Crop Monitoring of Paddy Field Using Landsat 8 OLI

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Abstract
There are times where paddy farmers faced crop yield production that does not meet their expectations although the crop has been well-tended. Especially when the growing and harvest seasons, farmers will be able estimate on cutting some production costs while increasing crop yields with crop yield monitoring and mapping if they could measure the different vegetitation indices of crop field. Therefore, to test the efficiency of this study, the crop health was monitored using vegetation index values obtained from multispectral remote sensing images, such as the Normalized Difference Vegetation Index (NDVI) and the Soil Adjusted Vegetation Index (SAVI). The objectives were to estimate the NDVI and SAVI values of a paddy field in Sabak Bernam, Selangor and create a crop health map using the calculated NDVI and SAVI during its resting period (January, February, July, August) and growing up period (April) in 2020. This study used Landsat 8 OLI images at a resolution of 30 meters. The data was then processed using Erdas Imagine and ArcGIS Pro to estimate the NDVI and SAVI values, as well as produce crop health maps. As a result, the estimated NDVI and SAVI crop health maps were displayed. In comparison to NDVI, SAVI estimates a greater vegetation index as the value of adjustment factor (L) applied in the SAVI can reduce the soil noise compared to the NDVI. Furthermore, the computation of planted areas revealed that some changes had occurred. The planted area decreased in a specific month, indicating the harvesting season.

1. Introduction

Acquisition of objects or phenomena on Earth without making any physical contact with the objects was defined as remote sensing. It has numerous remote sensing applications, including agriculture, photography, surveying, geology, forestry, and more. In agriculture, remote sensing has effectively monitored and predicted crop yield across many areas. Furthermore, to deliver crop growth condition information on time within a crop season, the Earth Observation (EO) data has proven its uses (Ghosh et al., 2018). According to the Group on Earth Observations Global Agricultural Monitoring Initiative (GEOGLAM) and Committee on Earth Observation Satellites (CEOS), high temporal resolution data would be required to observe critical growth stages of crops (Whitcraft et al., 2015).

Among the emerging innovations in agriculture, remote sensing has a ton of potential because it can make non-destructive assumptions about climate and vegetation environments. By collecting data across large areas with a high frequency of re-examination, satellite remote sensing provides efficient approaches to timely crop tracking and forecasting yields (Atzberger, 2013). Rice crops are monitored using biophysical crop parameters that are closely related to crop vigour and vegetative health. The main parameters that will be observed through remote sensing are crop productivity and crop conditions. Agriculture's primary use in remote sensing applications is to forecast crop yields at local and regional scales using a reliable, low-cost, and quick method (Ahmad et al., 2014). Furthermore, remote sensing acts as an advanced tool that provides a variety of classification approaches for mapping land use and land cover (Hashim et al., 2019).

Agriculture is an important activity that has an essential role in providing food security as the world population increases (Nasirzadehdizaji et al., 2019). The primary food for world food crops was rice, and in 2050, there were going to be two billion more mouths to feed (Dodds and Bartram, 2016). Yield estimation is a task to resolve food security problems, including the potential to estimate crop yields long before harvesting.

Agricultural monitoring, particularly in a developed country, could increase the production of food and help efforts of humanitarian in climate change and drought contexts (Tang, 2019). Paddy is by far the most consumed staple in Malaysia. In 2016, per capita, rice consumption of the Malaysian stood at 80kg, equivalent to about 26% of the total daily caloric intake (Omar et al., 2019). This was translated to an average of RM44/month per household (Tang, 2019).

The Normalized Vegetation Index (NDVI) has established itself as the gold standard for evaluating vegetation and crop health. The NDVI is the most widely used Vegetation Index (VI), and the other indices are refined versions of it (Ramli et al., 2014). The amount of chlorophyll in the leaves determines how healthy a plant is (Pavlovicet al., 2015). Near-infrared light is absorbed by chlorophyll, while visible light is reflected (NIR). By comparing NIR reflectance and visible light, healthy plants with strong photosynthetic behaviour can be studied (Mee et al., 2017). Vegetation indices, which are mathematical transformations of picture bands used to qualitatively extract specific spectral properties, such as vegetation cover, vigour, and growth dynamics, are used to measure these plant characteristics (Xue and Su, 2017). These vegetation indices were explicitly created for each application, and each one has its own set of advantages. Plant health classification and evaluation algorithms can also benefit from vegetation indices (She et al., 2015).

Remote sensing data is a valuable resource for monitoring and mapping vegetation cover. VI was created to track vegetation distribution and phenology. The Soil-Adjusted Vegetation Index (SAVI) is an optimized indices mixture of slope-based and distance-based vegetation indices (Sykas, 2021).

This study focuses on how remote sensing can monitor paddy field conditions using indices like NDVI and SAVI. According to the study that was conducted from (Kamaruddin, 2018) the values obtained from NDVI were classified into three categories (healthy, non-healthy and non-vegetation). The same method was also applied in this research. Not just that, the estimation values of NDVI and SAVI are also investigated in this study. Landsat 8 data is used and processed with Erdas Imagine and ArcGIS Pro software.

2. Methodology

2.1 Study Area

This research was carried out in Sabak Bernam, a northern Selangor district covering 997 square kilometres, as illustrated in Figure 1. Agriculture is Sabak Bernam's main economic activity, with paddy being one of the most important crops. Rice is harvested twice a year, primarily from August to January (wet season) and February to July (dry season). Paddy is an essential food crop, and Sabak Bernam is the nation's rice bowl, with Sabak Bernam being one of the country's top rice producers (Ngah, 2014).

Figure 1: Map showing study area of Sabak Bernam, Selangor (Source: Google Earth Pro)

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2.2 Data Acquisition

The Landsat 8 OLI satellite images of the block paddies acquired from the Kawasan Pembangunan Pertanian Bersepadu (IADA) Barat Laut Selangor. Bagan Terap, Panchang Bendena, Sungai Panjang, Sungai Nipah, Pasir Panjang, Sungai Leman, and Sekinchan are few of the block paddies in the area. Landsat 8 OLI images from January to October 2020 were used to monitor the paddy growing areas. These images were collected from the USGS Earth Explorer. Table 1 shows the date of images taken and the properties of the images. The images were taken on specific dates based on the different paddy plantation activities. Usually in January, February, July and August, it is cleanng up and resting time period for the crop. Whereas on April and October, the paddy is growing and on May, the paddy harvest matured. Table 2 shows the planting and harvesting dates for each block of paddy. This information was used to do the monitoring of the paddy field.

2.3 Data Processing

2.3.1 Image stacking

The method of combining several images into a single image is known as layer stacking. The images must have the same degree (number of rows and columns), which requires resampling other lower spatial resolution bands than the desired resolution. In this research, the band that was used was from band 1 until band 7.

2.3.2 Image subset

The method of subset image in Erdas Imagine was implemented to highlight the scope of the area. The shapefile of an area of Sabak Bernam was used to highlight the area. The image subset looks even brighter, so the analyzed area was easily done by doing the image subset.

2.3.3 NDVI calculation

This research used an image interpreter of spectral enhancement to calculate the NDVI. After pre-processing and filtering of images, the NDVI technique was used to monitor the vegetation condition. NDVI values range from -1 to +1, with higher values indicating healthier vegetation and lower values indicating unhealthy vegetation. Zero indicates that there is no vegetation. The NDVI was calculated using the NIR and red bands in the Equation 1 (Mosleh et al., 2015). The NIR band in Landsat 8 is band 5, while the red band is band 4.

$$NDVI = \frac{\rho NIR - \rho R}{\rho NIR + \rho R}$$

Equation 1

Table 1: Data obtained from USGS earth explorer

Data type	Date of images taken	Path and Row	Resolution
Landsat 8 OLI	1) 20.01.2020 2) 05.02 2020 3) 25.04.2020 4) 11.05.2020 5) 30.07.2020 6) 15.08.2020 7) 18.10.2020	Path: 127 Row: 58	30m

Table 2: Data obtained from IADA Barat Laut Selangor for Season 1 and Season 2

Block of Paddy	Season 1		Season 2	
	Planting date	Harvest Date	Planting date	Harvest date
Sungai Nipah	1.3.2020	1.6.2020	1.9.2020	1.12.2020
Pasir Panjang	1.3.2020	1.6.2020	1.9.2020	1.12.2020
Sungai Leman	1.3.2020	1.6.2020	1.9.2020	1.12.2020
Sekinchan	1.3.2020	1.6.2020	1.9.2020	1.12.2020
Bagan Terap	1.4.2020	1.7.2020	1.10.2020	1.1.2021
Panchang Bendena	1.4.2020	1.7.2020	1.10.2020	1.1.2021
Sungai Panjang	1.4.2020	1.7.2020	1.10.2020	1.1.2021

2.3.4 SAVI calculation

SAVI may be used to adjust for the impact of soil brightness on the NDVI. SAVI is calculated using the Equation 2 (Mosleh et al., 2015).

$$SAVI = \frac{NIR-R}{NIR+R+L}(1+L)$$

Equation 2

The NIR band in Landsat 8 is band 5, while the red band is band 4. The value of L varies according to the amount of green vegetation present. Whenever there is much green vegetation, the L is 0, and when there is not any green vegetation, the L is 1. In most situations, L=0.5 is sufficient, and it is the default value.

2.3.5 Image classification

The block paddy area was extracted and classified into three classifications, which were were non-vegetation, soil, and paddy. The total area of each classification can be determined with the number of pixels in each classes. The formula to calculate the total area using pixel classification is shown in the Equation 3.

Total area of class = ((the number of pixels) *(pixel dimension)) /10000

Equation 3

In this research, the dimension of pixel used was 30 metres*30metres, which made the 900 square metres of area. It needs to be divided by 10000 to convert from the square metres to hectares.

2.3.6 Map production

The crop health map was created using ArcGIS Pro for further analysis. The north arrow, the legend, and the coordinate grid were included on the final map. The NDVI and SAVI values from NDVI and SAVI computations with five classes were shown in the legend.

3. Results and Analysis

3.1 Crop Health Map of the Estimated NDVI and SAVI

Figures 2 and 3 show the crop health map for each month estimated from NDVI and SAVI, respectively.

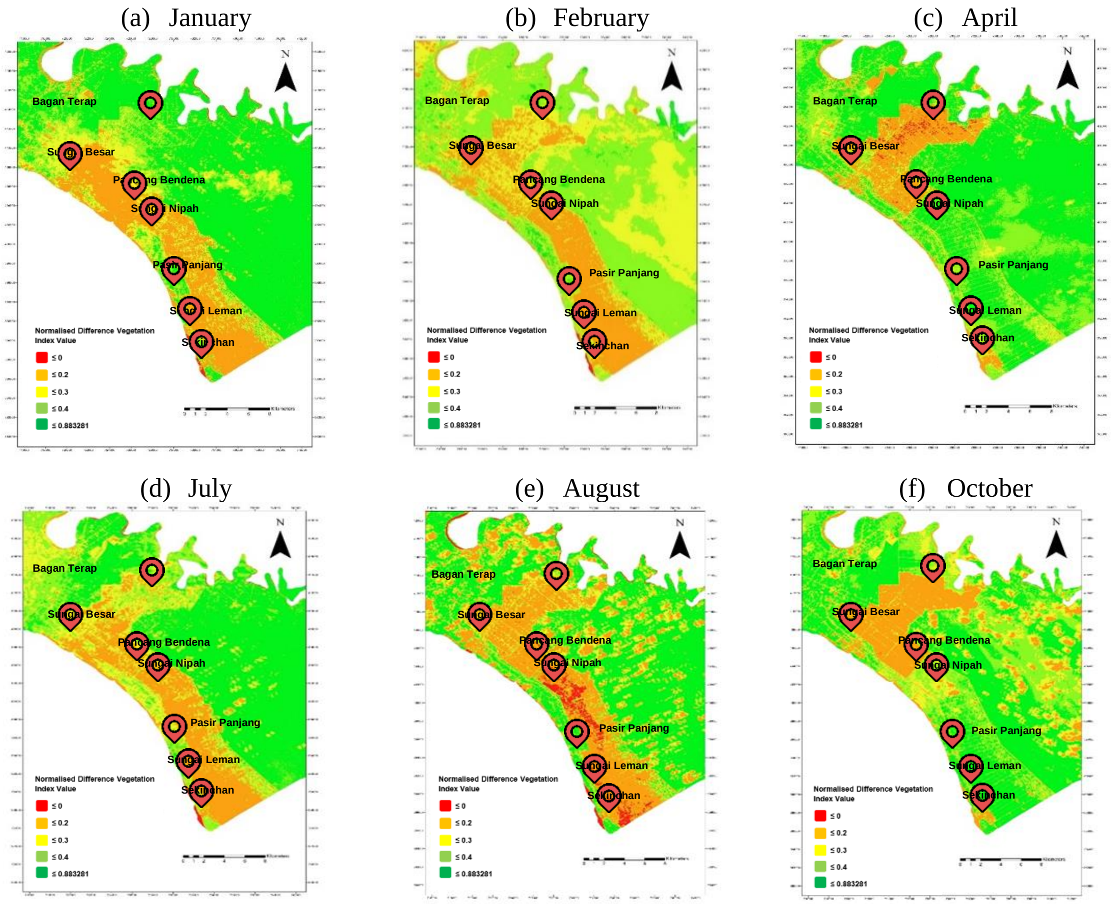

Figure 2: The crop health map of NDVI for each month

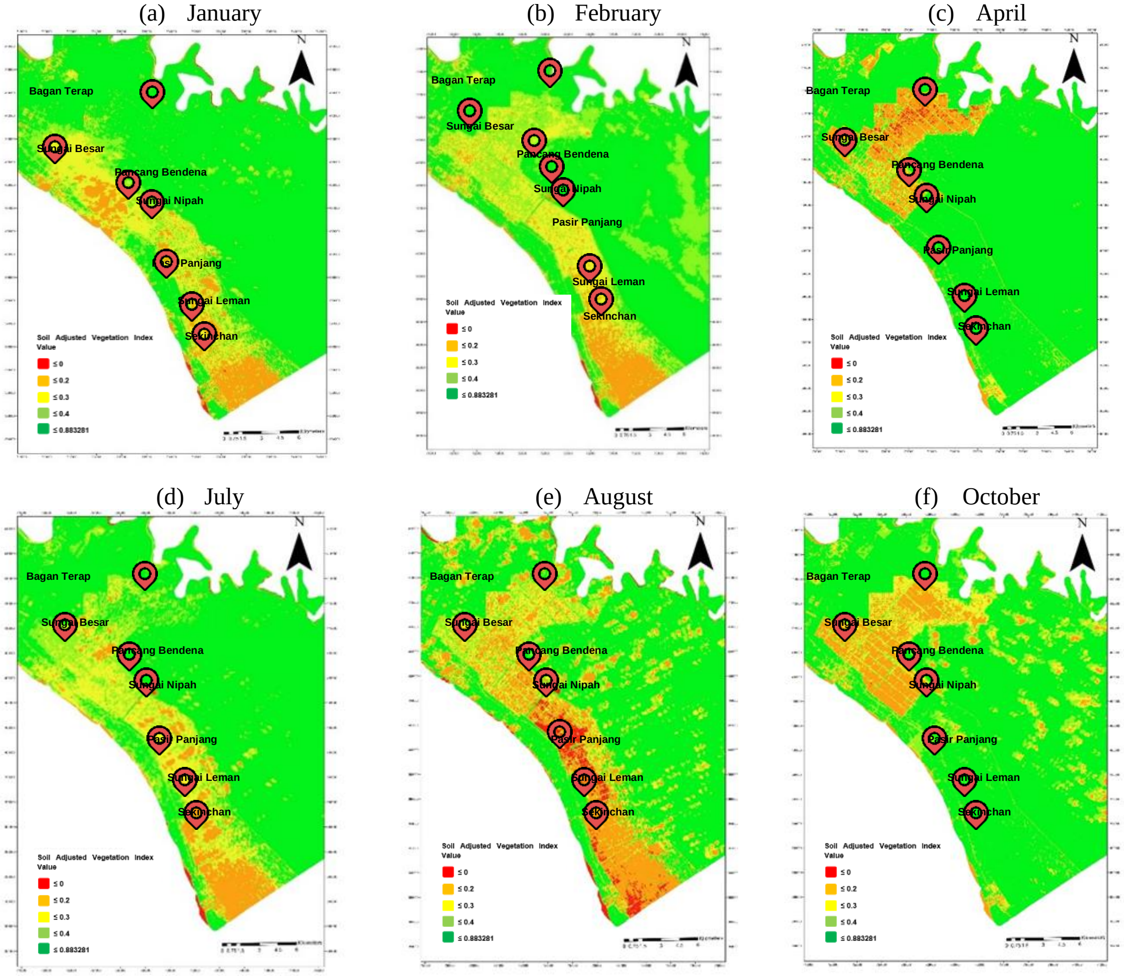

Figure 3: The crop health map of SAVI for each month

The NDVI and SAVI maps in Figures 2(a) and 3(a) indicate that the vegetation in certain regions was greener and denser. The NDVI and SAVI maps, respectively, with values of 0.58 and 0.88, demonstrate that the greater the value of each index, the higher or denser the area covered with vegetation. Since the planting date for each parcel began on 1st March, the land was covered with bare soil and little vegetation in the Sekinchan, Sungai Leman, Pasir Panjang, and Sungai Nipah. Based on Figures 2(b) and 3(b), the NDVI map shows that the vegetation of some areas were less green or less dense than the SAVI map. The values of ≤ 0.51 and ≤0.77 in the NDVI and SAVI maps show the highest values for the vegetation cover. The highest value for each index correlates to the highest vegetation in that area. The values of ≤ 0.20 and ≤ 0.30 indicate that the area was covered with bare soil and less vegetation. This happened because the phase of rice planting did not start yet for the area of Sekinchan, Sungai Leman, Pasir Panjang, Sungai Nipah, Sungai Panjang, Panchang Bendena, and Bagan Terap. The value of ≤ 0 indicates that the area was non-vegetative, water bodies, or urban. Based on Figures 2(c) and 3(c), the NDVI and SAVI maps show that the vegetation of some areas was greener and denser. The value of ≤ 0.58 and ≤0.87 in the NDVI and SAVI maps shows that the higher the value of each index, the higher or denser that area was covered with vegetation. This was due to the areas of the Sekinchan, Sungai Leman, Pasir Panjang, and Sungai Nipah were covered with vegetation since the planting date for each parcel started on 1st March 2020. The value of ≤ 0.20 and ≤ 0.30 indicates that the area was covered with bare soil and less vegetation. This happened because of the phase of rice planting for the Sungai Panjang. Panchang Bendena and Bagan Terap did not happen yet. From the Figure 2(c), some the area shows a yellow coding, ≤0.30 which indicates that area was covered with less vegetation.

However, in Figure 3(c), the same area shows that area was entirely covered with vegetation. Referring to the Figures 2(d) and 3(d), the areas of the Sekinchan, Sungai Leman, Pasir Panjang, and Sungai Nipah which located outside the East area were covered with bare soil and less vegetation since the harvesting date for each parcel started on 1st July 2020. The image for the maps of the NDVI and SAVI was taken on 30^{th} July 2020, thus it has been already 30 days later from the harvest date.

From Figure 2(d), most of the area shows an orange coding, ≤0.20, which indicates that area was partially covered with bare soil. However, in Figure 3(d), the same area shows that area was entirely covered with less vegetation. The difference in colour in both maps for the same place indicates that SAVI has done better than NDVI because of the L soil correction factor applied in SAVI. Based on Figures 2(e) and 3(e), the NDVI and SAVI maps show that the vegetation of some areas was greener and denser. However, the higher values of ≤ 0.62 and ≤0.93 in the NDVI and SAVI maps were in the areas of the outside block paddy. The blok paddy of the Sekinchan, Sungai Leman, Pasir Panjang, Sungai Nipah, Panchang Bendena, and Bagan Terap areas were covered with bare soil and less vegetation since the planting date for each parcel started on 1^{st} September and 1^{st} October 2020. Moreover, the value of ≤ 0 indicates that the area was non-vegetative, water bodies, or urban on some block paddy.

Based on Figures 2(f) and 3(f), the NDVI and SAVI maps show that the vegetation of some areas was greener and denser. The value of ≤ 0.58 and ≤0.87 in the NDVI and SAVI maps shows that the higher the value of each index, the higher or denser that area was covered with vegetation. The reason was because the Sekinchan, Sungai Leman, Pasir Panjang, Sungai Nipah, Panchang Bendena, and Bagan Terap areas were covered with vegetation as the planting date on each block of the parcel started on 1^{st} October 2020.

From the Figure 2(f), some area shows a yellow coding, ≤0.20 in Sungai Nipah which indicates that area was partially covered with bare soil. However, in Figure 3(f), the same area shows that area was entirely covered with vegetation. The difference in colour in both maps for the same place indicates that SAVI has done better than NDVI. This is because SAVI can read the values better than NDVI as NDVI only focus on the vegetation index. Most of crop monitoring studies can confuse between soil or unhealthy vegetation that have similar colour as soil. So by applying the L soil correction in Equation 2, this soil noise can be reduce so that it can show better and clear map presentation.

3.2 Calculation of Total Area (ha) for Planted Area

In Figure 4(a), the area for non-vegetation shows a total of 7570.98 hectares, and the area of vegetation shows a total of 1527.93 hectares. Some places such as Sg. Nipah, Pasir Panjang, Sungai Leman, and Sekinchan were considered non-vegetation because the vegetation was absent according to the image when those places starting the planting season on 1^{st} March 2020. As for the area of Bagan Terap, Panchang Bendena, and Sg. Panjang, it shows that some areas were covered with paddy.

As for Figure 4(b), the vegetation area covering the block paddy was 180.18 hectares only, while a large amount of soil and the non-vegetation regions were shown of 7402.77 and 7593.0 hectares. This happened because the planting activity for all block paddies did not happen yet. From Figure 4(a) and Figure 4(b), it can be observed that there was a drastic decrease in the total area of Bagan Terap, Panchang Bendena, and Sg. Panjang which the changes in total area decrease from 1527.93 hectares to 180.18 hectares. From these changes, it can be said that area has been through the harvesting stages.

In Figure 4(c), some places such as Bagan Terap, Panchang Bendena, and Sg. Panjang show non-vegetation area of 3646.08 hectares because the planting stage on 1^{st} April has taken over. The date of the image shown in Figure 4(c) was taken on 25^{th} April 2020. As for the vegetation area, Sg. Nipah, Pasir Panjang, Sungai Leman and Sekinchan it covered with 7101.9 hectares. This place offers the presence of paddy because the planting in those places started on 1st March 2020. Figure 4(d) shows that most of all block paddy area was covered with paddy. However, due to the presence of cloud, some part of the area was considered having a soil classification. Figure 4(e) and Figure 4(f) show that most of the area consists of only 410.58 and 407.97 hectares of vegetation. During this time, most of the paddy area of the block has been harvested on 1^{st} June and 1^{st} July. Most of the area was covered with non-vegetation and soil with 8305.92 hectares and 6405.57 hectares in July and 5181.30 hectares and 9532.80 hectares in August. From the Figures 4(e) and 4(f) as well, it can be observed that there were no drastic changes that occur in vegetation. The changes that can be seen were only from the decreasing non-vegetation type from 8305.92 hectares to 5181.30 hectares. From these changes, it can be said that most of the area's paddy field was not having through any planting and harvesting seasons.

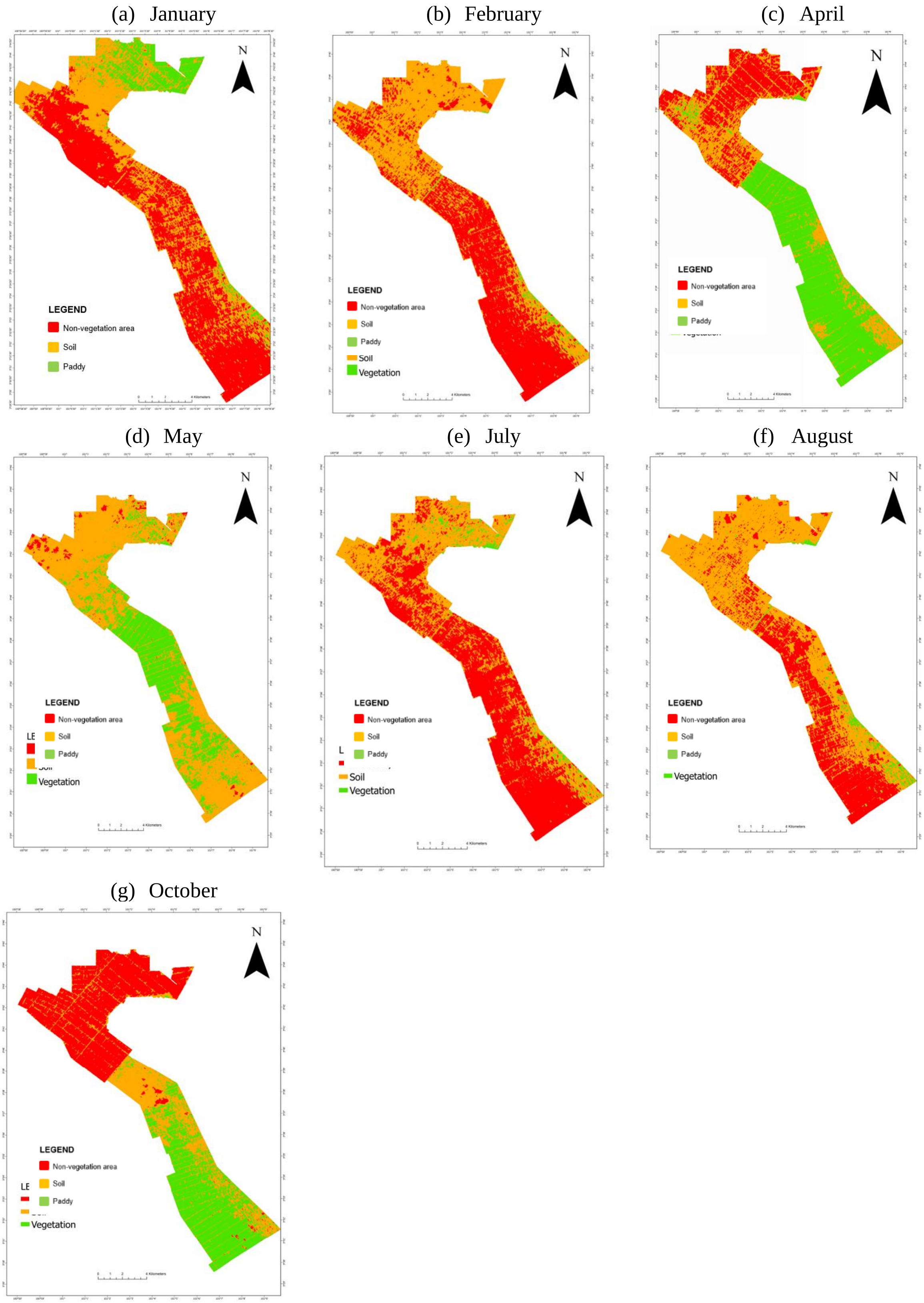

Figure 4: Image classification of block paddy for each month

Table 3: The total area (ha) for each classification for each month

Classification	Area (ha)						
	January	February	April	May	July	August	October
Non-vegetation	7570.98	7593.03	3646.08	359.91	8305.92	5181.30	6222.33
Soil	6023.07	7402.77	4374.09	10270.62	6405.57	9532.8	4141.8
Vegetation	1527.93	180.18	7101.9	4491.45	410.58	407.97	4757.94

Figure 4(g) shows some areas such as Sg. Nipah, Pasir Panjang, Sungai Leman and Sekinchan were covered with vegetation, 4757.94 hectares, and the non-vegetation regions such as Bagan Terap, Panchang Bendena, and Sungai Panjang shows no vegetation, 6222.23 hectares because the planting seasons for this block paddy starts on 1st October. The images of this satellite were taken on 18th October 2020. Due to that, it has been 18 days since the planting date starts for this block paddy area

4. Conclusion

The finding shows that both NDVI and SAVI have different index value. The crop health map shows that SAVI estimate higher vegetation index compared to NDVI. It happened because the L soil correction factor reduces the soil noise and estimates higher SAVI values. This can be seen by the differences in colour for both maps. Moreover, the calculation of area for each classification shows that some changes occurred on the planted area. The area decreases on a particular month due to the harvesting season. It can be conclude that the higher values for NDVI and SAVI, the healthier and denser vegetation appear.

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References

Ahmad, I., Ghafoor, A., Bhatti, M. I., Akhtar, I. U. H. and Ibrahim, M., 2014, Satellite Remote Sensing and GIS-based Crops Forecasting and Estimation System in Pakistan. *Crop Monitoring for Improved Food Security*, 1-16, https://www.fao.org/fileadmin/templates/rap/files/Project/Expert_Meeting__17Feb2014_/P2-2_Satellite_Remote_Sensing_and_GIS_based_Crops_Forecasting___Estimation_System_in_Pakistan.pdf.

Atzberger, C., 2013, Advances in Remote Sensing of Agriculture: Context Description, Existing Operational Monitoring Systems and Major Information Needs. *Remote Sensing*, Vol. 5(2), 949-981.

Dodds, F. and Bartram, J., 2016, The Water, Food, Energy and Climate Nexus: Challenges and an Agenda for Action, Routledge. 1- 292.

Ghosh, P., Mandal, D., Bhattacharya, A., Nanda, M. K. and Bera, S., 2018, Assessing Crop Monitoring Potential of Sentinel-2 in a Spatio-Temporal Scale. *ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science*s, Vol. 425, 227-231.

Hashim, H., Latif, Z. A. and Adnan, N. A., 2019, Land Use Land Cover Analysis with Pixel-Based Classification Approach. *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, Vol. 16(3), 1327-1333.

Kamaruddin, M. A., 2018, *Determination of the Relationship between NDVI and Oil Palm Yield*. Doctoral Dissertation, Universiti Teknologi Mara Perlis. https://ir.uitm.edu.my/id/-eprint/21696.

Mee, C., Siva, K. B. and Ahmad, H. M. H., 2017, Detecting and Monitoring Plant Nutrient Stress Using Remote Sensing Approaches: A Review. *Asian Journal of Plant Sciences*, Vol. 16(1), 1-8.

Mosleh, M. K., Hassan, Q. K. and Chowdhury, E. H., 2015, Application of Remote Sensors in Mapping Rice Area and Forecasting Its Production: A Review. *Sensors*, Vol. 15(1), 769-791.

Nasirzadehdizaji, R., Sanli, F. B. and Çakir, Z., 2019, Application of SENTINEL-1 Multi-Temporal Data for Crop Monitoring and Mapping. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. 42, 803-807.

Ngah, I., 2014, Exploring Rural Transformation in Malaysia: A Case of Rice Cultivation Area in Sabak Bernam. *Proceedings of the Ninth International Malaysia Studies Conference (MSC9)*, Kuala Terengganu, Malaysia.

Omar, S. C., Shaharudin, A. and Tumin, S. A., 2019, The Status of the Paddy and Rice Industry in Malaysia. Khazanah Research Institute, 1-220, http://www.krinstitute.org/assets/content-MS/img/template/editor/20190409_RiceReport_Full%20Report_Final.pdf.

Pavlovic, D., Nikolic, B., Djurovic, S., Waisi, H., Andjelkovic, A. and Marisavljevic, D., 2015, Chlorophyll as a Measure of Plant Health: *Agroecological Aspects*, Vol. 29(1), 21-34, DOI:10.2298/PIF1401021P.

Ramli, M. A., Shariff, A. R. M. and Bejo, S. K., 2014, Spot-5 Multispectral Image for 60-75 Days of Rice Mapping. *IOP Conference Series: Earth and Environmental Science*, Vol. 20(1), DOI:10.1088/1755-1315/20/1/012016.

She, X., Zhang, L., Cen, Y., Wu, T., Huang, C. and Baig, M. H. A., 2015, Comparison of the Continuity of Vegetation Indices Derived from Landsat 8 OLI and Landsat 7 ETM+ Data among Different Vegetation Types. *Remote Sensing*, Vol. 7(10), 13485-13506.

Sykas, D., 2021, SAVI and NDVI Spectral Index Comparison. (n.d.). GIS and Earth Observation University. Retrieved from: https://www.geo.un-iversity/pages/savi-and-ndvi-spectral-index-comparison.

Tang, K. H. D., 2019, Climate Change and Paddy Yield in Malaysia: A Short Communication. *Glob. J. Civil Environ. Eng*., Vol. 1, 14-19.

Whitcraft, A. K., Becker-Reshef, I. and Justice, C. O., 2015, A Framework for Defining Spatially Explicit Earth Observation Requirements for a Global Agricultural Monitoring Initiative (GEOGLAM). *Remote Sensing*, Vol. 7(2), 1461-1481.

Xue, J. and Su, B., 2017, Significant Remote Sensing Vegetation Indices: A Review of Developments and Applications. *Journal of Sensors*, Vol. 1, 1-17, DOI:10.1155/2017-/1353691.