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Suitability of Mangrove Tourism Areas in Cilamaya Wetan District, Karawang Regency

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Abstract

The research described here was conducted at the Tangkolak Marine Center (TMC) tourist attraction in Cilamaya Wetan District, Karawang Regency, Indonesia, in November and December 2019. This research aimed to analyze the suitability of the mangrove tourism area using PlanetScope sensor Dove-R satellite imagery. The research method consisted of a literature review, observation, calculation of the NDVI (Normalized Difference Vegetation Index) formula using PlanetScope sensor Dove-R satellite imagery, and direct transects and sample plots measurements. The variables used were thickness, density, mangrove types, biota objects, tides, area characteristics, and accessibility. The results showed that mangrove tourism in TMC could be classified into two categories: suitable (65%-80%) and conditionally compliant. According to the classification, the area is characterized by a mangrove thickness of up to 175.0 meters, a mangrove density between 15-25 tree/100 m^2, 3-5 types of mangrove species, and associated biota including mudskipper fish, shrimp, crab, and crane. Meanwhile, the other area classified as conditionally compliant is characterized by a thickness of up to 48.2 meters, a mangrove density of 5-10 tree/100 m^2, two species of mangrove, and associated biota in the form of mudskipper fish, shrimp, and crab. The research highlights the successful application of remote sensing data, specifically PlanetScope satellite imagery, for studying mangrove tourism areas, indicating its potential as a valuable alternative data source for such investigations.

Keywords: Suitability, Area, Tourism, Mangrove.

1. Introduction

In Indonesia, mangrove ecosystems cover about 3 million ha (Giri *et al.*, 2011). Mangrove is a type of woody plant that grows in coastal areas between land and sea. It is only found in the tropics and in some subtropical areas (Pin *et al.*, 2021). As one of the ecosystems along the coast, mangroves provide people with sites for recreation, aquaculture and fishing, research, and education, tourism, and they can be a source of firewood (Estoque *et al.*, 2018).

Mangroves have various benefits and are crucial in conservation efforts (Romañach *et al*., 2018). They are effective in mitigating the impact of natural disasters such as tsunamis, hurricanes, storms, and other natural phenomena (Nurdin et al., 2015; Alongi, 2008). Additionally, mangroves contribute to carbon absorption and the production of organic materials, which serve as a food source for organisms through litter decomposition (Giesen et al., 2007). As stated by Barbier (2016), mangroves offer significant benefits as a natural barrier, providing protection against wind and waves for coastal regions.

Additionally, the mangrove ecosystem is the most productive and biologically important ecosystem and it is a habitat for several commercial and non-commercial fish species (Veettil *et al.*, 2019). Nagelkerken *et al*. (2008) said that the mangrove ecosystem gives crabs, shrimp, and fish a place to live. Mangrove ecosystems also help coastal communities (Wardhani, 2011; Heriyanto & Subiandono, 2012) by being a site for coastal tourism activities. The species richness and diversity of mangrove ecosystems attract people as tourists interested in coastal ecosystems Purnomo *et al.*, 2013; Agussalim & Hartoni, 2014; Nelly *et al.*, 2020). The higher the diversity of flora and fauna, the higher the potential attractiveness of the area, and the higher the number of visitors wishing to visit the area (Rodiana *et al.*, 2019). The potential of the mangrove ecosystem in terms of ecology and in terms of playing a key role in processed products make it still more attractive to tourists (Mas'ud *et al.*, 2020).

The inauguration of a mangrove tourist attraction is an event which can generate interest and thus make the mangrove ecosystem part of the solution to humans' needs for social and economic activities. This indicates that the mangrove ecosystem can play an important role in human society (Utina *et al.*, 2017). According to Nurlailita (2015), the mangrove ecosystem is a place where reciprocal relationships flourish between living things and their environment and between particular living things themselves. The mangrove ecosystem is a fragile ecosystem because it is very sensitive to environmental change (Eddy *et al.*, 2016; Sahu *et al.*, 2019). The mangrove ecosystem in Karawang Regency covers about 10,005.46 hectares or about 28.76% of the total mangrove ecosystem in West Java (Directorate General of Natural Resources Conservation, 2019). One of the mangrove ecosystems that is a popular tourist attraction is the Tangkolak Marine Center (TMC), located in Sukakerta Village, Cilamaya Wetan District. In the five months after it was inaugurated, there was a significant increase in the number of tourist visits. Tourism poses a potential threat to the equilibrium of ecosystems and the food chain of associated biota due to the generation of plastic waste, including microplastics that are particularly persistent and challenging to decompose in mangrove ecosystems (Anggraini *et al.*, 2020; Martin *et al.*, 2019).

Tourism development must consider environmental factors that affect sustainability (Yulianda *et al.*, 2010). The most important aspect of the concept of utilizing natural resources for tourism purposes is the suitability of resources other than the carrying capacity of the area that supports tourism activities (Nawawi & Miswadi, 2020). Poedjirahajoe *et al.* (2019), Chakraborty *et al.* (2019), and Ruzanna *et al.* (2019) stated that the suitability of an area needs to be studied to maintain ecosystem sustainability. Moreover, protecting the sustainability of the mangrove ecosystem now is essential for future needs (Chakraborty *et al.*, 2019). However, measuring suitability presents a challenge and this challenge is even greater when the aim is to measure mangrove ecosystems.

Currently, remote sensing is one of the best, most efficient, and fastest ways to monitor mangrove ecosystems (Kuenzer *et al.*, 2011; Lu *et al.*, 2021), which existence is in areas that are difficult to reach. Then, field measurements are also difficult to obtain and expensive to generate (Fatmawati *et al.*, 2017). Klemas (2012) said that remote sensing is the most effective method for observing coastal formations and the seafront. The mangrove ecosystem is one of the objects that can be detected using remote sensing. The mangrove ecosystems are unique (Muzakki *et al.*, 2021; Purnamasari *et al.*, 2021), because they are located between the land and sea.

Satellite imaging is one of the remote sensing instruments that has often been used in the study of mangrove ecosystems (Wang *et al.*, 2019). PlanetScope satellite imagery is one of the services offered by Planet, a German company founded in 1998. In 2018, Planet launched PlanetScope satellite imagery which has three cohorts of satellites, Classic (PS2), *Dove-R* (PS2.SD), and SuperDove (PSB.SD). PlanetScope satellite imagery takes the form of Cubesat 3U measuring 10 cm x 10 cm x 30 cm. Planet generates a recording of the earth's surface covering 200 million km^2/day (equivalent to 130 satellite images). PlanetScope Satellite Imagery created with the *Dove-R* sensor is a second-generation satellite image (PS2.SD) that has four bands, Band 1 (blue), Band 2 (green), Band 3 (red), and Band 4 (near the infrared/NIR). Dove-R's PlanetScope sensor satellite imagery records both on land and over water on a daily basis, with a resolution of 3x3 meters per pixel. Two Dove-R satellites cross Indonesia every day. It produced atmospheric correction (Analytic_SR) data, which can minimize uncertainty in the spectral response and eliminate factors that degrade the quality of satellite image data and correct object position distortion (Nurmalasari, 2018). Therefore, PlanetScope Dove-R sensor satellite images, with their spatial specifications and resolution, can be used for regional suitability analysis designed to identify tourism development potential.

Suitability analyses can be processed spatially, modeled, and visualized with remote sensing instruments (Kalogirou, 2002; Hossain *et al.*, 2009; Ayhan *et al.*, 2020). This study aims to analyze the suitability of mangrove tourism areas in the context of tourism development. A clear picture of sustainability will help minimize the risk of damage to the mangrove ecosystem from tourist visits. The results of this study's analysis will contribute to assessing the potential for tourism development in mangrove ecosystems with the help of remote sensing instruments. sThis should later positively impact ecosystem communities, especially in the environmental, social, and economic spheres.

2. Research Methods

This research was conducted in November 4-7 and December 19-22, 2019, at the Tangkolak Maritime Center (TMC), Sukakerta Village, Cilamaya Wetan District, in West Tangkolak and East Tangkolak (Figure 1). This study considers mangrove ecosystem tourism in terms of the suitability of the area based on Yulianda (2019) and using 5 parameters, mangrove thickness, mangrove density, mangrove species, biota objects, and tides. Indicators for the suitability of mangrove tourism areas will be integrated based on criteria described in Murni (2000), with modification in the form of area characteristics and accessibility. Data on the suitability of mangrove tourism areas were gathered in several ways: field surveys for indicators of mangrove species, biota objects, tides, area characteristics, and accessibility. In addition, direct measurements were made in the field at observation stations in the form of transects (Setyobudiandi *et al.*, 2009) at a distance of 100 meters. Sample plots (tiles) measuring 10 x 10 meters were also used (Sofian *et al.*, 2012). These measurements served as indicators of thickness and density. These measurements identified the type of mangroves in the tree category with a trunk circumference of 16 cm (Nurdiansah & Dharmawan, 2021).

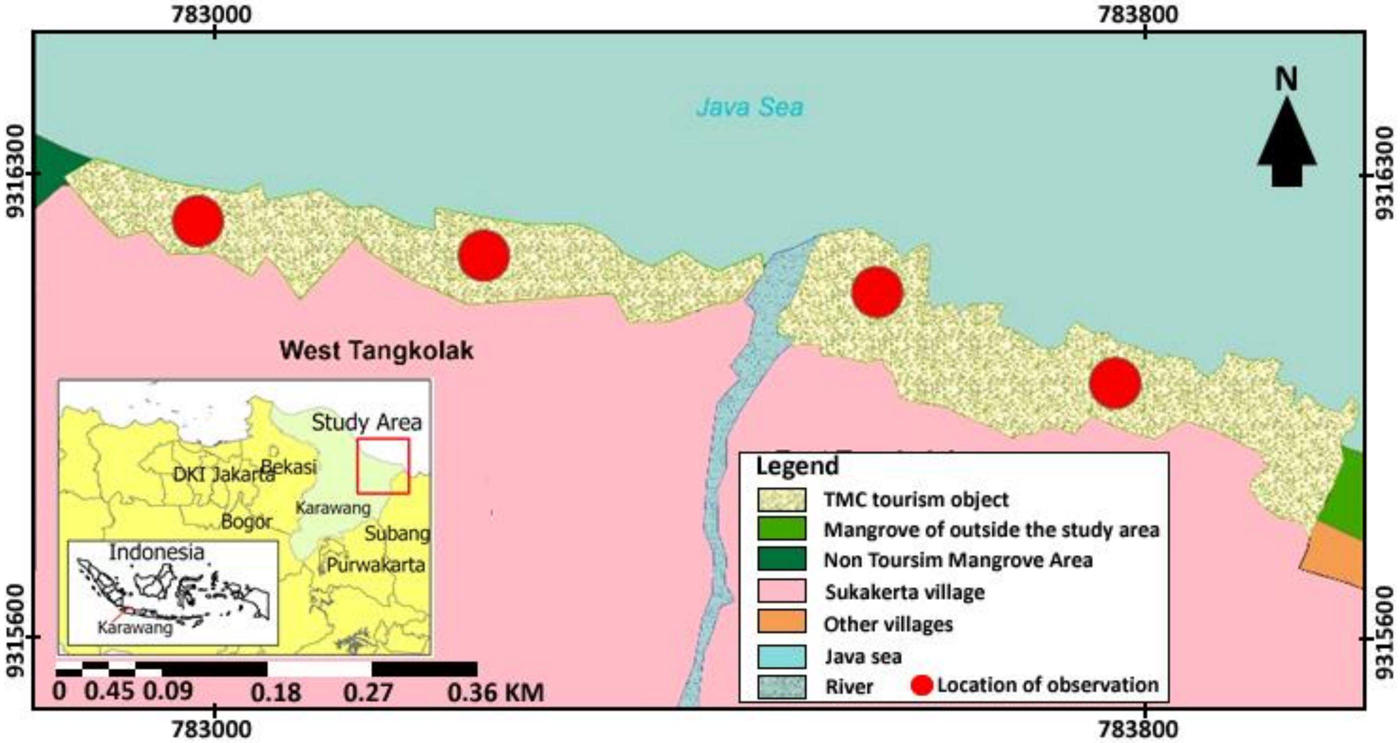

Figure 1. Research Area.

The determination of observation stations for transects and sample plots was based on the delineation of values derived from the NDVI (Normalized Difference Vegetation Index) formula based on Cabello et al. (2021) applied to the processing of PlanetScope satellite image data from the *Dove-R* sensor. The resulting values of the NDVI formula will be classified according to Badan Informasi Geospasial (2014) and Sidik *et al.* (2019), which is divided into several classifications **(**Table 1**).** For tidal indicators, the dataset came from *Badan Informasi Geospasial* (BIG) observation station data collected in 2019. Data on the suitability of mangrove tourism areas can be seen as a matrix in Table 2.

$$RCI = \sum_{i=1}^{s} \left(\frac{Ni}{N\ Max}\right) x\ 100\% \quad (1)$$

Formula 1 is employed as a method to assess suitability based on the parameters. These parameters include RCI (Regional Compliant Index), Ni (representing the value of the i-th parameter, obtained by multiplying weight and score), and N Max (the maximum value of the mangrove tourism category, set at 88). The analysis results are subsequently classified into four distinct classes to determine suitability levels. The first class, S1, denotes "Very Suitable" scenarios with scores ranging from 80% to 100%. The second class, S2, signifies "Suitable" situations, encompassing scores between 60% and below 80%. The third class, S3, encompasses "Conditionally Compliant" circumstances, incorporating grades from 35% to below 60%. Finally, the fourth class, N, indicates "Not Suitable" scenarios, where scores fall below 35%.

2.1. Satellite Image Data Processing

Satellite imagery recording data will be adjusted to the latest recording data according to field survey undertaken in December 2019. The data recording of PlanetScope sensor Dove-R satellite imagery is combined *(*mosaic*)* using ENVI 5.1 software, extracted by mask in ArcGIS 10.4 software, and imposed on the administrative map of Sukakerta Village, Cilamaya Wetan District. After that, the images were digitized to interpret the information about the mangrove ecosystem area of Sukakerta Village, especially at TMC. The interpreted mangrove ecosystem area will be integrated with the NDVI (Normalized Difference Vegetation Index) formula (Equation 2) to obtain a value that describes the density of mangroves. The NDVI formula associates the Near Infrared (NIR) band and the red band. Both bands are located in Band 4 and Band 3 in PlanetScope satellite imagery produced by Dove-R.

Table 1. Classification of Mangroves Based on NDVI Value.

Classification	Mangrove Percentage	NDVI Value
Rare Mangrove	<50%	0 - ≤0.26
Medium Mangrove	51-70%	0.27 - ≤0.56
Dense Mangrove	>70%	0.57 - ≤1.00

Source*:* Badan Informasi Geospasial (2014) and Sidik *et al.* (2019)

Table 2. Matrix Mangrove Suitability.

Parameter	Weight	Classification	Score
Mangrove thickness (m)	5	>500 (S1)	4
		200-500 (S2)	3
		50-200 (S3)	2
		<50 (S4)	1
Mangrove density (tree/100m^2)	4	15-25 (S1)	4
		10-15 (S2)	3
		5-10 (S3)	2
		<5 (S4)	1
Type of mangrove	4	>5 (S1)	4
		3-5 (S2)	3
		2 (S3)	2
		1 (S4)	1
Biota object	3	Fish, shrimp, crab, mollusk, reptile, and bird (S1)	4
		Fish, shrimp, crab, and mollusk (S2)	3
		Fish and mollusk (S3)	2
		One of the aquatic biotas (S4)	1
Tide (m)	3	0-1 (S1)	4
		1-2 (S2)	3
		2-5 (S3)	2
		>5 (S1)	1
Area characteristics (condition)	2	4 conditions (S1)	4
		3 conditions (S2)	3
		2 conditions (S3)	2
		1 condition (S4)	1
Accessibility (condition)	1	4 conditions (S1)	4
		3 conditions (S2)	3
		2 conditions (S3)	2
		1 condition (S4)	1

Source*:* Modified from Yulianda (2019); Murni (2000). Note: S1: Very suitable, with a score of 80%-100%; S2: Suitable, with a value of 60%-<80%; S3: Conditionally Compliant, with a grade of 35%-<60%; N: Not suitable, with a value of <35%.

$$\text{NDVI} = \frac{Band\ 4 - Band\ 3}{Band\ 4 + Band\ 3} \quad (2)$$

The resulting NDVI value will be classified according to Badan Informasi Geospasial (2014) and Sidik *et al.* (2019) (using reclassifying tools available in ArcGIS 10.4 software) into three classification categories, rare, moderate, and dense. The classification of NDVI values that has been obtained will be delineated based on the reclassification process carried out previously. This process was used to simplify the value of mangrove ecosystem density for researchers. This determines the observation station for gathering data on mangrove tourism site suitability.

2.2. Data Analysis

The data were analyzed spatially, quantitatively, and descriptively. Spatial analysis is aimed at determining the value of mangrove density based on the NDVI formula and mangrove tourism suitability areas based on each parameter at each observation station in the TMC area. Quantitative analysis aims to determine the distribution and value of the results of the delineation of the NDVI formula in order to determine the category of mangrove density. The descriptive analysis is then intended to explain the overall data obtained by field surveys and calculations made using the NDVI formula.

3. Results and Discussion

3.1. Mangrove Thickness

Mangrove thickness is one of the important parameters used in managing the development of mangrove tourism (Mas'ud *et al.*, 2020). The thickness of mangroves in all observation stations has an average of 82.0 meter. By calculation it can be shown that the thickness of mangroves in TMC tourism objects meets the criteria for the S3 classification with details of 50-200 meter and the S4 classification with details of <50 meter. The greatest thickness is located at observation station 3, which is in the eastern part of TMC, with a mangrove thickness of 125.0 meters, and the lowest is at observation station 2, which is in the western part of TMC. with a mangrove thickness of 48.2 meters (Figure 2). The community uses mangrove trees for household needs, such as building materials and cooking, causing mangrove thickness to vary between observation stations. These differences in mangrove thickness will have an impact on the biological aspects of the mangrove ecosystem (Mas'ud *et al.*, 2020), for example, the diversity of biota. Therefore, mangrove thickness is a concern for the preservation of ecological aspects in the ecosystem.

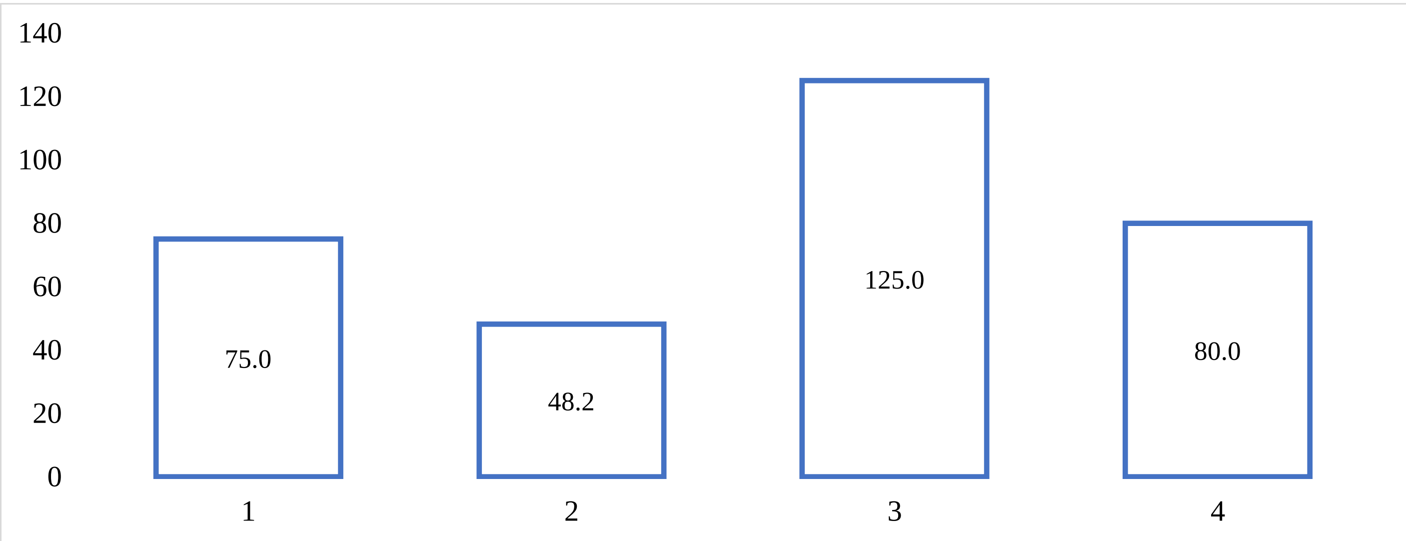

Figure 2. Mangrove Thickness of Each Observation Station (meters).

3.2. Mangrove Density

Mangrove density was classified and visualized based on the NDVI value recorded at each observation station and direct measurements were made in the form of line transects and sample plots measuring 10meter x 10 meters at each observation station. It is known that the NDVI values for TMC tourism objects is quite diverse, ranging between 0.19-0.76. The results of NDVI values are delineated and categorized based on Badan Informasi Geospasial (2014) and Sidik *et al.* (2019) into 3 classifications, dense, medium, and rare density. Based on the area calculated using the *Dove-R* satellite imagery data, mangroves with a dense classification are located in the eastern region of the TMC, at observation stations 3 and 4 with a total area of 30.9 Ha, while the mangroves with moderate classification are located in the western region (observation station 1) and cover 30.2 Ha, and those classified as having a density in the middle (observation station 2) cover 15.2 Ha.

Based on the direct measurements, mangrove density was calculated on a 100 meter transect adjusted from the mangrove thickness in the field. If the thickness of the mangrove in the field was 45 meters, the mangrove density measurement was carried out 5 times (10meter x 10meter). Mangrove density in TMC tourism objects results in S1 and S3 classification based on a matrix, namely 15-25 tree/100 meter^2 and 5-10 tree/100 meter^2. The average mangrove density of the entire observation station is 13.1 tree/100 m^2, which can be rounded down to 13 tree/100 m^2. The highest mangrove density is located at observation station 1 with 15.1 tree/100 m^2 and the lowest density is located at observation station 2 with 8.2 tree/100 m^2 (Figure 3). This direct measurement of density differs from observation station 1 to observation station 2 because people near observation station 2 use mangrove trees for cooking wood and building materials. Due to the community's substantial economic needs, land function has changed significantly, compared to mangrove ecosystem productivity.

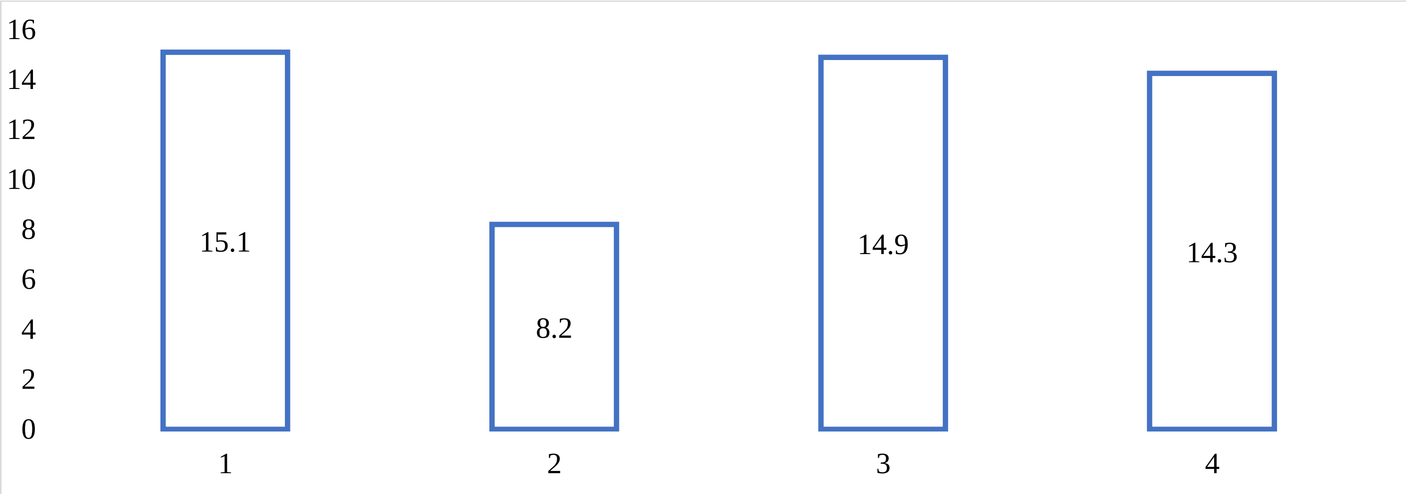

Figure 3. Mangrove Density.

3.3. Type of Mangrove

Mangrove species data were obtained through field observations and sorted according to the location of the observation station. The types of mangroves in the TMC tourism area include Rhizopora (Bako-Bako), Avicennia (Api-Api), Bruguiera, and Sonneratia. Each observation station has its own characteristics of the component types of mangroves. The mangrove species that were found in all observation stations included *Rhizhophora stylosa*, *Rhizhophora apiculata*, *Rhizhophora muncronata*, *Avicennia alba*, *Bruguiera gymnorhiza*, and *Sonneratia* (Table 3). The classifications of mangrove species found at tourist sites are the S2 and S3 classifications according to the matrix. S2 consists of 3 to 5 types of mangroves and S3 consists of 2 types of mangroves. The S2 classification is located at observation stations 1, 3, and 4. Meanwhile, the S3 classification is located at observation station 2. The most mangrove species were found at observation station 3 (5 species) and the lowest was at observation station 2 (2 species). The *Sonneratia* species was only found at observation station 3, which is in the eastern part of TMC, because that location has a *Sonneratia* mangrove seed planting program from the local government. *Rhizophora muncronata* was only found at observation station 4, where it was designated an object of interest.

Table 3. Types of Mangroves.

Mangrove Type	Observation Station			
	1	2	3	4
Rhizophora stylosa	√		√	√
Rhizophora apiculata	√	√	√	√
Rhizophora muncronata				√
Avicennia alba	√		√	√
Bruguiera gymnorhiza		√	√	
Sonneratia			√	

3.4. Biota Object

In field observations, several biotas were found around TMC tourism objects (Figure 4). The glodok fish biota was found in the estuary area, especially in the mud area. The mudskipper fish biota was found based on the identification information in the book by Anam & Mostarda (2012), that is identified as *Gobiidae*. Many of these biotas we observed live on the edges of the local people's ponds. These biotas were found at all observation stations, unlike the crab biota, which are mostly found in beach sand substrates. The type of crab biota found based on identification was *Macrophthalmus*. Usually, these crabs create their own habitats by making holes, and this is the hallmark of their existence. Crab biota were found at observation stations 1, 3, and 4; they were not found at observation stations 2.

The next biota found was a crane with white and black feathers, the *Mycteria cinerea* species. Usually, this stork is seen in the morning and evening. These biotas usually forage around ponds, rice fields, and estuary areas in the morning. Meanwhile, in the afternoon, it gathers in the mangrove trees in groups. It is very difficult to approach this bird because of it tends to avoid humans. This stork was also found at observation stations 1, 3, and 4, which is similar to crab biota. Shrimp biota were usually found in shallow waters close to mangroves in estuary areas. These biotas are usually found in groups between mangrove trees in low-wave waters. The type of shrimp biota found was *Solenoceridae*. This shrimp was found at all observation stations. Fish, shrimp, crabs, and birds were found, indicating mangrove tourism suitability S2. Observation stations 1, 3, and 4 were given the S2 classification. At observation station 2, the classification is S3, with observations made of fish, shrimp, and crab biota. Mollusc and reptile biota objects were not found at all during the field survey, so there were no calculations to consider.

Figure 4. Biota Objects Found in the Observation Stations. (a) Mudskipper Fish found at all observation station, (b) crane found at observation stations 1, 3, and 4, (c) crab found at all observation station, (d) shrimp found at all observation station.

3.5. Tides

Tidal data was obtained from the Badan Informasi Geospasial (BIG) tidal station from November to December 2019 at daily intervals (Figures 5 and 6). The table shows the dates of the gathering of tidal data during field surveys. This tidal data was gathered at the tidal observation station closest to Karawang Regency, specifically in Cirebon Regency (6°38'25.1"S 108°38'40.6"E) because in Karawang Regency there is no tidal observation station available.

The tides in Cilamaya Wetan subdistrict are of the semidiurnal type, with two high tides and two low tides in a period covering a day and night (Wibisono, 2005). The tides in Cilamaya Wetan District reach -0.43 meters at low tide and 0.28 meters at high tide. The lowest water level occurred on December 21, 2019, which is -0.429 meters at 6 p.m. Western Indonesian Time was the highest on December 19, 2019, which was 0.280 meters, at 10 p.m. Western Indonesian Time. Overall, the tides in Cilamaya Wetan District have an average daily sea level of 0.1 meters or 100 cm. According to the mangrove tourism suitability matrix, all observation stations have S1 tides (0-1 meter). The relatively high tides occur in the early morning and late afternoon, while the relatively low tides occur in the morning and late evening.

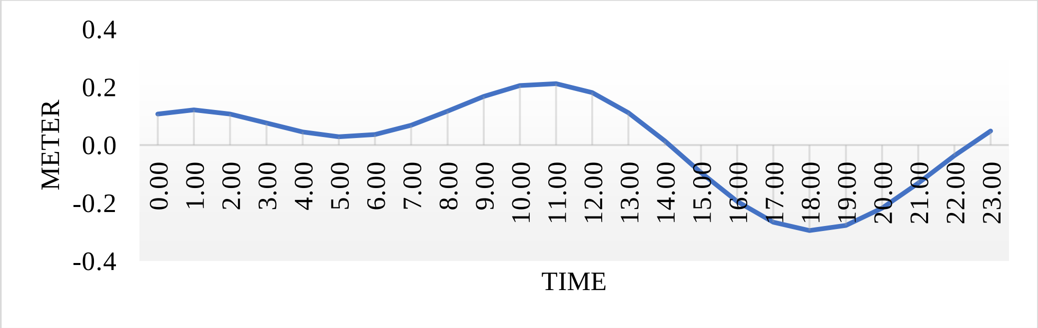

Figure 5. Tides on 06 November 2019.

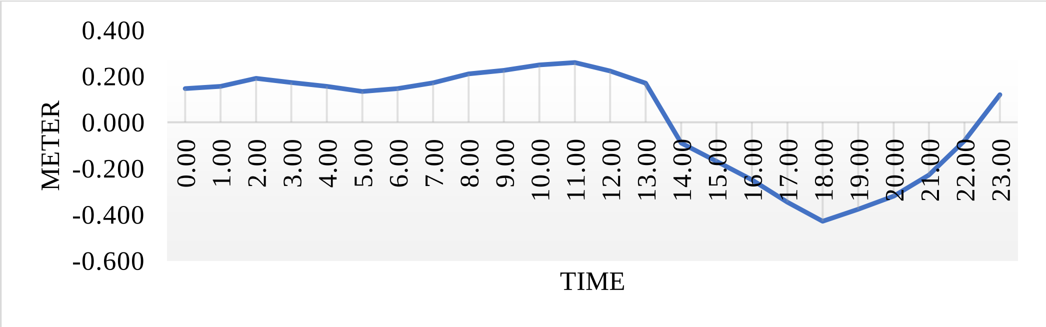

Figure 6. Tides on 21 December 2019.

3.6. Area Characteristics

The characteristics of the area from the observation results are dominated by the S2 classification in the form of 3 conditions found at observation stations 1, 2, and 3. In addition, the classification N at observation station 4 is also obtained in the form of 1 condition. At observation station 1, it was found that there was an interesting natural object in the form of fauna, namely mudskipper fish, which had a higher quantity compared to other observation stations. The area's proximity to the river estuary makes the afternoon sunset visible, adding to its beauty. Then, a good view is also found at this observation station in the form of a beautiful area that is still rarely visited by tourists. For observation station 2, there is an interesting natural object in the form of physical aspects, namely mangrove trees, that have provided materials for many tourist facilities such as swings and wooden bridges to support tourist activities.

In addition, tourists can also take selfies in the wooden boat-shaped building. Tourists can also observe the sunset at this observation station because the supporting buildings are slightly higher than the shoreline. Station 3 has a natural object of interest in the form of fauna, namely cranes that gather at the observation station. At observation station 2, the gazebo buildings and wooden bridges support tourist activities. Panoramic views of natural beauty are also an attraction at this observation station because the sunset is visible, and the location has the clearest view compared to other observation stations. This observation station also features the beauty of lush mangrove trees. For observation station 4, an object of interest in the form of flora was found, mangrove species with dominant gray stems, *Rhizophora muncronata*. More details can be seen in Figures 7a to 7d.

Figure 7. Observation Results of the Area Characteristics. (a) A group of mudskipper fish at observation station 1, (b) wooden a bridge at observation station 2, (c) a bird gathering place at observation station 3., (d) Gray trunk mangrove species at observation station 4.

Figure 8. Observation Results of Accessibility. (a) Accessibility in the form of roads used to reach the observation station, (b) accessibility of alternative roads to reach the observation station, (c) accessibility in the form of transportation to the location in the form of a boat.

3.7. Accessibility

Accessibility data obtained from observations are diverse for the various observation stations: classification N (1 condition) at observation station 1, classification S3 (2 conditions) at observation station 4, classification S2 (3 conditions) at observation station 2, and classification S1 (4 conditions) at observation station 3. At observation station 1, a road in good condition leads the location. The road can be safely used by motorbikes. For observation station 4, there were roads that have been paved, which is the same for observation station 1. There are many alternative routes to the location, some of which are not paved, and instead, they are dirt roads that pass-through people's property. Observation station 2 is the same as observation station 4, but at this location there are also supporting facilities in the form of a pier used by local people for all sorts of activities, such as working, buying and selling goods, etc. All the conditions are the same for observation station 3 as for observation station 2. Here, the community provides transportation around TMC tourist attractions, such as boats. More details can be seen in Figure 8a to 8c.

3.8. Suitability Mangrove Areas

The suitability of the TMC mangrove tourism area at each observation station was determined based on the processing of parameters according to the tourism area suitability matrix. Based on the data obtained, we have found that there are 2 patterns of compliant facilities among TMC tourism objects, namely those with a 'suitable' classification (60-<80%) and those deemed 'conditionally compliant' (35-<60%). Areas that fall in the suitable classification are located at observation station 1 (75.0%), observation station 3 (78.4%), and observation station 4 (73.9%). Meanwhile, the station compliant with the conditional classification is located at observation station 2 (59.1%). Observation station 1 has a mangrove thickness in the S3 classification (50-200 meter), a mangrove density in the S1 classification (15-25 tree/100 m^2), mangrove species in classification S2 (3-5 species), biota objects classified in category S1 (fish, shrimp, crab, and crane), the characteristics of a S2 classification area (3 conditions), and accessibility in the N classification (1 condition). Observation station 2 has a mangrove thickness of classification N (<50 meters), a mangrove density of classification S3 (5-10 tree/100 m^2), mangrove species classified as S3 (2 species), biota objects classified as S2 (fish, shrimp, and crab), the characteristics of a S2 classification area (3 conditions), and the accessibility of a S2 classification area (3 conditions).

Observation station 3 has a mangrove thickness in the S3 classification (50-200 meters), a mangrove density of the S1 classification (15-25 trees/100 m^2), mangrove species diversity matching the S2 classification (3-5 species), an S1 classification of biota objects (fish, shrimp, crabs, and crane), the characteristics of an S2 classification area (3 conditions), and the accessibility of the S1 classification (4 conditions). Observation station 4 has a mangrove thickness in the S3 classification (50-200 meters), a mangrove density in classification S1 (15-25 trees/100 m^2), mangrove species diversity classified as S2 (3-5 species), a biota object classification S1 (fish, shrimp, crabs, and cranes), the characteristics of an S3 classification area (2 conditions), and the accessibility of the S3 classification (2 conditions). Based on the mangrove tourism suitability matrix, data processing shows the classification and value of the mangrove tourism suitability area. The classification, value, and visualization of the mangrove tourism suitability area can be seen in Table 4 and Figure 9.

Table 4. Suitability of Mangrove Tourism Area.

Observation Station	Suitability Value	Classification
1	75,0 %	Suitable
2	59,1 %	Conditionally Compliant
3	78,4 %	Suitable
4	73.9 %	Suitable

The differences in the suitability pattern of mangrove tourism areas can be seen in the thickness, density, and object parameters of the biota of observation station 2. The thickness of the mangroves at the station is 48.2 meters and is included in the classification N (<50 meters). The weighting of this parameter is the largest, 5. Meanwhile, the density of mangroves with a weight of 4 is 8.2 trees/100 m^2 which is rounded to 8 trees/100 m^2 and is in the S3 classification (5-10 trees/100 m^2). The parameters of biota objects that have a value weight of 3 at this observation station are included only in the S2 classification. (The biotas are in the form of mudskipper fish, shrimp, and crabs).

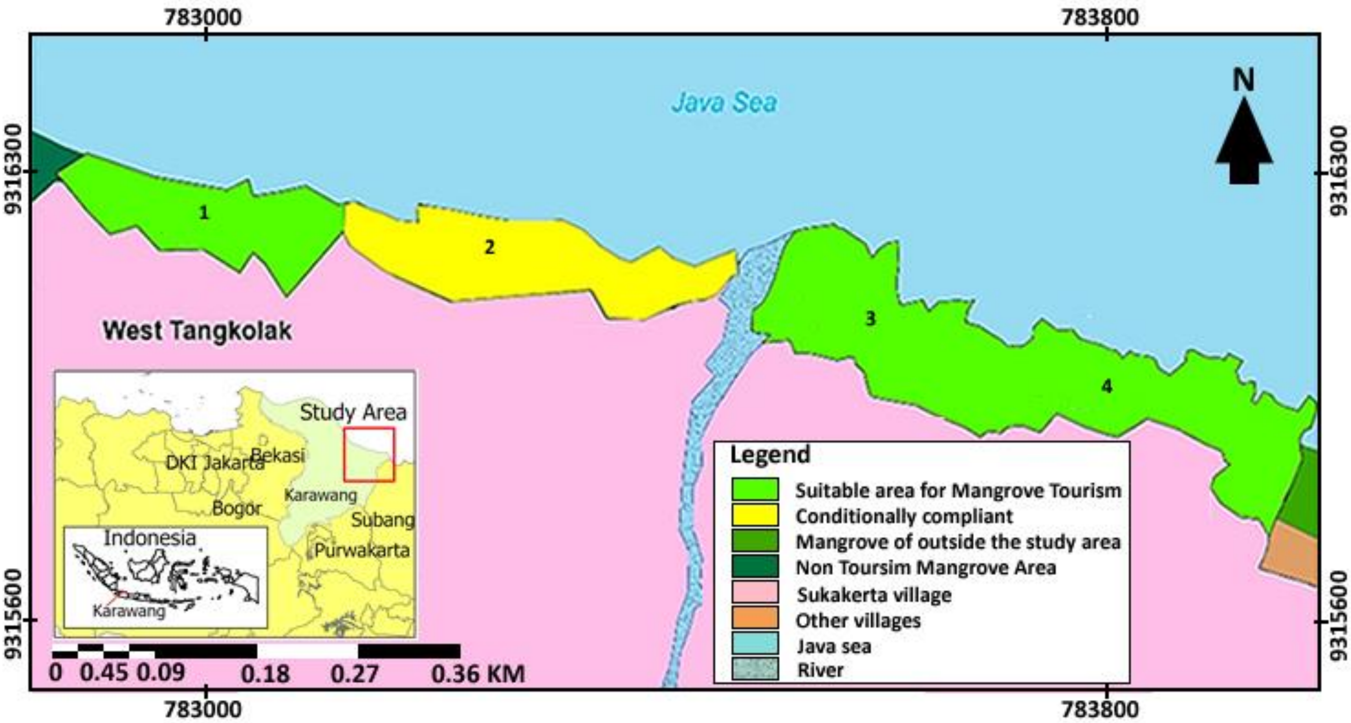

Figure 9. Suitability of Mangrove Tourism Area.

3.9. Discussion

The research demonstrates the utilization of remote sensing data to study mangrove tourism area. The result shows that observation stations 1, 3, and 4 are suitable for mangrove tourism with suitability values of 75.0%, 78.4%, and 73.9%, respectively. These stations have diverse mangrove species, panoramic views, and supporting facilities. However, observation station 2 is conditionally compliant with a suitability value of 59.1%, limiting the variety of biota objects. These findings can confirm that PlanetScope satellite imagery can provide an alternative of data for such study.

Many researchers have used remote sensing to study mangrove tourism areas, such as Mas'ud *et al.* (2020) using Sentinel-2A satellite imagery to determine the suitability of the area and the carrying capacity of the mangrove ecosystem. The suitability of the area is defined in terms of at developing sustainable ecotourism, but the parameters are only limited to the thickness, density, and type of mangroves, biota objects, and tides. The results indicate that the suitability of the tourist area is very important in assessing the development of mangrove tourism as the use of natural and environmental resources. This prevents the use of environmentally harmful and tourism-friendly resources. This is in accordance with the results in this study, which is based on the integration of parameters to assess the suitability of tourist areas. TMC tourism objects have the potential for tourism development because their condition is relatively more supportive from a physical point of view, but the potential for environmental damage due to tourism activities needs to be underlined. Plastic waste is the cause of the death of mangrove vegetation because it blocks or inhibits the photosynthesis process and seedlings are carried or dragged into the sea (Li *et al.*, 2018). Ivar do Sul *et al.* (2014) stated that plastic waste is one of the problems that need to be solved to prevent damage to the mangrove ecosystem.

Chakraborty *et al.* (2019) conducted other research that used ALOS PALSAR remote sensing to assess the suitability of mangrove areas. However, this study on the suitability of mangrove areas is not related to tourism development, but to the strengthening of sustainable development. It considers perceptions, solar radiation, minimum and maximum temperatures, wind speed, population, NDVI, LULC, geomorphology, slopes, soil texture, salinity, and lithology. This approach has its own advantages and disadvantages. Among the advantages, one can say that many factors and aspects can be studied to assess the suitability of mangrove areas, but the disadvantage is that the research is not focused on an aspect that could bias the results. Another study was conducted by Ar-Rasyidah (2014) who used Landsat 8 OLI for studying mangrove conservation. The NDVI formula was also used in his research to obtain mangrove density data which was combined with transects and sample plots of 10 meter x 10 meters, as in this study. Parameters measured in addition to density are tides, beach types, and sediment types. The suitability of the area mentioned here is only intended for adjusting conservation activities, not for tourism development or ecosystem assessment to create tourist attractions.

The transect method and sample plots were also used by Sukuryadi *et al.* (2020) to obtain data on tree thickness, density, and mangrove species. However, transects and sample plots of several sizes were used, the tree categories (stem diameter 10 cm and height 1.5 meters) were 10 meters x 10 meters, the sapling category (stem diameter <10 cm and plant height 1.5 meters) was 5 meters x 5 meters, and the seed category, (height <1.5 meters) measuring 2 meters x 2 meters. Data collection with various transect models has a drawback in the form of data complexity because it considers the size of the tree. The parameters are similar to those inthe research of (Mas'ud *et al.*, 2020). Meanwhile, Mascaro (2016) used PlanetScope satellite imagery from the Dove-R satelite in the context of current vegetation to map tree habitats based on species across a wide area, measuring phenomena such as the change of tree flowers from pink to red and yellow (The Pink Flowing) in the Amazon rainforest. Gillbert (2016) maps the northeastern area of Washington DC, United States, using this satellite imaging technique to provide an environmental picture of the northeast coast area, including detailed flood locations compared to the affected areas in the field. Zhang *et al*. (2022) used this same satellite imaging to monitor the expansion of macroalgae (sargassum) in the coastal areas of Miami and along the Cancun coast, where macroalgae contain chlorophyll that reflects infrared light that is easily captured by satellite imagery. Before the present study, the PlanetScope Dove-R satellite was not used, and there have been no reports on assessments of the suitability of mangrove tourism areas.

With band specifications, relatively high spatial resolution, and minimal data products for atmospheric disturbances, PlanetScope satellite imagery of the Dove-R satellite can provide updates to the analysis of the suitability of mangrove ecosystem tourism areas. This analysis used the NDVI formula by linking the activities of the surrounding community that can affect the physical conditions of the mangrove ecosystem, such as felling trees for household or building purposes and the use of fish and shrimp ponds. Based on the research results, the felling of trees for household or building purposes can still be said to be the main factor in the low density, thickness, and biota object in TMC tourism development. This research study's use of regional characteristics and accessibility criteria with certain conditions distinguishes it from other studies on mangrove tourism suitability. On the other hand, the shortcomings of this research are due to its lack of linking social aspects to see the connections with differences in the suitability values of mangrove tourism expressed in each parameter, for example, accessibility, which is certainly closely related to the involvement of the community around the mangrove ecosystem. In the future, we suggest linking additional physical and nonphysical parameters, such as coastal water clarity, depth, pH, current speed, community work, or activity for more granular analysis of mangrove tourism suitability. In addition, suitability can also be related to the involvement of regional stakeholders engaged in the use of mangrove ecosystems that can benefit from the creation of sustainable use.

4. Conclusion

The suitability of mangrove tourism areas in TMC tourism objects using PlanetScope sensor Dove-R satellite imagery was divided into two classifications, suitable and conditionally compliant. Stations 1, 3, and 4 met the conditions for the suitable classification. The conditionally-compliant classification of the suitability of the mangrove tourism area was found to apply to observation station 2. The highest suitability category was found at observation station 3, with a magnitude of 78.4%, while the lowest was found at observation station 2, with a magnitude of 59.1%. This range is due to how mangrove thickness, density, and biota objects vary in their suitability for mangrove tourism. Based on the suitability values obtained, we can conclude that observation stations 1, 3, and 4 conditions were still suitable as mangrove tourism sites. In contrast, observation station 2 is only compliant or on the threshold due to suitability parameter differences in the thickness and density of mangroves, characteristics which are influenced by the activities of the community around the TMC tourism object. Mangrove depletion will damage TMC tourism. The mangrove's biota is at risk of extinction if community use continues to degrade the mangroves. Restrictions are needed on local communities utilizing mangrove trees at TMC tourist sites, and if necessary, sanctions or penalties should be imposed on people who utilize them unwisely.

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