Analysis of Vegetation Index (NDVI, SAVI, LAI) on Coffee Productivity in Bener Meriah District, Aceh Province

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ABSTRACT
Vegetation index analysis Transformation of the Normalized Different Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI), and Leaf Area Index (LAI) of coffee plants based on 8 oli/tirs Landsat imagery in Bener Meriah district, Aceh Province This research used two periods to determine the level of productivity of coffee plants, namely the period before flowering (May 2018) and the fruiting period (August 2018). This vegetation index analysis uses red wave reflectance (band 4) and near infrared wave reflectance (NIR), or band 5. These two wave reflectants have a high level of sensitivity to chlorophyll and mesophyll (green leaf matter). The results of this calculation show that the production and productivity results of coffee plants can be seen from the calculation results of the NDVI index value, which ranges from -0.047 to 0.9867; the SAVI value ranges from -0.016 to 0.632; and the LAI index (0.655 to 5.389). This figure shows that the level of vegetation density in the research area is very good, especially in August 2018. The validation process was carried out by correlation testing the three vegetation indices. The correlation test was carried out in the fruiting period, with an average value of R2 = 0.954, and the average value of the correlation test results in the period before flowering is R2 = 0.794. Because the correlation test value in the period before flowering (May 2018) for the NDVI index is (-0.04 to 0.85), the SAVI value ranges from (-0.017 to 0.756), and the LAI value ranges from (0.652 to 18.236) Therefore, based on the correlation value test, the Normalized Different Vegetation Index (NDVI) Transformation is more effective in analyzing the level of productivity of coffee plants in Bener Meriah district.

***Keywords**: Landsat 8 OLI/TIRS, SAVI, LAI, coffee productivity*

1. INTRODUCTION

Bener Meriah Regency is one of the best coffee-producing districts in Aceh Province. The types of coffee that are widely cultivated in Bener Meriah Regency are Arabica coffee and Robusta coffee. Arabica coffee from this district is known worldwide because it has a distinctive taste with main characteristics including complex aroma and flavor and strong viscosity. The total cost of coffee exports during January to August 2021 was $476.76 million USD. Aceh was Indonesia's fourth-largest coffee exporting province during that time, with a US$49.89 million export value [1].

The undoubted existence of Gayo Coffee in the eyes of the world encourages farmers to continue to improve various monitoring techniques that can protect coffee production. Monitoring techniques here are expected to produce specific data without doing a lot of field work with faster and more accurate results, such as remote sensing techniques and geographic information systems. The techniques utilize satellite image data, which provides relatively complete information on the earth's surface in a short time and is able to cover large areas without directly touching the object of study. Remote sensing techniques using object-based image classification methods have been successfully carried out, especially with high-resolution images [2].

In this paper, we identify and analyze research objects based on spectral and spatial characteristics for mapping the transformation of the Normalized Different Vegetation Index (NDVI), the Soil Adjusted Vegetation Index (SAVI), and the Leaf Area Index (LAI). This aims to analyze the relationship between vegetation indices and vegetation health, growth, and productivity [3].

Arabica coffee plants are coffee plants that grow and produce quite well in tropical climates. This plant is an annual plant, so it can be harvested every year if the coffee plant is well cared for. As an annual plantation crop, coffee plantations are a long-term capital investment, and the plants also have a positive impact on the environment. Coffee plants can protect water resources, improve soil quality,

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withstand flooding, and absorb carbon dioxide over a long period of time [4].

As a result, this plant is very popular with the people of Bener Meriah, especially because it can improve the economy and increase employment opportunities. This coffee plant grows up to 4 m tall and usually grows under various other types of tall plants [5]. To accurately extract information about Gayo Arabica coffee plants from satellite imagery, it is necessary to know the characteristics of the coffee-growing land. Characteristics What is meant is temperature, altitude, water availability, slope, soil, and several other characteristics that are needed in making an identification map of coffee plantation land. Arabica coffee plants can generally produce optimally at an altitude of 700–1,700 meters above sea level with rainfall of 2,000–3,000 mm/year. Based on these characteristics, an approach is carried out that can be translated into creating height maps, slope maps, and other maps.

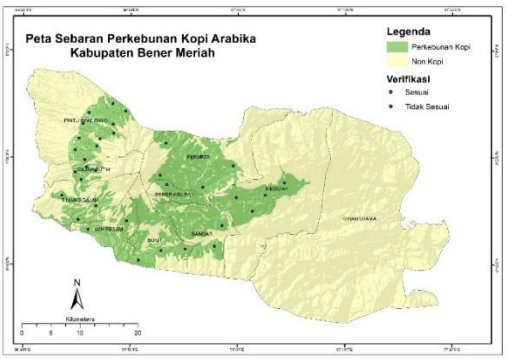

Figure 1 Map of the distribution of Arabica coffee plantations in Bener Meriah Regency

Based on Figure 1, a map of the distribution of Arabica coffee plantations in Bener Meriah Regency was obtained from the overlay between forest area maps, land use maps, and height maps [6].

The application of remote sensing techniques provides an excellent opportunity for detailed crop production estimates using the spectral, spatial, and temporal resolution of Landsat 8 OLI/TIRS imagery. Spatial resolution provides information about objects on the earth's surface according to the size of the object. Spectral resolution shows the ability of an electronic optical system to distinguish between reflected and radiated spectral rays from the object being analyzed. Meanwhile, the temporal resolution on Landsat 8 OLI/TIRS is once every 16 days. Various studies have been carried out regarding estimates of coffee plant production, where observations made from July to October have a very good spectral response for predicting coffee plant production. This is because in July–August the coffee plants are in their flowering period, and in mid-September–October the fruiting or fruit formation period begins [7, 8].

Based on inventory data from BPSA in 2015, there were around 121,273 ha of plantation area with a production output of 47,444 tons. Then in 2017, the plantation area was 123,749 ha, and the estimated production of coffee plants was 68,493 tons in Bener Meriah Regency [9].

2. RESEARCH METHOD

2.1 Research Area Study

The research object is an Arabica coffee plantation area in Bener Meriah Regency, Aceh Province, Indonesia. The coordinates of the research object are 96040'0"E and 96055'0"E, 4040'0"N and 4055'0"N, and path/row 130/57. This research uses hyperspectral images recorded by Landsat 8 OLI/TIRS in May and August 2018. Landsat 8 OLI/TIRS has a spatial resolution of 30 m/pixel (OLI) and 100 m/pixel (TIRS). This satellite records or takes pictures every 16 days. This satellite image has gone through the geometric correction stage. However, radiometric and atmospheric corrections can be done using ArcGis 10.3 software. In this research, the Landsat 8 OLI/TIRS images used correspond to the coffee growing period:

a. Coffee plant period (dormancy phase) before entering the flowering phase: Image of May 2018
b. The period when coffee plants are fruiting: Image of August 2018

It is hoped that the selection of these two coffee planting periods will make it easier for researchers to analyze the level of productivity of Arabica coffee plants in Bener Meriah Regency, Aceh Province. The use of a spatial pattern map (Fig. 2) can help researchers visually verify the map of research results.

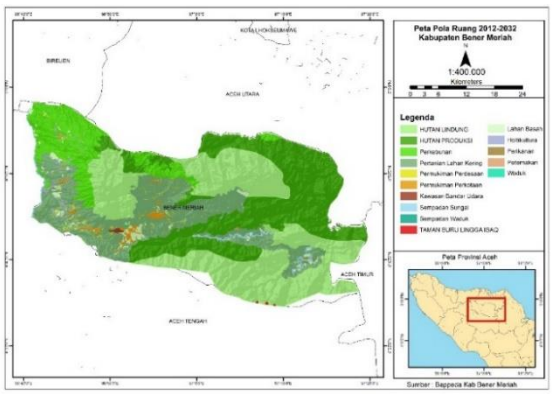

Figure 2 Map of spatial patterns 2012–2032 in Bener Meriah Regency (Iwan Tona et al.)

2.2 Satellite Imagery

a) Pre-processing Stage

Pre-processing is carried out in several stages, namely the radiometric correction stage (the digital number or DN value is converted into the TOA reflectance). This conversion is done using equation 1.

$$P\lambda' = MP \times Qcal + AP \quad (1)$$

Pλ' is TOA reflectance before correction for sun elevation (no units), Qcal is the pixel band value (digital number units), MP is the multiband reflectance value, and Ap is the add band reflectance value. Next, a correction is made to the sun's elevation angle (atmospheric correction stage) using equation 2.

$$P\lambda = P\lambda'/Sin(\theta) \quad (2)$$

Pλ is the reflectance resulting from the correction of the sun's elevation angle, and θ is the sun's elevation angle in degrees, so it needs to be converted into radians. Data regarding images can be seen in MTL.

b) *Processing* Stage

The Landsat 8 OLI/TIRS images used in this research are band 4 (red) and band 5 (NIR), which have gone through pre-processing stages (radiometric and atmospheric correction). These two bands are then used in vegetation index analysis. There are several indices used in this research, including the Normalized Difference Vegetation Index (NDVI), the Soil-Adjusted Vegetation Index (SAVI), and the tree cover or canopy-adjusted index (LAI).

Table 1. That description of spectral index data obtained from Landsat 8 data

Spectral index	Equality	reference
NDVI	NIR-Red/NIR+Red	(Tucker et.al., 1979)
SAVI	(((NIR-Red)(1+0.5))/(NIR+Red+(0.5)))	(Huete 1988)
LAI	(((-Ln (0.69-SAVI)/(0.59))/(0.9)))	(Waters et al. 2002)

The results of research conducted by [11] in the Bur NI Geureudong Volcano Area, Bener Meriah Regency, vegetation index (NDVI) distribution values were found to be 0.22 to 0.88, specifically for geothermal manifestation areas and hydrothermal mineral areas.

This research was carried out based on the research scheme shown in Figure 3.

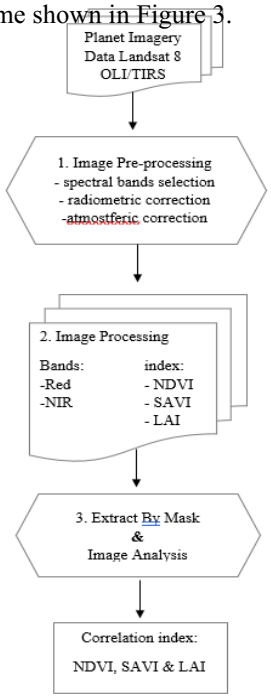

Figure 3 Research Scheme

That's why the SAVI equation includes a soil brightness correction factor (L), which is set at 0.5 to minimize the influence of soil brightness in classifying vegetation. Most studies have proven that the correlation results between the NDVI vegetation index and the LAI index can be used In this research, the Soil Adjusted Vegetation Index (SAVI) is used to analyze the vegetation index, which is influenced by the level of soil brightness, especially in areas with low vegetation.to estimate yield before harvest [10]. This means that this correlation is also able to show the level of plant productivity using remote sensing techniques. The range of NDVI index values is from -1 to 1, while the SAVI index value ranges from -0.3667 to 0.7895 [12].

The correlation of the level of accuracy of field measurements with measurements using remote sensing tools (NDVI, SAVI, and LAI) has been proven to produce very good values, namely values above 0.8R2 [13]. Based on these values, research using remote sensing can be a solution for carrying out observations, verification, validation,

and statistical analysis in making vegetation index maps.

3. FINDINGS AND DISCUSSION

3.1 Spatial Analysis of Vegetation Index (NDVI, SAVI, and LAI)

Spatial analysis of the distribution of vegetation indices (NDVI, SAVI, and LAI) was carried out based on the plant period before flowering (dormancy phase) compared to the fruiting period. The results of identifying the NDVI, SAVI, and LAI vegetation indices from this research are shown in Figures 4 and 5.

In general, the Transformation Normalized Different Vegetation Index (NDVI) index value uses electromagnetic waves of red light and near infrared light. These two wavelengths react to the chlorophyll and mesophyll content in the leaves. Chlorophyll in leaves has a high level of sensitivity (absorption) to red electromagnetic wavelengths. Meanwhile, the mesophyll in leaves has sensitivity in the form of the reflection of near-infrared light. Therefore, the level of brightness values received by satellite sensors will vary.

The NDVI vegetation index of Arabica coffee plants in this research area is considered very good, namely -0.04 to 0.85 in the period before flowering. Index values range from -0.08 to values below 0.187, indicating a non-vegetated density class.

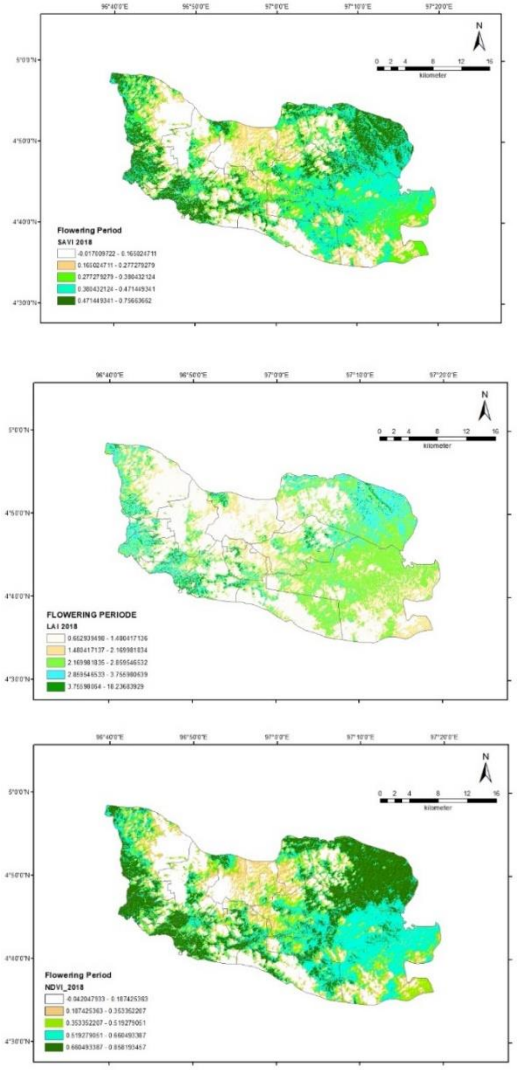

Figure 4 Arabica coffee plants before flowering (dormancy phase) in May 2018.

Vegetation index values between 0.187 and 0.353 indicate that the vegetation density class is not dense. The vegetation class with a medium density level is at a value of 0.353 to a value below 0.519. Vegetation classes with vegetation density levels are at vegetation index values of 0.519 to below 0.660. As for the very dense vegetation class, the index value ranges from 0.660 to 0.858.

The SAVI is a derivative of the NDVI vegetation index, so the values are not much different. The SAVI vegetation index has a value range of -0.017 to 0.756. On the SAVI index, the very low vegetation density class is at a value of -0.017 to below 0.165. The vegetation index in the low-density class ranges from 0.16 to below 0.380. For medium vegetation density, it is in the range of values from 0.380 to 0.471, and for high density, it is in the range of values above 0.471 to 0.756. The LAI index value ranges from 0.652 to 18.236.

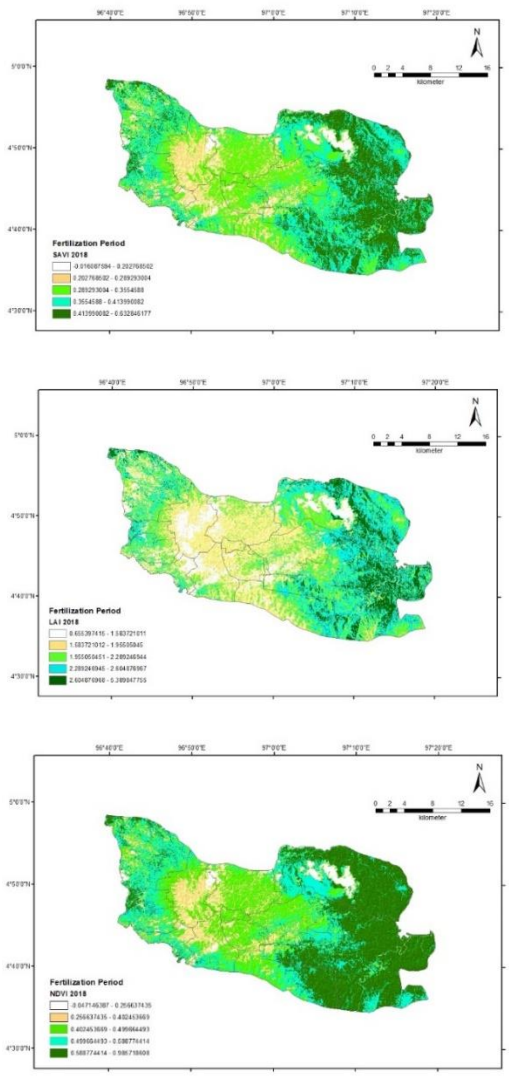

Figure 5 Arabica coffee plants fruiting period (August 2018).

The results of this test show that the research object area has a high level of leaf canopy cover and provide an overview of the productivity or production of Arabica coffee plants in the area.

The results of research on Arabica coffee plants have NDVI vegetation index values ranging from -0.047 to 0.9867, with very good vegetation density levels in August. During this month, Arabica coffee plants are in the fertilization phase. This means that there is clearly an increase in the vegetation index in this phase compared to the vegetation index value in the phase before flowering (May). Therefore, the productivity value or harvest value of coffee plants can be analyzed using the NDVI vegetation index.

The SAVI electromagnetic spectral value captured by the satellite sensor has a slightly different value, namely -0.016 to 0.632. This is influences by the brightness level of soil reflectance, which has been minimized or reduced by SAVI, so that the vegetation index value decreases slightly compared to the NDVI value.

Leaf Area Index (LAI) has a vegetation index value ranging from 0.655 to 5.389, where the value of 0.655 is close to the maximum value in SAVI.

3.2 NDVI, SAVI, and Lai Index Correlation Analysis

The correlation test results are said to be of high value if the R squared value is close to 1, whereas if it is close to 0, then the correlation value is low or not good. The results of correlation tests for several Arabica coffee plant vegetation indices are shown in Table 2.

Table 2 Vegetation Index Correlation Test Results R^2

NO	Vegetation Index Relationship	Pre-flowering period (May)	Fruiting period (August)
1	NDVI & SAVI		
2	SAVI & LAI		
3	NDVI & LAI		

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The results of the correlation test for the NDVI and SAVI vegetation indices have a high correlation value in both periods, namely a value above 0.974. Meanwhile, the correlation values for the SAVI and LAI vegetation indices have quite high differences in values between the two periods. The correlation value of the two vegetation indices in the period before flowering is $R^2 = 0.769$, and in the fruiting period it is $R^2 = 0.69$. This is influenced by the age of the plant, small leaf structure, planting deraction, and topography, so these things can reduce the accuracy of capturing the reflectance wavelength captured by the satellite sensor. This is also what can be seen in the results of the NDVI and LAI correlation tests during that period. So it can be seen that the correlation test results of several vegetation indices in the period before flowering have an average correlation value of $R^2 = 0.794$. Meanwhile, in the fruiting period, the average correlation value for the vegetation index is $R^2 = 0.954$.

4. CONCLUSION

The research results show that the remote sensing tools (NDVI, SAVI, and LAI) work very effectively during the fertilization period (August). The results obtained by the NDVI vegetation index value have a correlation coefficient value of R2 = 0.97, meaning that this vegetation index is able to estimate the productivity or yield of coffee plants very well. The SAVI and LAI vegetation index

values in this study still have inaccurate success rates. So it is necessary to carry out further research with various supporting factors in the field. This can be seen from the correlation value of the vegetation index. Based on the correlation test of the three vegetation indices (NDVI, SAVI, and 0.997 LAI), the correlation results are good and high in the fertilization phase.

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