Research Article
https://doi.org/10.33904/ejfe.1395676

Eur J Forest Eng 2024, 10(1):29-42

Monitoring Mangrove Forest Degradation in Mangrove Nature Tourism Park Angke Kapuk, North Jakarta, Indonesia Using NDVI

Tsaniya Nurafifah Suryana[1], Sherlina Purnamasari[2], Kevin Ewaldo[3,4]*

[1]Universitas Pendidikan Indonesia, Jawa Barat - Indonesia
[2]Universitas Multimedia Nusantara, Prop. Banten - Indonesia
[3]Universitas Indonesia, DKI Jakarta - Indonesia
[4]Yayasan Mangrove Indonesia Lestari, DKI Jakarta - Indonesia

Abstract

Mangrove forests in Angke Kapuk, North Jakarta, are integral parts of the coastal ecosystem and play important roles in supporting environmental sustainability. One component of the Angke Kapuk Mangrove Forest is the Mangrove Nature Tourism Park (MNTP), Angke Kapuk, covering an area of 99.82 hectares. This study aims to analyze mangrove forest degradation in Angke Kapuk Nature Reserve using the Normalized Difference Vegetation Index (NDVI, which allows for mapping mangrove vegetation density and monitoring changes in the vegetation density over time. The objective of this study is to determine the degradation of mangrove forests from 2018 to 2023 using the NDVI derived from Landsat 8 and Landsat 9 satellite imagery. The findings of this study showed a change of 13.16 hectares in forested areas between 2018 and 2023, suggesting forest degradation. Accuracy assessment resulted in 80% overall accuracy with a kappa coefficient of 76.2%. Based on the literature, our results are similar to the acceptable level of accuracy, which is considered to be above 80%. Monitoring mangrove forest areas can serve as a preventive measure to address the issue of mangrove forest degradation. These results underscore the necessity of sustainable forestry monitoring efforts in the MNTP area, as it contributes significantly to providing ecosystem services and maintaining environmental sustainability.

Keywords: Forest degradation, mangrove, NDVI, North Jakarta, tourism.

1. Introduction

The mangrove forest is a plant formation that thrives in coastal areas with high salinity and is inundated by water. Mangroves are resilient to survive in muddy and watery soil, and their roots can withstand the challenge of low oxygenation. This ecosystem plays a crucial role by providing various functions and benefits to both nature and humankind (Ewaldo et al., 2023). Mangroves also play an essential role in protecting coastlines from high waves and preventing erosion (de Silva and Amarangsinghe, 2023). Additionally, mangrove forests significantly contribute to the global carbon cycle (Zhu and Yan, 2022).

The distribution of mangrove vegetation in Indonesia is estimated at 3.2 million hectares, covering approximately 19% of the total global mangrove distribution (FAO, 2020; Sraun et al., 2022). Unfortunately, the extent of mangrove forests has been continuously shrinking since 1990 (FAO, 2020). As an archipelagic nation, Indonesia is an ideal habitat for mangrove trees. Several coastal areas in Indonesia are covered with mangroves, including the Mangrove Forest of Muara Angke Kapuk, located in the Jakarta Special Capital Region. This area spans 99.82 hectares and is utilized for various activities (Department of Forestry of DKI Jakarta Province, 2022). However, the sustainability of this area is continually threatened by forest degradation. Presently, the dominant factor catalyzing forest degradation is the conversion of forests into developed areas (Mayalanda et al., 2014). In the Mangrove Forest of Muara Angke Kapuk, there has been a decrease in vegetation cover by 272.79 hectares, classified as critically degraded land due to massive construction and other human activities (Sofian et al., 2019; Goldberg et al., 2020). One area vulnerable to degradation is the Mangrove Nature Tourism Park.

The Mangrove Nature Tourism Park (MNTP) is a section of the Angke Kapuk Mangrove Forest utilized for tourism activities. The high number of visitors to the tourist attractions adds pressure to the environment and poses potential damage. This condition is exacerbated by the construction of accommodations, tourist attractions, and other developed areas, putting additional strain on the mangrove ecosystem (Sofian et al., 2019). Therefore, research and monitoring of mangrove distribution and dynamics are crucial to understanding and minimizing

*Corresponding Author: Tel: + 62 82213311743 E-mail: kevinewaldooffice@gmail.com
Received: 24 November 2023; Accepted: 26 February 2024

the impacts of changes and ecological implications for both nature and society.

Remote sensing is a valuable tool for accurately mapping and monitoring mangrove forests at various scales (Giri, 2023). One method used in remote sensing to monitor the condition of mangrove forests is the Normalized Difference Vegetation Index (NDVI). NDVI is a method used to measure the amount and density of green vegetation in an area (Davis et al., 2023). This method can be employed to evaluate the level of mangrove forest degradation and categorize vegetation within the area (Sokolović et al., 2022; Pamungkas et al., 2023; Rondon et al., 2023). The level of mangrove forest degradation can be determined by identifying the density of mangrove forests and understanding the annual vegetation development patterns in response to environmental changes (Yengoh et al., 2015; Gerard et al., 2020; Faruque et al., 2022).

Research on mangrove ecosystems utilizing the NDVI method has been conducted for various purposes, such as comparing carbon absorption levels, climate variability, diversity and mangrove composition, and other studies (Fayech and Tarhouni, 2021; Purnamasari et al., 2021; Sraun et al., 2022). In this study, NDVI is used to assess the level of mangrove degradation occurring in the MNTP tourist area of Angke Kapuk. Previous research regarding the use of remote sensing in the Mangrove Forest of Muara Angke Kapuk focused solely on its Ecosystem Services Carrying Capacity (Sofian et al., 2019). However, these research was was limited to determining the extent of mangrove ecosystem usage without delving into changes in land cover and degradation. Therefore, this study examines mangrove forest degradation levels in the MNTP Angke Kapuk area to address this gap. The difference in this research lies in analyzing the level of mangrove forest degradation using Landsat 8 and 9 imagery in the Jakarta Special Capital Region, Indonesia, following the COVID-19 pandemic and island reclamation activities in Jakarta Bay. Furthermore, this research was conducted post-COVID-19 pandemic, during which various changes in community activities and infrastructure development occurred at the study site. Additionally, island reclamation activities in Jakarta Bay have affected the coastal ecosystem conditions. The study aims to analyze changes in vegetation cover in MNTP using Landsat 8 and 9 imagery, employing the Normalized Difference Vegetation Indonesia (NDVI) method as an effort for periodic monitoring of mangrove forest conditions.

2. Materials and Method

2.1. Study Area and Data

This study, conducted between April and October 2023, aims to investigate mangrove forest degradation within the Mangrove Nature Tourism Park (MNTP), Angke Kapuk. MNTP, spanning 99.82 hectares, is designated as a vital conservation area and natural tourist destination under the Decree of the Minister of Forestry (Number: 667/Kpts-II/1995) and located administratively in the Kamal Muara Subdistrict, Penjaringan District, North Jakarta, Indonesia, MNTP's geographical coordinates range from 106°43’ to 106°45’ East Longitude and 6°05’ to 6°07’ South Latitude (Figure 1). Situated in a lowland region with an elevation ranging from 0 to 2 meters above sea level, MNTP is demarcated by defined boundaries: to the north by the coastline, eastward by the Pantai Indah Kapuk area, and Protected Forest, southward by the access road to the radar tower and residential areas, and westward by MNTP fish ponds managed by the Fisheries Department. These boundaries delineate MNTP's unique ecosystem, encompassing environmental elements such as fish ponds, roads, coastline, and residential and protected areas, all integral to the region's ecological dynamics.

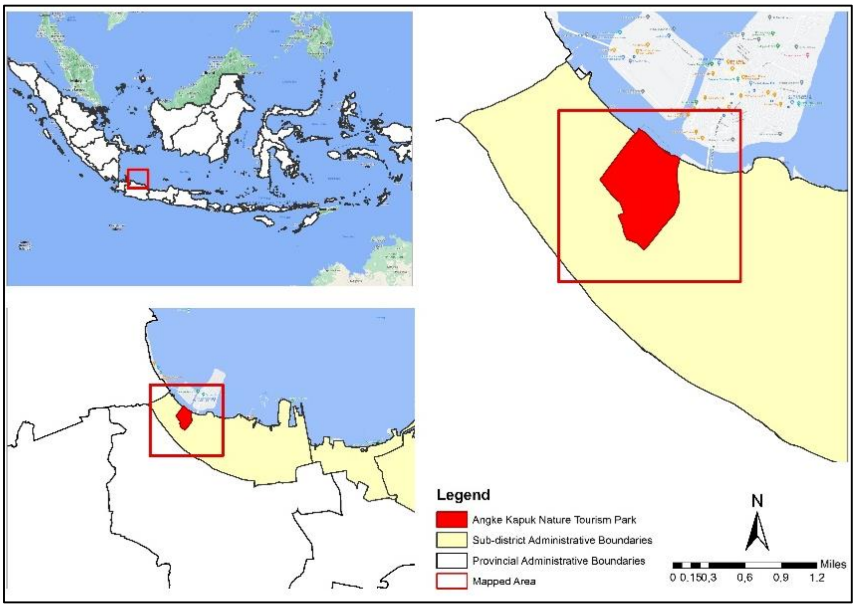


Figure 1. Location Research, Mangrove Nature Tourism Park Angke Kapuk, Kamal Muara, Penjaringan, North Indonesia, Indonesia.

Despite its proximity to urban areas, MNTP hosts diverse flora and fauna thriving within its premises. MNTP boasts a variety of flora species, including various mangrove species such as *Sonneratia caseolaris, Acrosticum areum, Avicennia marina, Ceriops sp, Excoecaria agallocha, Rhizophora mucronata, and Rhizophora stylosa*, as well as coastal and swamp forest species like *Hibiscus tilliaceus, Pluchea indica, Scripus litoralis, Polysia frutucosa, Erythrina variagate, Samanea saman, Delonix regia, Derisheterophyla, and Mimosa sp. Furthermore*, fauna species inhabiting this area include *Anhinga melanogaster, Nycticorax nycticorax, Egretta sp, Bubulcus ibis, Ardea cinerea, Ardeola sp, Anos grobcaritrous, Halcyon chloris, Glossogobius giuris, and Thalassina anomata*.

MNTP was selected as the research location because of its unique characteristics and the presence of diverse flora and fauna. Its strategic proximity to urban centers and its status as one of the largest mangrove conservation areas in Jakarta Province also influenced its selection as the study site.

This study utilized two methods for data acquisition: spatial data acquisition and field data collection. Spatial data, comprising images, were sourced from the United States Geological Survey Indonesia (USGS) and the Indonesian Geospatial Information Agency (Badan Informasi Geospatial Indonesia), with specifications for 2018 and 2023. The initial dataset was obtained from Badan Informasi Geospatial (BIG) Indonesia in a shapefile format, encompassing the administrative boundaries of the research area (Table 1).

Table 1. Shapefile Data.

Acquisition Date	Data Type	Description	Source
2023	Polygon/Shapefile	Administrative Boundaries of MNTP Angke Kapuk	World Database on Protected Area
2023	Polygon/Shapefile	Administrative Boundaries of Subdistrict Jakarta Utara	Badan Informasi Geospasial

Subsequently, the dataset consisted of Landsat images in raster format. This primary dataset will serve as the basis for evaluating the degree of mangrove forest degradation within the study area (Table 2). Furthermore, field data collection was conducted to validate the precision of the spatial analysis outcomes. Data acquired during field validation encompassed X and Y coordinate data, in addition to data pertaining to vegetation density classification.

Table 2. Landsat Data.

Acquisition Date	Data Type	Image	Resolution	Path/Row	Source
06/07/2018	Raster	LANDSAT-8 T1	30x30	126/40	United State Geological Survey
28/7/2023	Raster	LANDSAT-9 T1	30x30	126/40	United State Geological Survey

Field data collection was undertaken to validate the accuracy of the spatial analysis findings. Data acquired during field validation comprised X and Y coordinate data. The selection of field points was determined utilizing the stratified random sampling method, employing 20 sample points. The data obtained from these points will be utilized for accuracy assessment in this study. The execution of the stratified random sampling accuracy assessment is in accordance with Regulation No. 3 of 2014 issued by the Head of the Indonesian Geospatial Information Agency, which delineates guidelines for processing Mangrove Geospatial Data. The accuracy assessment, based on NDVI values, involves partitioning the study area into smaller, homogeneous groups known as strata, predicated on the values of each NDVI classification.

Additionally, supplementary data were acquired by analyzing literature from various pertinent sources, including government reports, scientific journals, books, and other scholarly articles. The secondary data considered encompassed the historical background of the research site, the area's dimensions, and other pertinent information associated with the mangrove ecosystem.

2.2. Data Processing

The data acquired in this study will be analyzed to assess mangrove forest degradation. The satellite images utilized in this research were georeferenced to WGS 1984 UTM zone 48S. The initial phase of this investigation involves radiometric correction, which serves as the primary preprocessing step prior to image data analysis. Radiometric correction aims to rectify discrepancies between sensor values, spectral reflectance, and the radiative brightness of spectral object radiation, encompassing both absolute and relative radiometric correction methodologies (Jianya et al., 2008). It is commonly applied as a preparatory step preceding change detection (Paolini, 2006). Landsat 8 imagery typically exhibits low radiometric accuracy when utilized for analysis-related purposes such as vegetation index determination, biomass estimation, and land cover/land use classification (Muchsin et al., 2022).

Hence, adjustments to the remote sensing imagery are essential to enhance pixel value quality and rectify potential radiometric errors.

Following radiometric correction, atmospheric correction procedures are conducted. Atmospheric correction aims to mitigate or eliminate atmospheric disturbances' effects on the imagery, enabling a more accurate depiction of Earth's surface conditions. After atmospheric correction, satellite images exhibit improved radiometric accuracy, enhancing contrast ratios and overall image quality. The radiometric and atmospheric correction processes for Landsat 8 and 9 images utilized in this study were executed using ENVI 5.2 software, employing the Quick Atmospheric Correction (QUAC) method.

The QUAC, one of the athmospheric correction algorithms, is renowned for its expedited atmospheric correction among the other algorithms, and it is recognized for its effectiveness in mitigating the influence of atmospheric aerosols, water vapor, and other atmospheric constituents (Guo and Zeng, 2012; Moravec et al., 2021). QUAC adopts an in-scene approach within the landscape, requiring solely estimates of sensor band specifications (e.g., central wavelength) and radiometric calibration (Bernstein et al., 2012). Subsequent to image enhancement through these correction procedures, the subsequent step involves image cropping. Image cropping entails the delineation of satellite images to delineate or define the specific area of interest for the research. Given that satellite images often cover a broader expanse than the research site, employing this method allows for the narrowing down of the focus or boundaries of the area depicted in the imagery.

2.3. Data Analysis

The acquired and corrected data was analyzed utilizing the Normalized Difference Vegetation Index (NDVI) method. The NDVI method entails calculating the difference between the red and near-infrared (NIR) channels and dividing this difference by the sum of the values from both channels (Picon et al., 2022). NDVI serves as a tool for extracting information concerning vegetation quantity, quality, and development (Iacono et al., 2023). This method facilitates the determination of mangrove forest density through image processing. The Vegetation Index value is calculated using the following equation:

$$\text{NDVI} = \frac{Near\ Infrared - Red}{Near\ Infrared + Red} \quad (1)$$

Red is the red portion of the electromagnetic spectrum (Band 4) and NIR is the near-infrared portion of the electromagnetic spectrum (Band 5). The NDVI classification is divided into four classes, as shown in Table 3. These classes can be identified through different color tones corresponding to vegetation index values and the level of greenness in the research area.

NDVI is derived from the ratio of near-infrared light (NIR) to red light, representing the sum of these two measurements. NDVI values fall within the range of -1 to +1, indicating the proportion of green leaf vegetation. Negative spectrum values or NDVI close to –1 denote coverage by water bodies, rocks, or built-up areas, as water reflects more visible light and less NIR. Conversely, NDVI values close to +1 (approximately 0.03–0.40) indicate healthy or dense green vegetation, as healthy vegetation absorbs more visible (red) light and reflects more near-infrared light. Thus, the NDVI classification method yields values indicative of the extent and distribution of green vegetation.

Table 3. Classification of Normalized Difference Vegetation Index (NDVI).

Vegetation Index Value	Classification
0.40 – 1	High Density
0.25 – < 0.40	Moderate Density
0.03 – < 0.25	Slightly Density
-1 – 0.03	Non-Vegetation

Data pertaining to the classification of mangrove forest density was processed utilizing the overlay method. Overlay constitutes a stage in the Geographic Information System (GIS) data processing methodology, aimed at comparing two datasets with identical area coverage to visualize disparities that yield new insights. The analysis of overlaid images in this study aims to identify areas of degraded forest based on two distinct image datasets: Landsat 8 images acquired in 2018 and Landsat 9 images acquired in 2023. The outcomes derived from this technique manifest as color tones delineating discrepancies between degraded and intact areas.

Subsequent to spatial analysis, the final step in the research process transcends mere map creation from remote sensing or other spatial data by means of printing. Instead, it necessitates a thorough evaluation of map accuracy or validity (Congalton, 1991). Accuracy assessment entails the utilization of the confusion matrix method, grounded in field observations. This method involves predicting data processing outcomes against ground-truth conditions. A confusion matrix table is frequently employed to elucidate the performance of a classification model on a dataset with known true values (Annatakarn et al., 2022). Evaluation of NDVI value accuracy across land use types is typically accomplished using Cohen's Kappa, a statistical measure assessing the agreement between raster interpretation and observed raster data (Van Anh, 2023). The confusion matrix serves as a crucial tool for ensuring the quality and reliability of land cover classifications and spatial information derived from remote sensing technologies (Congalton, 1991).

The accuracy assessment was conducted on Saturday, October 8, 2023, at the MNTP Angke Kapuk. The procedural steps undertaken in this study are illustrated in Figure 2.

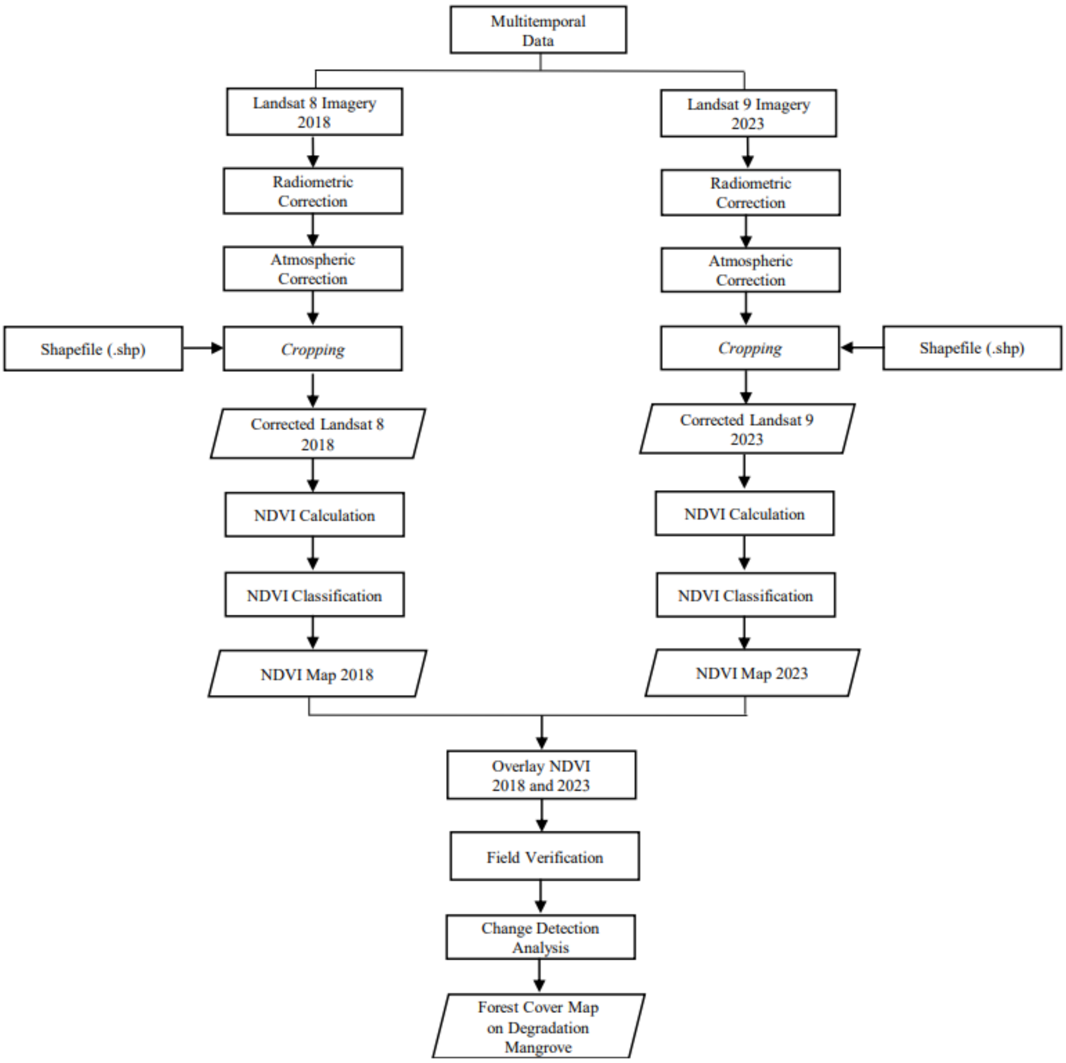
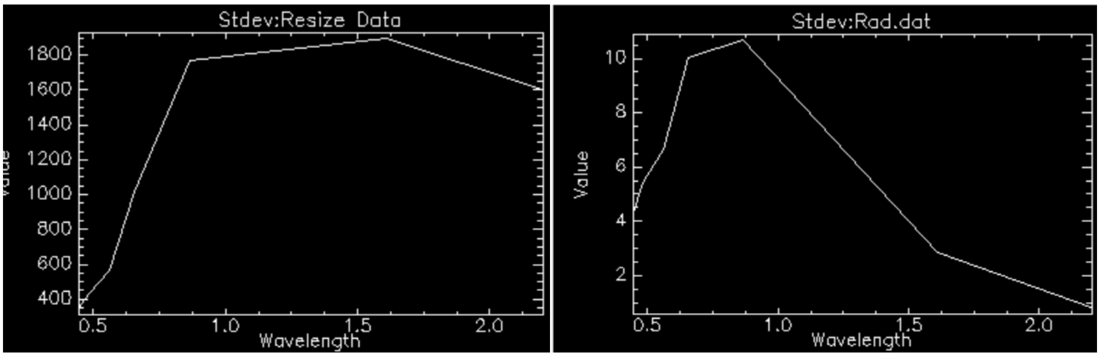


Figure 2. Research Flow Chart.

3. Results and Discussion

3.1. Data Correction

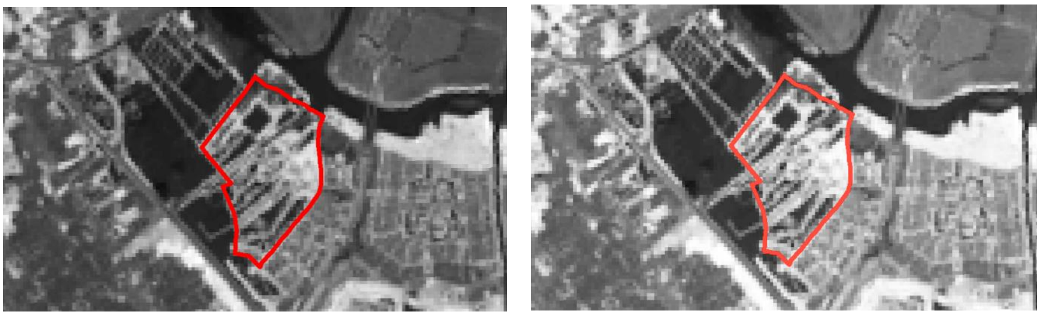
The outcomes of radiometric correction include enhancing pixel values and increasing color contrast, resulting in an accurate and visually appealing image display. Radiometric correction can decrease pixel values due to sensor saturation, noise reduction, or atmospheric correction. It is influenced by sensor properties, such as color processing through algorithms, camera settings or sensor errors, atmospheric effects, and sun position (Kędziorski et al., 2023). A comparison of satellite images that have undergone correction and experienced a wavelength decrease is depicted in Figure 3.



(a) (b)

Figure 3. (a) Before radiometric correction, (b) after radiometric correction (Source: Author's primary data, 2023).

Atmospheric Correction for Landsat 8 and 9 images was performed in the ENVI 5.2 software using the QUAC method. The initial principle of QUAC differs from the usual atmospheric correction methods because this approach is based on penetrating light values (Dewi and Trisakti, 2016). The results of atmospheric correction processing using the QUAC method lead to changes in the visual effects of the image, where an increase in brightness and contrast can be observed compared to uncorrected images, which tend to be darker (Figure 4). It occurs because the satellite image has been corrected for errors caused by atmospheric influences during image acquisition. After atmospheric correction, the satellite image will have higher radiometric accuracy and can be used for various applications such as land cover mapping and remote sensing. The QUAC method produces atmospheric effects with improved contrast ratios and enhanced image quality, indicating that atmospheric correction effectively eliminates the effects of atmospheric aerosols, water vapor, and other atmospheric factors (Guo and Zeng, 2012).



(a) (b)

Figure 4. (a) Before atmospheric correction, (b) after atmospheric correction.

Image cropping was performed using the shapefile data defining the boundaries of the mangrove forest area in MNTP Angke Kapuk. Cropping was carried out using the "extract by mask" tool in the ArcGIS application to restrict the study area to focus on a specific region. The stages of Landsat image cropping involve selecting an area from the larger image coverage and creating a new satellite image from the chosen area based on the study area.

3.2. Mangrove Forest Density Classification

Based on the analysis results, it can be observed that the classification of mangrove forests in MNTP in 2018 is predominantly characterized by mangrove vegetation with a moderate density, covering an area of 40.37 hectares (Table 4). Compared to the moderate density classification, areas with high-density mangrove vegetation exhibit a smaller extent, amounting to 19.36 hectares. Moreover, the high-density classification represents the lowest extent among other classifications.

Table 4. Classification of Mangrove Density Area Based on NDVI in 2018.

Classification	Density Area (Hectare)
Non-Vegetation	10.96
Slightly Density	29.11
Moderately Density	40.37
Highly Density	19.36
Total Area	99.82

In 2018, it is evident that the highest density of mangrove vegetation is concentrated along the coastal areas. This phenomenon is attributed to the influence of tidal intensity and the ecological conditions conducive to mangrove growth (Figure 5). This assertion is supported by previous research conducted by Efriyeldi et al. (2023) and Perri et al. (2023), which indicates that mangrove vegetation distribution tends to concentrate along the coastline due to favorable environmental conditions such as optimal salinity levels and easier access to seawater, facilitating mangrove growth and development.

The transformation equation for the red band (band 4) and the near-infrared reflectance value (NIR/band 5) reveal the presence of 19.36 hectares of high-density or expansive canopy mangrove forest. The identification of mangrove distribution focuses on the primary or dominant stands within the mangrove ecosystem. These characteristics suggest that the mangroves in MNTP are associated with coastal (downstream) Udang Watersheds.

In the eastern section of MNTP, mangrove forests exhibit high density attributed to tidal influence. Conversely, mangrove forests in the western section of MNTP display high density due to wave action. Areas with low to medium mangrove density, predominantly sparse, are situated primarily in the outer regions near the shoreline. It indicates the presence of young or burgeoning mangrove vegetation surrounded by medium-density mangroves.

The robust growth of mangroves is discernible by their seaward extension. Conversely, non-vegetative areas are characterized as water bodies or built-up regions resulting from mangrove habitats in aquatic environments. The analysis results for 2023 depict changes in the area. By 2023, the vegetation in the research location is expected to be predominantly classified as moderate, as indicated by yellow (Figure 6).

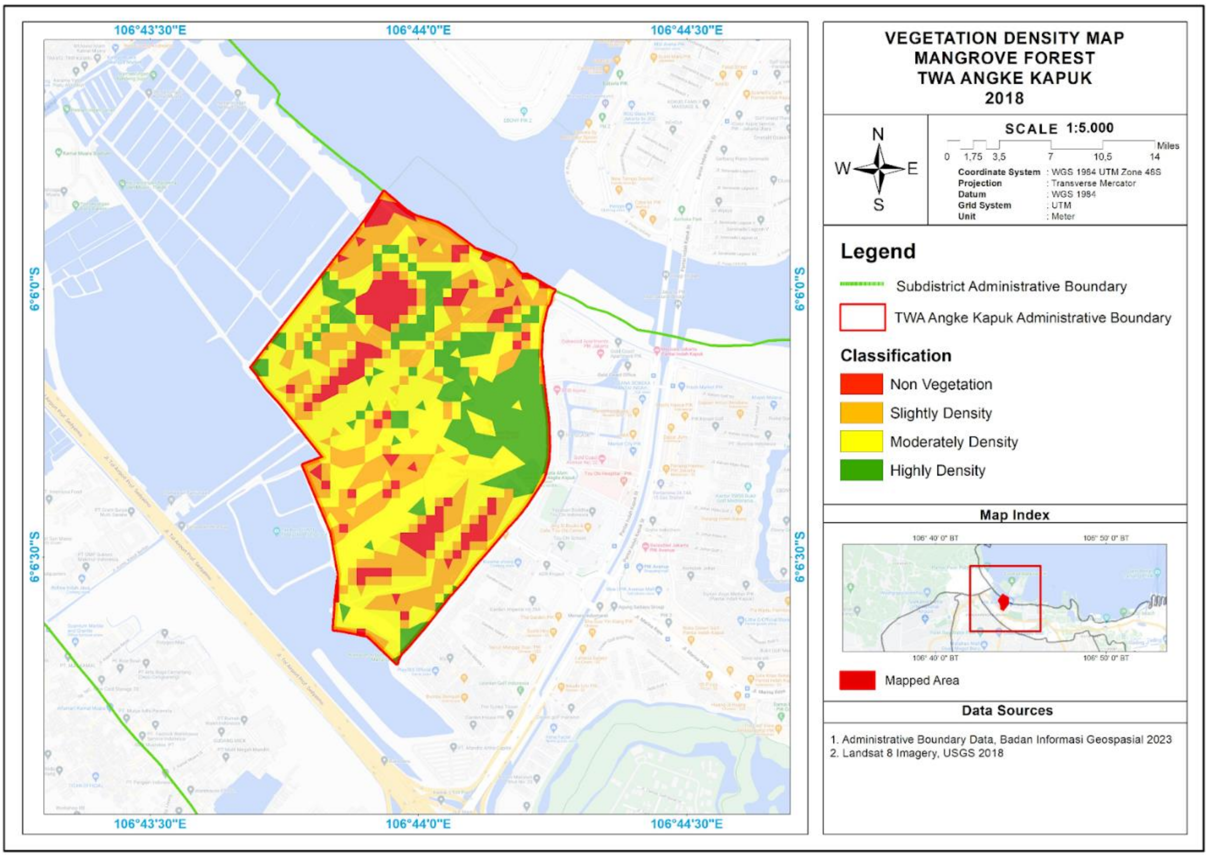


Figure 5. Map of Vegetation Density Classification in MNTP, 2018.

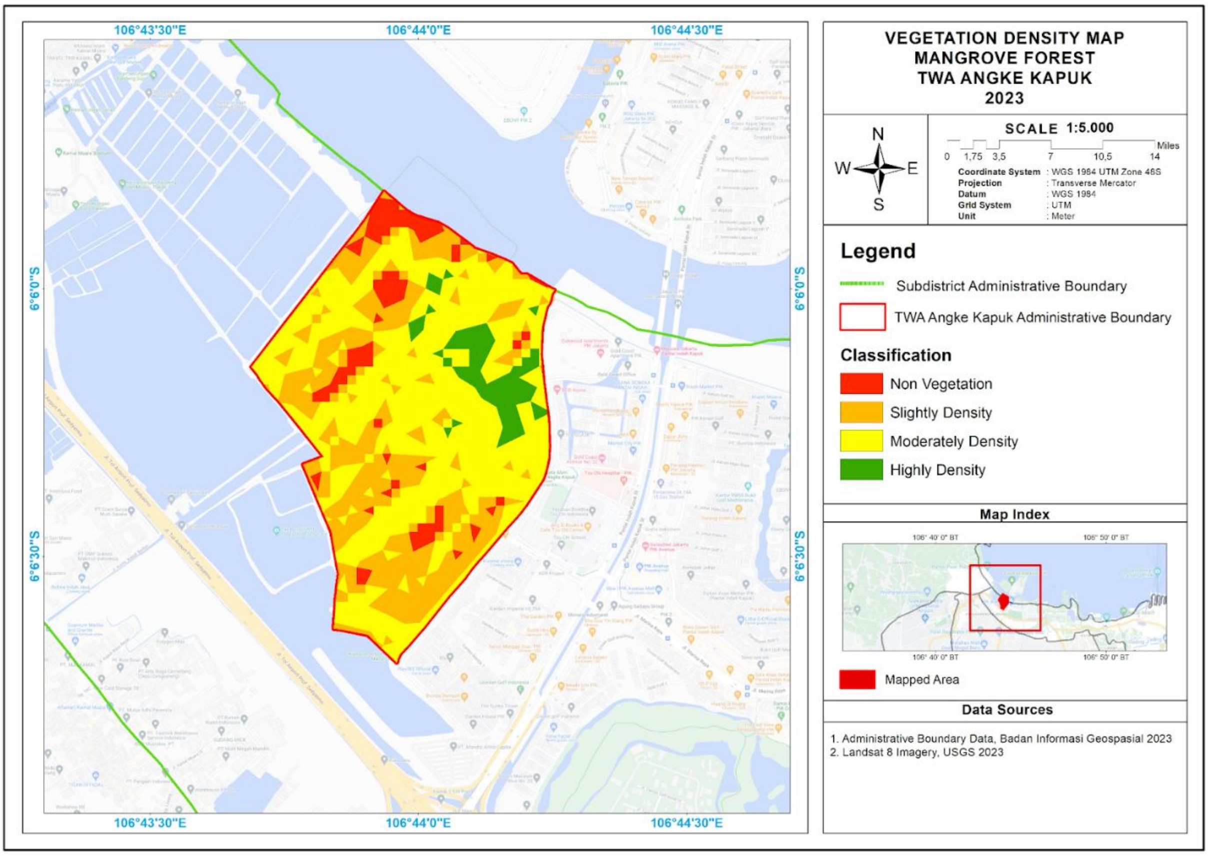


Figure 6. Map of Vegetation Density Classification in MNTP, 2023.

For 2023, the classification analysis indicated that the Mangrove Nature Tourism Park (MNTP) area was predominantly characterized by mangrove vegetation at a moderate density level, spanning an area of 55.48 hectares (Table 5). This data illustrates a significant development compared to 2018, signifying efforts or successes in restoring or enhancing the extent of mangrove forests in MNTP. This phenomenon holds importance in the context of mangrove conservation, considering the crucial role of mangrove ecosystems in maintaining coastal environmental sustainability and protecting against natural disasters such as coastal erosion and storms.

Table 5. Classification of Mangrove Density Area Based on NDVI in 2023.

Classification	Density Area (Hectare)
Non-Vegetation	7.29
Slightly Density	30.84
Moderately Density	55.48
Highly Density	6.20
Total Area	99.82

The area covered by mangrove vegetation classified as moderate in 2023 experienced an increase of 15.11 hectares compared to 2018 (Table 6). This increase reflects positive changes in the ecological conditions and vegetation in MNTP during that period. Meanwhile, the area under the classification of highly dense mangroves decreased by 13.16 hectares compared to 2018. The area under this classification amounted to only 6.20 hectares. This condition could have adverse effects on the mangrove ecosystem and the flora and fauna in the region.

Table 6. Comparison Classification of Mangrove Density Area Based between 2018 and 2023.

Classification	Density Change (Hectare)	Information
Non-Vegetation	(-) 3,67	Decrease
Slightly Density	(+) 1,73	Increase
Moderately Density	(+) 15,11	Increase
Highly Density	(-) 13,16	Decrease

Changes in the area under the Highly Dense classification could also lead to environmental changes in the region, such as temperature fluctuations, salinity variations, or humidity alterations that may affect the health and growth of living organisms nearby. The increase in the area covered by Moderately Dense mangrove vegetation in MNTP between 2018 and 2023 indicates significant mangrove planting efforts. However, the reduction in Highly Dense mangrove vegetation highlights the need for more attention to maintaining and preserving existing mangrove ecosystems. The causes of this reduction may involve various factors, including human activities such as deforestation, land conversion, and environmental degradation. Additionally, inadequate maintenance of existing mangroves, such as proper pruning and management, may also contribute to the decrease in the area of dense mangrove vegetation. If not adequately addressed, these ramifications may encompass disruptions to biodiversity equilibrium, alterations in coastal defense mechanisms, and shifts in the overarching ecological resilience of the mangrove ecosystem (Carugati et al., 2018; Hasani et al., 2023).

The density values generated through NDVI analysis can serve as a baseline for assessing the condition of mangrove vegetation in the research area. Higher values (green) may indicate healthier mangrove vegetation conditions compared to lower values (red) (Figure 7). Decreases in these values may also signify mangrove ecosystem degradation in the study area. NDVI can be utilized as a method to ascertain the extent of mangrove forest degradation by observing changes in vegetation structure, density decline, and tree mortality.

The degradation status in MNTP was validated through direct field observation activities. These observations revealed the presence of mangrove degradation in the research area, primarily affecting mature to old mangrove vegetation. Some mature mangroves appeared damaged due to various factors, resulting in a decline in density values. The dominant plant species in the research area are mature mangrove forests. Being inundated by water and influenced by tidal fluctuations makes it difficult for other trees and plants to thrive (Figure 8). While high salinity levels are suitable for mangrove plants, they are not conducive to the survival of other plant species. Thus, it can be evidenced that the MNTP mangrove forest area has experienced degradation due to a decline in density between 2018 and 2023.

Furthermore, healthy mangrove areas are characterized by dense vegetation cover and vigorous growth, typically observed in locations with optimal environmental conditions such as sufficient sunlight exposure, adequate water availability, and suitable soil composition (Figure 9). These areas exhibit lush greenery, abundant mangrove trees and rapidly growing understory vegetation, indicating a resilient and well-functioning ecosystem.

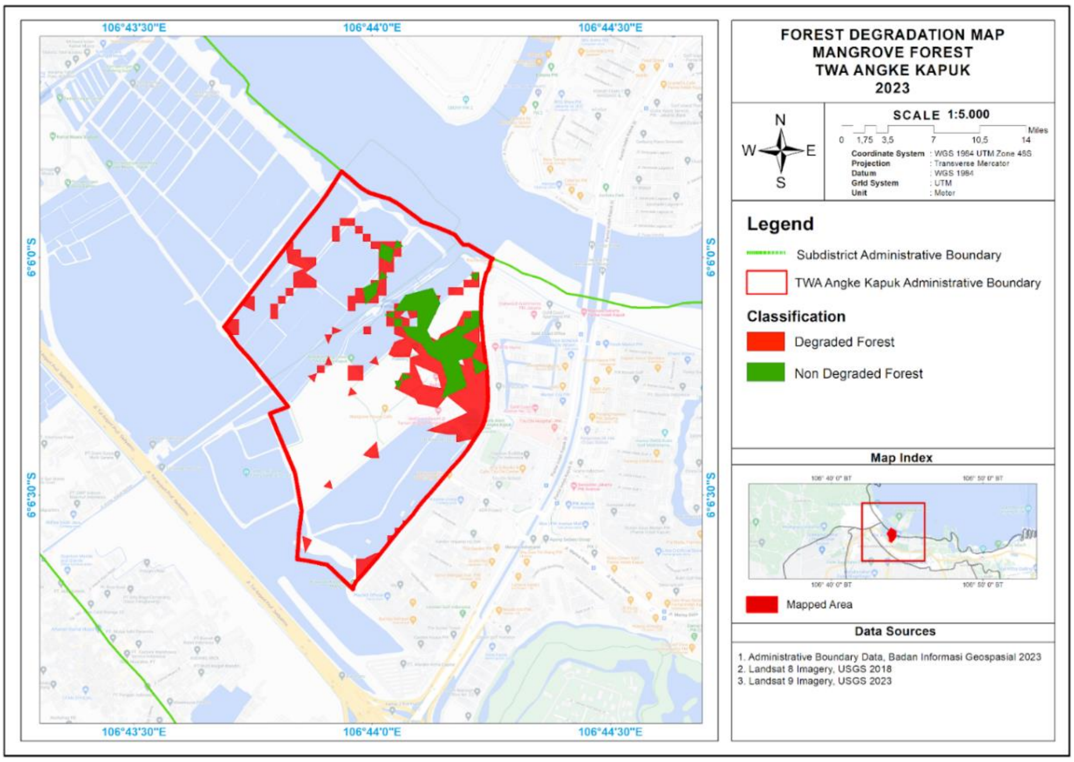


Figure 7. Forest Degradation Map in MNTP.

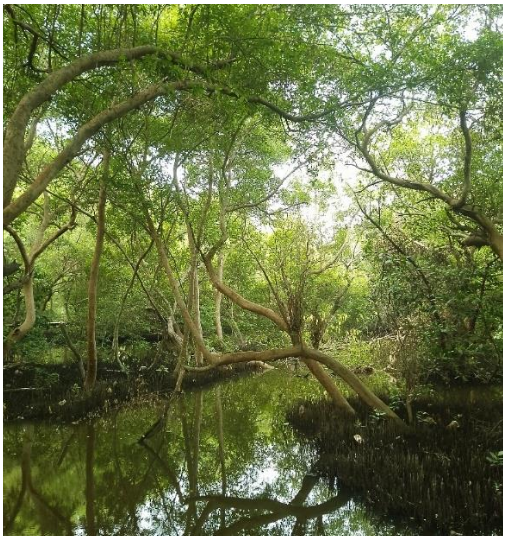


Figure 8. Mangrove Growth Site Conditions.


Figure 9. Healthy mangrove vegetation condition.

3.3. Accuracy Assessment

A field survey was conducted to determine the extent and density of mangroves in terms of quality, following the completion of multiple stages of mangrove identification and vegetation density index calculation. The accuracy assessment outcomes for non-vegetation classification (-1 - 0.03) indicated that the producer and user accuracy were both 100% (Table 7). It attests to the precision of the processing outcomes in this classification, where non-vegetation areas were identified in the field as Water Body (TA) land use and Residential (PM) structures.

Within the low classification range (0.03 – < 0.25), the Producer and User Accuracy results were 80% and 57%, respectively, suggesting a discrepancy between the polygon classification and actual field conditions. Similarly, in the accuracy assessment outcomes for low-density vegetation classification (0.25 – < 0.40), the Producer Accuracy was 30%, and the User Accuracy was 87%. Analogous to the low classification, there is an inconsistency between the processing outcomes and the actual field conditions, characterized by gaps in the mangrove trees.

In the high-density vegetation classification (0.40 – 1), both Producer and User Accuracy scores were 100%, indicating agreement between the processing outcomes and actual field conditions, recognized as areas with high-density mangrove cover. The accuracy assessment outcomes demonstrate an 80% accuracy level, affirming that the NDVI method's processing outcomes from the confusion matrix, providing overall accuracy data, pass the accuracy assessment if the result is > 80% (Short, 1982).

Table 7. Confusion Matrix Table.

Sample Data	Classification Categories				Total Rows	*User Accuracy*	*Error Commission*
	-1 – 0.03	0.03 – < 0.25	0.25 – < 0.40	0.40 – 1			
-1 – 0.03	2				2	100%	0
0.03 – < 0.25		4	3		7	57%	43%
0.25 – < 0.40		1	7		8	87%	23%
0.40 – 1				3	3	100%	0
Total Columns	2	5	10	3	20		
Producer Accuracy	100%	80%	30%	100%			
Error Commission	0	20%	70%	0			
Total Large Classifications			16				
Overall Accuracy			80%				
Kappa Index			76.2				

3.4. Monitoring Forest Degradation

Observations and analyses of the mangrove ecosystem conditions in the Mangrove Nature Tourism Park (MNTP) have revealed several significant challenges the area faces. Spatial analysis results have indicated the occurrence of mangrove forest degradation at the research site. Based on field observations, several factors have been identified as contributors to mangrove degradation. The primary finding of this study is the accumulation of waste entangled among mangrove seedlings, hindering their growth (Figure 10). Increased visitor numbers are directly proportional to the accumulation of waste. Improper waste management may lead to potential waste seepage into mangrove habitats. Furthermore, marine debris carried by ocean currents also contributes to the accumulation of waste.

Figure 10. The Garbage Trapped in Mangroves.

The accumulated waste subsequently creates stagnant water, leading to turbidity in the surrounding water bodies near the mangrove habitat (Figure 11). The turbidity serves as an indication of water body pollution. Stagnant water bodies near the mangrove habitat not only compromise the health of the ecosystem but also pose potential risks to the surrounding aquatic life. The turbid water, indicative of pollution, highlights the urgent need for mitigation measures to preserve water quality and safeguard the biodiversity of the area. Implementing effective waste management strategies and promoting awareness among visitors and local communities is essential to address this pressing environmental concern.

Figure 11. Water Turbidity Due to Garbage Around Mangroves.

The second finding pertains to morphological damage observed in the mangrove tree trunks (Figure 12). Damage to mangrove trunks can result from various factors, such as pest infestations, disease infections, and nutrient deficiencies, affecting the vegetation's ability to thrive in unfavorable environments (Arifanti et al., 2022; Meera et al., 2023). However, a limitation of this study is the lack of in-depth and comprehensive discussion regarding the factors contributing to mangrove morphological damage.

Figure 12. Damaged Morphology of Mangrove Stems

In summary, observations and analyses of the mangrove ecosystem in the Mangrove Nature Tourism Park (MNTP) have revealed significant challenges, including mangrove forest degradation attributed to waste accumulation, increased visitor numbers, and resulting water pollution. Additionally, morphological damage observed in mangrove trunks highlights potential environmental stressors affecting mangrove health. These findings underscore the urgent need for effective waste management strategies and comprehensive conservation efforts to safeguard the ecological integrity of mangrove habitats in MNTP. To comprehensively address the multifaceted challenges encountered within the Mangrove Nature Tourism Park (MNTP) and to facilitate sustainable mangrove conservation, a series of recommendations are proposed:

Firstly, the implementation of the Agrosilvofishery system stands as a pivotal strategy, embodying an integrated approach that harmonizes agriculture, forestry, and aquaculture. This system not only offers a pragmatic avenue for local communities to partake in fish farming endeavors but also mitigates the conversion of mangrove ecosystems into fishpond areas. Furthermore, the synergistic integration of agricultural and forestry systems holds promise in nurturing robust and fecund mangrove vegetation, thus underpinning the overarching goals of mangrove conservation and the perpetuation of coastal ecosystem sustainability.

Secondly, the augmentation of mangrove species diversity through deliberate species enrichment initiatives merits careful consideration. Such endeavors entail the selective introduction or planting of mangrove species tailored to suit specific environmental exigencies. By fostering genetic diversity, these efforts fortify mangrove resilience against environmental perturbations, particularly in the face of escalating sea levels or pervasive pollutant exposure. Noteworthy examples include the notable tolerance of certain mangrove species, such as Avicennia Marina, to adverse conditions, thereby offering potential avenues for mitigating metal toxins, as elucidated by antecedent scholarly investigations (Sari et al., 2019).

Thirdly, the imperative to undertake meticulous spatial planning reconstructions for sustainable mangrove conservation areas within the MNTP locale cannot be overstated. It mandates the periodic assessment of ecosystem restoration endeavors, coupled with the judicious implementation of water management systems to enhance water quality and alleviate pressures impeding mangrove proliferation. Concurrently, endeavors to bolster soil quality through strategic reconstructions of sustainable mangrove conservation areas assume paramount significance, alongside the systematic delineation of land suitability parameters tailored to the diverse requirements of targeted mangrove seedling species.

Finally, inculcating a visitor engagement and awareness culture emerges as an indispensable facet of sustainable mangrove conservation endeavors. Educational endeavors, including workshops, campaigns, and outreach programs, should be judiciously intensified to enhance visitor comprehension and environmental consciousness. Encouraging active visitor involvement in mangrove planting initiatives and waste cleanup drives within the MNTP precincts serves to deepen their appreciation of the intrinsic value of preserving mangrove ecosystems.

4. Conclusion

Based on the research findings, it can be concluded that the MNTP Angke Kapuk has undergone degradation. Analysis of Landsat 8 and 9 imagery reveals notable fluctuations in the extent of mangrove forest density between 2018 and 2023. Specifically, there was a discernible augmentation in the areas classified as low and moderate vegetation by 1.73 ha and 15.11 ha, respectively. Conversely, a notable decline of 13.16 ha was observed in the high vegetation classification. The observed degradation predominantly stems from anthropogenic activities. These empirical findings underscore the imperative of perpetuating rigorous, sustainable monitoring initiatives for mangrove ecosystem conservation and safeguarding. Such endeavors are indispensable, given the pivotal role of MNTP in furnishing vital ecosystem services and preserving environmental equilibrium.

Ethics Committee Approval: N/A.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept: T.N.S., S.P., K.E.; Design: T.N.S., S.P. Supervision: K.E.; Resources: T.N.S.; Data Collection: T.N.S., S.P., K.E.; Analysis: T.N.S., S.P., K.E.; Literature Search: T.N.S., S.P., K.E.; Writing Manuscript: T.N.S., S.P., K.E.; Critical Review: T.N.S.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: This work has been generously supported by Yayasan Mangrove Indonesia Lestari. The authors would also like to express their gratitude to the Department of Forestry of DKI Jakarta Province for their invaluable support.

Cite this paper as: Suryana, T.N., Purnamasari, S., Ewaldo, K. 2024. Monitoring Mangrove Forest Degradation in Mangrove Nature Tourism Park Angke Kapuk, North Jakarta, Indonesia Using NDVI, *European Journal of Forest Engineering*, 10(1):29-42.

References

Abd-El Monsef, H., Smith, S.E. 2017. A new approach for estimating mangrove canopy cover using LANDSAT 8 imagery. *Computers and Electronics in Agriculture*, 135:183-194. https://doi.org/10.1016/j.compag.2017.02.007

Arifanti, V.B., Sidik, F., Mulyanto, B. 2022. Challenges and Strategies for Sustainable Mangrove Management in Indonesia: A Review. *Forest,* 13(5): 695. https://doi.org/10.3390/f13050695

Annatakarn, K., Fooprateepsiri, R., Suwanprapab, M., Supunyachotsakul, C., Witchayangkoon, B. 2022. Finding threshold for NDVI to classify green area: case study in the central Thailand. *Journal of Hunan University Natural Sciences*, 49(4). https://doi.org/10.55463/issn.1674-2974.49.4.34

Bernstein, L.S., Adler-Golden, S.M., Jin, X., Gregor, B., Sundberg, R.L. 2012. Quick atmospheric correction (QUAC) code for VNIR-SWIR spectral imagery: Algorithm details. In 2012 4th *Workshop on Hyperspectral Image and Signal Processing: Evolution in Remote Sensing*. http://dx.doi.org/10.1109/WHISPERS.2012.6874311

Carugati, L., Gatto, B., Rastelli, E., Martire, M.L., Coral, C., Greto, S., Danovaro, R. 2018. Impact of mangrove forests degradation on biodiversity and ecosystem functioning. *Scientific Reports*, 8: 13298. https://doi.org/10.1038/s41598-018-31683-0

Congalton, R. G. 1991. A review of assessing the accuracy of classifications of remotely sensed data. *Remote sensing of environment*, 37(1), 35-46.

Davis, Z., Nesbitt, L., Guhn, M., van den Bosch, M. 2023. Assessing changes in urban vegetation using Normalised Difference Vegetation Index (NDVI) for epidemiological studies. *Urban Forestry and Urban Greening, 88*. https://doi.org/10.1016/j.ufug.2023.128080

Department of Forestry of DKI Jakarta Province. 2022. *Preparation of forest management plan for the management of the Angke Kapuk Forest Area, North Jakarta, DKI Jakarta Province*. Jakarta.

de Silva, W., Amarasinghe, M.D. 2023. Coastal protection function of mangrove ecosystems: a case study from Sri Lanka. *Journal of Coastal Conservation,* 27(6). https://doi.org/10.1007/s11852-023-00990-8

Dewi, E. K., Trisakti, B. 2017. Comparing atmospheric correction methods for Landsat OLI data. *International Journal of Remote Sensing and Earth Sciences (IJReSES)*, 13(2):105-120. http://dx.doi.org/10.30536/j.ijreses.2016.v13.a2472

Efriyeldi, E., Syahrial, S., Effendi, I., Almanar, I.P., Syakti, A.D. 2023. The mangrove ecosystem in a harbor-impacted city in Dumai, Indonesia: A conservation status. *Regional Studies in Marine Science*, 65. https://doi.org/10.1016/j.rsma.2023.103092

Ewaldo, K., Karuniasa, M., Takarina, N.D. 2023. Carrying capacity of mangrove ecotourism area in Pantai Indah Kapuk, North Jakarta, Indonesia. *Biodiversitas*, 24(10): 5808-5819. http://dx.doi.org/10.13057/biodiv/d241063

FAO [Food and Agriculture Organization of the United Nations]. 2020. *Global Forest Resources Assessment*

2020 Main Report. In Reforming China's Healthcare System. Rome. Italy. DOI: 10.4324/9781315184487-1.

Farras, H.R.H., Abdurrahman, U., Fadhil, P.I., Nur, A.A. 2022. *Mapping of Coastal Mangrove at Mangrove Nature Tourism Park, Angke Kapuk, North Jakarta, Indonesia*. Korea-Indonesia Marine Technology Cooperation Research Center. Jakarta

Faruque, M.J., Hasan, M.Y., Islam, K.Z., Young, B., Ahmed, M.T., Monir, M.U., Shovon, S.M., Kakon, J.F., Kundu, P. 2022. Monitoring of land use and land cover changes by using remote sensing and GIS techniques at human-induced mangrove forests areas in Bangladesh. *Remote Sensing Applications: Society and Environment*, 25, 100699. https://doi.org/10.1016/j.rsase.2022.100699

Fayech, D., Tarhouni, J., 2021. Climate variability and its effect on normalized difference vegetation index (NDVI) using remote sensing in semi-arid area. *Modeling Earth Systems and Environment,* 7(3): 1667–1682. https://doi.org/10.1007/s40808-02000896-6

Gerard, F.F., George, C.T., Hayman, G., Chavana-Bryant, C., Weedon GP. 2020. Leaf phenology amplitude derived from MODIS NDVI and EVI: Maps of leaf phenology synchrony for Meso- and South America. *Geosciences Data Journal*, 7:13–26. https://doi.org/10.1002/gdj3.87

Giri, C. 2023. Frontiers in Global Mangrove Forest Monitoring. *Remote Sensing*, 15(15). https://doi.org/10.3390/rs15153852

Goldberg, L., Lagomasino, D., Thomas, N., Fatoyinbo, T., 2020. Global declines in human-driven mangrove loss. *Global Change Biology*, 26(10), 5844-5855. https://doi.org/10.1111/gcb.15275

Guo, Y., Zeng, F. 2012. Atmospheric correction comparison of SPOT-5 image based on model FLAASH and model QUAC. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 39: 7-11. https://doi.org/10.5194/isprsarchives-XXXIX-B7-7-2012

Hasani, Q., Anisa, A., Damai, A.A., Yuliana, D., Yudha, I.G., Julian, D., 2023. *Biodiversitas*, 24(7): 3735-3742. https://doi.org/10.13057/biodiv/d240710

Iacono, L.E., Pacios, D., Vazquez-Poletti, J.L. 2023. SNDVI: A new scalable serverless framework to compute NDVI. *Frontiers in High Performance Computing*, 1, 1151530.

Jianya, G., Haigang, S., Guorui, M., Qiming, Z. 2008. A review of multi-temporal remote sensing data change detection algorithms. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 37(B7): 757-762.

Kędziorski, P., Kogut, T., Oberski, T. 2023. Impact of radiometric correction on the processing of UAV images. Scientific *Journals of the Maritime University of Szczecin*, 73 (145): 5-14. DOI: 10.17402/550.

Lintz, J., Simonett, D.S. 1976. Sensors for spacecraft. *Remote Sensing of Environment*, 323-343. https://doi.org/10.1177/030913337900300412

Meera, S.P., Bhattacharyya, M. Kumar, A. 2023. Dynamics of mangrove functional traits under osmotic and oxidative stresses. *Plant Growth Regul* 101, 285–306. https://doi.org/10.1007/s10725-023-01034-9

Moravec, D., Komárek, J., Medina, S. L., Molina, I. 2021. Effect of Atmospheric Corrections on NDVI: Intercomparability of Landsat 8, Sentinel-2, and UAV Sensors. *Remote Sensing*, 13(8): 3550. https://doi.org/10.3390/rs13183550

Mayalanda, Y., Yulianda, F., Setyobudiandi, I. 2014. Strategy for mangrove ecosystem rehabilitation throughout damaged level analysis at Muara Angke Wildlife Sanctuary, Jakarta. *International Journal of Bonorowo Wetlands*, *4*(1): 12-36. https://doi.org/10.13057/bonorowo/w040102

Muchsin, F., Harmoko, A., Prasasti, I., Rahayu, M.I., Fibriawati, L., Pradhono, K.A. 2022. Comparison of The Radiometric Correction Landsat-8 Image Based on Object Spectral Response and Vegetation Index. *International Journal of Remote Sensing and Earth Sciences (IJReSES)*, *18*(2): 177-188. http://dx.doi.org/10.30536/j.ijreses.2021.v18.a3632

Naser, M.A., Khosla, R., Longchamps, L., Dahal, S. 2020. Using NDVI to differentiate wheat genotypes productivity under dryland and irrigated conditions. *Remote Sensing*, *12*(5): 824. https://doi.org/10.3390/rs12050824

Pamungkas, B., Kurnia, R., Riani, E., Taryono. 2020. Classification of Mangrove Ecosystem Area in Pantai Bahagia Village, Muara Gembong, Bekasi Regency, Using Sentinel Imagery with Normalized Difference Vegetation Index Method. *Journal of Tropical Marine Science and Technology*, 12(3):821-831. https://doi.org/10.29244/jitkt.v12i3.32241

Paolini, L., Grings, F., Sobrino, J.A., Jiménez Muñoz, J.C., Karszenbaum, H. 2006. Radiometric correction effects in Landsat multi-date/multi-sensor change detection studies. *International Journal of Remote Sensing*, 27(4):685-704. https://doi.org/10.1080/01431160500183057

Perri, S., Detto, M., Porporato, A., Molini, A. 2023. Salinity-induced limits to mangrove canopy height. *Global Ecology and Biogeography*, 32(9):1561–1574. https://doi.org/10.1111/geb.13720

Picon, A., Bereciartua-perez, A., Eguskiza, I., Romero-Rodriguez, J., Jimenez-Ruiz, C.J., Eggers, T., Klukas, C., Navarra-Mestre, R. 2022. Deep convolutional neural network for damaged vegetation segmentation from RGB images based on virtual NIR-channel estimation. *Artificial Intelligence in Agriculture*, 6: Pages 199-210. https://doi.org/10.1016/j.aiia.2022.09.004

Purnamasari, E., Kamal, M., Wicaksono, P. 2021. Comparison of vegetation indices for estimating above-ground mangrove carbon stocks using PlanetScope image. *Regional Studies in Marine Science*, 44. https://doi.org/10.1016/j.rsma.2021.101730

Rondon, M., Ewane, B.E., Abdullah, M., Watt, M., Blanton, A., Abulibdeh, A., Mohan, M. 2023. Remote sensing-based assessment of mangrove ecosystems in the Gulf Cooperation Council countries: A systematic review. *Frontiers in Marine Science*, 10, 1241928. https://doi.org/10.3389/fmars.2023.1241928

Sari, N., Patria, M.P., Soesilo, T.E.B., Tejakusuma, I.G. 2019. The Structure of Mangrove Communities in Response to Water Quality in Jakarta Bay, Indonesia. *Biodiversitas*, 20(7): 1873-1879, DOI: 10.13057/biodiv/d200712

Schaduw, J.N.W. 2019. Community Structure and Canopy Coverage Percentage of Salawati Island Mangroves, Raja Ampat Regency, West Papua Province. *Majalah Geografi Indonesia*, 33(1): 26-34. https://doi.org/10.22146/mgi.34745

Shankar, V.S., Purti, N., Singh, R.P., Khudsar, F.A. 2020. Secondary Ecological Succession of Mangrove in the 2004 Tsunami Created Wetlands of South Andaman, India. In Mangrove Ecosystem Restoration. *IntechOpen*. DOI: 10.5772/intechopen.94113

Sofian, A., Kusmana, C., Fauzi, A., Omo Rusdiana. 2019. Evaluation of Angke Kapuk Jakarta Bay Mangrove Ecosystem and Its Consequences on Ecosystem Services. *Jurnal Kelautan Nasional*. http://dx.doi.org/10.15578/jkn.v15i1.7722

Sokolović, D., Bajric, M., Akay, A.E. 2022. Using GIS-based Network Analysis to Evaluate the Accessible Forest Areas Considering Forest Fires: The Case of Sarajevo. *European Journal of Forest Engineering*, 8(2):93-99. https://doi.org/10.33904/ejfe.1211687

Sraun, M., Bawole, R., Marwa, J., Sinery, A. S., Cabuy, R. L. 2022. Diversity, composition, structure and canopy cover of mangrove trees in six locations along Bintuni riverbank, Bintuni Bay, West Papua, Indonesia. Biodiversitas, 23(11): 5835–5843. https://doi.org/10.13057/biodiv/d231137

Van Anh, B.K. 2023. Evaluation The Changing of Can Gio Vegetation Index By The Sentinel-2 Database From 2015 to 2023.

Yengoh, G. T., Dent, D., Olsson, L., Tengberg, A. E., Tucker, C. J. 2015. *Use of the Normalized Difference Vegetation Index (NDVI) to assess Land degradation at multiple scales: current status, future trends, and practical considerations*. Lund University Centre for Sustainability Studies - LUCSUS. Lund. Sweden.

Zhu, J.J., Yan, B. 2022. Blue carbon sink function and carbon neutrality potential of mangroves. *Science of the Total Environment*, 822: 153438. https://doi.org/10.1016/j.scitotenv.2022.153438