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AN ASSESSMENT OF SPATIAL SUITABILITY AND INFRASTRUCTURE SUPPORT OF CORAL REEF IN PROMOTING ECOTOURISM IN THE PAHAWANG ISLAND, INDONESIA

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Abstract

Unorganized and constant changes in land use heighten flood risk in a region. Flood issues in Snorkeling tourism, which offers a range of stunning undersea natural resources, is another popular activity on Pahawang Island. Marine tourism should adhere to the idea of environmental preservation, such as avoiding harming and polluting marine habitats, in addition to helping the economy. The goal of this study is to spatially assess the condition of suitability and infrastructural support needed for coral reef ecotourism on Pahawang Island. Line Intercept Transect, coral reef ecotourism carrying capacity calculations, ArcGIS spatial processing, and infrastructure observation were the techniques employed. The findings of this study show that the value of suitability index for ecotourism involving snorkeling and diving had an average value of 2.21, falling into the appropriate category (S2) with a carrying capacity of 3,614 persons per day on an area of 90.35 Ha. Coral reef transplants, which enhance coral reef coverage, can be done to fully utilize the potential in this location in order to preserve and enhance coral reef tourist potential of Pahawang Island. There are a few things that need to be fixed in order to build integrated coral reef ecotourism management although the infrastructure was fairly good according to the findings of direct field observations. The conclusion is that, from a spatial standpoint, the suitability index and the area of snorkeling and diving ecotourism carrying capacity, as well as the supporting infrastructure, are in good condition. To enhance and advance this, integrated management and governance are necessary.

Keywords: Ecotourism, Coral Reef, Suitability, Carrying Capacity, Infrastructure

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INTRODUCTION

Pahawang Island tourism is one of the areas in tourism sector of Lampung Province that is now relatively well recognized. A marine tourism destination in the Teluk Lampung region, which is found in Marga Punduh District, Pesawaran Regency, is Pahawang Island (Badriawan, 2019). The island is also known for its snorkeling and diving tourism which presents a variety of beautiful underwater natural resources, especially in the coral reef ecosystem.

Coral reefs are ecosystem components that are composed of large-scale calcium carbonate lime (CaCO3) deposits or as a result of lime secretion by corals and other marine lives (Nontji 1993; Bengen 2002). Based on the main category, coral reefs are divided into acropora and non-acropora (Erviana et al 2020; Suryanti et all 2011; English et al, 1997). Coral reefs have become an attraction for marine tourism with their beauty as their main point of interest (Zulfikar et al, 2011; Fajar et al, 2019). Coral reefs are beautiful because they have a selection of fishes, algae, shellfish, sea lilies, sea anemones and other marine lives around them. Various types of coral reefs additionally attract tourists. This is what makes coral reefs one of the tourist locations for diving and snorkeling or glass bottom boats, specifically seeing the beauty of coral reefs from a ship covered with glass on the floor.

Appropriate management of coral reef ecotourism can help local income and open up possibilities for economic growth for local communities (Manahampi et al, 2015). Marine tourism should adhere to the idea of environmental preservation, such as avoiding harming and polluting marine habitats, in addition to helping the economy (Abdul et al, 2020; Adhiyaksa & Sukmawati, 2021). Ecotourism is more than simply ecological and natural tourism, but instead a tourism activity to bolster obligation in protecting the environment and natural assets ecologically (Azwar et al, 2022; Junaid et al, 2023; Koroy et al, 2017). Therefore, an appropriate management of coral reefs is necessary so that the income of the local community may increase.

The suitability and carrying capacity values in Pahawang are not yet acknowledged with certainty. Therefore, studies are needed concerning the suitability and carrying capacity values of areas on this island so that the potential for marine tourism on the island can be advanced. The feasibility value of an ecotourism area can be assessed simply by looking at an information (spatial) map. Coral reef ecotourism suitability maps can be acquired through processing data from satellite imagery. However, the accuracy of course differs from situations in the field. Therefore, spatial data and information regarding the distribution of coral reefs and further in-depth research on Pahawang Island is necessary. With the utilization of Geographic Information System (GIS) technology, coral reef mapping can be executed by processing data spatially and translating it into a coral reef distribution map (Fuad et al, 2022). In addition, GIS

has the capability of gathering, storing, processing, analyzing, and visualizing any geographic information (Zulkifli & Mohd, 2016). Perhaps research into the suitability of ecotourism has often been carried out before. However, previous research has never been reviewed from the infrastructure aspect, thus making this study more sophisticated.

The goal of this study is to spatially assess the condition of suitability and infrastructural support needed for coral reef ecotourism on Pahawang Island. Therefore, it is expected that the value of the suitability and carrying capacity of the area as well as elements of its infrastructure that can increase its value and support the ecotourism area can be found from this research.

LITERATURE REVIEW

Research Location

Pahawang Island, Punduh Pidada District, Pesawaran Regency, Lampung Province was the location in this research. This island is geographically located at coordinates 05° 40'36" South Latitude and 105° 13'05" East Longitude. There were 6 stations in the east, north and west. See figure 1.

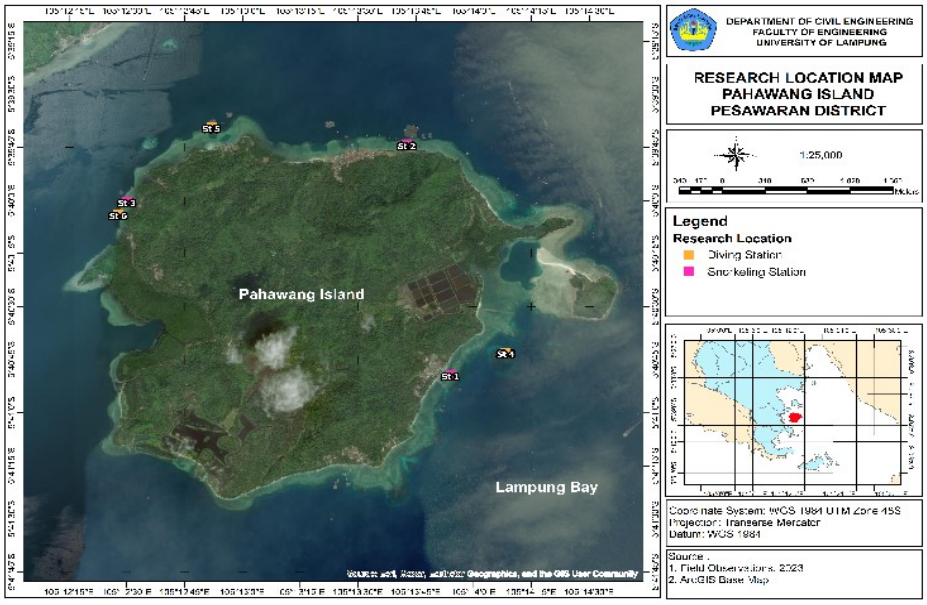

Figure 1: Location Map

Tools and Materials

This research used tools such as a laptop for processing data, GPS for location marking, scuba diving for diving aids, a Secchi disk for measuring visibility, a roll meter and an underwater camera for collecting transect data.

The materials used in this research include previous research which was used as a reference in this research, sentinel 2A satellite image data and Google Earth to map location conditions, also assisted by ArcGIS software for spatial map processing with license code: EFL123456789.

RESEARCH METHODOLOGY

Line Intercept Transect (LIT)

To acquire information on the coral reef cover percentage rate, the LIT method is employed. The percentage of substrate cover using the LIT method can be calculated using the following formula (English et al, 1997; Fadhillah et al, 2021):

$$\%\text{Coverage} = \frac{Lifeform\ Category\ Coverage\ Length}{Total\ Transect\ Line\ Length} \text{ x } 100 \quad \text{.....(1)}$$

In LIT method, the part of sample being collected is not the field area, but transect line length (Fadhillah et all 2021).

There are advantages in LIT method according to (English et all 1997) in (Fadhillah et all 2021). One of which suggested that the data obtained through this method is better and more extensive due to it includes the length of coral colonies, presentation of community structure such as live coral coverage, dead corals, species richness, dominance, frequency of presence, colony size and species diversity in which can be presented comprehensively depending on monitoring needs and location. These data are shown in table 12.

Tourism Suitability Analysis (TSI)

A scientific way to evaluate a tourist area's level of suitability or feasibility using objective criteria is the Tourism Suitability Index (TSI, also known as Indeks Kesesuaian Wisata or IKW). Snorkeling and diving are listed under the index of tourism suitability. The equation for tourism suitability index equation in this research is (Yulianda, 2019):

$$TSI = \sum (Bi \times Si) \quad \text{.....(2)}$$

Where:
TSI = Tourism Suitability Index
S1 (Very Suitable) : IKW ≥2,5
S2 (Suitable) : 2,0≤ IKW<2,5

S3 (Not Suitable) : 1≤IKW<2,0
TS (Very Not Suitable) : IKW < 1
Bi = Parameter weight ke-i
Si = Parameter score ke-i

This suitability index assessment has parameters for individual tourism activity types. The matrix of tourism suitability for the snorkeling and diving categories is shown in table 1 and table 2.

Table 1: Snorkeling Ecotourism Suitability Matrix

Parameter	**Weight**	**Category (S1)**	**Score**	**Category (S2)**	**Score**	**Category (S3)**	**Score**	**Category (TS)**	**Score**
Coral Coverage (%)	0.375	>75	3	>50-75	2	25-50	1	<25	0
Lifeform Type	0.145	>12	3	<7-12	2	4-7	1	<4	0
Coral Fish Type	0.14	>50	3	30-50	2	10-<30	1	<10	0
Brightness (%)	0.1	100	3	80-<100	2	20-<50	1	<20	0
Depth (m)	0.1	1-3	3	>3-6	2	>6-10	1	>10;<1	0
Current Speed (cm/s)	0.07	0-15	3	>15-30	2	>30-50	1	>50	0
Expanse width (m)	0.07	>500	3	>100-500	2	20-100	1	<20	0

Source: Yulianda (2019)

Table 2: Diving Ecotourism Suitability Matrix

Parameter	Weight	Category (S1)	Score	Category (S2)	Score	Category (S3)	Score	Category (TS)	Score
Coral Coverage (%)	0.375	>75	3	>50-75	2	25-50	1	<25	0
Lifeform Type	0.145	>12	3	<7-12	2	4-7	1	<4	0
Coral Fish Type	0.14	>50	3	30-50	2	10-<30	1	<10	0
Brightness (%)	0.1	100	3	80-<100	2	20-<50	1	<20	0
Depth (m)	0.1	1-3	3	>3-6	2	>6-10	1	>10;<1	0
Current speed (cm/s)	0.07	0-15	3	>15-30	2	>30-50	1	>50	0

Source: Yulianda (2019)

ANALYSIS AND DISCUSSION

Area Carrying Capacity (ACC)

The definition of Carrying Capacity is a measurement of an area's maximum allowable usage based on its sensitivity or tolerance, which is affected by a number of natural elements, including the availability of food, living space, shelter, and water (Maldonado 2004). The ecological potential of visitors and area units from diving and snorkeling activities is shown in table 3 (Yulianda, 2019). To calculate the carrying capacity of an area, this research uses the formula from (Yulianda, 2007; Mutabarat et al, 2009; Muflih et al, 2015; Sukuryadi et al, 2020), which are as follows:

$$ACC = K\ x\ \frac{Lp}{Lt}\ \text{x}\ \frac{Wt}{Wp} \quad \text{.....(3)}$$

Where:
ACC = Area Carrying Capacity
K = Ecological potential of visitors per unit area
Lp = The area/length of the area that can be utilized
Lt = Unit area for particular category
Wt = Time available for tourism activity in the area per day
Wp = Time spent by visitors for particular activity

Ecotourism Support Infrastructure

Tourism operations at a tourist destination must take into account the value of visitor demand and supply since ecotourism supporting infrastructure may add value and improve the excellence of a tourist attraction. Visitors can feel at ease while yet paying attention to the preservation of the ecosystem's natural resources thanks to the infrastructure that supports them.

Table 3: Diving Ecotourism Suitability Matrix

Activity Type	∑ Visitor (K)	Unit Area (Lt)	Description
Diving	2	2000 m2	2 people in each area of 200 m x 10 m
Snorkeling	1	500 m2	1 people in each area of 100 m x 5 m

Source: Yulianda (2007)

TSI and ACC Data Analysis

In this assessment, TSI and ACC values have been acquired which were presented descriptively. Then it was compared with the suitability and carrying capacity of coral reef ecotourism areas in other locations. The analysis was performed via looking at the existing parameters to see if there is a trend towards a better and more sustainable direction.

Integrated Coral Reef Ecotourism Management

Observation and mapping methods, documentation, descriptions of useful objects, and aesthetics of coral reef tourist management were all employed in the earliest phases of collecting and studying the materials. In this study, comparative studies are used, especially when discussing the infrastructure that supports ecotourism. On the basis of this, infrastructural guidelines for ecotourism on coral reefs were proposed. These findings will serve as the foundation for the author's recommendations for more coral reef ecotourism management initiatives on Pahawang Island.

Table 4: Snorkeling activity transect data summary

Parameter	East	North	West
Coral Coverage (%)	45.60	85.20	68.50
Lifeform Type	8	8	8
Jenis Coral Fish Type	51	51	51
Water Brightness (%)	90	96	96

Parameter	East	North	West
Depth (m)	3	3	3
Current Speed (cm/s)	30	15	17
Coral plains expanse width (m)	275	325	315

Table 5: Diving activity transect data summary

Parameter	East	North	West
Coral Coverage (%)	45.60	85.20	68.50
Lifeform Type	8	8	8
Jenis Coral Fish Type	51	51	51
Water Brightness (%)	90	96	96
Depth (m)	3	3	3
Current Speed (cm/s)	30	15	17
Coral plains expanse width (m)	275	325	315

Coral Reef Ecotourism Suitability Analysis

Based on the results obtained from the line intercept transect method in table 4, the index of tourism suitability value for snorkeling category can be calculated. The estimation results are shown in table 6.

Table 6: Diving activity transect data summary

Parameter	Weigh t	Location		
		East	North	West
Coral Coverage (%)	0.375	1	3	2
Lifeform Type	0.145	2	2	2
Coral Fish Type	0.14	2	2	2
Water Brightness (%)	0.1	2	3	2
Depth (m)	0.1	3	3	3
Current Speed (cm/s)	0.07	2	3	2
Coral plains expanse width (m)	0.07	2	2	2
N Total	1.00	**1.725**	**2.645**	**2.1**
Category		**Not Suitable (S3)**	**Very Suitable (S1)**	**Suitable (S2)**

The diving tourism suitability index is reffering to (Yulianda, 2007). Tourism suitability index calculation data is shown in table 8, which was obtained from the method of line intercept transect in table 4.

Furthermore, from the TSI results, the TSI for snorkeling and diving categories on Pahawang Island can be mapped. See figure 2.

Area Carrying Capacity

The outcomes of the calculation of the carrying capacity of the diving and snorkeling activity areas are shown in table 7.

Table 7: LP Calculation

Activity	K	The Area of Activity Region(m^2)					
		East	North	West	Lt	Wt	Wp
Diving	2	272,100	200,500	89,200	2000	8	2
Snorkeling	1	185,000	115,500	41,200	50	6	3

Table 8: Diving Category TSI Value Calculation

Parameter	Weight	Location		
		East	North	West
Coral Coverage (%)	0.375	1	3	2
Water Brightness (%)	0.15	3	3	3
Depth (m)	0.15	2	3	2
Lifeform Type	0.135	1	1	1
Coral Fish Type	0.12	2	2	2
Current Speed (cm/s)	0.07	1	3	2
N Total	1.00	**1.57**	**2.61**	**2.015**
Category		**Not Suitable (S3)**	**Very Suitable (S1)**	**Suitable (S2)**

The ACC values result for snorkeling and diving categories is shown in table 9, while for the mapping combined with the TSI results, see figure 2

Table 9: ACC Value for Snorkeling and Diving Category

Area Carrying Capacity	People/Day		
	East	North	West
Diving	1,088	802	357
Snorkeling	740	462	165

The area carrying capacity for snorkeling and diving activity is shown in figure 2.

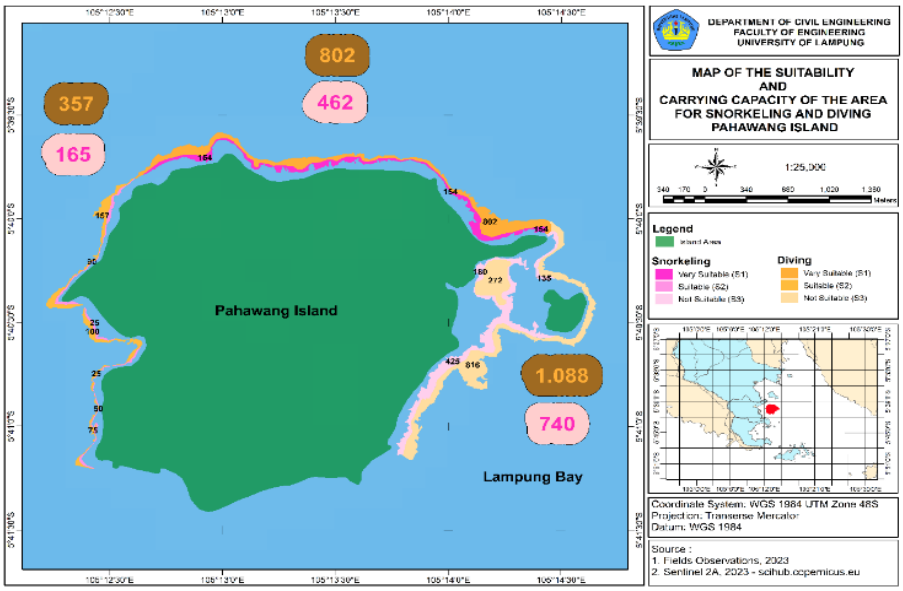

Figure 2: TSI and ACC Map for Diving and Snorkeling

Coral Reef Ecotourism Support Infrastructure

The presence of a supporting infrastructure on Pahawang Island was discovered based on field observations. Table 10 illustrates how key facilities are accessible to everyone in all of the island's villages. Some forms of supporting infrastructure, however, continue to be inadequate.

Table 10: Infrastructures on Pahawang Island

Infrastructure	Villages on Pahawang Island				
	Suak Buah	Pahawang	Penggetahan	Cukuh Nyai	Jeralangan
Road	v	v	V	V	V
Gazebo	v	v	v	V	V
Cottage	v	v	V	V	V
Mosque	v	X	V	V	X
Information Center	x	X	V	X	X
Toilet	v	V	V	V	V

Infrastructure	Villages on Pahawang Island				
	Suak Buah	Pahawang	Penggetahan	Cukuh Nyai	Jeralangan
Gift Shops	x	X	V	V	X
Clean Water	v	V	V	V	V

Snorkeling and Diving Ecotourism Analysis

The calculation of the sentinel-2a imagery analysis satellite image result shows that the coral reef area on Pahawang Island is 90.35 Ha, which was dominated by fringing coral types. With this area, the abundance of marine life such as various types of fish and coral became the main attraction of the island. Contained in a book with a similar discussion in the Australian Tropical Marine Park about the Influence of Snorkeling Routes on Coral Reefs, to maximize comfort for tourists, a variety of coral types is needed so that tourists can be interested in snorkeling and diving (English & Beker, 1997).

There are diving and snorkeling locations at these 6 stations, according to observations made at 6 stations in the villages of Suak Buah, Penggetah, and Taman Nemo. Tables 4 and 5 show specific coral cover, with station 2 having the maximum coral cover at 86.20%. Eight different life forms were identified overall, including coral branching (CB), coral foliose (CF), coral massive (CM), coral submassive (CS), coral encrusting (CE), coral mushroom (CMR), coral millepora (CML), and acropora branching (ACB). These life forms have beautiful colors causing visitors to feel attracted to them. Although this island's coral cover falls into the "good" category overall, there are two stations that indicate damaged coral reefs, which are shown at stations 1 and 4. With a cover percentage of 45.60%, station 4 has the lowest coral cover. The damage took place due to harming tourist behavior, extensive fishing, and fishing bombing by local communities. However, because of the growth of new coral colonies in this area, the state of the damaged coral reefs has started to improve. Additionally, coral reef transplants can be done to improve coral reef coverage in order to take full advantage of the potential in this region in order to preserve and enhance Pahawang Island's coral reef tourist potential.

Referring to the suitability analysis for snorkeling and diving activities, the suitability index for coral reef ecotourism on Pahawang Island is classified in the "suitable" category (S2). When compared with similar research in Tuapejat, the Mentawai Islands which used a similar analysis from (Yulianda, 2007) showed that the IKW results on the southwest coast of Tuapejat were 85.19% and were categorized as "Very Suitable" (S1) (Zulfikar et al, 2011). This is because the better percentage of coral cover, visibility, and the speed of current.

The diving and snorkeling carrying capacity can accommodate 3,614 people/day. The Mentawai Islands, which cover an area of 137.02 Ha, have an

area carrying capacity of 3,139 people/day, which is more than Tuapejat's carrying capacity (Zulfikar et al, 2011). In order to sustain and prevent harm to the coral reef ecosystem, management must supervise and inform tourists and local residents about snorkeling and diving activities.

Integrated Coral Reef Ecotourism Management

This analysis is assessed based on amenities and accessibility. The direct observations in the research location show that the infrastructure is good enough. However, there are several conditions that need to be improved so that integrated coral reef ecotourism management can be advanced. See table 11.

From the suggestions for infrastructure development, a master plan can then be created to produce orderly improvement so that it can rise the number of tourists on Pahawang Island. See figure 3.

This figure emphasizes the necessity for thorough development in each village on Pahawang Island. A mosque has to be built in Cukuh Nyai Village so that it may provide praying facilities for tourists, especially the local population, much as in Pahawang Village and Jeralangan Village. Both villages need road repairs and buildings at various spots. These findings may be taken into consideration by management or other relevant government bodies to ensure that both the quality and quantity of ecotourism infrastructure development on this island, particularly with regarding coral reef ecotourism, continues to improve.

Table 10: Integrated Ecotourism Suggestions

Infrastructure	Parameter	Suggestion	Development Timeline Suggestion
Clean Water	Clean water availability for tourists.	It is necessary to manage and control water resources according to the principles of sustainable conservation and tourism.	First Year
Security and Health Facility	Availability for security and health services for visitors.	Repairs and construction are needed at several points. Facilities are expected to always be active and can be visited at any time and maintain good communication with related parties.	First Year
Toilet and Public Bathroom	Availability and condition of toilets and public bathrooms to support sanitation and cleanliness.	It is necessary to build and repair toilets at several points so that cleanliness and sanitation management can be more optimal.	First Year

Infrastructure	**Parameter**	**Suggestion**	**Development Timeline Suggestion**
Praying Facility	Availability and condition of infrastructure to support praying activities of visitors and the community	It is necessary to develop and build in each area and repair praying facilities as well as increases supporting facilities.	Second Year
Recreational Support	Availability and condition of infrastructure for visitors to refresh body and mind.	It is necessary to build parks or special sports facilities for visitors in a local culture design.	Third Year
Information Center	Availability of infrastructure for services that make it easier for visitors to obtain information about tourist destinations.	It is necessary to develop, improve services, and active management of information centers.	Third Year
Gift Shops	Availability of conditions and infrastructure for visitors to buy souvenirs	It is necessary to build a creative space that accommodates the creativity of local communities	Fourth Year
ATM and Money Changer	Availability, conditions, and services of infrastructure for tourists to carry out financial transactions.	It is necessary to provide ATMs and money changer services in each destination area.	Fourth Year
Gazebo	Availability of infrastructure for tourists to relax and embrace the beauty of the island.	It is suggested to repair and increase this infrastructure.	Fifth Year
Road	Availability and condition of infrastructure makes it easier for visitors to access the location.	It is necessary to increase and build high quality roads as access for tourists.	Fifth Year

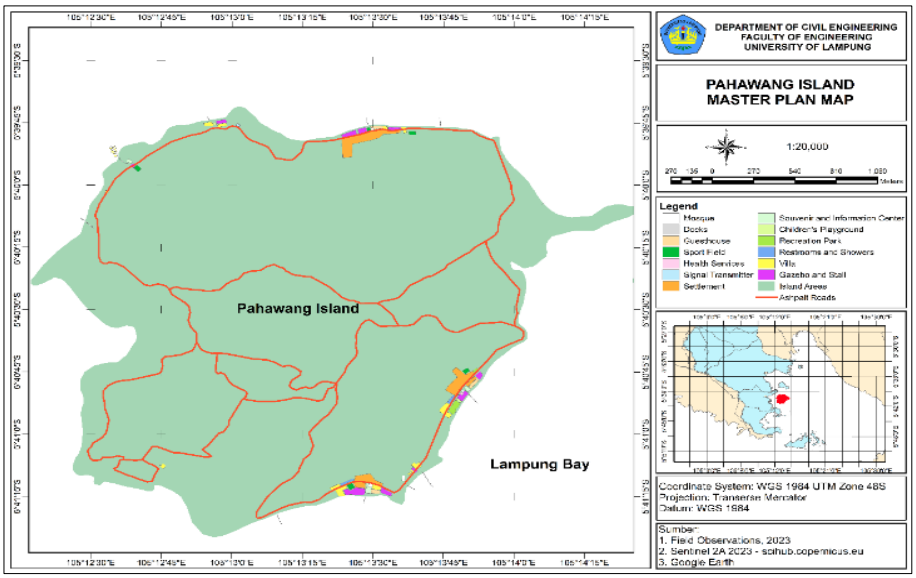

Figure 3: Pahawang Island Master Plan

CONCLUSION

The conclusion is that, from a spatial standpoint, the suitability index and the area of snorkeling and diving ecotourism carrying capacity, as well as the supporting infrastructure, are in good condition. To enhance and advance this, integrated management and governance are necessary.

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