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Article

Mapping of Mangrove Forest Areas in Kampung Bahari Nusantara, Sukawali Village, Paku Haji Sub-district, Tangerang Regency, Banten

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A B S T R A C T

Indonesia is an archipelagic nation with an extensive coastline that is synonymous with mangrove ecosystems. Mangrove forest areas in Indonesia are facing increasing pressure in the form of land conversion for various purposes and needs related to meeting human requirements (settlements and infrastructure development). Research aimed at mapping the extent of mangrove forest areas needs to be carried out to serve as a data reference, particularly in the archipelago's marine forest areas, given the reduction in their extent and the lack of identification of mangrove vegetation distribution; hence, mapping is necessary. The method employed involved analyzing processed satellite imagery (Landsat 8), utilizing the OLI (Operational Land Imager) sensor with the primary bands of near-infrared (Band 5), red (Band 4), and green (Band 3) with a spatial resolution of 30 meters, as well as RGB colour composites 564 or 563 to distinguish coastal vegetation density; the study also involved local communities in validating the data in the field (participatory approach). The results show that the mangrove forest in the Kampung Bahari Nusantara area covers an area of approximately 41.849 ha, divided into three classifications: open land (approximately 24.864 ha), water bodies (approximately 15.718 ha) and mangrove vegetation (approximately 1.267 ha).

1. Introduction

Indonesia is an archipelagic nation comprising approximately 17,508 islands and has a coastline of approximately 81,000 km. These geographical features mean that Indonesia possesses vast potential in terms of natural resources, particularly in coastal areas, from both an ecological and an economic perspective (Zefri, 2021).

One of the most important coastal ecosystems is the mangrove forest. According to data published by the Ministry of Environment and Forestry in 2024 (Ministry of Environment and Forestry (KLH), 2024), the total area of mangrove forests in Indonesia is approximately 3.40 million hectares, or 23% of the world's total mangrove habitat. Of the total area of 3.40 million hectares, the mangrove forests are further categorized according to their condition as follows: 3.16 million hectares are in a dense condition, 186.500 hectares are in a moderate condition, and approximately 53.000 hectares are in a sparse condition. This demonstrates that Indonesia plays a vital role in safeguarding the sustainability of the world's mangrove ecosystems (Alongi, 2020).

Table 1. Mangrove Forest Conditions in Indonesia

Mangrove Forest	Area (Ha)	Persentase	Categories
	3.16 million	92 %	Heavy
	186.5 thousand	5,4%	Moderate
	53.8 thousand	1,6%	Rare

Source: Kementerian Lingkungan Hidup dan Kehutanan (KLHK) 2024

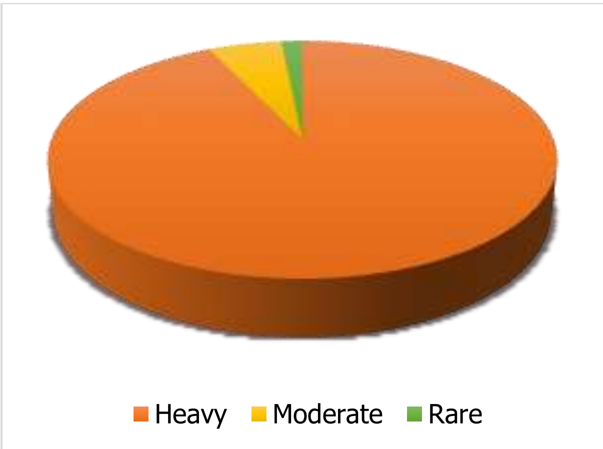

Figure 1. Percentage of Indonesia's Mangrove Forest Area in 2024

Mangrove ecosystems function as highly productive ecological systems that play a vital role in climate change mitigation, blue carbon sequestration, and the protection of coastlines from erosion and seawater intrusion (Kusmana, 2016; Zaryaningsih et al., 2022). Furthermore, mangrove forests provide a vital habitat for aquatic life, support coastal nutrient cycles, and possess high economic value through fisheries, tourism and non-timber forest products (Prihadi et al., 2024).

However, Indonesia's mangrove forests are coming under increasing pressure due to land conversion for housing, infrastructure and aquaculture (Rahmawati et al., 2024); these anthropogenic activities are causing land degradation and a decline in biodiversity, as well as increasing the risk of coastal erosion (Eddy et al., 2015); empirical evidence shows that, over the last two decades, more than 30 per cent of Indonesia's mangroves have been degraded as a result of uncontrolled land-use change (Alongi, 2020). Data from Global Mangrove Watch show that the area of Indonesia's mangroves has decreased from around 3.127 million ha in 1996 to 2.953 million ha in 2020, representing a net loss of approximately 173.904 ha.

As part of its conservation efforts, the Indonesian government has enacted Undang-Undang No. 1 of 2014 on the Management of Coastal Areas and Small Islands. This legislation aims to prevent the uncontrolled conversion of mangrove areas and sets out regulations concerning the restoration of damaged mangrove forests. The implementation of this law can have a positive impact on both the community and the environment, such as: Ecological Functions: Protecting the coastline from erosion and providing a habitat for various marine species. Ecotourism: Combining nature conservation efforts with recreational activities and environmental education. Economic Benefits: Increasing the income of local residents through the sustainable tourism sector (Mulyadi & Fitriani, 2010). However, existing regulations and policies on mangrove forest management in Indonesia still face obstacles and challenges regarding their implementation on the ground, such as: limited resources (both financial and human) and inter-agency coordination issues in the management process (overlapping responsibilities).

Data on the extent of mangrove forests in a given area is vital for various stakeholders, including government agencies and the private sector, as well as for educational and research purposes. However, the availability of annually updated mangrove forest data remains limited, despite the fact that changes in mangrove forest extent are both extensive and dynamic. Mapping is one of the initial steps that can be taken to monitor the condition of mangrove forests more effectively and efficiently, in order to obtain an overview of the distribution and extent of mangrove forests (Shobirin et al., 2016). The uses of mangrove forests are highly diverse, including environmental, social and economic benefits, and therefore up-to-date data on mangrove forest areas is essential.

In view of the importance of data on the extent of mangrove forest areas—for educational, economic and environmental purposes—it is necessary to carry out mapping of these areas, specifically the mangrove forest area of Kampung Bahari Nusantara, Sukawali Village, Pakuhaji Sub-district, Tangerang Regency, Banten Province. The use of satellite imagery will facilitate the research process, utilizing the NDVI method to simplify the identification of land cover, particularly vegetation (mangroves). To account for potential errors in the image processing (NDVI), a field survey must be carried out to validate the results of the mangrove vegetation identification.

2. Literature Review

2.1 Mangrove

Mangroves are unique ecosystems that act as a transitional zone between land and sea, characterized by high salinity, high temperatures, extreme wind and tidal conditions, muddy substrates, and oxygen-poor soil (Kusmana, 2014; Reski et al., 2024; Salampessy et al., 2024). Mangrove ecosystems have significant ecological and economic value for various countries in tropical and subtropical regions, whilst also playing a role in supporting the social lives of communities living in coastal areas (Leal & Spalding, 2024). Mangrove ecosystems play a vital role in maintaining the balance of the coastal environment, protecting coastal areas from erosion, and providing habitats for a wide range of species (Bimrah et al., 2022).

Furthermore, mangroves have a high capacity to absorb and store carbon (blue carbon), thereby making a significant contribution to climate change mitigation efforts (Alongi, 2020). However, mangrove ecosystems are currently facing serious threats due to anthropogenic pressures and the impacts of climate change, which are causing the degradation and decline of mangrove areas globally (Sasmito et al., 2020). Therefore, the monitoring and conservation of mangroves need to be carried out on a sustainable basis in order to preserve the ecological, economic and social functions of these ecosystems.

2.2 Geographic Information System

A Geographic Information System (GIS) is a geospatial technology used to integrate, manage, analyze and visualize data with a geographical reference. In coastal ecosystem research, GIS plays a vital role in integrating remote sensing data, field survey data and other spatial information to generate insights into the distribution, condition, changes and density of mangrove forests. The use of GIS in mangrove mapping enables spatial and multi-temporal analysis, allowing changes in the extent and condition of mangrove ecosystems to be identified more systematically (Sunkur et al., 2024). GIS-based mangrove forest mapping generally utilizes satellite imagery as the primary source of spatial information. Landsat is one of the most widely used data sources as it has a long record of multitemporal data and enables the monitoring of changes in mangrove cover over an extended period. Landsat data can be processed using a combination of spectral channels and vegetation indices, such as the Normalized Difference Vegetation Index (NDVI), to distinguish mangrove vegetation from other land cover types. Advances in image processing methods have also enabled the use of both supervised and unsupervised classification, as well as machine learning-based algorithms. Research on mangrove monitoring using dense Landsat time series shows that Landsat data can be used not only to map the presence of mangroves, but also to identify changes in condition, such as vegetation degradation and recovery (Yang et al., 2024).

2.3 Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is used to characterize the density and condition of vegetation in the study area. NDVI is one of the vegetation indices commonly used in remote sensing analysis because it is capable of representing the spectral response of vegetation to red and near-infrared (NIR) waveband reflectance. Vegetation generally exhibits low reflectance in the red channel due to chlorophyll absorption, and high reflectance in the near-infrared channel; consequently, NDVI values can be used to identify the greenness and density of vegetation (Hardianto et al., 2021).

The mangrove density classes derived from the NDVI transformation were subsequently validated against both true-colour and false-colour composites. Validation was carried out directly by comparing the vegetation density class results with the actual features visible in the image.

Table 2. NDVI Classification

Value Of NDVI	Categories
< 0	Clouds and Water
0 – 0,21	Non-Vegetation
0,21 – 0,42	Sparse Vegetation
0,42 – 0,63	Moderate Vegetation Density
0,63 – 0,85	Dense Vegetation

Source: Sunaryo & Iqmi (2015)

2.4 Participatory (Validation)

A participatory approach to research involves the active participation of local communities or stakeholders in the research process, from data collection through to interpretation, thereby enabling local knowledge to form part of the process of scientific knowledge formation (Cornwall & Jewkes, 1995; Sieber, 2006).

In remote sensing-based research, this approach is closely linked to ground validation, as communities can assist researchers in identifying and confirming actual conditions on the ground such as land cover types, vegetation conditions and vegetation density which are then compared with the results of satellite image interpretation. Consequently, community participation can strengthen the validation process, as ground truthing is indeed one of the primary forms of applying a participatory approach in remote sensing, particularly for verifying observational results from imagery (Sagan et al., 2024)

3. Research Methodology

This research was carried out by analyzing processed satellite imagery data. Landsat 8 imagery was utilized, alongside a participatory approach involving collaboration with the local community in the process of mapping mangrove forests, to ensure that the results were more accurate and reflected the actual conditions on the ground.

Pakuhaji Sub-district is a lowland area situated in the eastern coastal region of the northern part of Tangerang Regency, comprising 14 (fourteen) villages. The area of Pakuhaji Sub-district covers 46.02 km². Mapping of the mangrove forest area will be carried out in one of the villages in Pakuhaji Sub-district, namely Sukawali Village, covering an area of 2.43 km². Sukawali Village is a lowland area bordering directly on the Java Sea.

3.1 Instruments and Materials

This study utilizes two types of data: primary and secondary data. The data used in this study are as follows:

1. Secondary Data
   a. Landsat 8 satellite imagery
   b. Road data
2. Primary Data
   a. Facility data
   b. Field survey data (validation)

Research Equipment

1. Drone
2. Geodetic GPS
3. ArcGIS
4. Avensa application

3.2 Data Collection and Analysis

Data processing is a series of activities or methods carried out to process raw (secondary) data that has been obtained (Landsat 8 imagery) as input and converted into information. The data processing technique used in this study involves NDVI transformation. Image masking is intended to eliminate atmospheric disturbances or the appearance of objects that could introduce bias into the transformed values. The features eliminated during the masking stage are clouds, cloud shadows and rivers. Theoretically, water features (in this case, rivers) have a value range from -1 to close to 0 (Safitri et al., 2023) in the NDVI transformation results. In previous studies, this value range could be automatically classified as non-vegetation objects. However, this applies to transformations using images with low to medium spatial resolution.

The next step is image sharpening, to facilitate the identification or differentiation of objects and to simplify the delineation of areas. Following image sharpening, the next step involved image compositing; composite 564 was used, as it better highlights the distribution and density of mangrove forest objects. Once the mapping of the mangrove forest area had been completed, the subsequent activity was field validation, involving the local community (participatory approach) to identify the condition of the mangrove vegetation and the boundaries of the ecosystem. This approach enhances data quality by drawing on in-depth local knowledge of the coastal area (Setiawan & Supriatna, 2021).

This method aligns with research (Puspo et al., 2025) that applied a participatory mapping approach to village administrative boundaries as a collaborative model between the community and researchers. The study demonstrated that community participation in the mapping process can improve spatial accuracy, accelerate field validation, and strengthen the social legitimacy of the mapping results.

1. **Fieldwork**
   A. Collection of secondary data
   B. Surveys and observations
   C. Validation interviews
2. **Studio/Laboratory Work**
   A. Data compilation
   B. Data verification and validation
   C. Visualization of mapping results

4. Results and Discussion

Landsat 8 image data consist of separate image band files as well as composite images comprising several bands (multi-band composites). The use of satellite imagery (Landsat 8) presents several challenges, thus requiring a number of corrections, such as those relating to geometric and radiometric accuracy. The use of Landsat-8 satellite imagery in the study area (Pakuhaji Sub-district) does not present any challenges regarding geometric accuracy, which is related to the surrounding environmental conditions, as the terrain is gentle; consequently, the resulting accuracy is already good or clear given the resolution used, thereby facilitating the process of identifying vegetation (mangroves); however, radiometric corrections are required to correct for distortions caused by atmospheric disturbances (cloud cover), using the Top of Atmosphere (ToA) method to obtain accurate reflectance values.

The process of identifying objects from satellite imagery in this study (mangrove and non-mangrove forests) utilized the band composite method (564), the results of which focused on the distribution of mangrove vegetation; these results were then digitized to form polygons (areas) and display the area of each identified zone. Following data processing involving the identification of objects (mangrove and non-mangrove forests) using the composite band method, the next step to validate the results of the mangrove vegetation distribution identification was to process the NDVI from the image data, which produced values ranging from -1 to +1; positive values indicate that the object is vegetation, whilst low to negative values indicate non-vegetation areas or bodies of water (Friess et al., 2025; Utomo & Pulungan, 2023).

4.1 Presentation of Results

Mangrove forest areas play many roles that can be utilized in their management, including from social, economic and environmental (ecological) perspectives. From an ecological (environmental) perspective, mangrove ecosystems act as effective carbon sinks, help to mitigate pollution and erosion, prevent saltwater intrusion, and help to maintain the stability of coastlines (coastal plains) against waves and abrasion (Zaryaningsih et al., 2022). From a socio-economic perspective, mangrove forest areas can be utilized as conservation zones, which can be linked to education and research; furthermore, sound mangrove forest management will foster mangrove forest ecotourism, which is expected to boost the local economy and provide alternative employment opportunities in coastal areas beyond fishing (Eddy et al., 2015).

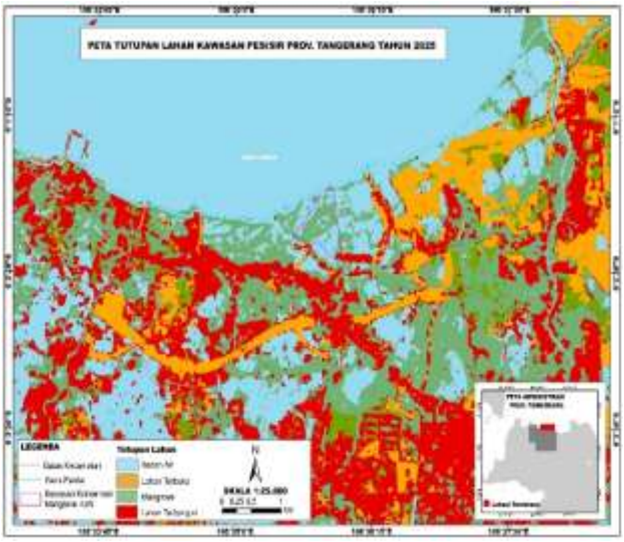

Figure 2. Map of Land Cover in the Coastal Areas of Tangerang Regency, 2025

The mangrove area, situated in the Kampung Bahari Nusantara area, Sukawali Village, Pakuhaji Sub-district, Tangerang Regency, Banten Province, covers an area of approximately 41.849 hectares. Not all of this area consists of mangrove vegetation; it also includes open land, water bodies, and, finally, mangrove vegetation. Of the total area of the mangrove area in Kampung Bahari Nusantara, the area covered by mangrove vegetation is only around 1.267 hectares, which is relatively the smallest compared to other classifications, such as water bodies (around 15.718 hectares) and open land (around 24.864 hectares), which are the largest classifications within the Kampung Bahari Nusantara area.

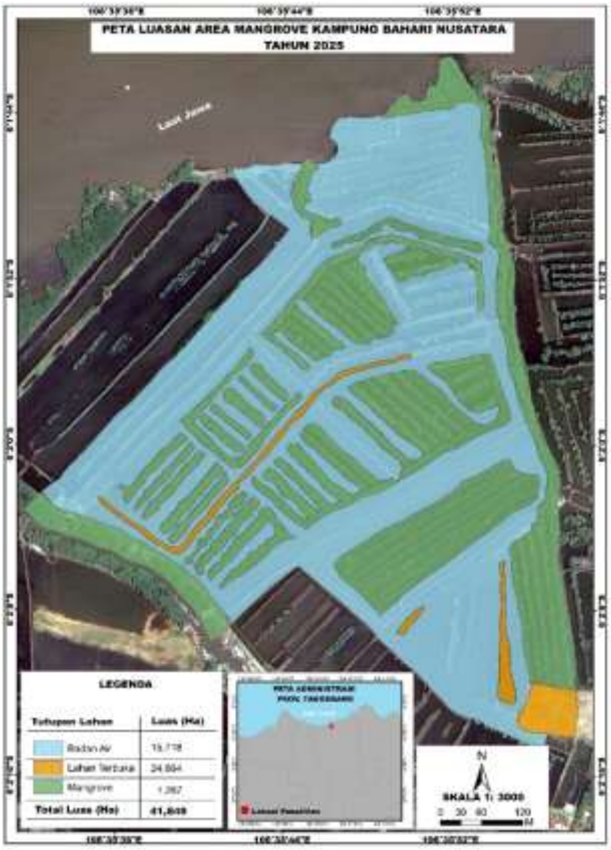

Figure 3. Map of the Kampung Bahari Mangrove Area, 2025

The mangrove area in Kampung Bahari Nusantara, classified as described above, indicates that coastal erosion has occurred as a result of relatively high sea waves, as evidenced by conditions on the ground. These findings indicate that the mangrove area is largely surrounded by water (± 15.718 hectares), as shown in Figure 3, with seawater and wave-borne material entering the land. During the field validation process, it was found that the water bodies on land at the study site are utilized by the local community as shrimp ponds. As shown in Figure 3, mangrove vegetation that still fulfils its ecological role in providing protection against waves and reducing coastal erosion by seawater (abrasion) is only found in the northern section, which borders directly on the Java Sea. The next classification is open land covering an area of approximately 24,864 hectares, a phenomenon linked to the population’s need for land, which is becoming increasingly limited. This vacant or open land is the result of the conversion of water bodies or shrimp ponds into open land, which will subsequently be developed for settlements or even housing; as can be seen in Figure 6, the area surrounding the site has already been converted into open land where the soil has dried out. (Giri et al., 2015) explain that such conversion is the main cause of the loss of more than 30 per cent of global mangrove cover, including in Indonesia.

Figure 4. Condition of the Kampung Bahari Mangrove Area, 2025

Mangrove vegetation serves a variety of functions for human life and the environment. The mangrove area in Kampung Bahari Nusantara also plays a role in maintaining important ecological functions as a carbon sink and a barrier against coastal erosion. (Alongi, 2020) states that mangrove ecosystems are capable of storing up to 1,000 tons of carbon per hectare and are a key component in climate change mitigation (blue carbon ecosystems). Furthermore, mangrove forests can reduce wave energy by up to 75 per cent, thereby protecting coastlines and settlements from coastal erosion (Kusmana, 2016). Hence, there is a need for the conservation of mangroves in Indonesia, particularly in the Kampung Bahari Nusantara area.

The mangrove forests in the Kampung Bahari Nusantara area serve purposes beyond their ecological (environmental) functions. The social and economic aspects there are also quite diverse; tourism management capitalizes on the attractions of the open sea and the areas around the coast or within the mangrove forests, whilst the majority of the local community utilize the land in their front gardens to run small stalls selling essential goods to visitors exploring the mangrove forests in the Kampung Bahari Nusantara area. These findings were obtained through direct field observations, as well as a participatory approach involving the community and key figures managing the mangrove area (Image showing the condition of the area)

Figure 5. Condition around of the Kampung Bahari Mangrove Area, 2025

Furthermore, in terms of education and research, the mangrove forests in the Kampung Bahari Nusantara area are also open to conservation and research activities. Conservation activities can be seen in Figure 3, which shows the distribution of mangrove vegetation around the waters. This demonstrates that Kampung Bahari Nusantara provides educational opportunities in the form of mangrove planting, as well as research activities involving the identification of mangrove vegetation, which will subsequently form the basis for recommendations regarding the density and priority of mangrove trees for conservation planting. As can be seen in the image below, there is a gazebo or gathering place frequently used by the managers to conduct educational sessions or awareness-raising activities; the managers also mentioned that several organizations carry out mangrove rehabilitation programmers, as well as awareness-raising initiatives organized by both local and central government.

Figure 6. Condition Kampung Bahari Mangrove Area

4.2 Discussion of Results

Based on the results of satellite image analysis, supplemented by field surveys, the remaining mangrove vegetation—which continues to function as a natural barrier against sea waves—is located in the northern part of the study area, which borders directly on the Java Sea, covering an area of 1,267 hectares. Mangrove vegetation provides numerous benefits for the local community and the environment, such as These ecological functions also support the habitats of various coastal species, such as fish, prawns and crabs, which form a source of livelihood for the local community (Arifanti et al., 2022).

In addition to its ecological aspects, this area also has social and economic value. Observations indicate that some members of the community have utilized the mangrove area as a nature tourism destination (based on photographs and direct observations); there are numerous small stalls around the Bahari Nusantara mangrove forest area. Mangrove-based ecotourism has been shown to improve community welfare without compromising environmental sustainability (Prihadi et al., 2024). Such a community-based management approach can enhance the effectiveness of conservation by involving the community in monitoring, planting and the sustainable use of forest resources. It can therefore be concluded that remote sensing technology and Geographic Information Systems (GIS) are effective tools for mapping and analyzing the condition of mangrove vegetation in Kampung Bahari Nusantara. The results of this mapping can serve as a vital foundation for local authorities and communities in formulating mangrove conservation and rehabilitation policies, in line with the principles of sustainable coastal management recommended by the United Nations Environment Programme (UNEP, 2019).

5. Conclusion

Mangrove forest areas play many roles that can be utilized in their management, such as: from an ecological (environmental) perspective, they act as effective carbon sinks and help maintain the stability of coastlines (coastal plains) against waves and erosion; whilst from a socio-economic perspective, mangrove forest areas can be used as conservation areas (for education and research), and sound mangrove forest management will foster mangrove ecotourism, which is expected to boost the local economy. The mangrove forests in the Kampung Bahari Nusantara area cover an area of approximately 41.849 hectares, divided into three classifications: open land (approximately 24.864 ha), water bodies (approximately 15.718 ha) and mangrove vegetation (approximately 1.267 ha). The utilization of mangrove forests in Kampung Bahari is diverse, including: their use as conservation areas (through mangrove planting); for educational purposes, such as research into the extent of mangrove areas; as marine tourism destinations that capitalize on the marine environment; and to provide income diversification within the surrounding mangrove area (through tourism, fish ponds and local eateries).

Suggestions

Mapping of the extent of mangrove forest areas in the Kampung Bahari Nusantara area, Sukawali Village, Pakuhaji Sub-district, Tangerang Regency, Banten Province, still requires further clarification regarding their density and potential as a priority for future mangrove planting. The existing mapping results can be used as a reference in determining priorities for mangrove planting, in line with the primary ecological (environmental) function of mangroves as a key buffer against coastal erosion caused by ocean waves. There is a need for mapping relating to abrasion and tidal conditions, so that key mitigation measures can be implemented to reduce the loss of area caused by ocean waves. Furthermore, there is a need for discussions and research concerning the socio-economic conditions in the Indonesian maritime region, so that this may lead to the establishment of development priorities or sound management practices in the future.

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