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Integrating Remote Sensing and GIS Techniques for Accurate Mapping and Analysis of Paddy Field Distribution in Kelantan: A Case Study

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Abstract. This research focuses on studying the distribution of paddy fields in Kelantan between 2016 and 2021, utilizing Geographic Information System (GIS) and satellite imagery from Landsat 8 acquired through remote sensing. The primary objective is to examine the spatial distribution of paddy fields within a specific area in Kelantan and analyze changes that occurred during the mentioned time frame. By combining satellite images, GPS technology, the study aimed to offer comprehensive insights into distribution patterns and changes in paddy fields, which can inform decisions related to paddy field production and agricultural management. Maps of Kelantan were obtained from Earth Explorer websites, processed, and analyzed to calculate vegetation indices like Enhanced Vegetation Index (EVI), Normal Difference Vegetation Index (NDVI), and Soil-Adjusted Vegetation Index (SAVI). The study's key findings reveal the distribution of paddy fields in Kelantan, with an area of 27,420.88 hectares in 2021, marking a 2.31% decrease compared to the previous year's 28,863.91 hectares. The research successfully achieved its goals, assessing vegetation indices and creating a distribution map of paddy fields in Kelantan. These findings have the potential to contribute to effective agricultural management and decision-making processes in the study area.

1 Introduction

Remote sensing is referred to the practise of detecting and monitoring the physical features of an area from a distance using measurements of the region's reflected and emitted radiation as the primary means of data collection. Images that have been "sensed" remotely by specialised cameras are then sent to a computer where they are analysed in order to provide

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researchers with information about the planet. Images of vast areas of the surface of the Earth can be acquired by satellites and aeroplanes, giving us the ability to observe much more than we would be able to see if we were standing on the surface ourselves. This gives us the ability to observe far more than we could see if we were standing on the surface of the Earth [1].

Meanwhile Geographic Information System (GIS) is referred to a piece of software that can compile, organise, analyse, and map different types of data. The Geographic Information System (GIS) combines several distinct types of location data (the coordinates of objects) with a variety of different kinds of descriptive data that are linked to a map (what things are like there). This creates the framework for subsequent procedures, including mapping and analysis, which are used in research as well as practically every other area of the economy. Users may have the opportunity to get a more in-depth grasp of patterns, connections, and the geographical environment with the aid of GIS. In addition to advances to productivity and communication, there will be changes made to management and decision-making. These improvements will also be made [2].

Paddy fields are good for the environment in a variety of other ways as well, including lowering the risk of flooding, restoring groundwater levels, fostering biodiversity, and encouraging the expansion of ecosystems in the surrounding area. The usage of paddy fields, on the other hand, requires a substantial quantity of water and disrupts the natural hydrological cycle. This may have a negative impact on the environment of the region that surrounds the paddy fields. When irrigation uses a significant quantity of water, a drainage system could be necessary to accommodate the excess. This need can throw off the equation that determines the amount of water that is supplied to and demanded in the area. This study examines the significance of paddy fields as a kind of artificial and transient wetland in the context of the hydrological setting of the region. Paddy fields are defined as "flooded rice fields." In this regard, paddy fields are taken into consideration [3].

Optical satellite images have been employed for agricultural remote sensing applications. These apps have many uses and crops. Using vegetation indices, optical sensors can gather multi-temporal and multi-spectral rice crop data. Several approaches exist to achieve this. Using multi-time period data might enable this. In Malaysia, optical sensors are employed in the rice industry. When initially created, the Landsat 5 Thematic Mapper (TM) sensor was utilised for paddy applications. Both the Ratio Vegetation Index (RVI) and the Normalize Difference Vegetation Index (NDVI) are used in paddy research [4]. Techniques based on machine learning and phenology can be broken down into a more general category when discussing the mapping of rice fields using remote sensing. The approach of machine learning is founded on the calibration of observations made in the field; while it is accurate, it takes a significant amount of data. The phenology-based approach is dependent on having prior knowledge of the rice growth stages, which are connected to a time series of reflectance data. During the process of crop transplanting, rice fields can be distinguished from those used for the cultivation of other crops by virtue of the presence of standing water. Phenology-based categorization is able to recognize the many stages of plant growth based on the changes in the plant's vegetative cover, even with just little data from the ground. The majority of the research that use the phenology-based method is based on spectral indices, and the classification of such indices can either be supervised or done manually. There are not nearly enough studies that use unsupervised categorization to separate spectral signatures into their respective phenological classifications [5].

2 Materials and Methods

2.1 Study Area

Kelantan located in between latitudes 4°33' and 6°14' North, and Longitudes 101°19' and 102°39' in the northeastern part of Peninsular Malaysia. The capitol city of the state is Kota Bharu. Nowadays, a total of 1.8 million people live in Kelantan [6]. The catchment area for the Sungai Kelantan can be found in the north-eastern part of the Peninsular Malaysia between the latitudes of 40° 30' and 60° 15' North and the longitudes of 101° and 102° 45' East. The Sungai Kelantan is one of the main rivers in Kelantan and is regularly subject to floods. It is the river that drains the most land in the state of Kelantan and is 248 kilometers long, making it the longest river in the state. The breadth of the River Kelantan ranges anywhere from 180 to 300 meters on average. The Kelantan River Basin is home to about 68.5% of the country's total population [7]. Mount Chamah may be found in the Titiwangsa Mountain Range, which is situated in the northwest corner of the Malaysian state of Kelantan. It is one of the mountains in the Malay Peninsula that is higher than 2,172 meters and it is the fifth tallest peak on the Malay Peninsula (7,126 ft). It has the distinction of being the highest peak in the whole state of Kelantan [8].

Fig 1: Map of Kelantan in Malaysia

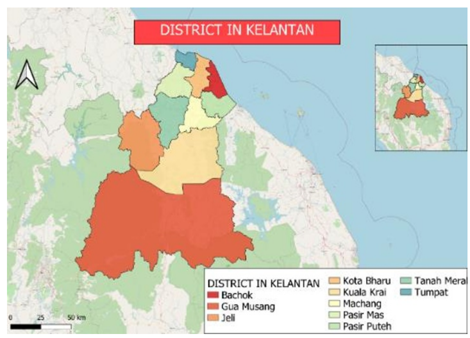

Fig 2: District in Kelantan

2.2 Data Collection

The field surveying and data gathering from farmers and villagers were completed in a total of ten districts. During the course of the field survey, the coordinates of the paddy fields were recorded, and then those data was compared to the information obtained from the Earth Explorer website of the United States Geological Survey (USGS Earth Explorer). The fieldwork consisted of collecting the positions of points located in the research region using various kinds of remote sensing applications and was carried out with the assistance of GPS devices. The horizontal plane is where this device's precision shines.

There were no barriers or restrictions preventing access to the main source of the data in any manner. In the years 2012, 2017, and 2022, the United States Geological Survey (USGS) made use of satellite image. It provided support for satellite photographs that made use of the Global Positioning System, and additional data was acquired from secondary sources, including the Ground Truth method (GPS) data acquisition.

A map of a paddy field was built by using satellite photos that were obtained from a number of various remote sensors. This data was used to create the map (Landsat 8). Landsat 8 was the source of the data that were used to create these maps. The large number of data sources makes it more difficult to analyze the data; however, the use of data from a variety of operational satellite sensors, such as the Operational Land Imager (OLI), and the Thermal Infrared Sensor (TIRS) may help solve some of the problems associated with data acquisition.

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2.3 Image Pre-Processing

Clipping and selecting a subset of the image are two methods that was used to discover the region of interest as well as the borders of the research area while the picture is being preprocessed. Clipping refers to the process of cutting out a portion of an image using a cropping tool and selecting a subset. This helps to ensure that the results are accurate, which adds to the overall correctness of the investigation. When executing the image processing, it is important to keep in mind both the goal of locating the area of interest and the objective of reducing the amount of time required for the processing of other processes. After that, the scanline error that had been present in the satellite images that had been taken from Landsat 8 for the year 2021 was fixed by making use of the pre-processing capabilities that had been included into ArcGIS. These capacities were used in the process of correcting the issue. A natural color composite was used to illustrate the band composition that was ultimately shown as part of the process of presenting the data. This was done so that the band composition could be accurately represented.

2.4 Image Processing

Following the selection of the images that were analyzed, the photographs were imported into the ArcGIS application so that an analysis were performed on the data that was contained within the photographs. This allowed for an analysis to be performed on the data that was contained within the photographs. This made it possible to carry out an investigation on the information that was included inside the images themselves. Because of this capacity to choose them, the images that were going to be judged could then be picked. It was able to have a better overall understanding of the circumstance as a result of this fact. The process of improving the picture by using the software in order to ensure a high degree of image quality, georeferencing and registration by using the software in order to ensure that the map projections are consistent with one another, and so on and so forth. All of these improvements are made possible by using the software. Afterwards, land uses land cover (LULC) maps for the years 2016 and 2021 were generated. The maps that were created for each of these years were done so in a way that was exclusive to that particular year.

2.5 Data Analysis

Paddy rice has a diverse phenology that encompasses a wide range of EVI, NDVI, and SAVI values, in addition to a number of different planting ages. A metric known as the Enhanced Vegetation Index (EVI), which is analogous to the Normalized Difference Vegetation Index, may be used to determine the degree of verdancy present in the surrounding vegetation (NDVI). EVI, on the other hand, is able to adapt for specific atmospheric conditions as well as canopy background noise, and it is more sensitive in regions that contain a lot of vegetation because of this ability. The NDVI index is able to detect and measure the presence of live green vegetation by making use of the reflected light in the visible and near-infrared wavelengths. The normalised difference vegetation index, often known as NDVI, is an indicator of the density of the vegetation as well as its overall health that is present in each individual pixel of a satellite image. This is following of the formula vegetation indices:

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

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

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

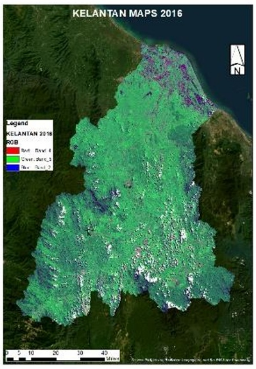
3 Results and Discussion

3.1 Introduction

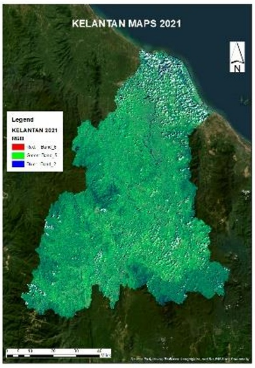
This chapter addressed the data obtained from satellite photos taken in Kelantan using two different years which is 2016 and 2021. Data were generated with the classification accuracy index utilising three vegetation indices, EVI, NDVI and SAVI, that classifier variety indices value of for paddy fields. The categorization is designed to establish distinction between three indices. The goals were to compare the difference between year 2016 and 2021 and to identify the vegetation indices suitable with paddy fields.

3.2 Data Processing

The pre-processing was done to combine Kelantan layer with the raw data downloaded in USGS websites to get one main layer of Kelantan image. This particular band combination employs blue (2), SWIR-1 (6), and near-infrared (5) wavelengths. Because it makes use of short-wave and near-infrared light, it is frequently applied in the field of crop monitoring. Healthy vegetation seems dark green. However, the colour of bare dirt is more of a magenta. Infrared radiation of a thermal nature can be detected by Band 6. Band 6 is the only frequency at which Landsat can capture images of the nighttime sky. Band 5 is sensitive to the turgidity of plants, which may be thought of as the quantity of water they contain. Band 5 has created clear distinctions between agricultural land, forested area, and bodies of water. In comparison to the croplands, which appear to have a light grey colour, the forests have a much deeper tone. Band 5 has differentiated between arid regions, croplands, and grasslands, which have a brighter tone, and aquatic bodies, which have a darker tone. Because responses from agricultural land and urban areas were essentially identical, the spectral reflectance band 5 was unable to differentiate between the two types of terrain. As a result of it covering the green reflectance peak from leaf surfaces, it has created a separation between the soil and vegetation (forest, croplands with standing crops). In this band, arid terrain, urban areas, roads, and highways have presented themselves as having a brighter (lighter) tone, whereas woodland, vegetation, bare croplands, and croplands with standing crops have presented themselves as having a dark (black) tone. Figure 3 shows the Kelantan maps with Band 2, 5 and 6 for both years.



a) Kelantan 2016

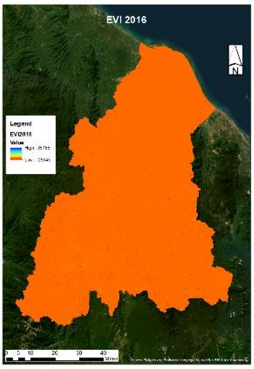


b) Kelantan 2021

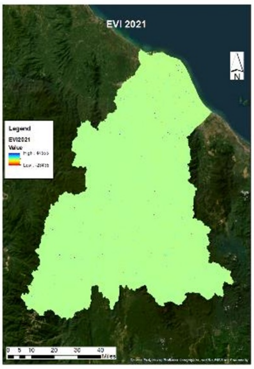
Fig 3: Data Extraction for 2016 and 2021

3.3 Production of Vegetation Index

The Enhanced Vegetation Index (EVI) takes into account certain atmospheric conditions and canopy background noise, and it is more sensitive in locations that have a lot of vegetation. Figure 4 shows the EVI for both years. The Normalised Difference Vegetation Index, or NDVI, has seen widespread application in research that investigates the connection between spectral variability and shifts in the growth rate of vegetation. Determining the production of green vegetation and detecting changes in vegetation are both valuable applications of this technique. Figure 5 displays the findings, which include a representation of the numerous characteristics that have been retrieved from the satellite image. Soil-Adjusted Vegetation Index (SAVI), which is a distance-based vegetation index, further demonstrated a stronger capacity to estimate production for the years 2016 and 2021. The general consensus on the year 2016 had a rather pessimistic outlook. Figure 6 shows the SAVI output for this research.

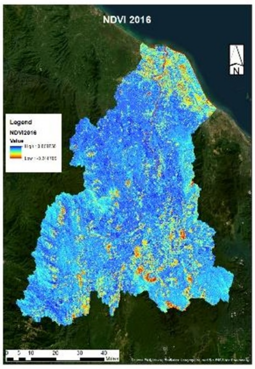


a) EVI 2016

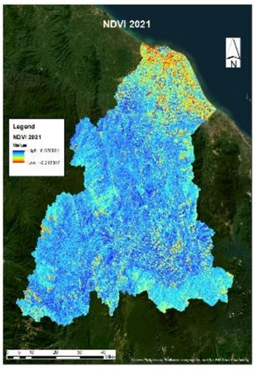


b) EVI 2021

Fig 4 : Enhanced Vegetation Indexfor 2016 and 2021



a) NDVI 2016



b) NDVI 2021

Fig 5 : Normalized Difference Vegetation Indexfor 2016 and 2021

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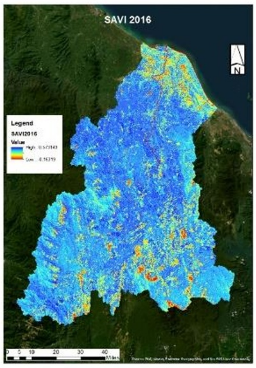
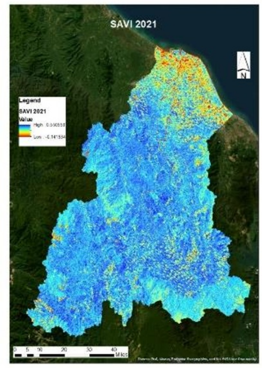


a) SAVI 2016



b) SAVI 2021

Fig 6: Soil Adjusted Vegetation Index for 2016 and 2021

3.4 Land Use Land Cover of Kota Bharu

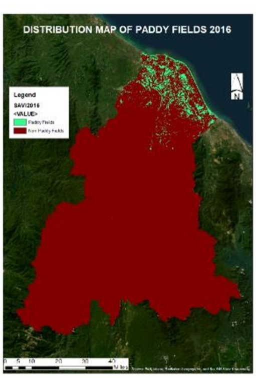
This study also produced the distribution map for paddy fields in Kelantan for 2016 and 2021. There are two legend shows classify as paddy fields and non-paddy fields. The distribution for 2016 and 2021 was different due to 5 years gap of year. Figure 9 shows the ditribution of paddy fields in 2016 and 2021.

In year 2016, the area of paddy fields was estimated to be 11863.91 hectares by the United States Department of Agriculture. The total area of rice fields had a rise of 2.31%, or 27420.88 hectares, in the year 2021.According to the Department of Agriculture (Table 1) , the average rice production (kg/ha) each state from 2016 to 2021 was 4237.20 kilogrammes per hectare in 2016, and 4453.00 kilogrammes per hectare in 2021.

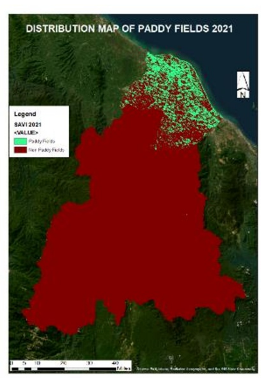
Table 1: The average rice production in Kelantan

Year	Average Rice Production (kg/ha)
2016	4,237.20
2021	4,453.00

According to the results of the recently revealed distribution map, the area of paddy fields in 2016 is less than in 2021. This could be owing to the pandemic condition, which caused paddy fields to be more fertile than in 2016.



a) Distribution Map 2016



b) Distribution Map 2021

Fig 7: Distribution Map of Paddy Fields for 2016 and 2021

4 Conclusion

The results of this research were able to accomplish two main objectives: one was to evaluate the vegetation indices of integrating remotely sensed data from Landsat 8 of paddy fields in Kelantan, and the other was to construct a distribution map of paddy fields in Kelantan. Both of these goals were successful. Enhanced Vegetation Index (EVI), Normalised Difference Vegetation Index (NDVI), and Soil-Adjusted Vegetation Index (SAVI) were developed for the years 2016 and 2021 as part of the first aim. These indices measure the degree to which soil conditions have been modified by the plant cover. The second goal was to build a paddy fields distribution map using the findings of the vegetation indices for two years.

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