Evaluating Oil Palm Cultivation using Geospatial Approach in Kerdau, Temerloh District

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Abstract. Oil palm is one of the cultivation that synonyms in Malaysia. Malaysia become one of the biggest palm oil producer globally after Indonesia. In order to achieve successful yield per year, oil palm need constant effort and labor to monitor them accordingly. Manual method in monitoring the palm oil consumes large amount of time and energy. Palm oil comes from the fleshy fruit of oil palms. Unrefined palm oil is sometimes referred to as red palm oil because of its reddish-orange color. Remote sensing technique utilizes usage of satellite imageries to analyzes healthiness and canopy features of palm oil plantation. There are several advantage in determining palm oil condition through multispectral and texture analysis in ERDAS Imagine and Envi. Utilizing Landsat-8 imagery, monitoring palm oil cultivation and yield can be effectively implemented in Malaysia. In this study, we will use three vegetation indices which are Normalized Differential Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI), and Ratio Vegetation Index (RVI). This study will demonstrate that selected satellite-derived vegetation indices can be used to estimate oil palm yields with reliable accuracy. In this work, the ability of selected vegetation indices, derived from a single-date archived high resolution satellite imagery, to estimate oil palm yields at the management block scale was demonstrated. This technique applied to determine the condition of the palm oil tree. Using remote sensing technique, the value of the vegetation indices will be determined and analyzed. Result from this process, palm oil condition can be evaluated. This study provides an important benchmark for applying remote sensing technology in the management of plantation-scale oil palm. Oil palm yield estimation based on empirical models, as described in this work, can be computerized using a simple spreadsheet interface so as to facilitate optimal agronomic intervention, particularly with regard to crop harvesting, crop stress alleviation and input application. However, it’s important to note that palm oil should not be confused with palm kernel oil. While both originate from the same plant, palm kernel oil is extracted from the seed of the fruit. It provides different health benefits.

1. Introduction

1.1. Background

The palm oil is one of tropical plant species. Palm oil thrives on high rainfall, adequate sunlight and humid conditions. It can be stated that the best growing areas are along with a narrow band around the equator. This oil palm has grown in many countries such as Africa, South America, and even Southeast Asia but nowadays it was dominated this two country which is Malaysia and Indonesia as
well. Basically, this oil palm cultivation is not well known before it becomes a trademark in yield production where it is just an ornamented plant at first. Either way, this oil palm tree is getting popular due this crude oil palm and many uses can be obtained from this plant alone. Where, this Oil palm (Elaeis guineensis) is become the most productive vegetable oil crops in the world [1].

The demand for palm keep increasing rapidly over the last decades in Malaysia. The global demand for this oil has grown exponentially during the last 50 years [2]. Malaysia has suitable climate and it encourages oil palm cultivation and yield. Situated in the center of Equator Belt, which provides most sun in a day and regular rainfall make yield can be produce twice a year. Oil palm is currently the biggest source of vegetable oil that have high yield and long productivity with a lifespan up to 25 years per tree. This continuous expansion makes 1.5 million hectares were planted in 1985. By 2007, the expansion gets about 4.3 million hectares in Malaysia which records about 250% from original colony. In this study vegetation indices are used to determine healthiness through NDVI, SAVI and RVI algorithm. In order to make the sustainability of oil palm, management started to require the use of remote sensing to monitoring (UNEP 2011).

2. Data and Research

2.1. Infected oil palm tree

Proper management such as early detection of infestation is important in oil palm cultivation, so that success in detection of infection at an early stage is the key to control G. boninense [5]. Usually there are three important physical characteristics for detection and health classification such as crown size, crown color, and crown density. These characteristics can indicate the age of the oil palm, lack of nutrients, and the presence of an epidemic disease called Ganoderma. This infection process of Ganoderma boninense switches from a biotrophic to necrotrophic phase. Infection also caused serious decreased in oil palm yield. This makes high loses in yield and reduction for quality of oil palm.

2.1.1. Relationship between temperature/rainfall/fertilizer and climate in oil palm. Oil palm is one of the tropical plants that grows in moist areas and thrives in areas with temperatures ranging from 22 degrees Celsius to 24 degrees (minimum) and 20 to 33 degrees (maximum), however if an increase in temperature by 2°C above optimum makes the loss of yield around 30% and if decrease in rainfall by 10% [7]. Apart from that, there are strong relationship between oil palm yield and climate. Extreme climate change situation will get worse for oil palm cultivation globally as the ground didn’t have enough nutrient to support the growth for the plant. Severe drought and extreme monsoon alters soil factors which could lead to restricted root growth causing nutrient stress to occur [13]. A good organic fertilizer is needed such as potassium that can secures yield and quality. High potassium content in soil can promote fruits growth and strong root support for the palm oil.

2.1.2. The Oil palm requirement for cultivation. Oil palm is one of the famous tropical plants. It grows and thrives in areas with temperatures ranging from 22°C to 30°C. Oil palm or Elaeis guineensis jacq is one of the most widely produced and consumed commodities around the world. Oil palm is also the most profitable oil crops commodities because it’s gives highest ratio of production per hectare [4]. In addition, oil palm needs sunlight within 5 to 6 hours and requires 80% humidity for optimal growth. In addition, the annual rainfall must be at least 2500 to 4000mm or 150 to 155 mm monthly. The oil palm usually need The ratio of fertilizer is 3N: 0.4P: 1.7K [8]. Generally, the nutrient that mainly needed for the oil palm is (P) phosphorus, (N) nitrogen and (K) potassium, where all this nutrient for oil palm growth [11]. Moreover, oil palm will be better if grown in undulating and moist areas as well as having soil drainage rich in organic matter, for the selection of soil for oil palm cultivation, it is better to avoid soils that have a very salty and alkaline soil content as well as in waterlogged areas.

2.1.3 Sentinel-2. The images of the satellite can be chosen in data set of the USGS platform depend on our study requirement. In this study the satellite imagery that will used is Sentinel-2 images (Table 1). Multispectral imagery can be used for estimating production of oil palm fruit in a plantation. One of
the multispectral imagery that capable for production estimation is Sentinel 2. Sentinel 2 is a free imagery that have great 10 m medium spatial resolution bands, which are red, green, blue, and near-infrared. These bands can be used to generate several generic vegetation index such as Ratio Vegetation Index (RVI) and normalized difference vegetation index (NDVI) also non-generic vegetation index such as modified soil adjusted vegetation index (MSAVI) and atmospherically resistant vegetation index (ARVI). Sentinel-2 with its Multi-Spectral instrument has shown its effectiveness in several studies on different subjects such as vegetation studies. [11]

2.2. Oil palm healthiness determinations

There are several indices of vegetation that used in determination of healthiness of the oil palm that used with using ERDAS and ArcGIS software, with combined multispectral bands with composite indices, such as the vegetation indices NDVI, and SAVI. There are a lot of vegetation indices that can be used such as Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI) [15]. The value of this indices will determine the condition of the oil palm tree such as the health and the severity or infected oil palm based from the value of it.

2.2.1. Normalized Difference Vegetation Index (NDVI). The NDVI algorithm used for leaf area (LAI), biomass, percentage vegetation covers and absorbed photosynthetic active radiation and leaf rust disease [12]. The Vegetation Normalization Difference Index (NDVI) is a simple graphical symbol that can be used to evaluate remote sensing measurements, mostly from spatial platforms, determining whether the monitored object contains living vegetative cover as well as forest. NDVI measures vegetation by testing the difference between near infrared light (which is highly reflective of plants) and red light NDVI tries to measure vegetation (which plants absorb). NDVI value usually between -1 and +1. However, for each land cover area, there was no clear distinction. NDVI is a systematic way of measuring healthy fields. It has healthier vegetation when you have strong NDVI values and less or no vegetation if you have low NDVI.

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

2.2.2. Soil Adjusted Vegetation Index (SAVI). This index also one of the method in healthiness determination. This vegetation indices can be carried out using the model maker in ERDAS software. The function of this SAVI is have similarity with NDVI but the different is just the formula but still used the same band. SAVI 1.5(NIR-R)/(NIR + R + 0.5) [17].

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SAVI = \frac{\text{Near Infrared Band} - \text{Red Band}}{\text{Near Infrared Band} - \text{Red Band} + L(1 + L)} \quad (\text{Eq.2})
\]

The L is a canopy background of the adjustment factor. An L value of 0.5 in reflectance space was found to minimize soil brightness variations and eliminate the need for additional calibration for different soils. The transformation was found to nearly eliminate soil-induced variations in vegetation indices.

2.2.3. Ratio Vegetation Index (RVI). Simplest ratio-based index is called the Simple Ratio (SR) or Ratio Vegetation Index (RVI). It ranges value are from 0.0 to more than 30.0 where the healthy vegetation usually has value of 2.0 to 8.0. RVI is the combination of near infrared divided by red band which highlight high for vegetation (plant) and low for soil (ice and water). It indicates amount of vegetation that exist in oil palm plantation and can reduce the effects of atmosphere and topography. In addition, this RVI indices also can be used for disease detection (Ganoderma Boneninse).
2.2.4. Radiometric Correction. Radiometric correction is performed to calibrate the pixel values and correct for errors in the values. It is preferred because no in situ atmospheric data at the time of satellite overpasses are required (Yang & Lo, 2000), where this process improves the generalise ability and accuracy of remotely sensed data. Apart from the radiometric correction is method of correction that applies one image as a reference and adjusts the radiometric properties of subject images to match the reference [16].

3. Methodology

3.1. Study Area

Temerloh is a town in Central Pahang, Malaysia. Located about 130 kilometres from Kuala Lumpur along the Kuantan-Kuala Lumpur trunk road, Temerloh is the second largest town in Pahang after Kuantan. It is situated at the junction of the Pahang River and the Semantan River. The district consists of two areas, the 1,442-square-kilometre (557 sq mi) Municipal Council Area (35.92%) and the 808-square-kilometre (312 sq mi) outer Municipal Council Area (64.08%). The study area of this research is the oil palm cultivation that located at Kerdau, Temerloh District in Pahang. This study area about 401.68 hectares with 8586.43 parameter in zone of 48N. In this study the selected area of interest is in mukim of Kerdau, Temerloh. Study area is in rectangle shaped color being highlighted with the red colour.

![Figure 1 Study area in Mukim Kerdau, Temerloh](image)

3.2. Data Acquisition

Data collection was conducted in this study is from secondary data which is from satellite imagery of Sentinel-2 from USGS platform where there are 12 bands and only 3 bands used as this study is for vegetation purpose which is band 8, band 4 and band 3. The data will be collected from open sources: map data. Open Street Map, Landsat8 and Google Earth Pro were used to create the maps. There are

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RVI = \frac{\text{Red}}{\text{Near Infrared}} \quad \text{(Eq. 3)}
\]
roads, hospitals, fire stations, and police stations on this data map. The data that will be collected is mentioned below.

**Table 1 Data acquisition that collected**

| No. | Raw Data   | Year | Department/Agency     |
|-----|------------|------|-----------------------|
| 1.  | Base-Map   | 2021 | ArcGIS Desktop        |
| 2.  | Sentinel-2 | 2021 | USGS (open source)    |

3.3. **Data Processing**

Data processing is where the data that collected before will be processed in order to produce final output of the study where in this study the satellite imagery of sentinel-2 from USGS then processed with ERDAS. The methods of network analysis will be used in this process.

3.3.1. **Staking of satellite image.** The staking image that carried out is to enhance the visualization of the vegetation where this study will stake the satellite image of band 8, band 4 and band 3, which this combination of band is to show the vegetation clearer which can be seen in red colour and this combination usually performed in vegetation purpose.

3.3.2. **Subset and clip.** Subset and clip is the process where the whole coverage of the Sentinel-2 image that captured will be clipped and subset into small area depend on the area of study of the research. Simply it is the process to pin point and focusing the image on the selected study area. This process can be conducted whether using ArcGIS or ERDAS imagine but in this study the process on subset and clipping carried out in ERDAS software.

3.3.3. **Method used in oil palm healthiness determination.** The method used in this study in order to determine the healthiness of the oil palm tree is using the vegetation indices which is the vegetation indices(VI) will be conducted using the model maker in ERDAS Imagine. In this model maker, the first stages are input the raster data and then second stage is the functional model. In this stage it is need to input the formula of calculation of the input raster image in the first stage. While the third stage is part of the input raster and it calculation will be stored. The fourth stage is the part of the functional modal will analyze the memories or the stored data and the final is on output. In the final process of the model maker is just have to decide where will the output will be saved. The whole process for the NDVI, SAVI and RVI of indices model is same ways but haveto be careful on the part of the functional model part. It is because if the formula that input is wrong than the final result will be affected.

3.3.4. **NDVI, SAVI and RVI process using model maker.** In NDVI process of model maker, the input raster will be NIR and RED where it is band 8 and band 4. While the formula that will be used in the stage of the functional model is NIR-RED/NIR+RED and than the third stage is the phase where the calculation will be stored which called as memory. After that in the fourth phase is where the memory will be analyzed and calculated and produce the final result of the model maker in the final stages. While in SAVI it remains the same process as the NDVI however it is different in the part of functional because the SAVI formula of calculation is not the same as NDVI. It is same as the RVI vegetation indices, where the functional part also different due the different formula.

3.4 **ArcGIS interpretation and implementation**

In this part, the result of the vegetation indices from model maker in ERDAS will be opened in the ArcGIS software to classes it using the symbology option than change the colour differently based on each of the value of vegetation indices. In this study the classes selected is 5 class. After completing the
classing, it and change the colour as the colour vegetation indices from ERDAS is black and grey only. In ArcGIS also will be used to do the mapping of the final output of the study which is the NDVI, SAVI and RVI.

4. Result and Analysis
In this part, after all the processing of the data was completed then the final output will be carried out and will be analyzed. In this study the final output is the map of NDVI, SAVI and RVI. However, in this part also will be included the result of the supervised classification and the accuracy assessment report.

4.1. Supervised classification and accuracy assessment result
The supervised classification was carried out for this study which is classified the features in in the study area with 7 classes of feature which is classified as barren soil, oil palm, new oil palm, sparse vegetation, water bodies, build up area and the last one is forest.

4.2. The Map of Vegetation indices

![Figure 2 NDVI in Kerdau plot](image)

As this study objective is to produce the map of the vegetation indices so that the map below is the map output of this research. From this map, the study area is located at Kerdau, Temerloh in the highlighted in the red colour which is on the mini map on the second box of the right side of the main map. From
this map also can be determined that the NDVI was classed into 5 classes which is class 1 is represented by the red colour with the value of 0.2 until 0.5. while the second class is represented with the orange colour with the value is 0.5 to 0.6, while the third is in yellow colour box which is the value of it is from 0.6 to 0.7 and the fourth is with the light green boxes with value of NDVI is about 0.7 to 0.75. Lastly, the fifth class is represented with the green colour where the value of it is from 0.75 until 0.8.

4.2.1. The analysis of the NDVI. Based on Table 2, Class1 is represented with the value about 0.2 until 0.5. which means that in this range there is oil palm that might be infected with diseases and it is also as unhealthy oil palm. However, when the value is nearest to the 0.5 means that the oil palm in this coverage area value it is the healthy oil palm condition. It is because the value above 0.45 is categorized as a healthy vegetation so that the value from 0.45 until 0.8 is represent the oil palm which is in healthy condition. From the figure of 4.10 also can be stated that from the end of the range in class1 until class5 which has the value 0.8 as the highest value means in this coverage area of this value 0.5 until 0.8 is determined as a good condition of the oil palm tree. While in the first classes in the range value 0.2 until 0.39 is the unhealthy oil palm tree. Which means that in the coverage of the area between this ranges shows that the unhealthy condition of oil palm tree due the infestation such as BSR.

It because the percentage of the reflected NIR of the vegetation is low while the visible red is higher means that the tree is unhealthy due to some disease and infestation on the tree that makes the reflected of NIR is low. An infested tree makes the leaf of the tree that have function on reflecting the near infrared become not function and reflect low values. However, through the value of NDVI which is from the class2 until class5 shows that have a healthy oil palm tree because a healthy and high dense of vegetation will reflecting higher near infrared light (NIR) than unhealthy oil palm tree. It also because a healthy leaf of the oil palm tree will reflect high value of NIR and absorb most of the visible red compared to unhealthy and sparse vegetation as well.

Simply, closer the NDVI value to +1 the healthier the vegetation while in vice versa the closer the value of NDVI to 0 means that there is unhealthy, infested, having disease and also in this area having the sparse vegetation. From the result of the NDVI value and if refer to the map of NDVI in figure 4.7, it is clearly can be determined that the map of NDVI is almost fully green and just little of the area is red-coloured which means that the area of it so healthy oil palm tree. So that it can be concluded that the condition of the oil palm tree in selected area of study at Kerdau Temerloh mostly covered with bright green-colour which is in range value 0.5 to 0.7 is dominating which is around 78 percent means a healthy oil palm.

Table 2 The classes and value of NDVI

| CLASSES | VALUE       |
|---------|-------------|
| Class1  | 0.2131 - 0.5442 |
| Class2  | 0.5442 - 0.6389 |
| Class3  | 0.6389 - 0.7075 |
| Class4  | 0.7075 - 0.7548 |
| Class5  | 0.7548 - 0.8163 |
4.3 SAVI map
From the Figure 4.8 the map of SAVI, the study area was located in Kerdau, Temerloh which is the highlighted with red colour below the map of SAVI. In this map there is logo of UITM on the top box of right side of the map, mini map of Temerloh District, study area and legend. From this map there is 5 classes that represented the value of the SAVI. Whereas the red box colour as the class1 with the value of 0.3 to 0.8, while second class is represented by the orange colour with the value from 0.8 to 0.9, next is the class4 with the SAVI value is about 1.0 to 1.1 and followed with the last box which is class5 with value of it from 1.1 until 1.2.

4.3.1 The analysis of SAVI. For the SAVI it is same as the other vegetation indices of NDVI and RVI which is to determine whether the selected area of oil palm is in what condition. So that with the value from the processing phase the result of it will be determined the condition of the oil palm tree on the selected area of this study. The value of SAVI values which is categories and classed into 5 classes. For the class1 which is in red colour basically indicates the sparse vegetation, unhealthy vegetation also infested. However, the value in class1 is reaching to the value of 0.8. This means that not all in the range value of class1 is unhealthy and infected tree. It is because for SAVI value it is almost same as NDVI where the value around 4.5 and above that nearest to +1 is healthy vegetation. So that only the 0.3 that represent the oil palm that infested and unhealthy oil palm.
Because of the lowest value of the SAVI is 0.3 which can be seen only in the first class and the rest class is above 0.5 means that the area of oil palm of the selected study area is very healthy and containing high dense of vegetation. The classes from 2 until 5 shows that value of SAVI is very high which nearest to the +1. It is because of the reflection of the greenest of the leaf that reflecting NIR efficiently.

Meanwhile in vice versa of the lowest SAVI values is because of the ability of the vegetation that cannot reflect the NIR efficiently. Referring to the map of SAVI in figure 4.8, can be stated that most of the area of SAVI map in Kerdau Temerloh was dominated with green colour were almost 90 percent of green colour. This means that the area that covered with the green colour with value is a healthy oil palm tree. From this SAVI value also can be conclude that the respond of the oil palm tree with high dense vegetation values is good oil palm tree. As stated for indices value for vegetation the closer the value to +1 the healthier and good the vegetation.

| Table 3 The classes and value of SAVI |
|-------------------------------------|
| **CLASSES** | **VALUE** |
| Class1 | 0.3976 - 0.8417 |
| Class2 | 0.8417 - 0.9747 |
| Class3 | 0.9747 - 1.0719 |
| Class4 | 1.0719 - 1.1368 |
| Class5 | 1.1368 - 1.2243 |

4.4. RVI map

In this map of RVI. It also classed into 5 classes, same as previous map of NDVI and SAVI this RVI also classed with each of the classes represented with different colour and each of the class have their own value range. For the first class it is represented with the red colour box also while the second and third is orange and yellow colour box. In the class4 and class5 is with light green and dark green. The lowest value of the RVI is 1.5 while the highest value is 9.8. the middle value of it is on the third class with value of 5. For the last box in the legend is the legend that representing the study area in Kerdau, Temerloh.

4.4.1. The analysis of RVI. RVI is the indices that sensitive specifically for vegetation. NDVI and RVI are well-known indices and are the most commonly used ratio-based vegetation indices (Gilabert et al. 2002; Jackson and Huete 1991). From this study, RVI showed better correlation with yield than NDVI. Such a finding is in agreement with Aparicio et al. (2002) and Serrano et al. (2000). Both studies concluded that RVI is a better indicator than the traditional NDVI in estimating physiological response in wheat. The capability of RVI in extraction of vegetation information of young oil palm was demonstrated by Salleh (1993). Meanwhile, the higher the value of the RVI the higher the dense vegetation or the more the vegetation healthier was detected. Based on the result of this study there is still five classes where the lowest value of the result is in class1 which is with 1.5 RVI value while the highest value of the RVI is 9.8 which is represented with the green colour. Murthy et al. (1994) found that vegetation indices computed from satellite imagery taken at panicle initiation and heading stages of rice showed a high correlation with yield.

Simply in RVI the leaves will absorb relatively more red than infrared light. According to the spectral characteristics of vegetation, bushy plants have low reflectance on the red band and have shown a high correlation with LAI, Leaf Dry Biomass Matter (LDBM), and chlorophyll content of leaves. The lower the value of RVI means that there is sparse vegetation and can be infected oil palm and unhealthy oil palm. If referring the map of RVI in figure 4.9 also shows that their big coverage of greenest colour
which it is representing the high value of vegetation. However, the red colour seems clear due the RVI indices also sensitive with the soil. So that if some area has unhealthy vegetation it will be lowest value and will be in range of the red colour because the RVI cannot detect the vegetation dense on it. From map and the classes of RVI it can be concluded that the area of the the selected area which is at Kerdau, Temerloh District almost 90% oil palm tree is have a good healthiness. In addition, the relationship of oil palm canopy area and the age of oil palm stands using WorldView-2 in Africa has demonstrated a good relationship (R2 =0.88) for stands less than 13 years of age but no relationship was observed for older stands (Chemura, 2012).

Figure 4 RVI in Kerdau plot

5. Conclusion
The remote sensing application are capable in monitoring productivity and yield production for palm oil. Based on this research the value from vegetation indices shows that the selected area of study in Kerdau, Temerloh has high productive yield. The oil palm trees in the study are has shown a good NDVI values ranging from 0.656 to 0.722. This allows us to interpret that the covered vegetation is healthy and can help us to predict that it is productive palm. It is important to know the NDVI of the oil palm stand to enable the plantation manager to gauge the level of effectiveness in the management of the palms. It is recommended to allow the NDVI analysis on wider age stand intervals. RVI indices produce greater value due the high sensitivity in dense vegetation. In addition, the RVI values that resulted from this research shows there is almost zero percentage of tree infection and unhealthy growth in palm oil. So that it can be concluded that the study area that conducted in Kerdau, Temerloh still maintain its productive level. It is crucial in monitoring palm oil cultivation in order to maximise yield production in future. Hence, evaluating palm oil using GIS are far superior due to cost saving technique and covers
large area for plantation. Recommendation for the future research, it is better if the image data has a very high resolution such as airborne Lidar or UAV. It is because the higher the resolution the more accurate the result that will be produced.

References
[1] Li L, Dong J, Tenku S N, & Xiao X 2015. Mapping oil palm plantations in cameroon using PALSAR 50-m orthorectified mosaic images. Remote Sensing, 7(2), 1206–1224.
[2] Srestasathiern P, & Rakwatin P. 2014. Oil palm tree detection with high resolution multi-spectral satellite imagery. Remote Sensing, 6(10), 9749–9774.
[3] Kushairi A, Ong-Abdullah M, Nambiappan B, Hishamuddin E, Bidin, M. N. I. Z, Ghazali R, Subramaniam V, Sundram S, & Parveez G. K. A. 2019. Oil palm economic performance in Malaysia and r&d progress in 2018. Journal of Oil Palm Research, 31(2), 165–194
[4] Unep. 2011. Oil palm plantations: threats and opportunities for tropical ecosystems. UNEP GlobalEnvironmental Alert Service (GEAS), (DECEMBER), 1–8.
[5] Hushiarian R, Yusof N. A., & Dutse S W. 2013. Detection and control of Ganoderma boninense: Strategies and perspectives. SpringerPlus, 2(1), 1–12.
[6] Koo V C, Chan Y K, Gobi V, Chua M Y, Lim C H, Lim C S, Sew B C. 2012. A new unmanned aerial vehicle synthetic aperture radar for environmental monitoring. Progress in Electromagnetics Research, 122(November 2011), 245–268.
[7] Paterson R R M, Kumar L, Taylor S, & Lima N. 2015. Future climate effects on suitability for growth of oil palms in Malaysia and Indonesia. Nature Publishing Group, 1–11.
[8] Broschat T K, Sandrock D R, Elliott M L, & Gilman E F. 2008. Effects of fertilizer type on quality and nutrient content of established landscape plants in Florida. HortTechnology, 18(2), 278–285.
[9] Turner W, Rondinini C, Pettorelli N, Mora B, Leidner A K, Szanto Z, Woodcock C. 2015. Free and open-access satellite data are key to biodiversity conservation. Biological Conservation, 182, 173–176.
[10] Frampton W J, Dash J, Watmough G, & Milton E J. 2013. ISPRS Journal of Photogrammetry and Remote Sensing Evaluating the capabilities of Sentinel-2 for quantitative estimation of biophysical variables in vegetation. ISPRS Journal of Photogrammetry and Remote Sensing, 82, 83–92.
[11] Ashourloo D, Mobasher M R, & Huete A. 2014. Developing two spectral disease indices for detection of wheat leaf rust (Puccinia triticina). Remote Sensing, 6(6), 4723–4740.
[12] Volenc J n d. Impact of climate change on crop nutrient and water use efficiencies.
[13] Liaghat S, & Balasundram S K. 2010. A review: The role of remote sensing in precision agriculture. American Journal of Agricultural and Biological Science, 5(1), 50–55.
[14] Marzukhi F, Elahami A L, & Bohari S N. 2016. Detecting nutrients deficiencies of oil palm trees using remotely sensed data. IOP Conference Series: Earth and Environmental Science, 37(1).
[15] Hall F G. 1991. Radiometric Rectification : Toward a Common Radiometric Response Among Multidate , Multisensor Images. 27, 11–27.
[16] ZarcoTejada P J, Ustin S L, & Whiting M L. 2005. Temporal and spatial relationships between within-field yield variability in cotton and high-spatial hyperspectral remote sensing imagery.
[17] Azahar T M, Boursier P, & Idris A S. 2008. Spatial Analysis of Basal Stem Rot disease using Geographical Information System. GIS Development, May 2014, 7