Journal of Information Systems and Informatics
Vol. 5, No. 4, December 2023 e-ISSN: **2656-4882** p-ISSN: **2656-5935**
DOI: 10.51519/journalisi.v5i4.622 Published By DRPM-UBD

Analysis of Vegetation Changes Using Satellite Imagery and Normalized Difference Vegetation Index (NDVI): A Case Study in Tuntang District, Semarang District

Samuel Tommy Cadalora Wirawan[1], Hanna Pryllisca Chernovita[2]

[1,2]Information Systems Study Program, Satya Wacana Christian University, Salatiga, Indonesia
Email: [1]682017075@student.uksw.edu, [2]hanna.chernovita@uksw.edu

Abstract

Changes in land use from agriculture to residential and industry continue to occur in Tuntang District, and analysis is needed to identify areas experiencing the most significant changes. Development growth triggered by an increase in population can cause significant changes, such as the conversion of land from forests to agricultural land or plantations, as well as from agricultural land to residential and industrial areas. To monitor land changes, Remote Sensing is used as an effective tool. This method allows data analysis without direct contact with the object being studied. The use of Landsat-8 imagery, as a remote sensing tool, can help identify variations in vegetation. Analysis using the Normalized Difference Vegetation Index (NDVI) calculation method can provide information about the level of vegetation density in the area. The research results show significant changes in vegetation density in Tuntang District from 2019 to 2022. This change is believed to be related to the increase in population, which may be a driving force for several areas to experience development and changes in land function.

Keywords: changes in vegetation, land, Landsat 8 imagery, NDVI, remote sensing

1. INTRODUCTION

Tuntang District is located in Semarang Regency, Central Java Province, with an area of 56,242 km². This region consists of 16 villages, including Karanganyar, Kalibeji, Candirejo, Delik, Gedangan, Jombor, Karangtengah, Kesongo, Lopait, Ngajaran, Rowosari, Sraten, Tlogo, Tlompakan, Tuntang, and Watuagung. The Tuntang River, which originates from Rawa Pening Lake, crosses Tuntang District. Over time, changes in land use occurred in this region, mainly caused by community activities. This change in land function can affect soil structure and the ability to absorb soil water. Without serious action in managing land use, the risk of increasing water discharge and potential flooding around the Tuntang river could increase every year [1].

p-ISSN: **2656-5935** http://journal-isi.org/index.php/isi e-ISSN: **2656-4882**

Changes in land use from agriculture to residential and industry continue to occur in Tuntang District, and analysis is needed to identify areas experiencing the most significant changes. Development growth triggered by an increase in population can cause significant changes, such as the conversion of land from forests to agricultural land or plantations, as well as from agricultural land to residential and industrial areas. Complex interactions between space, time, biophysical and human dimensions create land use changes [2].

Tuntang District, like many regions, may have diverse ecological zones, including forests, agricultural areas, and urban landscapes. Understanding the various vegetation types is crucial for accurate analysis, as different vegetation responds differently to environmental changes. The region may undergo changes in land use over time due to urbanization, agricultural expansion, or other human activities. Monitoring these changes is essential for assessing the impact on vegetation dynamics. The local climate and weather patterns play a significant role in influencing vegetation. Factors such as precipitation, temperature variations, and seasonal changes can impact the growth and health of vegetation. Researchers need to account for these variables in their analysis [3].

The success of the analysis depends on the quality and availability of satellite imagery. Issues such as cloud cover, sensor limitations, and the frequency of image acquisition can affect the accuracy of NDVI calculations and the overall reliability of the study. Satellite imagery comes with different temporal and spatial resolutions. Researchers need to choose appropriate data based on the study objectives [4]. High temporal resolution allows for tracking changes over short periods, while high spatial resolution enables the identification of specific vegetation types. Understanding NDVI values and their interpretation is crucial. NDVI is a measure of the health and density of vegetation, but factors such as soil brightness and atmospheric conditions can influence the index. Researchers must carefully interpret NDVI values in the context of the study area [5].

To validate satellite-based findings, ground truthing is essential. Field visits and on-the-ground data collection help confirm the accuracy of satellite imagery interpretation and NDVI values. This process helps to identify any discrepancies between remote sensing data and the actual conditions on the ground. Human activities, such as deforestation, agriculture, and infrastructure development, can have a direct impact on vegetation. Researchers should consider the influence of these activities on vegetation changes and factor them into the analysis. The research should be situated within the broader policy and management context of the region. Understanding local policies related to land use, conservation, and sustainable development provides insights into the driving forces behind vegetation changes. Involving local communities in the research process can enhance the understanding of vegetation changes. Local knowledge can provide

p-ISSN: **2656-5935** http://journal-isi.org/index.php/isi e-ISSN: **2656-4882**

valuable insights into historical trends and contribute to a more comprehensive analysis [6].

To monitor land changes, Remote Sensing is used as an effective tool. This method allows data analysis without direct contact with the object being studied. The use of Landsat-8 imagery, as a remote sensing tool, can help identify variations in vegetation. Analysis using the Normalized Difference Vegetation Index (NDVI) calculation method can provide information about the level of vegetation density in the area. Survey methods, image processing and NDVI analysis are used to understand the structure and composition of vegetation, with the use of GIS software and accuracy tests in the field. Thus, remote sensing and NDVI analysis can help understand land changes and vegetation density in Tuntang District.

This research will analyze the potential for flooding around the upstream Tuntang watershed, especially in villages in Tuntang District. The data used comes from Landsat 8 OLI imagery with Bands 3, 4, 5, and 6, in the period 2019 to 2022. The method used involves NDVI calculations. In this research, the application of Radiometric correction is a method used to correct individual pixel values in the image. This is done with the aim of correcting atmospheric factors as the main source of error. The vegetation index refers to a measure of the greenness of plants produced through processing brightness data from several satellite sensor channels using digital signals [7]. To observe vegetation in the research area, the Normalized Difference Vegetation Index (NDVI) is used which functions as an indicator of the level of greenness and photosynthetic activity in plants. NDVI can show parameters such as green leaf biomass, which can be estimated for the classification of various types of vegetation. The NDVI formula can be found in Equation 1.

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

Where NON = Infrared channel reflectance value (Band 5) and RED = Red channel reflectance value (Band 4).

Table 1. NDVI Classification [8]

Class	NDVI value	Greenness Level
1	-1 < NDVI < -0.03	Non-vegetated land
2	-0.03 < NDVI < 0.15	Very Low Vegetation
3	0.15 < NDVI < 0.25	Low Vegetation
4	0.26 < NDVI < 0.35	Medium Vegetation
5	0.36 < NDVI < 1	High Vegetation

The vegetation indices in Table 1 are calculated based on the difference between the maximum absorption of radiation in the red channel, which is caused by

p-ISSN: **2656-5935** http://journal-isi.org/index.php/isi e-ISSN: **2656-4882**

chlorophyll pigments, and the maximum reflectance in the near infrared (NIR) channel, which occurs due to the cellular structure of the leaves. NDVI has a value range from -1 (nonvegetation) to 1 (vegetation). Areas with NDVI vegetation greenness levels below 0.3 are considered non-vegetative, possibly water areas or rocky soil. Areas with NDVI above 0.3 can be identified as areas covered by forests or lush vegetation. After image correction, a raster map is produced and used in NDVI analysis using band4 and band5 from the Landsat 8 [9]. The NDVI transformation in this analysis produces an index between -1 and 1. After NDVI analysis, image cropping was carried out to delimit the research area. Cropping was carried out after the image was corrected and analyzed using NDVI, according to the administrative map of Tuntang District. The cropped image will be used in the classification process [5]. The survey results, which compared random coordinate points with Google Earth, were used for classification, and the results are documented in Table 2.

Table 2. NDVI Value Based on Density

No.	Vegetation Class	NDVI value	Information
1	Non-Vegetation	< 0.1652	House, Grass, Rice Fields
2	Seldom	0.1652 - 0.2814	Bush Dominance
3	Quite thick	0.2814 - 0.319	Trees
4	Heavy	> 0.319	Forest

Table 1 notes that in the non-vegetation category, there are houses, grass and rice fields. In the Sparse Vegetation class, shrubs and bushes can be seen. Meanwhile, in the Moderately Dense Vegetation class, trees are dominant, and in the Dense Vegetation class, it characterizes the existence of a City Forest [10].

2. METHODS

The location of this study involves villages located in Tuntang District, along the Tuntang River in the upstream area of Rawa Pening Lake. Geographically, the upstream part of the Tuntang River Basin is located between 10° 15' 50" East Longitude - 110° 33' 20" East Longitude and 06° 51' 25" South Latitude - 07° 26' 40" South Latitude, with the main river stretching around 139 kilometers. Apart from the main river, the Tuntang River Basin area is also traversed by two supporting rivers, namely the Senjoyo River (area 120 km2) and the Bancak River (area 140 km2). The map in Figure 1 clearly shows the location of the study [1].

Journal of Information Systems and Informatics
Vol. 5, No. 4, December 2023

p-ISSN: 2656-5935 http://journal-isi.org/index.php/isi e-ISSN: 2656-4882

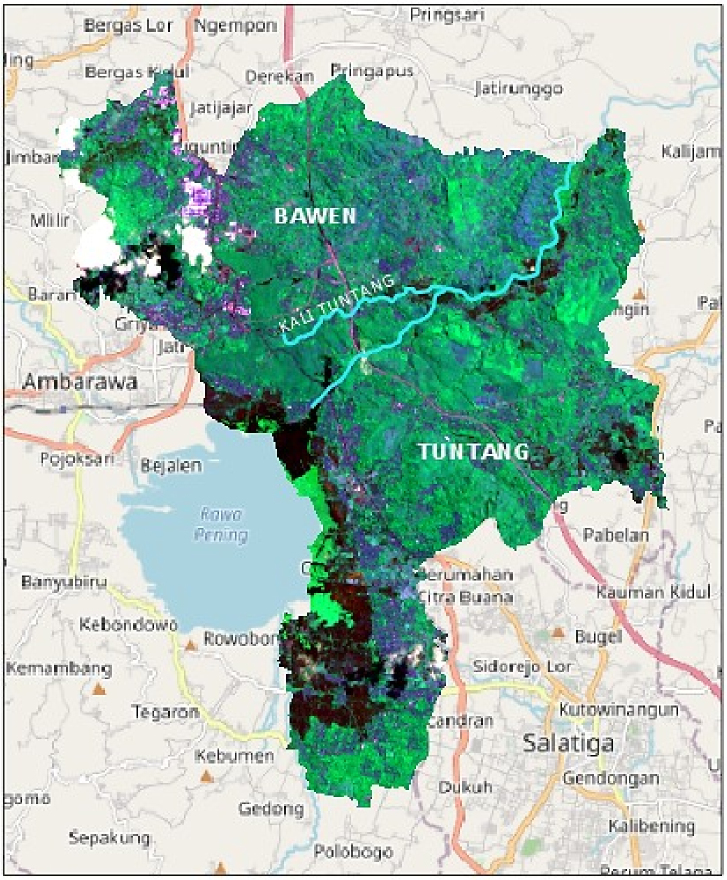

Figure 1. Research Area Map

This research utilizes the Normalized Difference Vegetation Index (NDVI) analysis method, around the river basin in Tuntang District. Data processing was carried out using Quantum GIS (QGIS) software (Anggraini, 2018). The image data used comes from Landsat 8 OLI using bands 3, 4, 5, and 6. The research period covers 2019, 2020, 2021, and 2022, with a focus on the peak of the rainy season and the peak of the dry season. The image is then subjected to atmospheric correction and cropped according to the study area. Next, analysis of the study area was carried out using the NDVI formula, to produce a vegetation classification, which was then concluded as a land cover map [11]. The research stages can be depicted in Figure 2.

p-ISSN: **2656-5935** http://journal-isi.org/index.php/isi e-ISSN: **2656-4882**

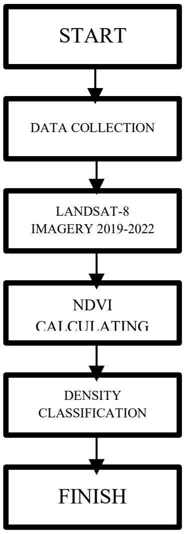

Figure 2. Research Stages

Analyzing vegetation changes using satellite imagery and the Normalized Difference Vegetation Index (NDVI) is a common approach in remote sensing and environmental monitoring [12]. The NDVI is a numerical indicator that uses the reflective properties of vegetation in the near-infrared (NIR) and red bands of the electromagnetic spectrum [13]. The following are key methods typically employed in research on the analysis of vegetation changes using satellite imagery and NDVI [14], with a case study focus on Tuntang District, Semarang District:

1) **Data Acquisition:**
   a) **Satellite Imagery:** Acquire satellite images covering the study area over multiple time periods. Common satellites used for vegetation monitoring include Landsat, Sentinel-2, and MODIS.
   b) **Temporal Resolution:** Choose imagery with appropriate temporal resolution to capture seasonal variations and changes in vegetation over time [15].
2) **Pre-processing:**
   a) **Image Correction:** Correct for atmospheric effects, such as haze and cloud cover, to ensure accurate reflectance values.
   b) **Geometric Correction:** Ensure all images are in the same coordinate system to facilitate comparison [16].
   c) **Mosaicking:** If multiple images are used, create a seamless mosaic to cover the entire study area.

3) **NDVI Calculation:**
   a) **Band Selection:** Calculate NDVI using the formula (NIR - Red) / (NIR + Red). NIR and Red bands are selected from the satellite imagery.

p-ISSN: **2656-5935** http://journal-isi.org/index.php/isi e-ISSN: **2656-4882**

   b) **Image Stack:** Stack NDVI images for different time periods to create a time series dataset.
4) **Change Detection:**
   a) **Thresholding Techniques:** Apply thresholding methods to classify areas into different vegetation density categories based on NDVI values.
   b) **Supervised or Unsupervised Classification:** Use classification algorithms to identify and classify changes in vegetation cover.
5) **Spatial Analysis:**
   a) **GIS (Geographic Information System):** Utilize GIS software to analyze and visualize spatial patterns of vegetation changes.
   b) **Zonal Statistics:** Calculate statistics (mean, standard deviation, etc.) for different zones within the study area to quantify changes.
6) **Temporal Analysis:**
   a) **Time Series Analysis:** Examine the temporal patterns of NDVI over the study period to identify trends, seasonality, and anomalies.
   b) **Statistical Analysis:** Use statistical methods to assess the significance of observed changes.
7) **Validation:**
   a) **Field Validation:** Validate the results by comparing them with ground truth data collected from field surveys or other reliable sources.
   b) **Accuracy Assessment:** Perform accuracy assessments to evaluate the reliability of the classification results.
8) **Interpretation and Reporting:**
   a) **Spatial Patterns:** Interpret spatial patterns of vegetation changes in the study area.
   b) **Temporal Trends:** Discuss temporal trends and variations in NDVI values.
   c) **Implications:** Provide insights into the potential causes and consequences of observed vegetation changes.
9) **Case Study Specifics:**
   a) **Local Factors:** Consider local factors such as land use changes, climate, and human activities that may influence vegetation dynamics in the Tuntang District.

3. RESULTS AND DISCUSSION

This research uses Landsat 8 OLI imagery taken during the peak rainy and dry seasons every year, from 2019 to 2022. This data will be used as a reference for assessing the condition of vegetation, humidity levels and the status of green open spaces around the river Basin (DAS) Tuntang. Comparisons will be made from year to year during this period, with the research focus focused on Tuntang District, Central Java.

p-ISSN: 2656-5935 http://journal-isi.org/index.php/isi e-ISSN: 2656-4882

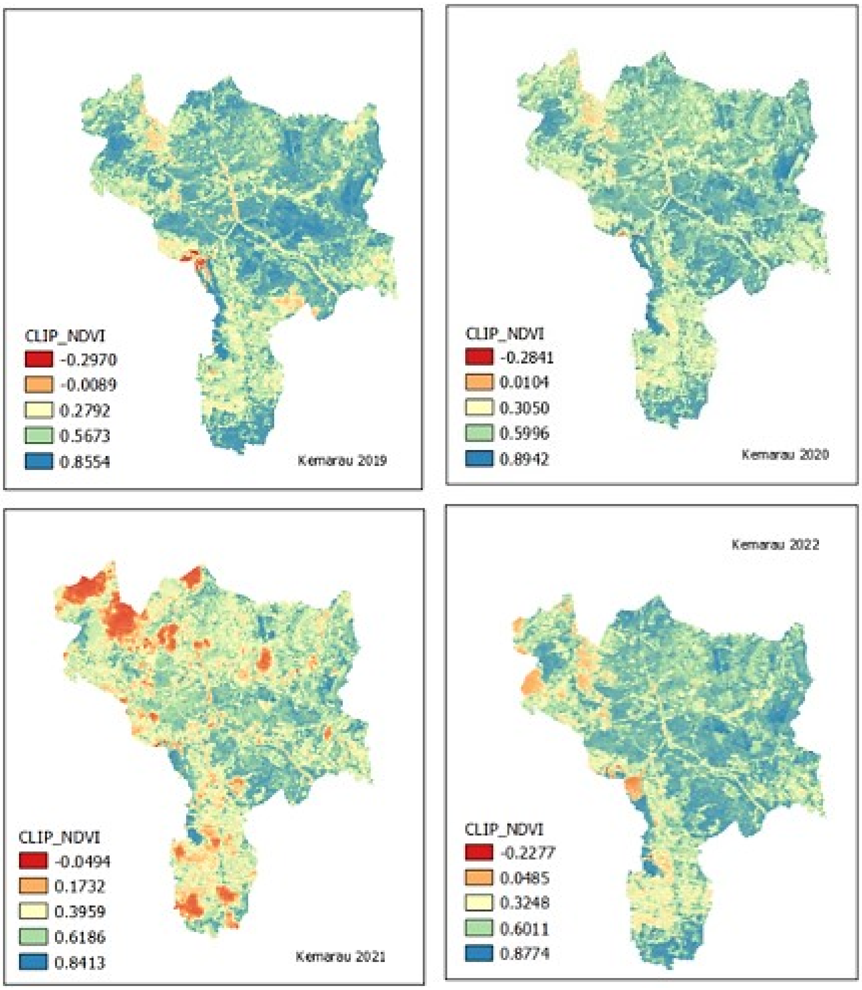

Figure 3. NDVI peak dry season 2019 – 2022

Evaluation of the results of the calculation of the Normalized Difference Vegetation Index (NDVI) in Figure 3 illustrates that the condition of the vegetation in the area remains satisfactory. The NDVI classification shows a relatively uniform level of greenness, from medium to high levels of greenness. For example, even though there was a decrease in the NDVI value from 0.4515583318 in 2019 to 0.408982064 in 2022 in Sraten Village, this value is still in the moderate greenness category. In contrast, Tlompakan Village recorded the highest increase in NDVI value from 0.6777772025 in 2019 to 0.6829112817 in 2022. Therefore, NDVI analysis in Tuntang District shows small fluctuations in the greenness of vegetation during this period. In other words, the vegetation can be still in good condition. Detailed comparisons of NDVI values from the four years can be found in Figure 4.

Journal of Information Systems and Informatics
Vol. 5, No. 4, December 2023

p-ISSN: **2656-5935** http://journal-isi.org/index.php/isi e-ISSN: **2656-4882**

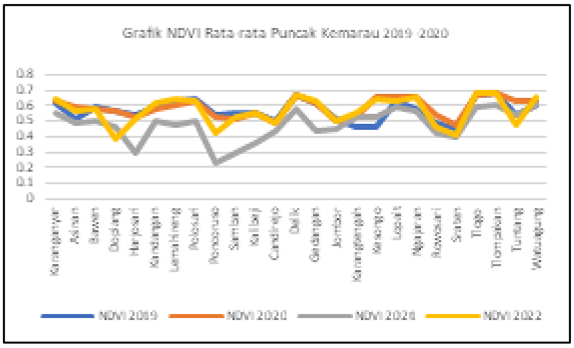

Figure 4. 2019-2022 Dry Peak Average NDVI Graph

The resulting classification of vegetation density levels in Landsat-8 images in Tuntang District in the 2019-2022 period is divided into five classes, using class intervals based on NDVI density in satellite images. These classes include:

1. High Density Class

This class category can be identified if the entire land area is covered with lush vegetation and is characterized by a dense number of trees, blocking direct sunlight from reaching the ground. In 2019, the vegetation density area reached 60,369 hectares, decreased to 55,054 hectares in 2021, and decreased further to 5,925 hectares in 2022.

Table 3. Vegetation Area in the High-Density Class Category in 2019-2022

Year	High Density Class Vegetation Area (ha)
2019	60,369
2021	55,054
2022	5,925

2. Medium Density Class

This class can be recognized if the vegetation cover on the ground surface is quite abundant with many trees growing touching or not touching each other, while buildings are rare. In 2019, the area of this vegetation density class was 1,692.74 hectares, but in 2021 the area increased to 3,648.54 hectares, while in 2022 the area reached 2,652.19 hectares. So, the difference in density between 2019 and 2022 is 2,652.19 hectares.

Table 4. Vegetation Area in the Medium Density Class Category in 2019-2022

Year	Medium Density Class Vegetation Area (ha)
2019	1,692.74
2021	3,648.54
2022	2,652.19

p-ISSN: **2656-5935** http://journal-isi.org/index.php/isi e-ISSN: **2656-4882**

3. Low Density Class

This class can be recognized by looking at the proportion of land that is still dominated by vegetation rather than buildings in an area, with the plants planted not being to spread out. In 2019, this class had an area of around 1,136.47 hectares, while in 2021, the vegetation area increased to 2,329.93 hectares, but in 2022 it decreased to 1,268.03 hectares.

Table 5. Vegetation Area in the Low-Density Class Category in 2019-2022

Year	Low Density Class Vegetation Area (ha)
2019	1,136.47
2021	2,329.93
2022	1,268.03

4. Very Low-Density Class

This class can be recognized if the land area has experienced an increase in the number of buildings and a decrease in open land that is not covered with grass. There are only a few scattered shade trees resulting in direct sun exposure on non-vegetated surfaces. In 2019, the area of this class reached 906.49 hectares, then in 2021 it increased to 2,933.85 hectares, and in 2022 it decreased to 1,674.71 hectares.

Table 6. Vegetation Area in the Very Low-Density Class Category in 2019-2022

Year	Very Low-Density Class Vegetation Area (ha)
2019	906.49
2021	2,933.85
2022	1,674.71

5. Class Not Vegetated

This class can be identified when the land conditions are reservoirs, waters, lake ponds. Apart from that, in the irrigated rice fields there is still a lot of stagnant water, and the rice plants are still in the initial growth stage. In 2019, the class area without vegetation reached 128.96 hectares; in 2020, it increased to 265.33 hectares; and in 2022, it will reach 1695.29 hectares. So, significant changes occurred in this class between 2019 and 2022, with an increase of approximately 1,866.33 hectares.

Table 7. Vegetation Area in the Density Class Category Not Vegetated in 2019-2022

Year	Vegetation Area Density Class Not Vegetated (ha)
2019	128.96
2021	265.33
2022	1695.29

p-ISSN: **2656-5935** http://journal-isi.org/index.php/isi e-ISSN: **2656-4882**

4. CONCLUSION

Based on the analysis carried out in this research, it can be concluded that there has been a significant change in vegetation density in Tuntang District from 2019 to 2022. In the high vegetation density class category, it decreased by 54,444 hectares. In the medium, low, very low and non-vegetated density classes, there was an increase of around 1,866.33 hectares. This change is believed to be related to the increase in population, which may be the impetus for some areas to experience development and changes in land function. Research suggestions can be developed to conduct research on flood potential analysis to analyze areas, especially villages that are potentially prone to flooding around the Tuntang River Basin in Tuntang District.

REFERENCES

[1] K. Semarang, "Semarang Regency District, 'Strategic Data for 2019, 2021 and 2022', [Online]. Available: https://ppid.semangkab.go.id/. [Accessed: Oct. 25, 2023]."
[2] P. U. Hardianto, T. Urmala Dewi, T. Feriansyah, N. F. Sekar Sari, and N. S. Rifiana, "Utilization of Landsat 8 Imagery in Identifying Vegetation Density Index (NDVI) Values for 2013 and 2019 (Study Area: Bandar Lampung City)," *J. Geosci. Remote Sens.*, 2021.
[3] M. Lestari et al., "Analisis Daerah Rawan Banjir Pada Daerah Aliran Sungai Tuntang Menggunakan Skoring dan Inverse Distance Weighted," *J. Comput. Model.*, vol. 4, no. 1, pp. 1–9, 2021.
[4] S. Garcia et al., "Temporal Analysis of Vegetation Changes in Urban Areas Using Landsat Imagery and NDVI," *Remote Sens. Lett.*, vol. 15, no. 4, pp. 321-334, 2022.
[5] M. A. Lasaiba and A. W. Saud, "Utilization of Landsat 8 OLI/TIRS Imagery to Identify Vegetation Density Using the Normalized Difference Vegetation Index (NDVI) Method in Ambon City," *Geogr. J.*, 2022.
[6] A. K. Patel et al., "Comparative Study of NDVI and MODIS Time Series for Vegetation Analysis in Arid Regions," *J. Environ. Monit.*, vol. 18, no. 6, pp. 789-801, 2022.
[7] Y. Riko et al., "Land Conversion Changes Using NDVI, EVI, SAVI and PCA on Landsat 8 Imagery (Case Study: Salatiga City)," *Indonesia, J. Comput. Model.*, vol. 1, pp. 25–30, 2019.
[8] Mangiri, "GIS-Based Land Use Analysis Using Landsat 8 Imagery in Enrekang Regency," 2018.
[9] M. Fauzan et al., "Analysis of Changes in Vegetation Density Using Multitemporal Landsat-8 Imagery in West Bandung Regency," *Geogr. J.*, 2022.
[10] L. Zhang et al., "Remote Sensing of Vegetation Changes in Wetlands Using NDVI Time Series," *Wetlands Ecol. Manag.*, vol. 22, no. 5, pp. 567-578, 2022.

p-ISSN: **2656-5935** http://journal-isi.org/index.php/isi e-ISSN: **2656-4882**

[11] M. C. Williams et al., "Assessing Land Cover Changes with MODIS NDVI Time Series Analysis," *Int. J. Appl. Earth Obs. Geoinf.*, vol. 25, no. 3, pp. 123-135, 2022.

[12] J. A. Smith and R. B. Johnson, "Vegetation Monitoring Trends: A Review of Satellite Imagery and NDVI Applications," *J. Remote Sens.*, vol. 10, no. 2, pp. 45-67, 2022.

[13] Q. Yang and Z. Li, "Integration of Landsat and Sentinel-2 Data for Improved NDVI Monitoring of Vegetation Dynamics," *Int. J. Remote Sens.*, vol. 30, no. 8, pp. 1123-1134, 2022.

[14] L. Xu and A. Samanta, "Satellite-based analysis of vegetation dynamics in relation to climate variability," *Adv. Space Res.*, vol. 60, no. 3, pp. 542-553, 2019.

[15] H. Saidah et al., "Analysis of Drought Index and Distribution Using the Standardized Precipitation Index (SPI) and Geographical Information System (GIS) Methods for Lombok Island," *J. Spektran*, vol. 5, no. 2, pp. 173–179, 2017.

[16] N. Anggraini et al., "Ujung Pangkah Shoreline Change Analysis Using Edge Detection Method and Normalized Difference Water Index," *J. Remote Sens. Process. Digit. Image Data.*, vol. 14, no. 2, pp. 65–78, 2018.