resources. This data used in Shapefile format. In USGS data, raster can be defined as in contrast to geoprocessing tools, which create a new raster, raster functions apply processing directly to the pixels of images and raster datasets. Other than that, the formula suggested easy-to-understand user interface and simple tools make it quick and easy to look at and explore images. The Formula also used can look at large datasets and metadata, compare

images visually, make powerful 3D visualisations, make scatter plots, investigate pixel signatures, and do other things.

2.4 Vegetation Analysis

EVI, NDVI, and SAVI values as well as formula that can be used to examine an oil palm plantation. Similar to the Normalized Difference Vegetation Index, the Enhanced Vegetation Index (EVI) can be used to determine the greenness of vegetation (NDVI). EVI is more sensitive in vegetated situations because it can adapt to different air conditions and background noise from the canopy. To identifying and rating living green plants, NDVI analyses reflected visible and near-infrared light. A satellite image's individual pixels are measured for vegetation density and health using NDVI. Formula for vegetation indices. SAVI, on the other hand, is a vegetation index that is used to reduce the influence of soil on the vegetation data, and it is suggested that this will increase the sensitivity to colour intensity because SAVI does try to minimise the effects of soil brightness using a soil-brightness correction factor.

$$EVI = 2.5 * ((NIR - R) / (NIR + C1 * R - C2 * B + L)) \quad (1)$$

$$SAVI = \frac{NIR - RED}{NIR + RED + L}(1 + L) \quad (2)$$

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (3)$$

2.5 Study Area

The study area is covering the whole state of Kelantan. This study area was located in the north-eastern part of Peninsular Malaysia between latitudes 4°33' and 6°14' North, and longitudes 101°19' and 102°39' [9].

Fig 1. Map of Study Area

3 Results and Discussion

3.1 Image Processing

The result started with adding image data from 2016 and 2017 which is respectively with 2 layers different in the same date but different part of Kelantan. This image data taken from Landsat 8. Image data divide into two part which is at upper side given code which is upper side coded "_127056_" and bottom side "_127057_".

3.1.1 Data Acquisition

Processing analysis result started with processing the EVI, NDVI and SAVI. It is to ensure determining the distribution can be done directly based on vegetation analysis. Image data for each formula contained Band 5 (Near Infrared), Band 4 (Red) and Band 2 (Blue). For NDVI, figures show the result for each year 2016 and 2021. NDVI range value was around -1 to 1 which is the more it closer to 1 it become sensitive to vegetation area and less sensitive define as close to -1 that area was non vegetation area for example bare area.

The formula was using Band 5 and Band 4 as it to detect the differentiation and correlation vegetation area and non-vegetation area. EVI was used to enhance that specific area that detect vegetation. Same as the NDVI, EVI range value was around -1 to 1. This formula used Band 5, Band 4, and Band 2 which was bring this formula as more sensitive to vegetation than NDVI because the ability to detected vegetation area without any influenced from atmospheric and soil surface. SAVI used Band 5 and 4 only which is the formula focusing on soil sensitivity that help to detect well on soil indices in that area. Also same as EVI and NDVI, the range value from -1 to 1.

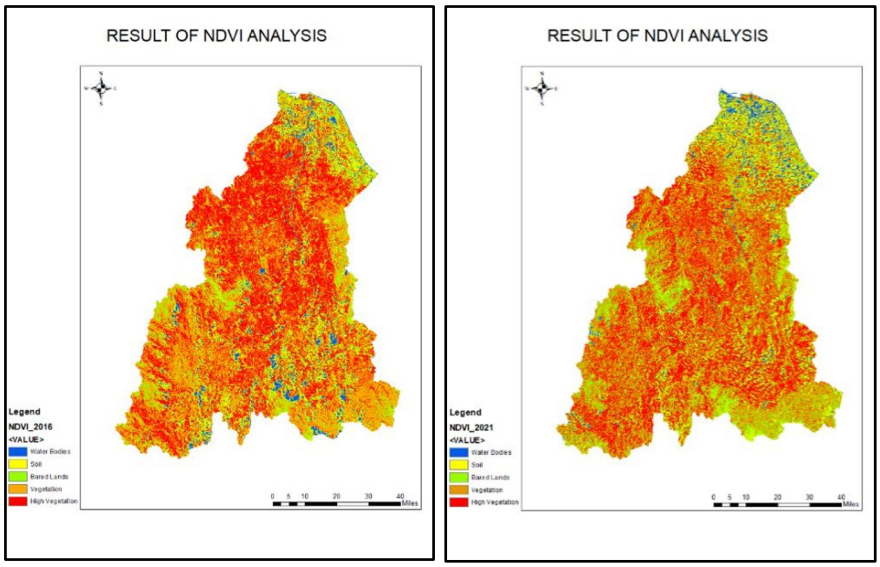

Fig 2. NDVI Results

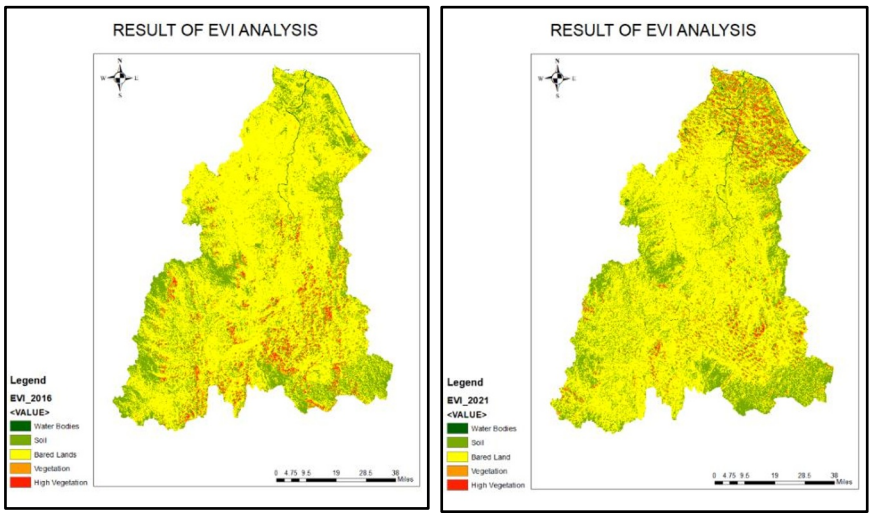

Fig 3. EVI Results

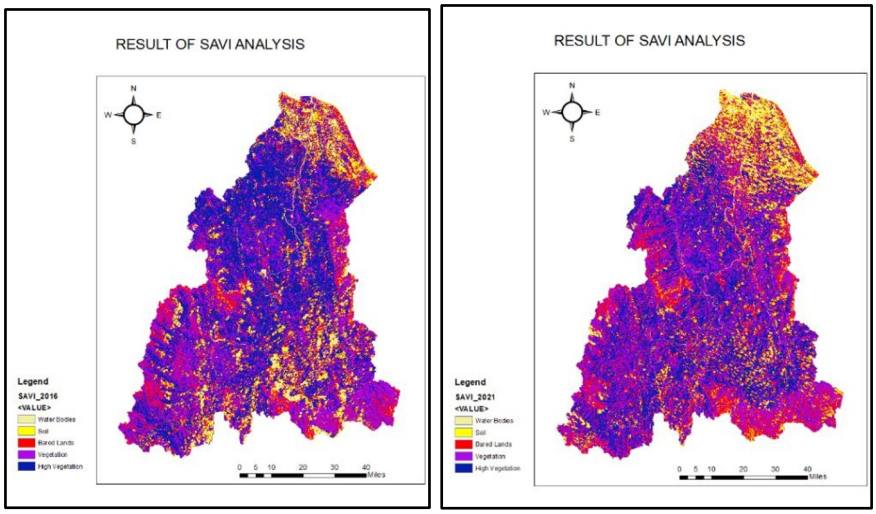

Fig 4. SAVI Results

3.1.2 Supervised Classification Maximum Likelihood

In this analysis, interpreting data from the NDVI, SAVI and EVI analysis used to determine the oil palm plantation distribution area. EVI formula calculates to increase the vegetation variability. Because of existing C1 and C2 as the coefficient it helps to adjusting the pixel or indices. The NDVI formula simply calculates to provide the measurements between the vegetation and non-vegetation area. While for SAVI, this formula calculates to get the differentiate of the soil, which is the characteristic of this indicator assign as sensitivity to soil area.

Based on the results of vegetation analysis, the distribution of oil palm plantation can be determined by doing the classification of oil palm plantation and non-oil palm plantation

area. Maximum Likelihood observed differentiate between those 2 results. The NDVI, EVI and SAVI provide image data that already classified the image data based on pixel numbers and colour. The band 5 as the Near Infrared play a main role in identifying the vegetation stress.

The regions that have been classified area Oil Palm Plantation and Non-Oil Palm Plantation that consist of elements on the surface of earth such as bare soil, water bodies, and urban area. Oil palm plantation coordinates also includes in image data to shows the accuracy of data image. NDVI result for 2016 and 2021 shows the data in green area was generated as the vegetation health which mean that correlate with the oil palm plantation. Therefore, in Figure 2, NDVI 2016 applying classification using maximum likelihood method, it was set as the blue colour for oil palm area. Random coordinate of oil palm plantation also set inside blue colour. While remain was non-oil palm plantation area.

3.2 Discussion

Based on the result, EVI (Enhanced Vegetation Index) offers improved sensitivity in high biomass regions and minimizes aerosol effects but is more complex to calculate and less interpretable for non-experts. SAVI (Soil-Adjusted Vegetation Index) reduces soil background influence and provides better sensitivity in low vegetation areas, but its effectiveness relies on choosing the right soil adjustment factor and may not perform well in dense vegetation regions. NDVI (Normalized Difference Vegetation Index) is widely applicable, simple to interpret, and sensitive to changes in vegetation density, but it saturates in high vegetation areas, is sensitive to atmospheric effects, and lacks sensitivity to canopy structure variations.

For this research, compared to the method of vegetation indices, The Enhanced Vegetation Index (EVI) demonstrates superior sensitivity to canopy structure by considering the red and blue bands' influence, resulting in reduced vulnerability to canopy background variations and atmospheric conditions in sensitive areas compared to NDVI. Therefore, it chosen as the best method to detect the oil palm plantation, which it’s design prioritizes enhanced sensitivity in high biomass regions, making it particularly effective for monitoring regions with dense vegetation cover. Furthermore, EVI's incorporation of the blue band minimizes the impact of aerosols and atmospheric disturbances, rendering it well-suited for use in sensitive areas where atmospheric interference can be a concern.

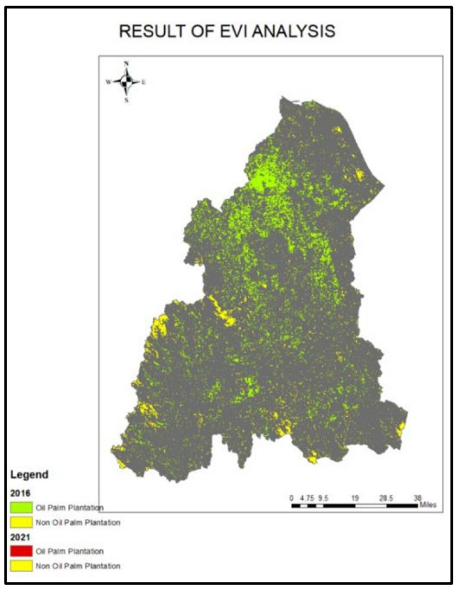

Fig 5. Results of Oil Palm Plantation comparison between 2016 and 2021

Table 1. Area of Oil Palm Plantation in 2016 and 2021

No	Type	Area for Year 2016 (km^2)	Area for Year 2021 (km^2)
1.	Non Oil Palm Plantation	9114	9113.5512
2.	Oil Palm Plantation	5916	5915.5551
	Sum	**15030**	**15029**

In the satellite imagery, the red color is assumed to represent oil palm plantations in 2021, while the green color represents oil palm plantations in 2016. The comparison of these two time points reveals that there have been only minimal changes in the extent of oil palm plantations from 2016 to 2021. The visual analysis of the imagery suggests that the expansion or contraction of oil palm plantations during this five-year period is limited, indicating relatively stable land-use patterns in the oil palm industry.

Table 1.0 displays the results of the oil plantation assessment in 2016. The data reveals that there were approximately 9914 square kilometers of non-oil palm plantation areas and around 5916 square kilometers of land dedicated to oil palm cultivation in that year. The results of the oil plantation assessment in 2021, indicating that there were still approximately 9914 square kilometers of non-oil palm plantation areas and around 5916 square kilometers of land allocated to oil palm cultivation. The negligible difference between the two tables reinforces the observation from the satellite imagery, demonstrating that the oil palm plantation areas have experienced only minor changes during the five-year interval.

The data from both the satellite imagery and the quantitative assessment in Table 1.0 collectively suggest that the oil palm plantation landscape has remained relatively stable from 2016 to 2021. Despite potential variations in localized regions, the overall extent of oil palm plantations has not significantly expanded or contracted during this period. This information is crucial for understanding the dynamics of land-use changes in the oil palm industry and can serve as a valuable baseline for future land management and conservation efforts.

4 Conclusion

In conclusion, there were data has been met the goals of the objective which is the result shows the application of distribution of oil palm plantations in Kelantan by integrating remote sensing and GIS based on NDVI, EVI and SAVI. The data shows using the raw data from remote sensing and interpret it in GIS to do the vegetation analysis widely in this thesis. Landsat 8 including the Band 5, Band and Band 2 were the elements of the data that used in analysing the image data. Combining data analysis and vegetation analysis showing that the map consists of categorial of vegetation which is the oil palm and non-oil palm plantation which is opposite element on the surface of the Earth. Oil palm plantation indices can be based on the map of NDVI, EVI and SAVI results. Each colour iconic the oil palm, coordinate of the oil palm and non-oil palm plantation.

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