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Evaluation of Pre-Replanting Oil Palm Plant Health using the NDVI Index from Landsat 8 Satellite Imagery

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ABSTRACT

NDVI analysis was calculated based on the ratio of the reflection of red and near infrared waves. Aims of this study is to determine the density condition and health level of oil palm plants that have entered the age of replanting using the NDVI index from Landsat 8 satellite imagery and evaluate the plant health level based on the NDVI index compared with the LSU data. The research was conducted at Afdeling 1 Rantau Baru Plantation, PT. Pusaka Megah Bumi Nusantara, which is a plantation with old oil palm plant that have entered a period of replanting (22-29 years). The NDVI analysis results show the NDVI value is 0.034 -0.469. Object identification shows that non-vegetation objects have an NDVI index value of 0.034-0.245 and vegetation objects have a value of 0.273-0.454. The result of the NDVI index shows the density of oil palm plants are categorized in the high category (dense). These results are appropriate with the actual condition of oil palm plantations which have an average density of 118 trees/hectare. The average NDVI value for vegetation objects is 0.423, that indicates the plants are in fairly healthy condition. The level of plant health as the result of the NDVI analysis was in appropriate with the LSU data which showed that the content of macro and micro nutrients in the leaves was quite high. Therefore, NDVI analysis can be an alternative to evaluate the condition of oil palm plantations efficiently.

1. INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is a plantation crop that has an important economic role in Southeast Asia, including Indonesia (Malinee *et al*., 2021). Fairhurst & Griffiths (2014) explained that the process of cultivating oil palm plants applies best management practices ranging from land preparation, nursery, cultivation process, to harvesting process. Monitoring and evaluation of plant health conditions is carried out to maintain plant productivity until the plant enters a period of rejuvenation or replanting (Yusuf *et al.*, 2015; Corley & Tinker, 2016).

1.1. Oil Palm Rejuvenation

Oil palm rejuvenation is carried out on oil palm plantations that are more than 25 years old, the number of plants is less than 80 trees/per hectare, and productivity is less than 13 tons on plants more than 25 years old (Pahan, 2015; Yusuf *et al.*, 2015). Oil palm production will decline after entering old age, therefore it needs to be rejuvenated or replanted (Fairhurst & Griffiths, 2014). In some cases, oil palm replanting is postponed due to the production of oil palm fresh fruit bunches produced was still high and in other cases rejuvenation was carried out before the plant was 25 years old due to low plant density due to many dead plants (Sutarta *et al.*, 2012; Yusuf *et al.*, 2015).

Before entering the rejuvenation period, it is important to evaluate the condition of the plant and the productivity of the oil palm produced. It is important to evaluate the condition of oil palm plantations when they enter the rejuvenation period to determine the health condition of oil palm plants in the block to prepare the right land management process at the time of rejuvenation in accordance with plant conditions (Yusuf *et al.*, 2015).

Old oil palm plants are susceptible to basal stem rot disease caused by infected of *Ganoderma* sp. (Azahar *et al*., 2011; Corley & Tinker, 2016). This fungal attack is a deadly disease that can reduce the number of oil palm plant populations (Santoso *et al.*, 2011). Basal stem rot disease is a soil-borne disease, so oil palm plantations that are attacked by this disease require rejuvenation techniques to prevent the source of the fungal inoculum from spreading to other plants in the next planting period (Shafri & Anuar, 2009; Shafri *et al*., 2009; Fairhurst & Griffiths, 2014).

1.2. Landsat 8 Satellite Image

Utilization of a geographic information system (GIS) is one way to quickly evaluate and monitor the condition of plantations and the health of oil palm plants (Ansar *et al.*, 2020). Utilization of Landsat-8 satellite imagery which is a form of remote sensing is the right choice to evaluate the condition of oil palm plantations with large area (Kaban & Darmawan, 2020). This is because the image has a medium resolution (30 meters for visible light waves, NIR, SWIR) which is good enough for monitoring landscape scales such as oil palm plantations. In addition, Landsat-8 imagery also has a relatively short temporal resolution of 16 days. Thus, the use of Landsat-8 satellite imagery is good for monitoring the condition of oil palm plantations both spatially and temporally (Lillesand *et al*., 2015; U.S. Departement of the Inferior, 2017a).

Landsat-8 satellite imagery is a multispectral satellite image that is able to capture the reflection of visible light waves and near infrared waves. The specifications of the reflected waves recorded by the Landsat-8 satellite image are shown in Table 1. This capability allows us to analyze the plant health based on the vegetation index. Vegetation index can also be used to distinguish between vegetation and non-vegetation objects and the level of plant density (Amliana *et al*., 2016).

1.3. NDVI Index

According to Vadivelu *et al*. (2014), the Normalized Difference Vegetation Index (NDVI) is an index that describes the greenness of a plant. The NDVI index is calculated mathematically by taking into account the ratio of reflected red and near infrared waves. Lillesand *et al*. (2015) explained that healthy plants provide low reflectance values in red waves and high reflectance values in near infrared waves. The NDVI vegetation index has the lowest value of –1 and the maximum value of +1. NDVI values close to +1 are detected as healthy vegetation while those far from +1 are detected as

unhealthy vegetation, and values close to –1 are detected as non-vegetation (U.S. Departement of the Inferior, 2017b).

Table 1. Wavelength and spatial resolution sensor of Landsat-8 satellite

Band	Wavelength (mm)	Resolution (m)
Band 1 – Coastal aerosol	0,43 – 0,45	30
Band 2 – Blue	0,45 – 0,51	30
Band 3 – Green	0,53 – 0,59	30
Band 4 – Red	0,64 – 0,67	30
Band 5 – Near Infrared (NIR)	0,85 – 0,88	30
Band 6 – SWIR 1	1,57 – 1,65	30
Band 7 – SWIR 2	2,11 – 2,29	30
Band 8 – Panchromatic	0,50 – 0,68	15
Band 9 – Cirrus	1,36 – 1,38	30
Band 10 – Thermal Infrared (TIRS) 1	10,60 – 11,19	100
Band 11 – Thermal Infrared (TIRS) 2	11,50 – 12,51	100

Source : U.S. Departement of the Inferior (2017a)

Leaf sampling unit (LSU) is a technique to determine the level of plant health in oil palm plantations (Goh & Hardter, 2003; Fairhurst & Griffiths, 2014). In LSU analysis, leaf samples from sample trees will be taken to then be analyzed for macronutrient and micronutrient content in the leaves. The results of the LSU analysis are an indicator of the level of plant health, besides that the LSU results are also used as a reference for fertilization recommendations (Pahan, 2015; Corley & Tinker, 2016). To validate the accuracy of the classification of plant health levels based on the NDVI index, it can be done by comparing the results of the existing LSU.

Based on the description above, this study aims to determine the density condition and health level of oil palm plants that have entered the age of rejuvenation using the NDVI index from Landsat-8 satellite imagery, and evaluate the health level of plants based on the NDVI index compared with the results of LSU oil palm plantations.

2. MATERIALS AND METHODS

The research was conducted by analyzing the NDVI index from Landsat-8 satellite imagery at Afdeling 1 oil palm plantation of PT. Pusaka Megah Bumi Nusantara, Riau in June 2021 – January 2022. Oil palm plants planted in Afdeling 1 are plants with the first planting period and are plants with an old age and have entered a period of rejuvenation (aged 22-29 years).

2.1. Materials

The data needed to carry out this research are given in Table 2.

Table 2. Type and source of data required for this research

No.	Data	Source
1.	The Landsat-8 satellite imagery recorded on October 27, 2020	Website USGS : https:// earthexplorer.usgs.gov/
2.	Oil palm plantation map of Afdeling 1	PT. Pusaka Megah Bumi Nusantara
3.	LSU oil palm data in Afdeling 1	PT. Pusaka Megah Bumi Nusantara
4.	Oil palm yield data of Afdeling 1	PT. Pusaka Megah Bumi Nusantara

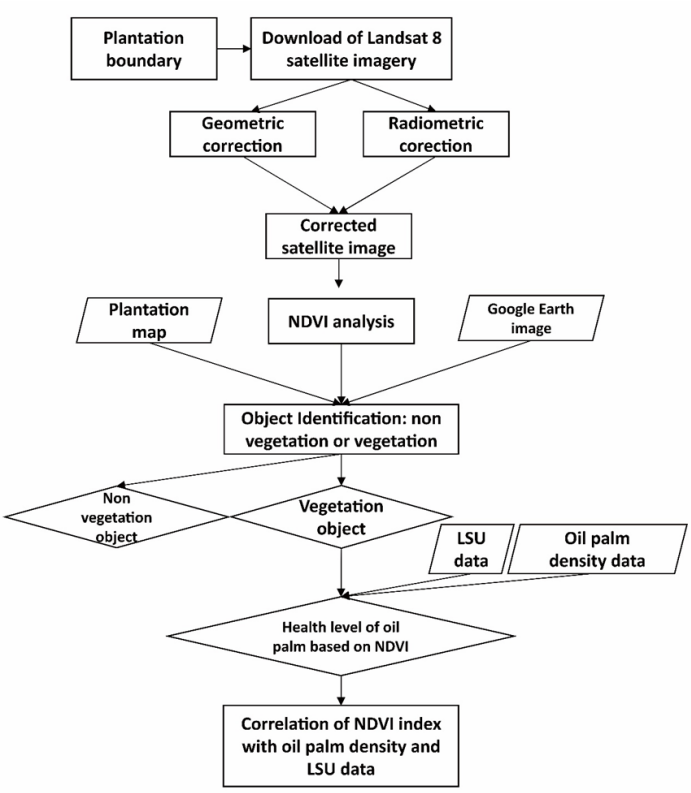


Figure 1. Flowchart of experiment

2.2. Method

The research flowchart looks like Figure 1. The research was performed in several steps as detailed in the following.

1. Downloading Landsat-8 Satellite Imagery. The Landsat-8 satellite image recorded on October, 27 2020 covering the research area was downloaded via the USGS website at https://eartheexplorer.usgs.gov/ (open source).
2. Calculating the NDVI index. The NDVI index is calculated using the Raster Calculator tool in ArcGIS 10.3 software. The NDVI formula used is as follows (Lillesand *et al*., 2015):

$$NDVI = \frac{(NIR-R)}{(NIR+R)} \quad (1)$$

   where: *NIR* is the reflected spectral value of the near infrared band, and *R* is the spectral value of the red band wave reflection.
3. Identification of vegetation and non-vegetation objects. Identification of vegetation and non-vegetation objects is carried out by validation using plantation maps and original objects in oil palm plantations. Identification of objects is important to prevent errors in the classification of density levels and plant health.
4. Analyze the density level of oil palm plantations. Tree density is classified according to the regulation of the minister of forestry of the Republic of Indonesia (Peraturan Menteri Kehutanan RI Nomor P.12/Menhut-II/2012) as shown in Table 3 . Plant density from the NDVI classification was also compared with secondary data on plant density or Basic Units per Hectare (SPH) from oil palm plantation companies.
5. Analyzing the health level of oil palm plants. Plant health is classified according to Table 4.

Table 3. Classification for tree density based on NDVI index

Tree density	NDVI value
Low	-1 to 0.32
Medium	0.32 to 0.42
High	0.42 to 1

Source: (Kementrian Kehutanan dan Lingkungan Hidup, 2012)

Table 4. Classification for plant health level based on NDVI index

Plant helath	NDVI value
Death plant	-1 to 0
Unhealthy plant	0 to 0.33
Fairly healthy plant	0.33 to 0.66
Very healthy plant	0.66 to 1

Source: (Lillesand *et al*., 2015)

6. Validate the health level of oil palm plants with LSU data. Secondary data on the content of macronutrients and micronutrients came from the results of the analysis of the company's LSU Afdeling 1 compared to the standard nutrient content that should exist in mature oil palm plants.
7. Comparing the level of plant health with LSU results. Then the results of the evaluation of the level of plant health based on the NDVI index were compared with the results of LSU.

3. RESULTS AND DISCUSSION

Landsat-8 satellite imagery can be used to monitor and evaluate plant health conditions on large area such as oil palm plantations using the NDVI index (Lillesand *et al*., 2015). The NDVI index is calculated based on the ratio of the reflected values of red and near infrared waves (U.S. Departement of the Inferior, 2017b; Kaban & Darmawan, 2020). The display of the Landsat-8 satellite imagery in red light, near infrared, and the results of the NDVI index recorded on October 27, 2020 looks like Figure 2.

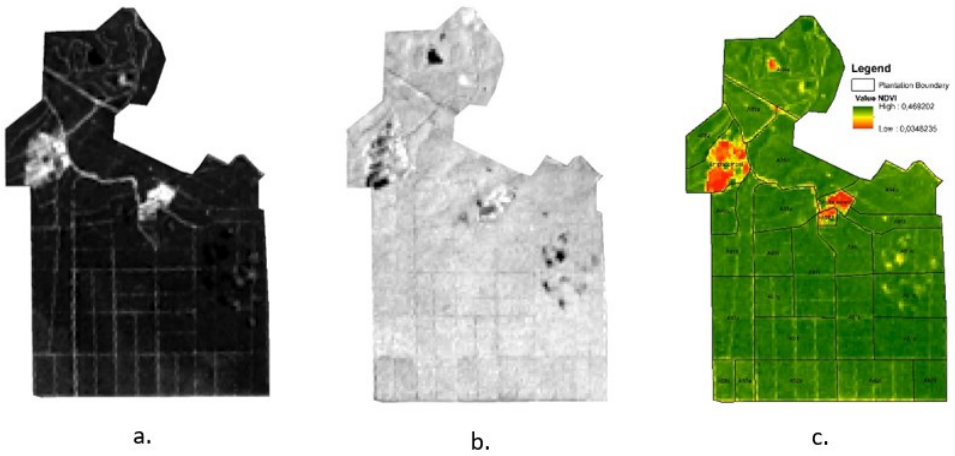


Figure 2. Landsat-8 satellite imagery recorded on October 27, 2020: a) At red wavelength, b) At NIR (near infra red) wavelength, c) Results from NDVI index processing.

Based on the results of the NDVI index analysis, the minimum NDVI value is 0.034 and the maximum is 0.469. A low NDVI value indicates non-vegetated or dead vegetation objects (Lillesand *et al*., 2015). The identification results show that non-vegetation objects have an NDVI index value range of 0.034-0.245 and vegetation objects have an index value range of 0.273-0.454. Based on the validation of conditions in oil palm plantations, vegetation objects are oil palm plants planted in plantation blocks while non-vegetation objects in the plantations are residential areas (emplacement) and reservoirs.

Recording of Landsat-8 Satellite Imagery on October 27, 2020 resulted in a relatively high NDVI value obtained due to the recording time including the rainy season. Rainfall in October 2020 for the research location based on data from the BMKG Meteorological Station Sultan Syarif Kasim II was recorded at 233 mm/month. The research location which is located around the equator makes the location has high and evenly distributed rainfall throughout the year so it is suitable as a location for oil palm plantation.

Based on the classification of plant density from the regulation of the minister of forestry of the Republic of Indonesia (Peraturan Menteri Kehutanan RI Nomor P.12/ Menhut-II/2012), it was found that in general the density of oil palm plantations in Afdeling 1 Rantau Baru Plantation was included in the high or dense category. These results are in accordance with secondary plant density data from oil palm companies where the plant density is 99-132 trees/hectare with an average tree density of 118 trees/hectare (Kebun PT. Sawitakarya Manunggul, 2020). Plant density and NDVI value per block in Afdeling 1 plantation are shown in Figure 3. For oil palm plantations with old age, the yield of existing plant density is still relatively high compared to the initial plant density of 143 trees/ha. The spatial conditions of density and health of oil palm plantations in Afdeling 1 Rantau Baru Plantation are shown in Figure 4.

The average NDVI value for vegetation objects is 0.423, indicating the health condition of oil palm plants in a fairly healthy condition (Lillesand *et al*., 2015). The high level of plant density in old plants is also an indication that the plants are in a healthy condition (Fairhurst & Griffiths, 2014; Yusuf *et al.*, 2015). The level of density and plant health from the analysis of the NDVI index can be used as an indication that plants are not attacked by basal stem rot disease due to infection by the fungus *Ganoderma* sp. (Azahar *et al*., 2011).

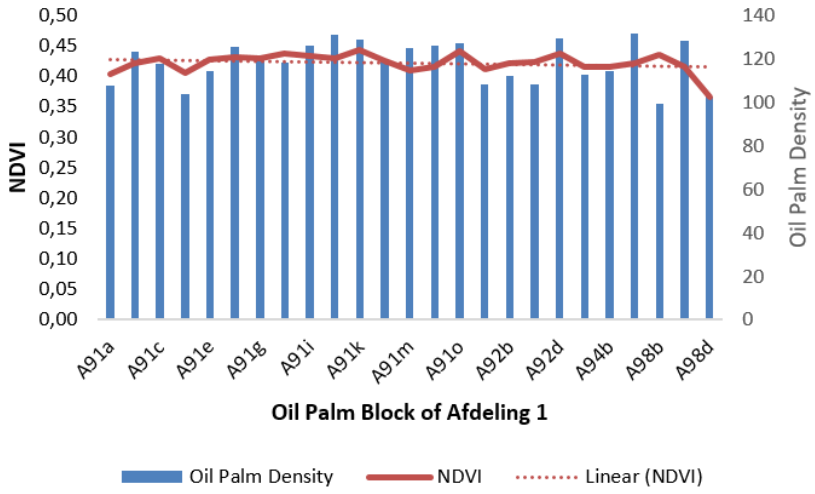
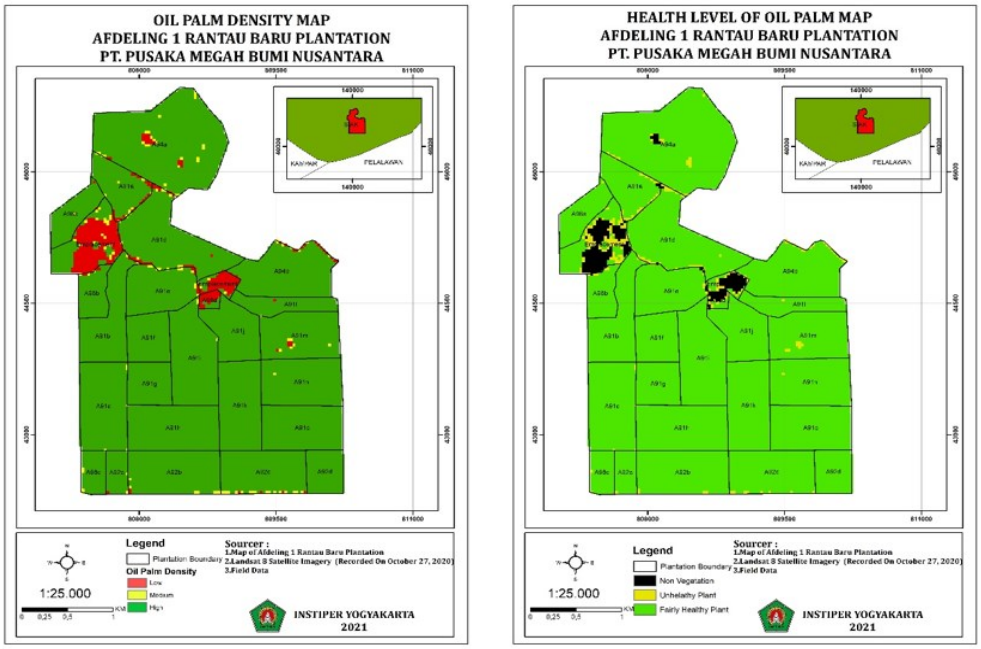


Figure 3. NDVI value and plant density per block in Afdeling 1 Rantau Baru Plantation



a. b.

Figure 4. Palm oil plant condition of Afdeling 1 Rantau Baru Plantation, PT. Pusaka Megah Bumi Nusantara: a) Oil palm plant density level, and b) Oil palm health level

Basal stem rot disease is a deadly disease and can cause a large decrease in the number of oil palm trees. Plants that are attacked by basal stem rot disease at the initial level of attack are marked by broken midribs and at the level of severe attacks are marked by the appearance of fungal fruiting bodies at the base of the stem which indicates the plant vascular tissue has been attacked and causes the plant to fall due to death (Azahar *et al.*, 2011; Santoso *et al.*, 2011). The number of broken midribs on a plant or plants that die due to falling will cause the value of the red wave reflection to be high because the red wave absorbed for the photosynthesis process is low (Fairhurst & Griffiths, 2014; Corley & Tinker, 2016). Thus, NDVI is also suitable for indicators of attack by *Ganoderma* sp. in oil palm plantations. The results of the leaf sampling unit (LSU) Afdeling 1 are shown in Table 5.

Table 5. LSU from Afdeling 1, Kebun Rantau Baru PT. Pusaka Megah Bumi Nusantara

Nutrient	Element	Amount	Category	Old oil palm standard
Macronutrient (% DM)	N	2.56	High	0.44 - 0.65
	P	0.17	Optimal	0.052
	K	1.02	Optimal	1.0 - 1.3
	Mg	0.3	Very high	0.22
	Ca	0.8	Very high	0.25
Micronutrient (mg/kg)	B	18.55	High	7.0 - 8.5
	Cu	3.93	Optimal	7.0 – 10
	Zn	13.37	Low	18 – 31
	Fe	79.68	Optimal	25

Source: (Goh & Hardter, 2003; PT. Pusaka Megah Bumi Nusantara, 2020)

Based on the results of LSU Afdeling 1 Rantau Baru Plantation, PT. Pusaka Megah Bumi Nusantara in 2020 compared to the standard from Goh & Hardter (2003), information was obtained that the content of macronutrients and micronutrients was greater than the standard amounts commonly found in mature oil palm plants except for the Zn element which was lower than the standard. The LSU results support the NDVI results which show that the oil palm plantations in Afdeling 1 Rantau Baru Plantation are in healthy condition.

Magnesium is one of the macronutrients that make up chlorophyll. The high content of Mg is an indicator of a plant in a healthy condition. The high content of Mg in the leaves shows that the chlorophyll in the leaves is high enough so that the photosynthesis process can run well (Goh & Hardter, 2003; Fairhurst & Griffiths, 2014). A good photosynthesis process will absorb a lot of high red waves so that the reflected red waves are low. The low reflection of red waves and high reflection of near infrared waves will produce high NDVI values as a marker of plants in healthy condition (Lillesand *et al*., 2015).

The results of this study indicate that the NDVI index from Landsat-8 satellite imagery is efficient for rapid evaluation of the density and health conditions of oil palm plants quickly (Pohl *et al*., 2016; Chong *et al.*, 2017). The NDVI map can provide an overview of the health condition of oil palm plants spatially. Utilization of NDVI can be used for early detection of plant health conditions for a large area when compared to LSU analysis which only takes leaf samples from sample trees in oil palm plantation blocks. The results of the health level of plants from the NDVI analysis are also in accordance with the results of the leaf sampling unit (LSU). The level of plant health from the NDVI index can also be used as an indicator of the presence of *Ganoderma* sp. cause of basal stem rot disease.

4. CONCLUSIONS AND RECOMMENDATION

4.1. Conclusion

The conclusions of this study are:

1. The density of oil palm plantations in Afdeling 1 Rantau Baru Plantation is included in the high density category with an average NDVI value of 0.423 which corresponds to the existing plant density of 99-132 trees/hectare with an average tree density of 118 trees/hectare.
2. The health level of oil palm plants is included in the fairly healthy category which is indicated by an NDVI value > 0.33.
3. The results of the analysis of the health of oil palm plants based on the NDVI value are in accordance with the results of the leaf sampling unit (LSU) analysis which analyzes the level of nutrient content in the leaves.

4.2. Recommendation

1. It is better to use more data with various ages of oil palm plants to evaluate the health level based on the NDVI value.
2. Further research on the utilization of various indices resulting from satellite image processing can be used as an alternative method of evaluating the condition of oil palm plantations quickly and efficiently.

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