Monitoring The Crowns Of Palm Oil Plants in Central Lampung Regency Using Remote Sensing Techniques

Ridwan[1*], Elhamida Rezkia Amien[1], Sandi Asmara[1], Ahmad Tusi[1]

[1]Agriculture Engineering, Faculty of Agriculture, University of Lampung, Bandar Lampung, Indonesia.
Email*): ridwan.1965@fp.unila.ac.id

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Abstract: Crude palm oil (CPO) productivity in Central Lampung Regency, at 2.25 tons/ha/year, remains below the national average of 3.90 tons/ha/year. One of the contributing factors is that oil palm plants are not growing optimally. This is reflected by the fact that the canopy cover is not dense or uniform. The objective of this study was to assess the dense or crown of oil palm trees using remote sensing technology from satellite imagery. In this study, Sentinel-2 imagery was used to oil palm canopy closure, and Landsat 8 imagery was used for land suitability analysis. The research method includes the vegetation index analysis by Normalized Difference Vegetation Index (NDVI), land moisture index by the Normalized Difference Moisture Index (NDMI), Land Surface Temperature (LST), and land suitability parameters. The results of the analysis are then macthed with the conditions of oil palm plants in the field. The results obtained from this study indicate that oil palm plantations in the Bekri District can be categorised into two discrete classes: Class S2 (sufficiently suitable) and Class S3 (marginally suitable). The total area encompassed by these classes is 8,903 hectares, with Class S2 covering 7,615 hectares and Class S3 covering 218 hectares. Moreover, the study revealed that 3,721 hectares were conducive to optimal plant growth with a dense crown, 765 hectares exhibited normal crown and growth, and 310 hectares displayed suboptimal growth with an indicated uniform dense crown. The overall accuracy rate of the study is 81.82%. There is a positive correlation between NDVI and NDMI values with a correlation coefficient (R^2) of 0.8426, but there is a negative correlation between the NDVI and LST values with a correlation coefficient of -0.586.

Keywords: monitoring; palm oil plants; remote sensing

INTRODUCTION

Background

Oil palm (*Elaeis guineensis* Jacq.) is a major plantation crop originating from West Africa and widely cultivated in Southeast Asia for crude palm oil (CPO) production (GAPKI, 2024). Lampung Province is one of the Indonesian provinces that plays an active role in the agricultural sector, one of its commodities being palm oil. According to the Central Bereau of Statistics of Lampung (2023), in 2022, Central Lampung Regency ranked second as a palm oil producing region, with a total plantation area of 19,179 hectares and a total production of 43,148 tons, with a crude palm oil (CPO) productivity of 2.25 tons/ha/year. This productivity is still below the national average CPO productivity of 3.90 tons/ha. This may be due to the quality of the plantation land affecting the growth of oil palm tress, resulting in suboptimal production of fresh fruit bunches (FFB), as is the case at the PTPN 7 Bekri Unit oil palm plantation with a covers an area of 4,324 hectares in Bekri

Sub-District, Central Lampung Regency. Therefore, it is necessary to monitor plant growth periodically in order to determine the conditions, changes and trends that may occur in a plant.

Monitoring the growth of oil palm trees is usually done directly by observing the canopy cover or crown of each tree individually, but this method is ineffective and inefficient given the large area of the plantation and the fact that it requires a lot of manpower, time and money. This problem can be overcome by utilizing remote sensing technology from satellite imagery. The use of satellite imagery in assessing oil palm growth has been reported by Li et al (2016), Arini et al. (2022), Yuniasih and Adji (2022), Yurianda et al. (2022), Pangestu and Banowati (2023), and Sakinah and Prarikeslan (2024), using the analysis of differences in vegetation index (NDVI) with both Sentinel-2 and Landsat 8 OLI imagery.

The vegetation greenness index value obtained from NDVI analysis shows the chlorophyll content in plant leaves, which is closely related to plant biological functions such as photosynthesis and respiration, metabolism, absorption and translocation of nutrients and water. The growth and productivity of oil palm plants, according to Yulistriani et al (2017), are influenced by abiotic factors (climate, soil, topography), biotic factors (weeds, pests, plant density), genetic factors (innate) including seed varieties and plant age, and cultivation technique (induce) including fertilization, soil and water conservation measures, plant pest and diseases control, and other activities. Soil surface temperature and humidity as one of the abiotic factors that affecting plant health can also be identified using remote sensing techniques with LST (Land Surface Temperature) and NDMI (Normalized Difference Moisture Index) analysis, as reported by Bryani et al (2025) in estimating the land surface temperature (LST) level in pineapple plantations and Rahmah et al (2024) using NDMI to estimate soil moisture distribution levels in rice fields.

The present paper, introduce methodolgy for the remote monitoring of oil palm tree based on analysis of NDVI, NDMI, and LST from Sentinel-2 and Landsat 8 OLI satellite imagery.

Objective

This study used Landsat 8 OLI satellite imagery to assess the impact of land suitability on oil palm canopy cover, based on the vegetation index (NDVI) derived from Sentinel-2 satellite imagery. It also examined the relationship between oil palm canopy cover and land surface temperature (LST) and soil moisture (NDMI) indices based on the vegetation index (NDVI).

RESEARCH METHODS

Description of Location and Time of Research

The study was conducted in Bekri Sub-district, Central Lampung Regency, Indonesia (105°03'–105°12' E; 5°04'–5°12' S), with elevations ranging from 45 to 85 m above sea level. The area has a tropical climate with average annual rainfall of 2,500–2,800 mm. Remote sensing data were collected from 2019 to 2023.

Tools and Matrerials

The tools used in this study are hardware (laptop, mouse, printer, and cellphone camera), Thermohygrometer with Humidity measurement, and software (ArcGIS 10.3, SNAP, GPS Map, Microsoft Word, and Microsoft Excel). The materials used in this study are secondary data as shown in **Table 1**.

Table 1. Reseach Materials

No.	Data	Function	Source
1.	Sentinel-2 Level 2A satellite imagery	Vegetation index analysis including oil palm growth.	Sentinel Hub or Google Earth Engine
2.	Landsat 8 OLI/TIRS satellite imagery	Analysis of land suitability, soil moisture (NDMI), and land surfavce temperature (LST)	*Earthexplorer.usg s.gov* or *Google Earth Engine.*
3.	Administrative bounderies of Bekri District	Guidelines for data analysis and ground check in Bekri District.	Geospatial Information Agency.
4.	Soil Type and description	Analysis of land suitability	Food And Agriculture Organization (FAO) https://www.fao.org/land-water/land/
5.	Rainfall	Analysis of land suitability	CHIRPS https://www.chc.ucsb.edu/data/chirps

Research Design and Workflow

The research procedure consists of data collection, image and supporting data interpretation, analysis, and data presentation (see Figure 1). The collection of data was conducted with the objective of obtaining secondary data to support the research. Subsequently, pre-processing was performed, including radiometric and geometric corrections, on Sentinel-2 and Landsat 8 satellite imagery

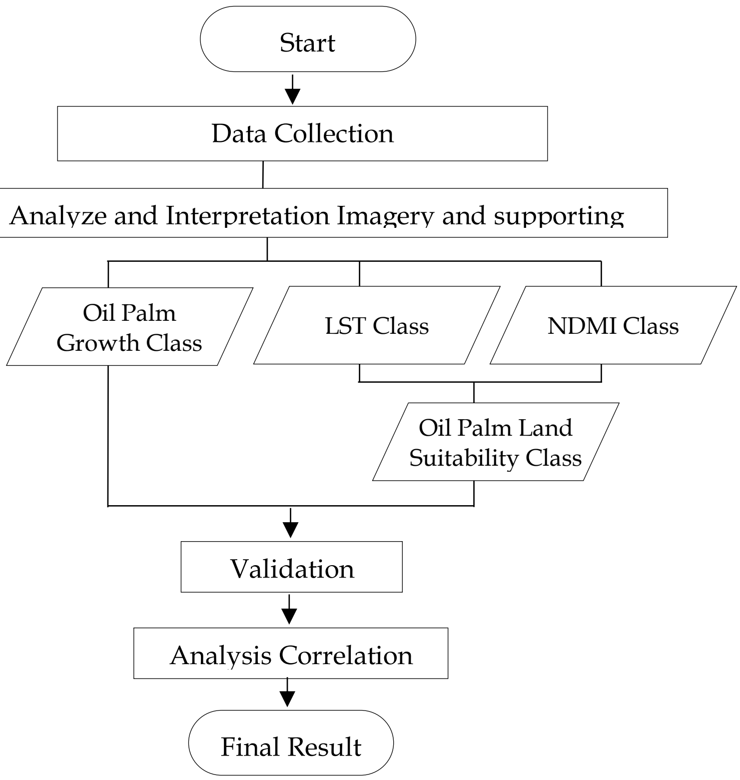


Figure 1. The flowchat of research procedure

The radiometric and geometric correction process of Sentinel-2 images is carried out automatically in the SNAP software, while for Landsat 8 images it is carried out by means of Top of Atmosphere (ToA) correction which includes ToA reflectance for bands 1 to 7 by changing the DN value to reflectance value and solar correction while ToA radiance for bands 10 and 11 by changing the DN value to radiance value.

The conversion equation for ToA reflectance correction is as follows:

$$\rho\lambda' = (M\rho Qcal) + A\rho \tag{1}$$

Where:
ρλ' = ToA planetary reflectance, without correction for solar angle
Mρ = Band specific rescalling factor [REFLECTANCE_MULT_BAND_x, where x is the band number]
Aρ = Band specific additive factor [REFLECTANCE_ADD_BAND_x, where x is the band number]
Qcal = Digital Number (DN)

Meanwhile, the conversion equation for ToA reflectance is as follows:

$$L\lambda' = (ML.Qcal) + AL \tag{2}$$

Where:
Lλ' = ToA radiance, without correction for solar angle [W/(m^2 sr µm)]
ML = Band specific Rescalling factor [RADIANCE_MULT_BAND_x, where x is the band number]
AL = Band specific Additive factor [RADIANCE_ADD_BAND_x, where x is the band number]
Qcal = Digital Number (DN)

Landsat 8 imagery data is utilised as auxiliary data for determine of land surface temperature (LST) in a given area, with the objective of ascertaining its suitability. The surface temperature assessment process requires the consideration of parameters such as emissivity and atmospheric transmission (Rozenstein et al., 2014). Subsequent to the LST, data processing is also conducted to obtain maps of rainfall, slope, soil type, erodibility, soil pH, soil texture, and soil Cation Exchange Capacity (CEC). This maps are then overlaid to obtain the results of the oil palm land suitability analysis based on planting requirements.

The procedure for analysing the Normalized Difference Moisture Index (NDMI) as a humidity index in a specified area or land is derived from the processing of band 8A as the Vegetation Red Edge band and band 11 as the Short Wave Infrared (SWIR) band of Sentinel-2 satellite imagery, as outlined below:

$$\text{NDMI} = \frac{(band\ 8A - band\ 11)}{(band\ 8A + band\ 11)} \tag{3}$$

Where:
band 8A = *Vegetation Red Edge* Band
band 11 = Short Wave Infrared (SWIR) Band

The oil palm growth class is derived from the processing of the Normalized Difference Vegetation Index (NDVI) as a vegetation index on Sentinel-2 imagery, which is essential for plant growth monitoring. The processing in question involves the utilisation a combination of band 8 as the Near Infrared (NIR) band and band 4 as the red band. The formula employed in this process is as follows:

$$\text{NDVI} = \frac{(band\ 8 - band\ 4)}{(band\ 8 + band\ 4)} \tag{4}$$

Where:
band 8 = Near Infrared Band
band 4 = Red Band

Following the acquisition of the NDVI value range, the correlation with the level of plant growth can be ascertained. This assertion is supported by research undertaken Rahaldi et al., (2015) and Pangestu and Banowati (2023) as illustrated in Table 2.

Table 2. NDVI Values and Plant Growth.

Plant Growth Classes	NDVI Value
Non Crop	-1 to 0
Poor Growth	0.1 to 0.22
Normal Growth	0.23 to 0.42
Good Growth	0.43 to 0.92

Source: Rahaldi et al., (2015)

In order to ascertain the land surface temperature, an estimate is made using the LST (Land Surface Temperature) approach. This is a method of mapping the distribution of surface temperature of a land cover using the Onboard Operational Land Imager (OLI) channels, namely bands 5 and 4, and the Thermal Infrared Sensor/TIRS on bands 10 and 11. Satellite temperature is converted to surface temperature using the following Stathopoulou and Cartalis (2007) equation:

$$LST = \frac{TB}{\left[1 + \left(\lambda * \frac{\text{TB}}{\rho}\right) * \ln(\text{e})\right]} \tag{5}$$

Where:
LST = Land Surface Temperature (^oK)
TB = Brightness Temperature (^oK)
λ = Radian wavelength
ρ = h* c/σ =1.4388*10^{-2} mK = 14388 µK
h = Plank constanta 6,626 x 10^{-34}
c = 2.998 x 10^8 m/s
σ = Boltzmann constanta 1.38 x 10^{-23} J/K
e = emissivity = 0.004 * Pv + 0.986

$$Pv \frac{NDVI - NDVI_{min}}{NDVI_{max} + NDVI_{min}} \tag{6}$$

Following the acquisition of the plant growth class, a ground check is conducted to validate the imagery results with the environmental conditions and plant growth in the field. The random sampling method is employed for each plant growth class. The formula employed to ascertain the minimum sample size, is as follows (Geospatial Information Agency, 2014):

$$N = TSM + \left(\frac{Area\ (ha)}{1500}\right) \tag{7}$$

Where:
N = Number of Samples
TSM = Minimum Total Sample

In order to ascertain the total accuracy value (overall accuracy) from field checks in accordance with the provisions of the Geospatial Information Agency, the following formula is employed:

$$A = \left(\frac{(\sum_{i=1}^{r} Xii)}{N}\right) \times 100\% \tag{8}$$

Where:
A = Total Accuracy (%)
Xii = Diagonal Matriks
N = Number of sampels

The basis used as a reference for the accuracy of interpretation results is a minimum of 70% for land coverage interpretation results (Geospatial Information Agency, 2014).

RESULTS AND DISCUSSION

Regional Overview

As illustrated in Figure 2, the regional administrative map indicates that the majority of land use in Bekri District is used for plantations, amounting to 5,445 hectares, and for rice fields, covering 1,989 hectares. The majority of these plantations are owned by PT Perkebunan Nusantara VII Unit Bekri, which cultivates two crops: oil palm and sugar cane.

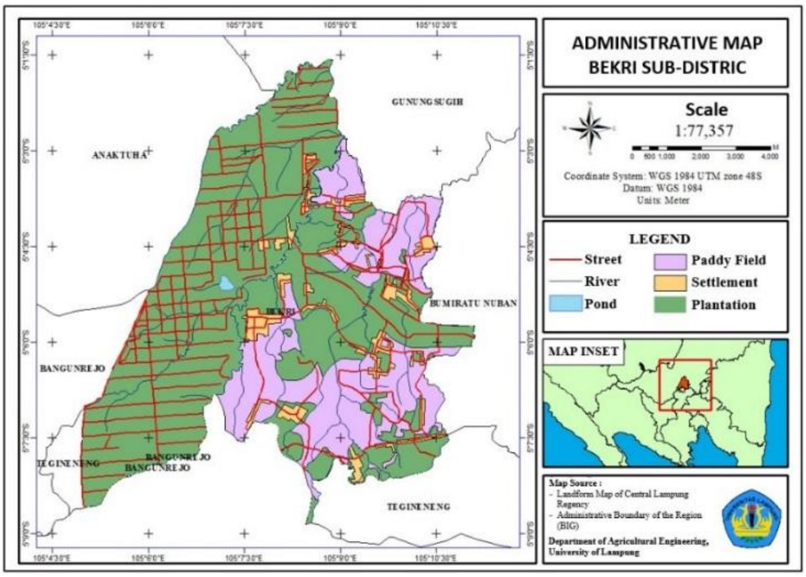


Figure 2. Administrative Map of Bekri District

Land Surface Temperature (LST)

The results of the analysis of the Landsat 8 OLI/TIRS image path row 1231064, acquired on 16 January 2023 and 31 October 2023 after the radiometric correction process using equations 1 and 2, yielded LST values for the entire Bekri District area. These values are presented in Tables 3 and 4, and Figures 3.

Table 3. Report presents the mean value of band 10 and 11 for January and October 2023

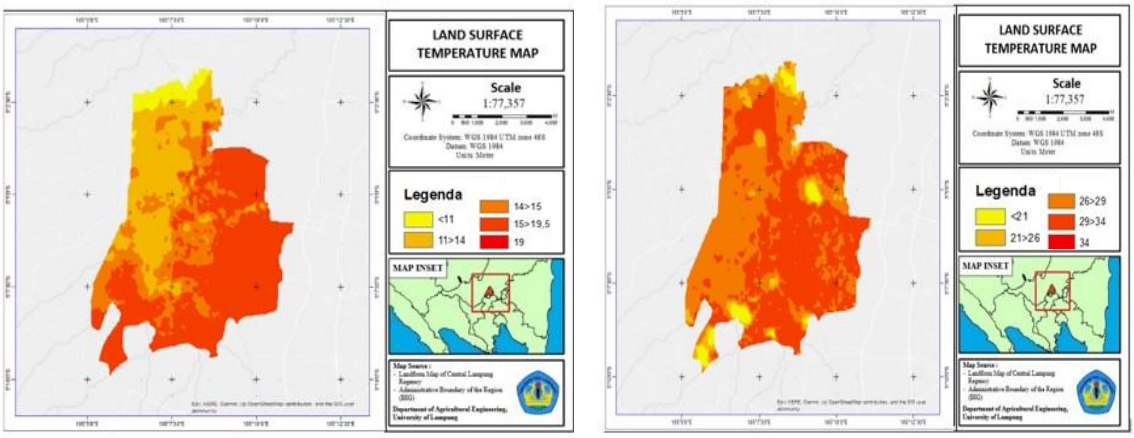
Acqusition time	Band	Pixel Value			
		Min	Max	Mean	St.Dev
January 2023	10	9,438	22,559	17,579	1,725
	11	-1,024	16,708	12,025	1,963
October 2023	10	16,029	37,438	30,972	2,997
	11	14,914	30,852	26,219	2,366

Table 4. Mean values of land surface temperature Bekri Sub-district

Month	LST Value			
	Min	Mean	Max	St.Dev
January 2023	4.44	14.8	19.6	1.82
October 2023	15.47	28.6	34.12	2.67

Source: The result of imagery analysis conducted in 2024

As showed in Figures 3, the majority of surface temperature results in the Bekri Sub-district area are characterised by temperatures ranging of 22°C to 24°C (class as moderately suitable, S2), with temperatures of 20°C to 22°C (marginally suitable, S3) and temperatures of 24°C to 28°C (highly suitable, S1) also being observed .



(a) (b)

Figure 3. The following map illustrates land surface temperature of the Bekri sub-district as recorded in (a) January 2023 and (b) October 2023

Rainfall Conditions

The average rainfall in the last five years in the Bekri Sub-district has been found to be within the range of 2,500 to 2,800 mm/year, falling into the S1 class (highly suitable), as presented in Figure 4. The high average annual rainfall in the study area is likely to have a significant impact on the humidity and air temperature under oil palm trees. As demonstrated in Figure 3, regions exhibiting high average rainfall demonstrate comparatively lower land surface temperatures. Conversely, Figure 5 illustrates that these regions experience elevated surface moisture levels in comparison to other regions.

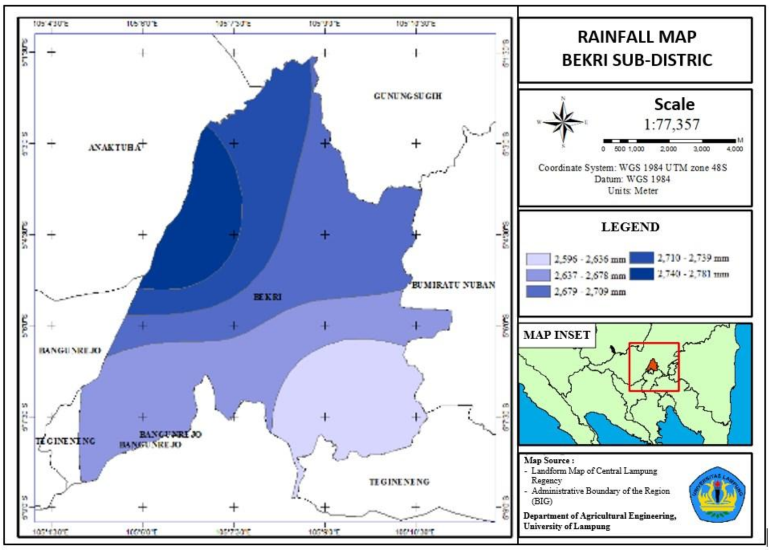


Figure 4. The following map illustrates rainfall of the Bekri sub-district

Land Surface Moisture (NDMI)

The analysis results of sentinel-2A images, which were acquired on 18 May 2019, 20 October 2020, 31 July 2021, 2 April 2022, and 24 September 2023, have been radiometrically and geometrically corrected. The results, as presented in Table 5 and Figure 5, demonstrate a range of values from -1 to 0.8809, with a standard deviation of 0.14.

Table 5. Results of Land Surface Moisture Index (NDMI) values

No.	Date of Image Recording	Value			
		Min	Max	Mean	Std. Dev
1.	18 Mei 2019	-1	0.8809	0.2027	0.1496
2.	20 October 2020	-0.4244	0.8109	0.1705	0.1477
3.	31 July 2021	-0.4576	0.8144	0.1398	0.1464
4.	02 April 2022	-0.9391	0.8244	0.2122	0.1405
5.	24 September 2023	-0.7891	0.8066	0.0237	0.1463

Source: The result of imagery analysis conducted in 2024

As illustrated in both Table 5 and Figure 6, the majority of these plantations are owned by PT Perkebunan Nusantara VII Bekri, have a high moisture content for extended periods of time. The findings of the moisture analysis conducted on the land surface beneath oil palm plantations are deemed to be in alignment with the prevailing average rainfall conditions experienced over the preceding five-year period, which are categorised as high throughout the year.

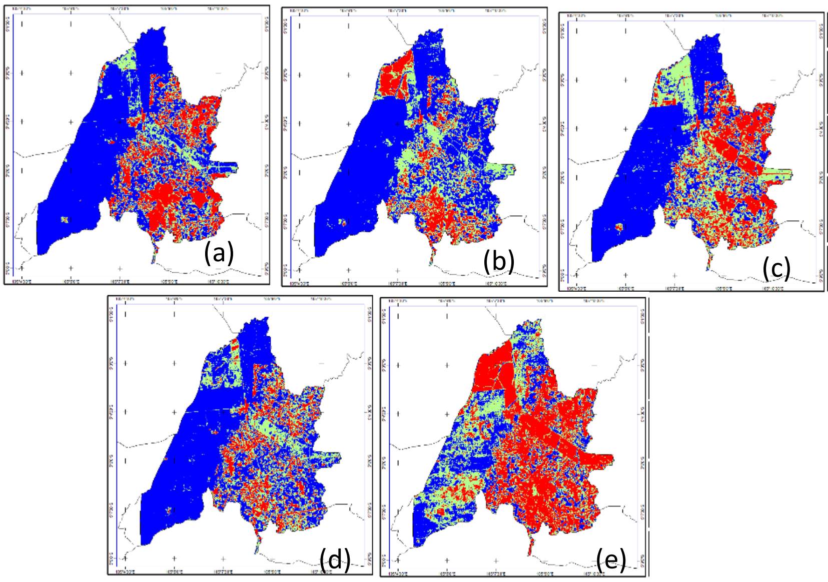


Figure 5. Results of Land Surface Moisture analysis
(a: May 18, 2019; b: Oct. 20, 2020; c: July 31, 2021; d: April 02, 2022; e: Sep 24, 2023)

Slope Condition

The topography of the Bekri Sub-district is characterised by a preponderance of flat areas, with the majority of the land slope falling within the range of 0-8% (class S1, designated as "very suitable"), 8-15% (class S2, designated as "moderately suitable"), and 15-30% (class S3, designated as "marginally suitable"), as illustrated in Figure 6.

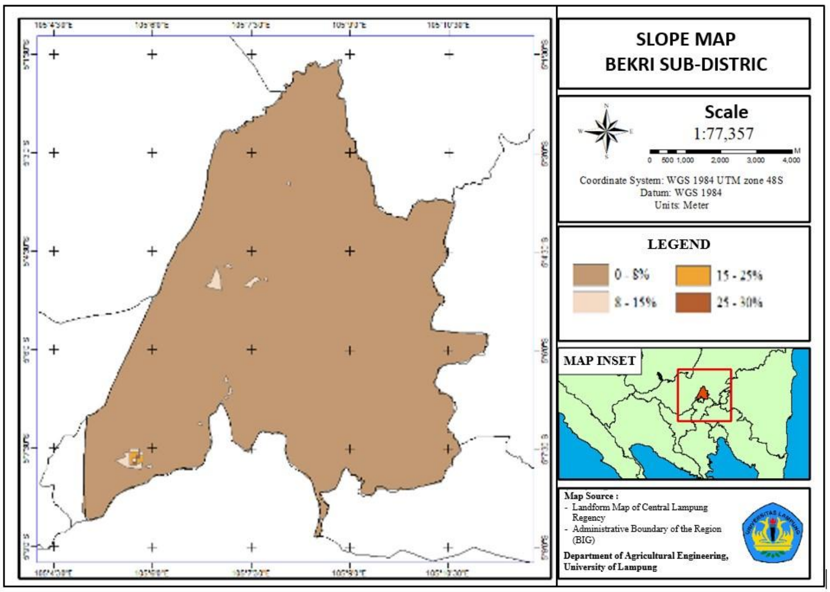


Figure 6. The following map illustrates slope of the Bekri sub-district

Soil Condition

As demonstrated in Figure 7, the soil in the Bekri Sub-district is predominantly comprised of soil types conducive to the growth of oil palm, namely alluvial, andosol, regosol, gleihumus, yellow red podzolic, latosol, and gray hydromorph, which are classified under class S1 (highly suitable).

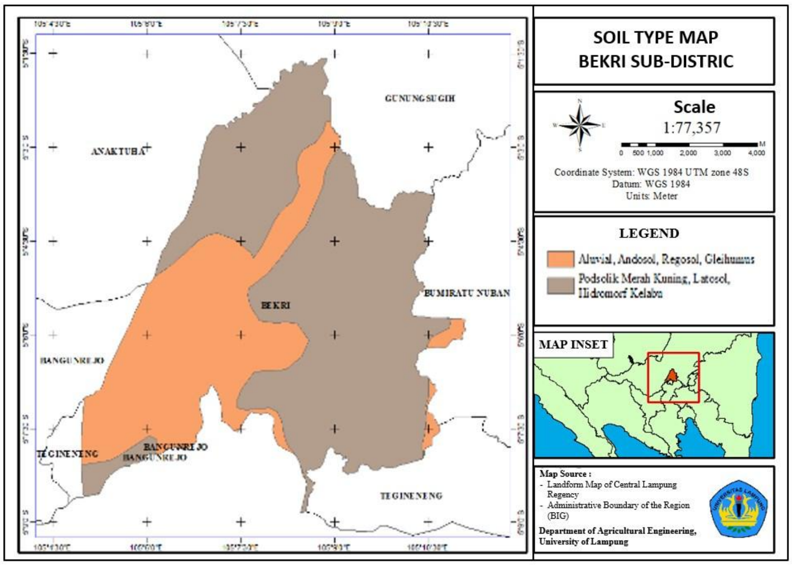


Figure 7. The following map illustrates Soil type map of Bekri sub-district

The analysis yielded results indicating that the soil in the Bekri area is predominantly characterised by textured clay and sandy clay loam, which are categorised as class S2 (moderately suitable) and class S1 (very suitable), respectively. The results of the soil pH values in the Bekri area range from 5-7.2, and are thus classified as being within the S1 class (very suitable) with regard to the capacity of the soil to absorb and exchange cations. In certain parts of the Bekri area, however, the results are classified as being within the S2 class (quite suitable) with a CEC value of >16, although in these instances the maximum value of CEC is 29.8. The erodibility of soil in the Bekri area exhibits considerable variation, ranging from low to medium levels, with a minimum value of 0.04 and a maximum value of 0.32. The erodibility suitability class is categorised as S1 (highly suitable) and S2 (moderately suitable). The soil in question is characterised by a C:N ratio ranging from 1.32 to 6.56%, which is indicative of a high level of suitability (class S1). However, in certain areas, this ratio exhibits a lower range of 0.46 to 0.8%, categorised as moderately suitable (class S2). The nutrient content of nitrogen (N), phosphorus (P), and potassium (K) is characterised by percentage values that are predominantly in the low category, thus categorising them as S2 (moderately suitable).

The Suitability of Oil Palm Land

The determination of actual land suitability (current land suitability) for oil palm in Bekri Sub-district is defined as the standards of growth requirements and land suitability for oil palm plantations issued by the Palm Oil Plantation Fund Management Agency (BPDPKS). The BPDPKS is a organisational unit in the field of oil palm plantation fund management under the jurisdiction of the Minister of Finance (https://www.bpdp.or.id). The results of the analysis demonstrate that the vast majority of the land in the Bekri Sub-district is classified as S2 (moderately suitable), encompassing an area of 7,615 hectares, particularly within the oil palm plantation area under the ownership of PT Perkebunan Nusantara VII Bekri Unit. The factors that limit the S2 suitability class are obtained from soil conditions, especially the availability of nutrients in the form of N, P, and K, each of which is in the low category. In the event of an enhancement to the limiting factors, the soil can be designated as a potential land suitability of S1, which is deemed to be highly suitable. Subsequently, the suitability class S3 (which is designated as 'quite suitable') is allocated to an area of 218 hectares, distributed across multiple locations within the plantation. This area is subject to limitations in terms of land slope and land surface temperature. The results of the analysis of land suitability for oil palm cultivation are presented in Table 6 and Figure 8.

Table 6. Land Suitability Class for Oil Palm in Bekri Sub-district

Land Suitability Classes	Description	Coverage Area (Ha)	Percentage (%)
No Data	No Data	132.27	1.66
S2	Sufficiently Suitable	7,615.53	95.59
S3	Marginally Appropriate	218.97	2.75
Total		7,966.78	100.00

Source: The result of analysis conducted in 2024

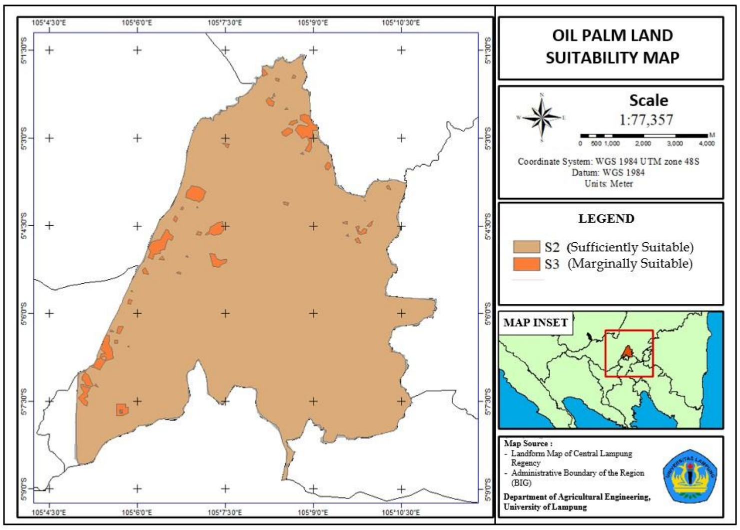


Figure 8. The following map illustrates land suitability for oil palm in Bekri sub-district

Oil Palm Plant Growth Analysis (NDVI)

The growth of oil palm trees can be determined using the vegetation presence index (NDVI), which in this study refers to the crown density of oil palm trees. The crown density is measured between one tree and another, and the area is calculated using the oil palm plantation area of PT Perkebunan Nusantara VII Bekri Unit. The results obtained with the NDVI value range from -0.4710 to 0.8957. These data will be classified into growth levels of oil palm plants, as presented in Table 7 and Figure 9.

Table 7. Oil palm growth class of Bekri sub-district

Growth class	NDVI Value	Coverage Area (Ha)	Percentage (%)
Non-vegetation	-1 – 0	6	0.12
Poor Growth	0.1 – 0.22	310	6.46

Growth class	**NDVI Value**	**Coverage Area (Ha)**	**Percentage (%)**
Normal	0.23 – 0.42	765	15.93
Good Growth	0.43 – 0.92	3,721	77.49
Total		4,802	100.00

Source : The result of analysis conducted in 2024

As illustrated in Figure 10, blue objects with NDVI values ranging from -1 to 0 are classified as non-vegetation classes, such as waters or cloud cover. Orange objects with NDVI values ranging from 0 to 0 are identified as vegetation classes.A total of 22 samples were identified as being part of the poor growth class, with an area of 310 hectares. Samples with light green objects and NDVI values ranging from 0.22 to 0.42 were categorised as normal growth class, with an area of 765 hectares. Dark green objects with NDVI values ranging from 0.42 to 0.92 were designated as good growth class, with an area of 3,721 hectares.

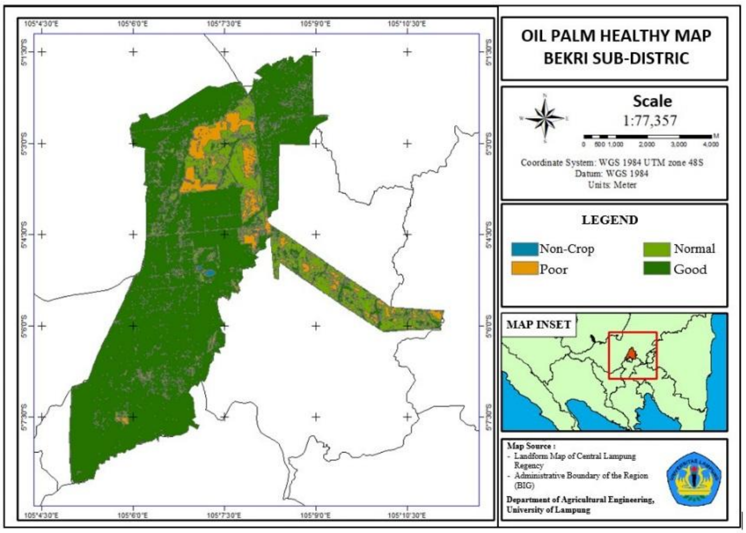


Figure 9. The following map illustrates Oil Palm Plant Growth of Bekri Subdistric

Subsequent to the analysis of the results of the plant growth classification, a ground check was then conducted, utilising the number of sample points employed in this study, which amounted to 33 points. The data is then divided into three growth classes: good growth, normal growth, and poor growth. The results of the oil palm growth validation process are presented in Table 8.

Table 8. Palm Growth Class Field Validation Calculation

NDVI Klasification	Field Validation			Total
	Good	Normal	Poor	
Good	8	0	3	11
Normal	0	8	3	11
Poor	0	0	11	11
Total	8	8	17	33

Source: The result of analysis conducted in 2024

The utilisation of equation 8 enables the calculation of validation results, thereby facilitating the determination of total accuracy in accordance with the following formula:

$$\text{Total Accuration} = \frac{27}{33} \text{ x } 100\%$$
$$= 81{,}82\%$$

The accuracy result obtained from the oil palm growth class in this study is 81.82%, which can be accepted, since this value is greater than 70%, as determined by the Geospatial Information Agency for results of land coverage interpretation. Preliminary field investigations have revealed that in the poor growth class, the samples were not identified as oil palm plants, but rather as shrubs, replanting areas, and hilly areas that are very rarely overgrown by vegetation. Within the designated normal growth class, it has been established that 80% of the samples are oil palms, with the remaining 20% comprising shrubs present within the oil palm plantations. Oil palms that are thriving in optimal conditions typically exhibit a sparse density, as evidenced by the spongy texture of their leaves. The midrib of their leaves is not as pronounced, and their colouration tends towards a muted green. This is attributable to the fact that a proportion of the samples are from unproductive areas (planting age >25 years) and a number of trees have fallen due to stem base rot disease.

In the 'good growth class', it has been established that eight out of 11 samples are oil palms displaying optimal growth. These palms exhibit optimal inter-tree density, with an evenly distributed green canopy. Their supporting physical characteristics include a uniform trunk width diameter from bottom to top, a dense midrib condition, tight leaf cover, and a shiny dark green leaf colour. As demonstrated in Figure 10, samples TS6, TS10 and TS11 were planted in 2010, 2011 and 2000, respectively. The results show that these samples had high NDVI values of 0.735294 and 0.511236, but this is inversely proportional to the moisture index, which falls into the medium category with values of 0.096158, 0.029544 and 0.156133 (see Figure 10). The rationale behind this phenomenon is that the canopy of the oil palm in both samples does not extend to the maximum extent across the land surface below it.

Figure 10. a clear distinction is evident in the midrib figures of oil palm trees (a) Normal crown and (b) Bad crown Oil Palm Plants.

Correlation Analysis between NDVI and NDMI under Oil Palm Stands

The present study hypothesised that there is a close correlation between the growth of oil palms and the moisture condition of the land surface. The NDVI index (see Table 9) and the NDMI index (see Table 5) were utilised to assess the correlation between oil palm growth, as measured by crown density, and surface moisture. The results obtained are illustrated in Figure 11.

Table 9. Results of Vegetation Crown Density Index (NDVI) Values

No.	Imagery Recording Date	Value			
		Min	Max	Mean	Std. Dev
1.	18 Mei 2019	-0.8390	0.9993	0.6088	0.2230
2.	20 October 2020	-0.5255	0.9993	0.5401	0.2153
3.	31 July 2021	-0.4350	0.9703	0.4993	0.1950
4.	02 April 2022	-0.5023	1	0.6049	0.2154
5.	24 September 2023	-0.8150	0.9453	0.4130	0.2134

Source: The result of analysis conducted in 2024

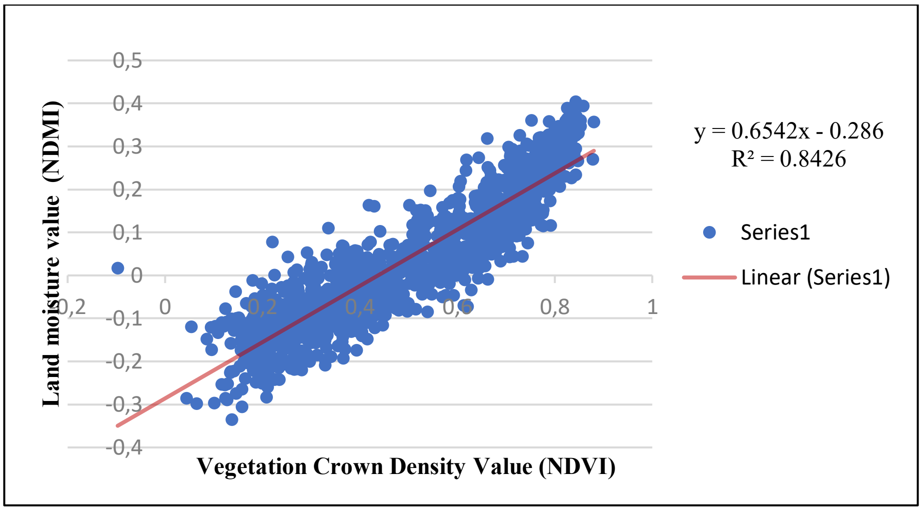


Figure 11. Correlation between NDVI and NDMI Index Values

As demonstrated in Figure 12, there is a close relationship between NDVI and NDMI, with an R^2 value of 0.8426 (84.26%). It is evident that these values exhibit a direct proportional relationship; when one decreases, the other also decreases, and vice versa. The findings of this study also demonstrate a strong relationship between oil palm growth and vegetation density and soil surface moisture.

Analysis of NDVI and LST Correlation under Oil Palm Stands

The data employed in the correlation analysis of NDVI and LST was sourced from field validation points, with a total of 33 sample points analysed. This analysis yielded a correlation value of -0.586, as illustrated in Figure 12. In accordance with the correlation coefficient interpretation guidelines established by Sarwono (2006), the range of -0.5 to -0.75 is designated as the strong negative correlation criteria. The findings of the correlation analysis indicate a negative relationship between the LST and NDVI values. That is to say, an increase in NDVI is accompanied by a decrease in LST, and vice versa. The presence of dense vegetation has been shown to result in a decrease in temperature beneath the canopy of oil palm plants. This phenomenon pertains to the capacity of vegetation to modulate ambient temperature through the process of evapotranspiration.

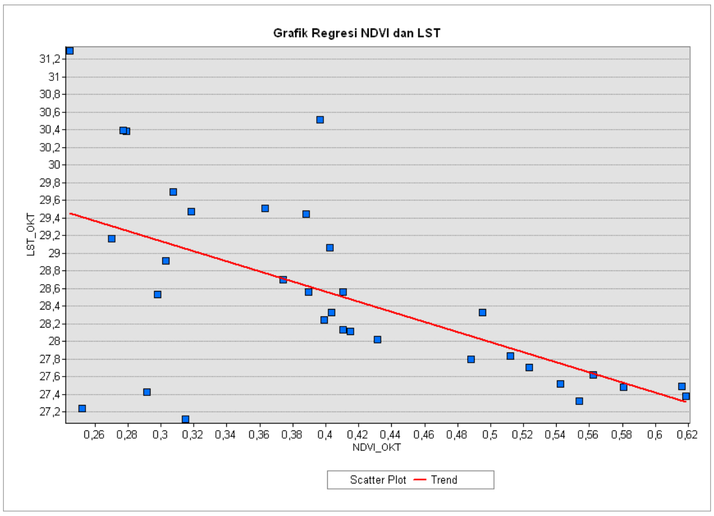


Figure 12. The relationship between NDVI and LST in the context of oil palm plantations.

CONCLUSION AND SUGGESTION

The growth of oil palm plants and the environmental factors that can affect their growth, especially temperature and humidity in large planting areas, can be monitored with relatively satisfactory results using remote sensing techniques. These techniques include NDVI analysis using Sentinel-2 satellite imagery and NDMI and LST analysis of Landsat 8 OLI satellite imagery, which has undergone geometric and radiometric correction processes. The research results revealed that 6.46% of PTPN VII Bekri's oil palm plants exhibited poor growth conditions, while the majority were classified as growing either normally or very well. The study also showed that some land was marginally suitable (S3) for growing oil palm plants, with slopes of 15–30% being the main limiting factor. Other land was classified as quite suitable (S2), where soil fertility was the main limiting factor, particularly with regard to the availability of nutrients such as nitrogen (N), phosphorus (P) and potassium (K). These results can inform targeted nutrient management and land rehabilitation initiatives, particularly in regions designated as marginally suitable or exhibiting suboptimal plant growth. To enhance classification precision and capture seasonal dynamics, future studies should incorporate multi-seasonal imagery and higher-resolution data.

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CONFLIC OF INTEREST

The author asserts that there is no conflict of interest with any party in carrying out this research, and that the company data of PTPN 7 Bekri Unit provided to the author is not used for the benefit of other parties and or interests other than this research. The findings of this study are exclusively intended for the advancement of science and technology in the domain of agricultural engineering.

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