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MAPPING AND ANALYSIS OF MANGROVE VEGETATION DISTRIBUTION ON PANJANG ISLAND, SERANG BANTEN USING SENTINEL-2A IMAGERY

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ABSTRACT

Mangroves serve as vital ecosystems in coastal zones, providing ecological, economic, and protective functions. This study aims to map the distribution and estimate the density of mangrove vegetation on Panjang Island, Serang-Banten, using Sentinel-2A satellite imagery and the Normalized Difference Vegetation Index (NDVI). The study was conducted on Panjang Island, Serang District, Banten Province, within the geographic coordinates of 106.130°BT to 106°174BT and 5.915°LS to 5.950°LS. The data used were Sentinel-2A satellite images taken throughout 2024, from January 1 to December 31. Data were collected and processed using Google Earth Engine and GIS software to extract NDVI values and classify mangrove density into sparse, moderate, and dense categories. The results indicate a dominant presence of dense mangrove vegetation (NDVI 0.6–1.0), accounting for 79.3% of the study area, while moderate and sparse covers made up 15.57% and 5.26%, respectively. This analysis highlights the importance of continuous mangrove monitoring to support conservation and sustainable management strategies in coastal regions.

INTRODUCTION

Mangrove ecosystems are among the most productive and ecologically significant environments in coastal areas. They provide essential services such as coastal protection, nursery grounds for fish and invertebrates, and carbon sequestration. Despite their importance, mangrove forests are under increasing threat from anthropogenic pressures, including land reclamation, aquaculture expansion, and pollution. As a response to these threats, accurate mapping and regular monitoring of mangrove cover have become crucial. Mangrove ecosystems are among the most productive and ecologically significant environments in coastal areas. They provide essential services such as coastal protection, nursery grounds for fish and invertebrates, and carbon sequestration (Alongi, 2002; Donato et al., 2011). Despite their importance, mangrove forests are under increasing threat from anthropogenic pressures, including land reclamation, aquaculture expansion, and pollution (Valiela, Bowen, & York, 2001; Giri et al., 2011). As a response to these threats, accurate mapping and regular monitoring of mangrove cover have become crucial (Kuenzer et al., 2011).

Remote sensing technologies offer a cost-effective and scalable approach for monitoring mangrove forests. Among these, the Sentinel-2A satellite, with its high-resolution multispectral capabilities, is widely used for vegetation analysis. The Normalized Difference Vegetation Index (NDVI) is a well-established method to evaluate vegetation health and density. While many studies have utilized NDVI to assess mangrove ecosystems across Indonesia, specific studies focusing on small offshore islands like Panjang Island remain limited. This research aims to fill that gap by mapping mangrove distribution and estimating vegetation density on Panjang Island, Serang-Banten, using Sentinel-2A data processed through Google Earth Engine. The outcomes are expected to support local conservation efforts and inform sustainable management strategies.

LITERATURE REVIEW

Mangrove vegetation mapping has evolved significantly with the development of remote sensing tools. NDVI, introduced by Rouse *et al.* (1974), has become a widely accepted index for vegetation monitoring due to its simplicity and reliability. Several recent studies have successfully applied NDVI to mangrove environments. For example, Giri *et al.* (2011) conducted a global-scale mangrove distribution study using Landsat data, while Phiri *et al.* (2020) highlighted Sentinel-2A's potential in capturing vegetation variability in smaller regions. Local studies, such as those by Badola *et al.* (2012), emphasize the socio-ecological role of mangroves in community resilience. In the Indonesian context, efforts by Simarmata *et al.* (2021) and Fariz *et al.* (2021) illustrate the integration of remote sensing with machine learning and cloud computing to enhance mangrove analysis. These developments underline the potential for scalable, repeatable mangrove assessments that can support policy-making and conservation

METHOD

The study was conducted on Panjang Island, Serang District, Banten Province, within the geographic coordinates of 106.130°BT to 106°174BT and 5.915°LS to 5.950°LS. The data used were Sentinel-2A satellite images taken throughout 2024, from January 1 to December 31. Satellite data were obtained from Sentinel-2A, focusing on imagery to ensure minimal 10% cloud cover. Analysis was carried out visually on the spectral characteristics of the image, using a composite of band 8 and related bands that reflect near-infrared wavelengths. Image processing was carried out using Google Earth Engine (GEE).

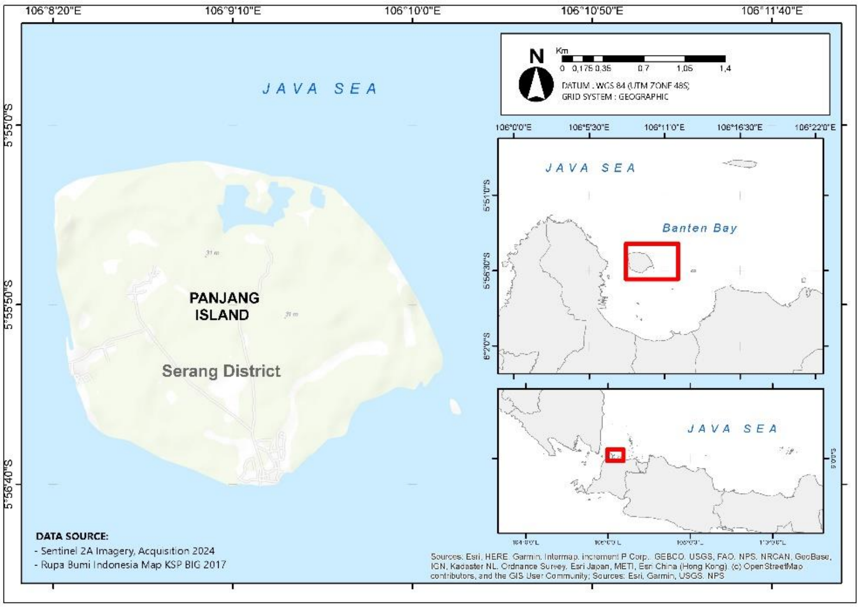

Figure 1. Map of Study Area

Identification of the difference between the color of the image results for mangrove vegetation is used using the composite band image 8 11 4. The digital process includes multispectral merging, image sharpening, and filtering. A subset of images was taken to match the area of the study, making it easier to determine the distribution, area, and changes in mangrove cover.

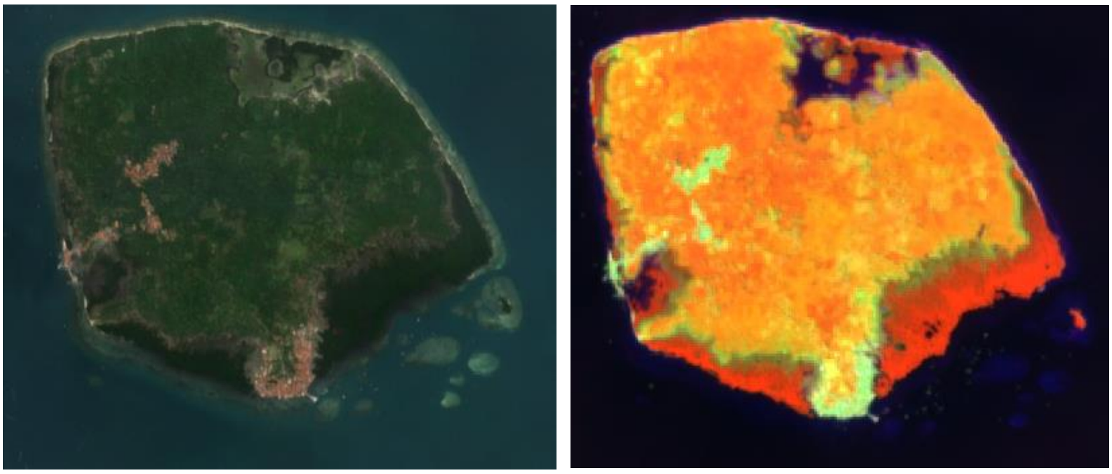

Figure 2. Image Composite Band (432) & (8114)

For classification, the Classification and Regression Trees (CART) algorithm was used, which is a decision tree-based machine learning method and is widely used in land cover classification. In this study, the classification was limited to three main land cover types: water bodies, mangrove vegetation, and non-mangrove vegetation, where the last category includes other green covers (Tamiminia *et al.,* 2020). Mangrove density values were calculated using the Normalized Differential

Vegetation Index (NDVI) equation. NDVI was calculated using Band 8 (near-infrared) and Band 4 (red). The resulting NDVI values were classified into three categories: sparse: 0.1–0.3; moderate: 0.31–0.59; and dense: 0.6–1.0. Post-processing was conducted in QGIS for area calculation and map visualization. The classification results were cross-validated with visual interpretation to assess the accuracy of vegetation delineation.

RESULT AND DISCUSSION

Optical images in the near-infrared (NIR) channel, especially band 8, show high reflectance levels in mangrove vegetation (Munandar *et al.,* 2023). This allows for a clear visual separation between mangrove and non-mangrove vegetation. This difference is due to the spectral characteristics of mangroves which significantly reflect more NIR wavelengths than other vegetation, mainly due to the structure and air content of the leaves. NIR wavelengths are known to be very sensitive to air content in leaves, making them an important indicator in assessing the health of vegetation. In addition, the reflectance of vegetation in the NIR spectrum tends to be higher than that of built-up areas and open land, providing a clear contrast in the interpretation of multiband satellite imagery (Xie *et al.,* 2008; Phiri *et al.,* 2020).

Mangrove ecosystem classification can be performed using a range of digital image classification techniques, each with varying levels of complexity and accuracy. Traditional methods such as pixel-based classification analyze individual pixels based on their spectral values, while object-based classification incorporates spatial and contextual information, often producing more accurate results in heterogeneous landscapes. In addition, knowledge-based approaches apply expert rules for delineating land cover types. With the advancement of computational power, supervised and unsupervised machine learning methods have become increasingly popular in remote sensing applications (Phiri et al., 2020).

Among the supervised machine learning techniques, the Classification and Regression Trees (CART) algorithm is frequently employed due to its simplicity, interpretability, and robustness in handling large datasets. CART creates decision trees based on training data that represent different land cover types, including mangroves. When trained with well-distributed sample data, CART can effectively differentiate mangrove forests from other land covers, such as urban areas, water bodies, or other vegetated zones (Jiang et al., 2021; Maurya et al., 2021). Furthermore, the precision of classification results—especially those obtained via deep learning—depends not only on the algorithm used but also on the quality and quantity of training data, as well as on the appropriate tuning of model parameters. Zhao and Qin (2021) highlight the importance of choosing a classification framework that suits the specific mapping goal.

In large-scale mangrove mapping, the choice of classification type should align with both the goals of the study and the resolution of available remote sensing data. For example, binary classification might be enough for detecting mangrove versus non-mangrove areas, while multiclass classification enables finer differentiation among various land cover types. In visual outputs (Figure below), the use of distinct color codes (e.g., green) helps to highlight the spatial extent of mangrove coverage identified by CART or other classifiers. The NDVI analysis produced a classified map indicating three vegetation density levels. Dense mangrove vegetation (NDVI 0.6–1.0) was found to dominate the eastern and southern portions of the island, comprising 79.3% of the total mangrove area. Moderate density zones (NDVI 0.31–0.59) made up 15.57%, while sparse vegetation (NDVI 0.1–0.3) was mostly located along the western and northen coast, accounting for 5.26%.

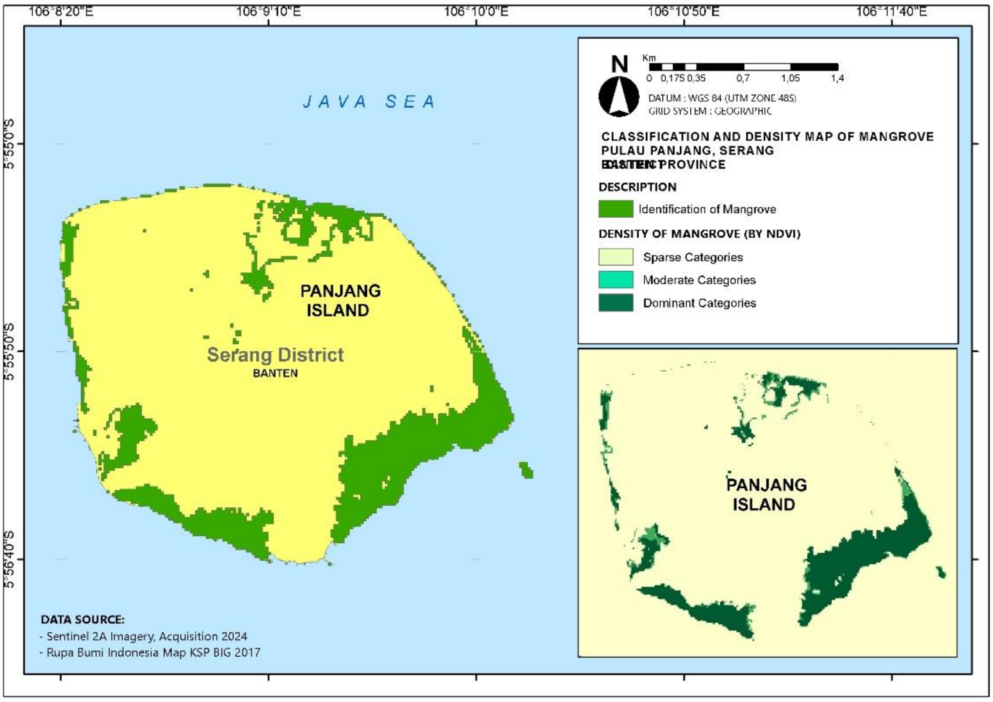

Figure 3. Mangrove Classification Results Based on Machine Learning CART (Red Is Mangrove) and NDVI Mangrove Density (Below)

Compared to previous studies in similar coastal zones, the mangroves on Panjang Island show relatively robust health. This may be attributed to the island's limited accessibility and absence of large-scale development. However, small signs of degradation near the island's southern margin suggest the need for continued monitoring. These findings are consistent with the work of Giri *et al.* (2011) and Simarmata *et al.* (2021), who noted that remote sensing indices can reliably distinguish vegetation health and density. The successful application of NDVI on Panjang Island reaffirms its utility in tropical coastal environments and highlights the importance of timely, high-resolution data for conservation.

CONCLUSSION

This research successfully mapped and classified mangrove vegetation density on Panjang Island using Sentinel-2A imagery and NDVI analysis. Dense vegetation dominates the landscape, indicating a relatively healthy mangrove ecosystem. The application of NDVI proves effective in distinguishing density levels and can serve as a reliable monitoring tool. These results contribute to localized coastal management efforts and underline the importance of integrating remote sensing in environmental monitoring. Future research should incorporate ground validation and explore seasonal variation in mangrove cover to enhance long-term conservation strategies.

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