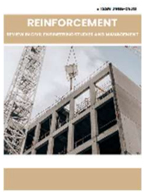
Reinforcement Review in Civil Engineering Studies and Management 4(2), pp. 62-76 (2025)
https://doi.org/10.38043/reinforcement.v4i2.7014



Reinforcement Review in Civil Engineering Studies and Management
E-ISSN: 2986-0520

Journal homepage:
https://journal.undiknas.ac.id/index.php/reinforcement/index

NDVI Based Vegetation Dynamics in Jember Regency from 2019 to 2024 Using Multitemporal Landsat 8 Imagery

Igor Aviezena Eris[a,], Syavitri Sukma Utami Rambe[b], Loetvy Wahyuningtiyas[c]
[a,b,c]Universitas Jember, Jember
**Corresponding author, e*mail address: igor.a.e@unej.ac.id

A R T I C L E I N F O
Article history:
Received: 3 Mei 2025
Revised: 5 Juli 2025
Accepted: 20 Agustus 2025
Available Online: 25 November 2025

Kata Kunci:
Normalized Difference Vegetation Index (NDVI), Dinamika Vegetasi, Perubahan Lahan, Landsat 8, Kabupaten Jember

Keywords:
Normalized Difference Vegetation Index (NDVI), Vegetation Dynamics, Change Detection, Landsat 8, Jember Regency

A B S T R A K

Dinamika perubahan vegegtasi di Kabupaten Jember merupakan salah satu indikator penting yang menggambarkan keadaan lingkungan yang banyak dipengaruhi oleh faktor antropogenik. Kabupaten Jember sebagai wilayah dengan sektor pertanian dan kehutanan yang sangat penting dalam perekominia wilayah, menyumbang 25,71% terhadap PDRB. Sehingga, berdasarkan kondisi tersebut, pemantauan perubahan vegetasi ini dirasakan merupakan langkah yang sangat penting. Penelitian ini dilakukan untuk menganalisis perubahan vegetasi secara temporal dari tahun 2019 hingga 2024 menggunakan citra Landsat 8 OLI/TIRS pada platform cloud computing Google Earth Engine. Metode yang digunakan meliputi kalkulasi Normalized Difference Vegetation Index (NDVI), klasifikasi tiap hirarki perubahan vegetasi menggubakan metode Natural Breaks (Jenks), serta analisis statistik zonal untuk membandingkan tren perubahan kerapatan vegetasi antar wilayah perkotaan dan perdesaan. Hasil dari penelitian ini menunjukan kesenjangan perubahan kerapatan vegetasi antar wilayah perdesaan dan perkotaan (Kecamatan Patrang, Kaliwates dan Sumbersari). Wilayah kota mengalami degradasi, terlihat dari nilai mean NDVI menurun rata-rata sebanyak 8% per tahun dari 0.500 pada tahun 2020 menjadi 0.460 di tahun 2024 yang menunjukkan konversi lahan pertanian/bervegetasi menjadi lahan terbangun. Sebaliknya, wilayah perdesaan cenderung stabil di angka 0.584 hingga 0.554 dalam periode yang sama. Analisis zona pada peta perubahan vegetasi menunjukkan bahwa lebih dari 12.000 hektar lahan mengalami degrasai vegetasi yang didominasi di wilayah perkotaan Kabupaten Jember. Sementara di wilayah perdesaan, seperti di sekitar wilayah Gunung Gambir menunjukkan stabilitas atau justru mengalami peningkatan kerapatan vegetasi berkat pengeloaan perkebunan yang berkelanjutan. Temuan ini menberikan bukti kuantitatif dampak urbanisasi terhadap kelangsungan lingkungan hidup dan menegaskan perlunya kebijakan untuk menyeimbangkan pembangunan dengan konservasi lahan bervegetasi untuk memelihara kelestarian alam dan vegetasi yang menopang keberlangsungan ekonomi dan ekosistem di Kabupaten Jember.

A B S T R A C T

Vegetation dynamics in Jember Regency serve as a crucial indicator of environmental conditions influenced by anthropogenic factors. As a region where the agriculture and forestry sectors play a vital role in the local economy, contributing 25.71% to the Gross Regional Domestic Product (GRDP), monitoring vegetation change is highly important. This study aims to analyze temporal vegetation change in Jember Regency from 2019 to 2024 using Landsat 8 OLI/TIRS imagery processed on the Google Earth Engine cloud computing platform. The methods employed included calculating Normalized Difference Vegetation Index (NDVI), classifying vegetation change hierarchy using the Natural Breaks (Jenks) method, and conducting zonal statistical analysis to compare vegetation density trends between urban and rural areas of Jember Regency. This research revealed a disparity in vegetation density change between rural and urban areas (Patrang, Kaliwates, and Sumbersari Sub-Districts). Urban areas of Jember experienced degradation, with the mean NDVI value decreasing by 8% per year, from 0.500 in 2020 to 0.460 in 2024, indicating the conversion of agricultural/vegetated land into built-up areas. In contrast, rural areas were determined to be relatively stable, with NDVI mean value ranging from 0.584 to o.554 during the same period. Zonal analysis of the vegetation change map showed that more than 12,000 hectares of land underwent vegetation degradation, predominantly in urban areas of Jember Regency. Meanwhile, rural areas around Mount Gambir exhibited stability or increased vegetation density due to sustainable plantation management. These findings provide quantitative evidence of the impact of urbanization on environmental sustainability and emphasize the need for policies that balance development with the conservation of vegetated land to maintain ecological integrity and support the local economic and ecosystem sustainability of Jember Regency.

1. INTRODUCTION

Vegetation plays a fundamental role in terrestrial ecosystems, particularly in maintaining environmental stability and supporting human socio-economic activities [1]. It regulates the climate, prevents soil erosion, supports biodiversity, and sustains human life through agriculture and forestry [2], [3]. However, vegetation sustainability constantly changes due to natural processes and human intervention. The increasing population and demand for space drive the conversion of natural landscapes into agricultural and urban development areas [4], [5], [6]. According to the Central Bureau of Statistics of Jember, the population in Jember is reaching about 2.61 million people in 2024. This significant population pressure inevitably increases the demand for land and natural resources, making it essential to monitor the spatiotemporal pattern of vegetation change to understand the impacts of human intervention and formulate future sustainable spatial management policies.

In the context of Jember Regency, where agriculture and forestry become the primary commodities of the local economy, contributing to 25,71% of total Gross Regional Domestic Product (GRDP or PDRB) according to the Central Bureau of Statistics of Jember in 2024, monitoring vegetation change is not just an environmental concern, but also an economic imperative. The primary commodities, such as tobacco (covering 3,233 hectares), coffee (5,290 hectares), and sugarcane (4,901 hectares) [7], are directly represented by their vegetative health and spatial extent, making these crops one of the primary indicators of the region's economic and environmental health. However, in this case, the vegetative cover is dynamic, it fluctuates annually due to the agricultural cycle [8], [9], expands or contracts with the forestry management [10], and is increasingly pressured by urban and infrastructural development [11]. These conditions highlight the need for accurate and systematic vegetation monitoring in Jember Regency.

Thus, there is a pressing need to develop a dynamic, multi-temporal map of vegetation change. Existing research on land cover change in Indonesia often still focuses on major deforestation events or the availability of green spaces in the urban area, without assessing vegetation change or utilizing outdated data. However, a comprehensive analysis quantifying subtle, yet critical, vegetation density, especially in a non-dominant region like Jember, remains limited. This research fills this void by leveraging the power of Google Earth Engine cloud computing to process entire Landsat 8 archives, creating annual cloud-free composites that minimize noise and enable a precise assessment of temporal change trends. By doing so, it provides a contemporary and detailed baseline of the most recent vegetation dynamics that are relevant to current development pressures. This research is purposed to quantify where vegetation is being lost, maintained, and potentially regenerating or increasing in density, providing the objective evidence base for spatial planning, agricultural sustainability, conservation monitoring, and policy evaluation. Landsat 8 imagery which utilized in this reseach is a well-known remote sensing image with a consistent and long-term archive, ideal for vegetation dynamic distribution change, by the Normalized Difference Vegetation Index (NDVI) transformation method, which is widely utilized to detect the vegetation distribution according to the vegetation's unique reflectance, pigment absorptions, and leaf wetness [12] by estimating the normalized difference of Near Infrared (NIR) and red bands [13], [14]. Using multi-temporal NDVI analysis, enabling effective classification and tracking of change in vegetation coverage overtime.

2. THEORETICAL FRAMEWORK

2.1. Theoretical Foundation of Remote Sensing for Vegetation Monitoring

Remote sensing, the art and science of acquiring information about Earth's surface without direct contact, typically from aircraft or satellites, is founded on the principle that every material uniquely absorbs and reflects electromagnetic radiation, resulting in a distinct spectral signature [15]. The Red and NIR bands reflectance becomes the most important electromagnetic spectrum for detecting vegetation health [16] since healthy vegetation's leaf green chlorophyll might absorb the visible red band radiation [17] and could potentially reflect 40% to 60% of NIR infrared radiation [18]. This contrast between radiation absorption and reflection forms the basis for most vegetation indices.

2.2. The Normalized Difference Vegetation Index (NDVI): Concept and Application

NDVI is a simple yet powerfull transformation numerical indicator that reveal the spectral contrast in vegetation. It utilized Near Infrared and Red band which the output values range from 0.1 to -0.1 [19], generally the positive or high value represent dense, healhty vegetation while low value represent water, open space and build up area, and near zero value indicating rock or soil object [20], [21]. Due to its simplicity and reliability, NDVI become one most popular method in remote sensing and GIS that might resulting diverse maps such as vegetation health index map, vegetation density, crop health assessment, monitoring drought stress, deforestation [22], [23], [24].

2.3. The Use of Landsat Multitemporal Data for Vegetation Chane Detection

Lansat 8 image is continously acquisiting imagery data since 1972 which in this case is providing unparalled multitemporal analysis. The Landsat 8 which launched in 2013 ensured the continuity of this data data stream by improved censor system. The Landsat 8's 30 meters spatial resolution is suitable for 1:50.000 to 1:100.000 map's scale might capture a wide area and its 16 days of temporal resolution or revisit period allow for the construction of dense time series.

Studies by Raynolds et al. [25] and Bervegliere et al. [26] demonstrated robust method using Landsat time series to detect vegetation change in gradual trends of vegetation using NDVI method. The use of cloud computing platform like Google Earth Engine has now made the processing of satellite imagery which has large size in files became more feasible and efficient, enabling the type of analysis conducted in present studies.

3. METHODS

This research was compiled with a structured workflow to analyze the vegetation change in Jember Regency. The process started by importing Jember's regional boundary into Google Earth Engine and calling the USGS Landsat 8 Collection 2 Tier 1 TOA Reflectance image collection from the library. Then, after applying the cloud masking and calculating the annual NDVI composites, the vegetation change was compiled by subtracting the 2019 NDVI composite from the 2024 composite and reclassifying the subtracted maps by the Natural Break (Jenks) method. The last process was zonal analysis, which was used to observe the vegetation change distribution within the Jember area and quantify the vegetation change. The final output is a comprehensive vegetation change distribution map, highlighting the areas of gain and loss.

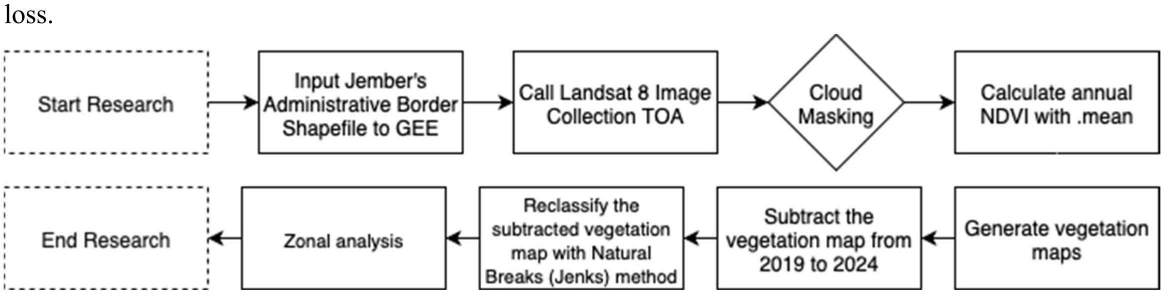


Figure 1. Research Flowchart

3.1. Data Collection

The primary data used in this research were multispectral imagery obtained from Landsat 8 OLI/TIRS imagery. The image were collected and processed in the Google Earth Engine (GEE) cloud computing platform using the "LANDSAT/LC08/C02/T1_TOA" image collection. This collection provides Top-of-Atmosphere (TOA) reflectance data, which has undergone systematic radiometric and geometric correction, and classified as Tier 1, representing the highest quality data suitable for time-series processing analysis. The Landsat 8 OLI/TIRS in this research that TOA corrected applies censor-specific radio calibration coeffecients [27] minimizes inter scene variability caused by solar illumination angles and atmospheric effects. This image correction standarization ensures the data is geographically consistent and temporally comparable [28] providing a reliable basis for multi-temporal analysis of vegetation dynamic across Jember Regency. To minimize atmospheric contamination from clouds and haze, the image collection of Landsat 8 OLI/TIRS offers per pixel mask, which in this image properties might mask cloud, cirrus cloud, cloud shadow and snow [29] which the dataset also allow filtered within GEE using the image's inheren cloud cover metadata which in this research, selecting scene with less than 15% of cloud coverage over the Jember area.

Prior to analysis, the Landsat 8 imagery was pre-processed to minimize the clouds which is the atmospheric disturbance. Cloud masking procedure was implemented using quality assessment "QA_PIXEL" that available within the Landsat 8 collection dataset. This band was used to mask out pixels classified as clouds, cirrus cloud and cloud shadows, ensuring that only clear sky observation were included in the subsequent compositing process.

To generate a cloud-masked, representative image for each annual epoch from 2019 to 2024, all available scenes within each full calendar year from the first of January to 31st of December were compiled. for each year, an annual composite image was created by calculating the mean value for each pixels across all available observation. To accommodate this the ".mean ()" used on compositing image, aggregating all images in the collection library into a single image where each pixel's value represent the mean of corresponding pixels across all image to create a cloud free compositing image over the specific research period that will significantly provides better accuracy and performance [30].

3.2. NDVI Calculation

The Normalized Difference Vegetation Index (NDVI) in this research was calculated for every individual Landsat 8 scene in the collection for each year in 2019 to 2024. The cloud free images on each observation time calculated using standard NDVI calculation as follows:

$$NDVI = \frac{NIR-R}{NIR+Red} \tag{1}$$

Where NIR (Near Infrared) is band 5 and red is Band 4 of Landsat 8 OLI/TIRS TOA reflectance data. As mentioned in the dataset sub-section, annual composite NDVI image for each year was generated by applying the ".meas ()" reducer to all calculated NDVI values for each pixel across the entire calendar year. This process resulted in six annual NDVI maps which each map representing the average vegetation density for its respective year which already been minimized atmospheric and seasonal noise.

The annual NDVI composites were classified into distinct vegetation density classes using Natural Breaks (Jenks) classification method which will minimize the variance within classes and improving statistical accuracy [31], [32], thereby identifying inherent groupings in the data distribution specific to Jember Regency. The vegetation density in this research classified into 5 classes namely non-vegetated, sparse vegetation, moderate vegetation, dense vegetation and very high vegetation.

https://doi.org/10.38043/reinforcement.v4i2.7014

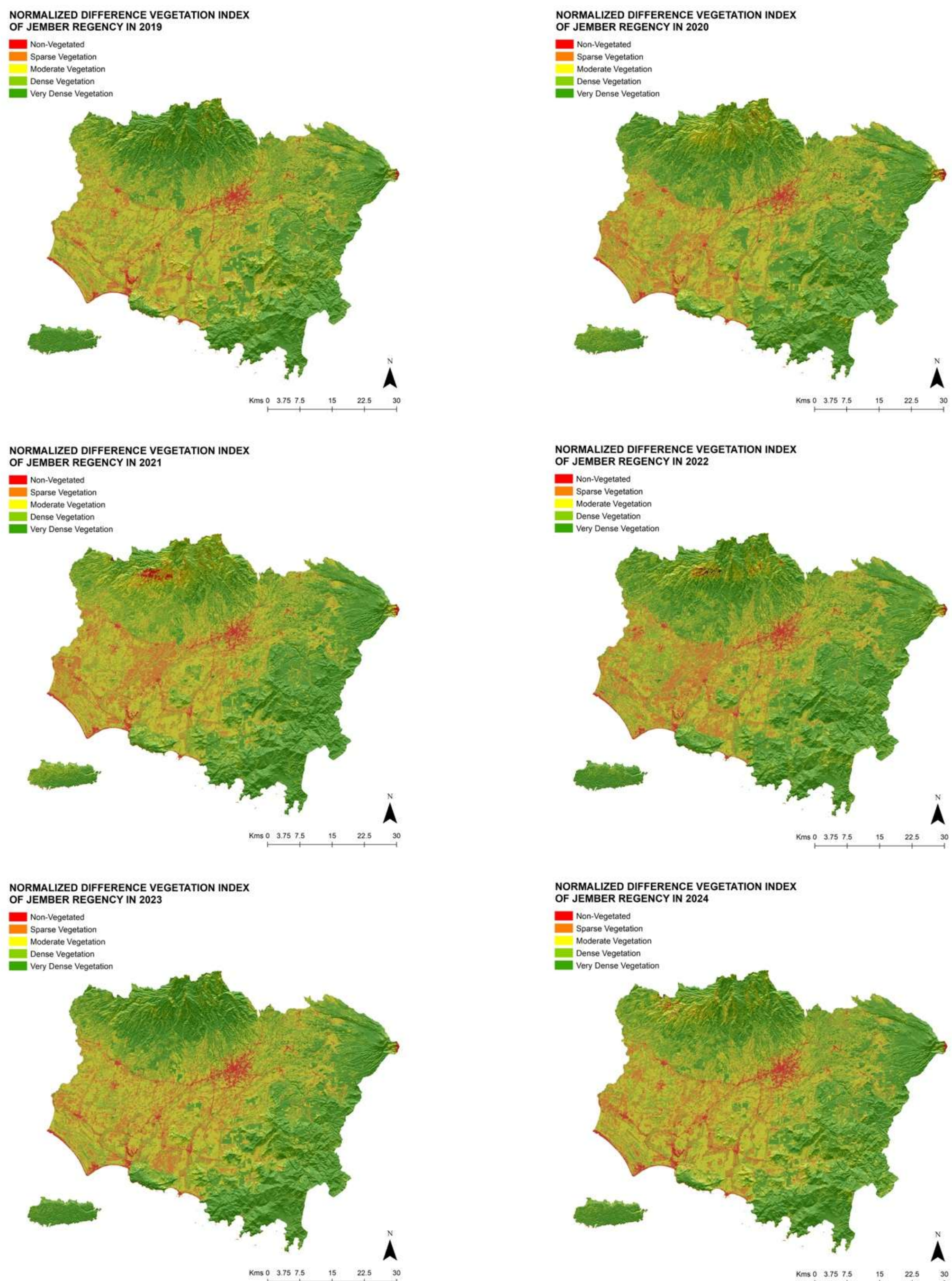


Figure 2. NDVI Transformation of Jember in 2019 to 2024

3.3. Change Detection and Trend Analysis

To visualize and quantify the geographical distribution of vegetation change, the map was creatied by subtracting the longer year with the latest year, for example "NDVI_2024 – NDVI_2019". This simple differencing technique highlights pixels that indicates regenerating vegetation (positive value) or degrading (negative value) over the five years of period. The geographical distribution visualization of vegetation change created by comparing the classified maps for 2019 to 2024. The map highlights pixel that changes such as from the high density to moderate or lower and vice versa, providing spatial context to the areal statistic.

Then, to quantify and compare the trends in vegetation density between land use types, a zonal statistical analysis was conducted on compiled vegetation change map (2019 – 2024) derived from the reclassification process. The objective of this analysis was to calculate the area and precentage of each type of vegetation change category within Jember area. This allows for a direct comparison of how landscape has been transformed in urban versus rural context in the five years of research period. The result of this process was statistical summary table that provides the information of proportion of land that experienced degradation, improvement or remained stable within the Jember Regency area.

4. RESULT AND DISSCUSSION

4.1. Spatial Distribution and Temporal Dynamics of NDVI

The NDVI serves as a critical remote sensing tool, providing a standardized measure to quantify and monitor the density of green vegetation across diverse landscapes. By calculating the contrast between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs), NDVI allows for the effective comparison of vegetation dynamics over time and space. To move beyond simply mapping where changes have occurred and towards a more nuanced understanding of why they happen, it is essential to interrogate the relationship between observed vegetation trends and underlying land use functions. A pivotal step in this process is to analyze not just the total area of change, but the proportional contribution of each land use type to specific categories of vegetation dynamics. **Table 1** below presents the results of this proportional analysis, which contains a comparison of vegetation cover in land use based on 5 classifications.

Table 1. Vegetation Density Classification Based On Land Use 2019-2024

DISTRICT	CLASSIFICATION (Km^2)				
	1	2	3	4	5
Ajung	4.1514	12.1255	22.6642	16.0110	5.0569
Ambulu	3.3196	15.2643	42.3704	41.8402	11.9410
Arjasa	0.2342	2.5387	13.4617	15.3992	2.5627
Balung	3.2882	17.5928	18.0933	9.2836	2.3529
Bangsalsari	9.6506	44.8840	60.3317	35.3541	9.2818
Gumukmas	4.7021	19.0284	33.5502	26.6415	8.0656
Jatiroto	0.0001	0.0015	0.0020	0.0018	0.0021
Jelbuk	0.7308	10.9004	33.6706	24.2507	4.1750
Jenggawah	1.0980	10.4097	27.8505	18.2537	3.7057
Jombang	2.2957	15.9269	20.4302	13.0490	3.8085
Kalibaru	0.0000	0.0001	0.0006	0.0006	0.0001
Kalisat	0.8217	5.1311	22.1146	21.4131	3.0316
Kaliwates	1.1210	3.3541	9.8413	8.1196	1.9014
Kencong	3.2837	19.0606	21.9630	12.3625	2.7831
Krucil	0.0000	0.0001	0.0004	0.0004	0.0001
Ledokombo	1.4979	17.9630	52.1738	45.4034	14.7424
Maesan	0.0000	0.0000	0.0002	0.0001	0.0000
Mayang	1.2967	6.2525	20.1010	23.5155	6.5036
Mumbulsari	3.9376	14.5608	28.4079	29.0200	21.2539
Pakem		0.0000	0.0001	0.0001	0.0000
Pakusari	0.5394	3.2050	13.5832	12.1889	1.6645

DISTRICT	**CLASSIFICATION (Km²)**				
	1	**2**	**3**	**4**	**5**
Panti	3.9310	46.9968	80.0694	42.1798	7.5197
Patrang	1.1975	5.4673	16.5154	12.3401	2.4923
Pesanggaran	0.0001	0.0003	0.0007	0.0003	0.0001
Puger	3.2134	30.9438	72.7451	42.4440	9.4140
Rambipuji	1.5351	9.0614	22.8522	18.7108	4.4351
Randuagung	0.0001	0.0007	0.0013	0.0029	0.0034
Rowokangkung	0.0004	0.0009	0.0011	0.0009	0.0002
Semboro	0.4401	5.5799	12.3309	13.1910	5.6775
Silo	7.4479	30.9647	99.6834	133.3600	51.4867
Sukorambi	0.4974	8.7106	22.6241	12.9286	2.1968
Sukowono	0.4439	3.4641	15.9226	20.6419	4.2317
Sumberbaru	9.5467	26.9476	44.3905	47.7953	24.5199
Sumberjambe	1.3199	11.1766	38.6954	53.7487	26.9206
Sumbersari	1.8744	6.8180	15.6628	9.9323	2.3301
Tamanan	0.0000	0.0000	0.0002	0.0004	0.0001
Tanggul	23.2323	57.9175	62.6325	46.6352	21.7068
Tempurejo	17.1643	77.9348	201.6540	185.0920	44.8024
Tiris	0.0000	0.0002	0.0003	0.0002	0.0001
Tlogosari	0.0000	0.0000	0.0001	0.0002	0.0003
Umbulsari	2.4249	18.5877	25.1859	19.1735	5.8348
Wuluhan	2.0633	20.2589	45.3917	41.8386	14.4116
Yosowilangun	0.0000	0.0010	0.0009	0.0013	0.0025
Total	**118.3014**	**579.0325**	**1216.9712**	**1052.1269**	**330.8195**

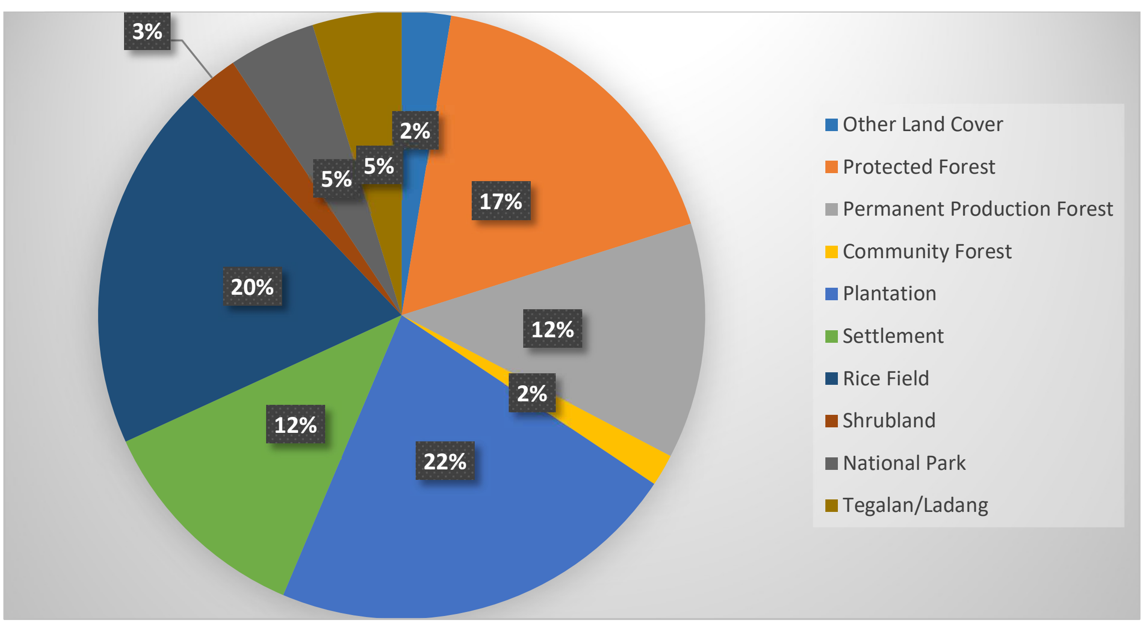


Figure 3. Land use in Jember Regency 2019-2024

The data reveals a clear inverse relationship between urban development and vegetation stability. The districts with the most stable and extensive vegetation cover are Silo, Tanggul, and Tempurejo, among the largest in Jember and, significantly, are characterized by lower population growth rates [33] . In stark contrast, the districts of Kaliwates, Patrang, and Sumbersari show the most diminished vegetation cover. This is not merely a function of their smaller areal size but is directly driven by their higher population growth rates and their official designation as Regional Activity Centers (PKW) based on the Jember Regency Spatial Plan (RTRW) 2015-2035. This PKW status prioritizes land allocation for organizational, commercial, service, and educational functions, leading to extensive built-up expansion. Consequently, the minimal vegetation cover in these urban cores exemplifies the direct impact of planned urban sprawl, increasing their vulnerability to the urban heat island effect and reducing environmental resilience. This can also be observed from the changes in land use in Jember Regency from 2019 to 2024 (Figure 3).

Analysis of the land cover transition matrix, as illustrated in the diagram, indicates that the most substantial vegetation dynamics between 2019 and 2024 occurred within plantation and rice field ecosystems, categories collectively classified as agricultural land. This significant conversion suggests a systematic land-use change, likely driven by a confluence of socio-economic pressures. These include regional population growth, accelerated urbanization, expansive infrastructure development, and rising demand for land allocated to residential and industrial sectors. This trend is quantitatively exemplified by the housing sector in Jember Regency, where areal demand increased from 34,427.41 hectares in 2005 to 35,010 hectares in 2013, reflecting a net gain of 583.17 hectares [34]. The observed attrition of agricultural land is consistent with and corroborates prior spatial projections. Specifically, modeling studies by Setiawan (2025) forecasted a significant and sustained decline in rice field extent throughout Jember Regency for the 2012–2032 period, a prediction that aligns with the empirical findings of this study [35]. This study not only analyzes vegetation cover and land use but also examines the annual average NDVI (Normalized Difference Vegetation Index) values from 2020 to 2024. The goal is to highlight significant trends in vegetation health and density in the Jember area. This approach provides a quantitative foundation for comparing the urban core with the surrounding suburban areas.

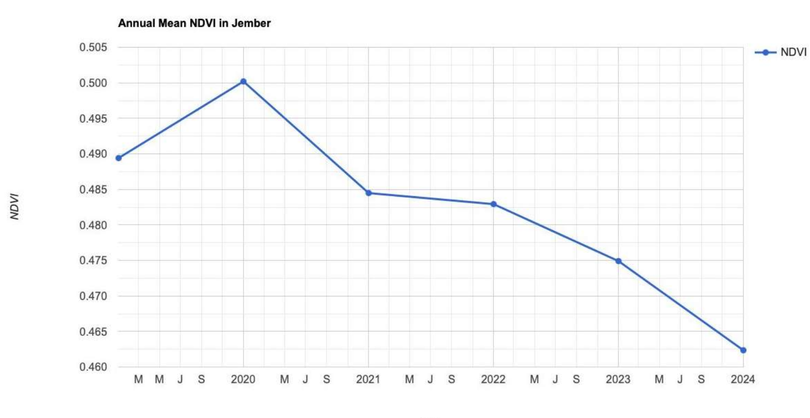


Figure 4. NDVI of Jember Urban Area in 2019 to 2024

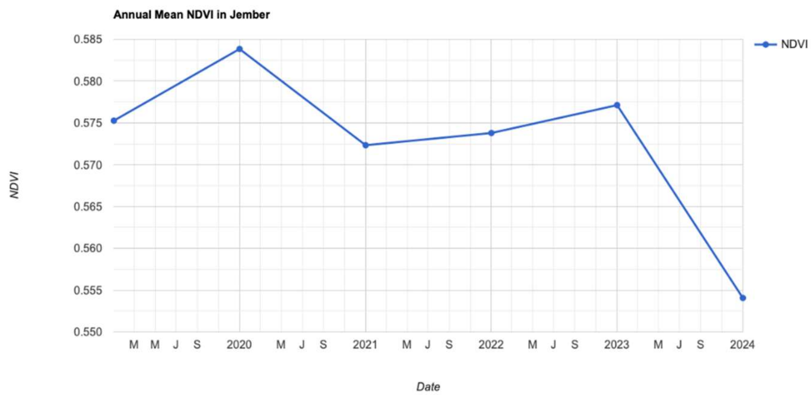


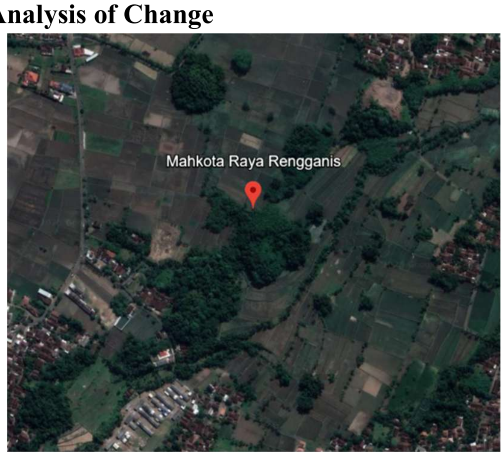
Figure 5. NDVI of Jember Regency in 2019 to 2024

Based on Figures 3 and 4, show significant differences in the trend of vegetation quality changes between the two regions. In the Jember urban area, the NDVI value has tended to decline consistently since 2020. The NDVI value peaked in 2020 at around 0.500, then gradually decreased to around 0.460 in 2024. This trend indicates a significant degradation of vegetation quality in urban areas due to land conversion, increased residential development, and reduced green open space.

Meanwhile, in Jember Regency, the downward trend in NDVI was not as rapid as in urban areas. The NDVI peaked in 2020 at around 0.584, then declined briefly in 2021, but then rose slightly in 2022 and 2023 to around 0.579. It was not until 2024 that the NDVI dropped significantly, reaching 0.554. This indicates that overall, the regency still has relatively better vegetation quality than urban areas, primarily due to the presence of well-maintained plantations, forests, and green open spaces, such as those in and around Mount Gambir.

Based on these conditions, it can be concluded that the decline in NDVI in Jember was driven by vegetation degradation in urban areas. In contrast, rural areas and plantations in Jember Regency have maintained their vegetation quality in recent years. However, the downward trend in 2024 in both regions indicates that development activities and land-use changes are beginning to have a broader impact on the overall environment. This indicates the need for spatial management strategies and vegetation conservation policies to balance urban growth and ecosystem sustainability.

4.2. Analysis of Change

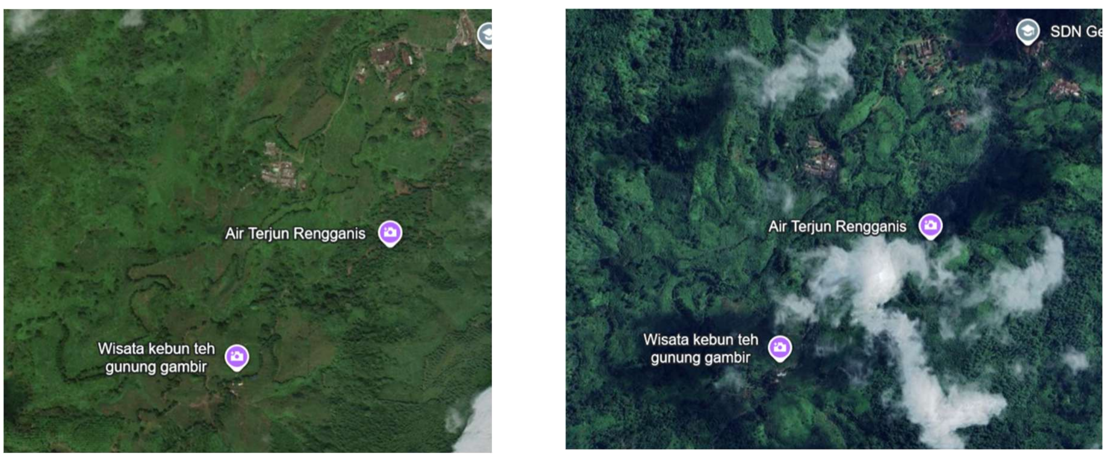


(2019) (2024)

Figure 6. Vegetation Transformations of Jember Urban Area

Satellite imagery of the Mahkota Raya Rengganis area from 2019 and 2024 (Figure 5) shows significant changes in land cover. Agricultural land, green vegetation, and dense tree cover still dominated the area in 2019. However, by 2024, much of this area had been converted into dense residential areas, while green open spaces and vegetation dwindled. These changes indicate a rapid and massive urbanization over the past five years. These land-use changes align with the trend in the Annual Mean NDVI graph in Jember, which shows a significant decline in vegetation quality. In 2019, the NDVI value hovered around 0.490 and peaked at 0.500 in 2020, indicating that the vegetation remained in relatively good condition. However, after 2020, the NDVI value gradually declined, reaching 0.460 in 2024. This decline reflects a decline in vegetation density and health, consistent with the expanding built-up area around Mahkota Raya Rengganis and the Jember urban area in general.

The correlation between satellite imagery and the NDVI graph shows that increased residential development directly impacts the degradation of vegetation quality. The loss of green open space and reduced vegetation cover has led to a consistent decline in the NDVI index. This condition can trigger various environmental problems, such as increased surface temperatures, decreased water absorption capacity, and reduced vegetation's ability to absorb carbon. The change in land cover in Mahkota Raya Rengganis is clear evidence that urbanization significantly impacts the degradation of vegetation quality in the Jember urban area.



(2019) (2023)

Figure 7. Vegetation Transformation Around Mount Gambir, Jember Regency

In contrast, the Jember Urban Area experienced a decline in vegetation. Figure 6 shows a significant increase in vegetation cover around the foot of Mount Gambir. In 2019, the vegetation around the Mount Gambir Tea Plantation appeared less dense, with some areas remaining open. However, in 2023, the vegetation appeared denser and greener, indicating more optimal plant growth. This increase was due to the development of the Mount Gambir tea plantation, now managed by PTPN XII, resulting in better management and maintenance of the area. Compared to the Annual Mean NDVI graph in Jember (Figure 4), this condition aligns with the trend in NDVI values in 2022 and 2023. After declining in 2021 to around 0.573, the NDVI value rose again in 2023 to around 0.578, indicating improved vegetation conditions in several areas, including the Mount Gambir plantation area. This improvement reflects the success of planned land management in maintaining and improving vegetation quality.

However, it should be noted that although the Mount Gambir area shows a positive trend, the overall NDVI graph decreased in 2024, reaching approximately 0.554. This indicates that increased vegetation in certain areas, such as tea plantations, has not offset the decline in vegetation quality in other areas of Jember, especially in urban areas experiencing massive land conversion. Therefore, analysis of satellite imagery and the NDVI graph indicates a complex dynamic of vegetation change, where successful land management in one area is insufficient to offset vegetation degradation due to urbanization in other areas.

5. CONCLUSIONS

This study mapped and quantified the vegetation dynamics in Jember Regency from 2019 to 2024, achieving the research objective of prviding a data-driven analysis of spatiotemporal vegetation change. Integrating multitemporal Landsat 8 OLI/TIRS imagery and the cloud computing power of Google Earth Engine proved to be a robust method for conducting such over a large area of Jember. The key finding of this research is the identification of a stark contrast in vegetation trends between urban and rural zones. The urban core sub-district, namely Patrang, Sumbersari, and Kaliwates, designated as regional activity centers, exhibited a significant and consistent decline based on the NDVI mean value, directly linked to planned urban expansion and the conversion of vegetated land into built-up areas. Conversely. The rural area of Jember Regency, particularly those dedicated to managed plantations, demonstrated greater stability in vegetation cover. This divergence underscores that the primary driver of vegetation degradation in Jember is not random or natural, but a direct consequence of concentrated anthropogenic pressure in urban centers. The empirical evidence provided in this study highlights the urgent need for strategic spatial planning policies that mitigate urban sprawl. Law No. 26/2007 policy is irrelevant to Jember Area since it only regulates 30% of the total regency administrative law, while the built-up and conversion of vegetated land occurred in the urban center part. This study is reliable evidence for controlling urban sprawl, protecting agricultural areas, and integrating green infrastructure into development plans. However, future research might be deepen the understanding of these vegetation dynamic and inform more targeted policy intervention such as employing spatial regresion models to statistically link the observed vegetation change to specific variables such as population density, land value fluctuations, infrastructure projects, and economic performance of key agricultural sectors that would receal the primary economic pressures fueling land conversion, that will provide an evidence based foundation for targeted economic and zoning policies. By pursuing this direction, future research might build upon the empirical foundation laid by this study, not only monitoring the vegetation dynamics but also predicting, explaining, and ultimately helping to mitigate the adverse effects of vegetation loss.

REFERENCES

[1] Z. Xiang, Y. Liu, Y. Fu, Y. Gao, L. Liu, and F. Wang, “Spatiotemporal change characteristics of NDVI and response to climate factors in the Jixi Wetland, Eastern China,” Environ Monit Assess, vol. 196, no. 9, Sep. 2024, doi: 10.1007/s10661-024-12959-7.

[2] X. Wang et al., “Spring temperature change and its implication in the change of vegetation growth in North America from 1982 to 2006,” Proceedings of the National Academy of Sciences, vol. 108, no. 4, pp. 1240–1245, Jan. 2011, doi: 10.1073/pnas.1014425108.

[3] Y. Lu et al., “NDVI based vegetation dynamics and responses to climate change and human activities at Xinjiang from 2001 to 2020,” Sci Rep, vol. 15, no. 1, Dec. 2025, doi: 10.1038/s41598-025-11677-5.

[4] M. D. A. Rounsevell et al., “Challenges for land system science,” Land use policy, vol. 29, no. 4, pp. 899–910, Oct. 2012, doi: 10.1016/j.landusepol.2012.01.007.

[5] A. M. Hersperger et al., “Urban land-use change: The role of strategic spatial planning,” Global Environmental Change, vol. 51, pp. 32–42, Jul. 2018, doi: 10.1016/j.gloenvcha.2018.05.001.

[6] A. Reenberg, “Land systems research in Denmark: Background and perspectives,” 2006, Royal Danish Geographical Society. doi: 10.1080/00167223.2006.10649552.

[7] Kabupaten Jember, “Sebaran Pertanian.” Accessed: Aug. 27, 2025. [Online]. Available: https://portal-data.jemberkab.go.id/portal-099365c0ebb3344cecaa558c46945ee7.html

[8] T. Fidalgo Fonseca and A. C. Gonçalves, “Introductory Chapter: Vegetation Dynamics,” in Vegetation Dynamics - Ecosystem Management, Conservation, and Protection, A. C. Gonçalves and T. Fidalgo Fonseca, Eds., Rijeka: IntechOpen, 2025. doi: 10.5772/intechopen.1009828.

[9] S. Dong and Y. Shi, “Impact of the dynamic vegetation on climate extremes during the wheat growing period over China,” Science of The Total Environment, vol. 819, p. 153079, 2022, doi: https://doi.org/10.1016/j.scitotenv.2022.153079.

[10] A. Juutinen et al., “Forest owners’ preferences for contract-based management to enhance environmental values versus timber production,” For Policy Econ, vol. 132, p. 102587, 2021, doi: https://doi.org/10.1016/j.forpol.2021.102587.

[11] Shahfahad, S. Talukdar, M. W. Naikoo, and A. Rahman, “Urban expansion and vegetation dynamics: The role of protected areas in preventing vegetation loss in a growing mega city,” Habitat Int, vol. 150, p. 103129, 2024, doi: https://doi.org/10.1016/j.habitatint.2024.103129.

[12] W. Chouari, “Assessment of vegetation cover changes and the contributing factors in the Al-Ahsa Oasis using Normalized Difference Vegetation Index (NDVI),” Regional Sustainability, vol. 5, no. 1, Mar. 2024, doi: 10.1016/j.regsus.2024.03.005.

[13] L. Jiang, Y. Liu, S. Wu, and C. Yang, “Analyzing ecological environment change and associated driving factors in China based on NDVI time series data,” Ecol Indic, vol. 129, p. 107933, 2021, doi: https://doi.org/10.1016/j.ecolind.2021.107933.

[14] [N. S. Naguib and S. Daliman, “Analysis of NDVI and NDRE Indices Using Satellite Images for Crop Identification at Kelantan,” in IOP Conference Series: Earth and Environmental Science, Institute of Physics, 2022. doi: 10.1088/1755-1315/1102/1/012054.

[15] T. M. Lillesand, R. W. Kiefer, and J. W. Chipman, Remote Sensing and Image Interpretation, 7th Edition. Hoboken: John Wiley & Sons, Inc, 2015.

[16] A. A. Gitelson, Y. Gritz †, and M. N. Merzlyak, “Relationships between leaf chlorophyll content and spectral reflectance and algorithms for non-destructive chlorophyll assessment in higher plant leaves,” J Plant Physiol, vol. 160, no. 3, pp. 271–282, 2003, doi: https://doi.org/10.1078/0176-1617-00887.

[17] T. R. Putri and S. Supriatna, “A spatial study of rubber plant health using sentinel 2-A imagery in Cibungur Plantation, Sukabumi, West Java,” in IOP Conference Series: Earth and Environmental Science, IOP Publishing Ltd, Jan. 2021. doi: 10.1088/1755-1315/623/1/012078.

[18] A. Roman and T. Ursu, “Multispectral satellite imagery and airborne laser scanning techniques for the detection of archaeological vegetation marks,” 2016. [Online]. Available: https://www.researchgate.net/publication/315797574

[19] N. Pettorelli, NDVI from A to Z’, The Normalized Difference Vegetation Index, Online edn. Oxford: Oxford Academic, 2015. doi: ,https://doi-org.ezproxy.ugm.ac.id/10.1093/acprof:osobl/9780199693160.003.0003,.

[20] A. Zaitunah, Samsuri, and F. Sahara, “Mapping and assessment of vegetation cover change and species variation in Medan, North Sumatra,” Heliyon, vol. 7, no. 7, p. e07637, 2021, doi: https://doi.org/10.1016/j.heliyon.2021.e07637.

[21] A.-M. Tudorescu, C. Negru, B.-C. Mocanu, and F. Pop, "Quality sustaining vegetation index for natural resources monitoring using satellite images," Engineering Science and Technology, an International Journal, vol. 59, p. 101847, 2024, doi: https://doi.org/10.1016/j.jestch.2024.101847.

[22] K. Mehmood et al., "Analyzing vegetation health dynamics across seasons and regions through NDVI and climatic variables," Sci Rep, vol. 14, no. 1, p. 11775, 2024, doi: 10.1038/s41598-024-62464-7.

[23] B. Shrestha, L. Zhang, S. Shrestha, N. Khadka, and L. Maharjan, "Spatiotemporal patterns, sustainability, and primary drivers of NDVI-derived vegetation dynamics (2003–2022) in Nepal," Environ Monit Assess, vol. 196, no. 7, p. 607, 2024, doi: 10.1007/s10661-024-12754-4.

[24] P. Thanabalan, R. Vidhya, R. S. Kankara, and R. Manonmani, "Time-series analysis of MODIS (LST and NDVI) and TRMM rainfall for drought assessment over India," Applied Geomatics, vol. 15, no. 2, pp. 383–405, 2023, doi: 10.1007/s12518-023-00505-y.

[25] M. Raynolds, D. Walker, D. Verbyla, and C. Munger, "Patterns of change within a tundra landscape: 22-year landsat NDVI trends in an area of the northern foothills of the brooks range, Alaska," Arct Antarct Alp Res, vol. 45, no. 2, pp. 249–260, May 2013, doi: 10.1657/1938-4246-45.2.249.

[26] A. Berveglieri, N. N. Imai, L. E. Christovam, M. L. B. T. Galo, A. M. G. Tommaselli, and E. Honkavaara, "Analysis of trends and changes in the successional trajectories of tropical forest using the Landsat NDVI time series," Remote Sens Appl, vol. 24, Nov. 2021, doi: 10.1016/j.rsase.2021.100622.

[27] G. Chander, B. L. Markham, and D. L. Helder, "Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors," Remote Sens Environ, vol. 113, no. 5, pp. 893–903, May 2009, doi: 10.1016/j.rse.2009.01.007.

[28] Y. Sun, B. Wang, S. Teng, B. Liu, Z. Zhang, and Y. Li, "Continuity of Top-of-Atmosphere, Surface, and Nadir BRDF-Adjusted Reflectance and NDVI between Landsat-8 and Landsat-9 OLI over China Landscape," Remote Sens (Basel), vol. 15, no. 20, Oct. 2023, doi: 10.3390/rs15204948.

[29] S. Foga et al., "Cloud detection algorithm comparison and validation for operational Landsat data products," Remote Sens Environ, vol. 194, pp. 379–390, 2017, doi: https://doi.org/10.1016/j.rse.2017.03.026.

[30] Z. Zhang, M. Wei, D. Pu, G. He, G. Wang, and T. Long, "Assessment of annual composite images obtained by google earth engine for urban areas mapping using random forest," Remote Sens (Basel), vol. 13, no. 4, pp. 1–21, Feb. 2021, doi: 10.3390/rs13040748.

[31] J. Y. Anchang, E. O. Ananga, and R. Pu, "An efficient unsupervised index based approach for mapping urban vegetation from IKONOS imagery," International Journal of Applied Earth Observation and Geoinformation, vol. 50, pp. 211–220, 2016, doi: https://doi.org/10.1016/j.jag.2016.04.001.

[32] Y. E. D. Sultan, K. R. A. Pillai, A. Sharma, and S. Gautam, "Comprehensive assessment of fire risk in Latakia forests: Integrating indices for vegetation, topography, weather and human activities," Geosystems and Geoenvironment, p. 100419, 2025, doi: https://doi.org/10.1016/j.geogeo.2025.100419.

[33] Badan Pusat Statistik Kabupaten Jember, "Kabupaten Jember dalam Angka 2024," Jember, Feb. 2024. Accessed: Aug. 30, 2025. [Online]. Available: https://jemberkab.bps.go.id/id/publication/2024/02/28/06ff1b2512ce355752be8d2f/kabupaten-jember-dalam-angka-2024.html

[34] A. F. Sunartomo, "PERKEMBANGAN KONVERSI LAHAN PERTANIAN DI KABUPATEN JEMBER," 2015.

[35] W. Setiawan, A. Habibi, A. R. Setiawan, C. Nathanael, N. Silvia, and A. Wahyudi, "Analisis Proyeksi Penggunaan Lahan Sawah untuk Kebutuhan dan Ketersediaan Beras di Kabupaten Jember Tahun 2032," Tunas Agraria, vol. 8, no. 2, pp. 219–235, May 2025, doi: 10.31292/jta.v8i2.440.