Geographic information system application in small islands management (case study: assessment of jetty suitability distribution in Derawan Island)

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Abstract. Derawan Island, with an area of 35.99 hectares, is a small island in Derawan Archipelago, located in Berau Regency, East Kalimantan Province. The waters in the Derawan archipelago rich in biodiversities such as coral reefs, mangroves, and seagrasses, so designated as a conservation area in 2016 and currently known as marine tourism destinations in Kalimantan, which contribute to the economy. Tourism in the Derawan islands increased significantly along with supporting infrastructures such as hotels, restaurants, and jetties. A study on jetty facilities conducted by comparing the changes of jetties infrastructure in Derawan island, wherein 2003, the jetties area was 6,977 m², while in 2018, about 66,011 m². Changes of jetties area mostly occurred in the western and southern parts of the island due to safety reasons, bathymetry, and hydrodynamic conditions. This condition raised an issue concerning water quality, aesthetics, and natural condition, decreasing its beauty and impact on the tourism sector. Spatial analysis for jetty distribution using GIS carried out and resulted in recommendations where the maximum number of jetties needed was five units with a length of about 70 m towards the sea. This recommendation may also be used to provide an alternative location for a jetty in Derawan Island in the future.

1. Introduction

Derawan Island in Berau Regency, East Kalimantan Province designated by the Indonesian government as a protected area based on the Minister of Marine Affairs and Fisheries, the Republic of Indonesia Decree No. 87/Kepmen-KP/2016 on Coastal Conservation Areas and Small Islands of Derawan Islands and Surrounding Waters. Derawan Islands has several small islands, namely Derawan Island, Maratua Island, Kakaban Island, Samama Island, Panjang Island, Rabu-rabu Island, and Sangalaki Island. These islands play a role as an essential habitat, such as coral reefs, mangroves, seagrasses, and saltwater lakes, including the biota. Derawan Islands is an essential part of the Sulu-Sulawesi Ecoregion Sea that crosses Indonesia, Malaysia, and the Philippines, which famous for its "The Coral Triangle" region with great potency of coral reefs biodiversity where 53% of the world's coral reefs are found in this region [1] and also known as one of the essential multi countries feeding ground in the world [2].

The conservation area of the Derawan Islands has an area of about 285,548,95 ha, with 53% of the area as a Marine Protected Area (MPA) and the rest as a small island conservation park. Marine Protected Areas were managed into three zones, where the first zone is a core zone (red zone), there should be no utilization activity. The second zone (green zone) is a limited utilization area used for habitat protection, fish populations, tourism, research, and education. The third zone as another
utilization zone. Fisheries are the backbone of economic activities in Derawan, where most of the population livelihood worked as fishermen. The types of fisheries commodities utilized by the Derawan Island inhabitant are pelagic fish and coral fish. Fish catch and other associated products (including holothurians of the synaptic type) are generally sold in Derawan Island, Maratua Island, Tanjung Redeb, Surabaya, and several cities outside the province, some of the commodities exported abroad [3].

Compared to the other island in Derawan Archipelago, Derawan Island has a better and excellent infrastructure, especially in the tourism sector, such as hotels, restaurants, and jetties, supported by sufficient freshwater resources for the island and its inhabitant [4]. The total tourism visitation, both domestic and international tourists to Derawan Island, escalated remarkably, especially with the domestic visitor's domination. Massive development followed this condition to facilitate the visitation trend to Berau in general and Derawan Island, particularly with resorts and infrastructures developed in the region. Most of the resort has its restaurant and jetties to accommodate the tourist mobilization and other entertainment purposes.

Derawan Island is a small island that functioned as a Marine Protected Area (MPA), so that infrastructure development ideally should be based on the function and size of the island. However, a condition in the field indicates that the presence of the jetties on the western and southern part of the island was very dense and more than needed, which disturbing the beauty of the beaches, threatening the marine biota, aquatic ecosystem, and degrading the aesthetics value, which prone to the tourism sector. Development planning in a small island should consider its carrying capacity to manage and maintain the environment and sustainability. Unplanned development and poor waste management, especially in a coastal region, affected the water quality with its pollution, influencing the health index and may threaten the biodiversity, marine biota, coastal ecosystems, and its environment and end up with abrasion [5]. As a small island with huge potency, Derawan Island is considered an important asset to the region and plays a vital role which vulnerable, causing instability regarding social, economic, and politics [6–9]. Therefore, maintaining the Derawan Archipelago, natural resources is essential and crucial without neglecting the environmental issue and its sustainability.

The research was aimed to describe the land use condition and overexploitation on Tourism infrastructures in Derawan Island regarding small islands management, particularly jetty distribution in Derawan Island. The research objectives are to observe and evaluate the jetties distribution in Derawan Island and providing policy recommendations to the local government.

2. Methodology
The research was conducted in March 2019, continued with data processing until October 2019 using ground-truthing methods assisted by the local people (Figure 1). Derawan Island is part of the Derawan Archipelago located in the Makassar Strait directly adjacent to the Sulawesi Waters, considered an open sea or deep sea, which is part of the Coral Triangle region with high marine biodiversity [1]. The population in Derawan Island reached 1,491 people, and the rate of population increase of 1.18 inhabitants per year from 2010-2017 [10]. Other islands in Derawan Archipelago, which famous for its tourism sector, include Maratua Island, Kakaban Island, Semama Island, and Sangalaki Island, where each island has a unique natural resource and marine ecosystem attractiveness [11].

This research was conducted by analyzing several high-resolution satellite imagery from sources such as Worldview from Digital Globe, and Google Earth High-Resolution Image, combined with photos taken using drone DJI Phantom-3 in four different time frames (2003, 2011, 2015, and 2018) as shown in table 1.

Satellite imagery data processed using ArcGIS 10.1 applications to obtain land use cover in 2003, 2011, 2015, and 2018. The land use cover analysis in this study focused on infrastructures, coastal buildings, jetties, docks, houses, restaurants, and other supporting infrastructures. Specific tasks focused on the jetties’ existence in Derawan Islands and assessing the suitability of jetties distribution in the region, which significantly increased from 2003 until now.
Table 1. Derawan Island

| Acquisition Time | Satellite | Source          | Resolution (m) |
|------------------|-----------|-----------------|----------------|
| 02-10-2003       | Worldview 2 | Digital Globe   | 1.84           |
| 20-09-2011       | Worldview 2 | Digital Globe   | 1.84           |
| 04-07-2015       | Worldview 2 | Digital Globe   | 1.84           |
| 01-09-2018       | UAV       | DJI Phantom-3   | 0.5            |

Figure 1. Map of Derawan Islands (Source: Field Observation)

Figure 2. Flowchart Assessment

Manual digitation was carried out to identify several issues such as coastline, coastline changes, and tourism infrastructures in the island, especially jetties. Digital Coastline Analysis System (DSAS)
is used to compare the coastline changes through the available years, as shown in figure 2. The assessment on the suitability for jetties distribution in Derawan island examined using the distance assumption with 500 m based on Yulianda and Atmadipoera [12] study and combined with the island characteristics, especially in oceanography.

3. Results and Discussions

3.1. Tourism Visitation

Tourism visitation to Derawan Island in 2015 until 2019 increased significantly, where the domestic tourist visit reached 77,574 people, while international visitors around 9,527. Visitation trends, particularly for local visitors, continuously increase in 2016, 2018, and 2019 even though there was a slight decrease in 2017. The opposite trend occurred in international visitors where the tourist visitation shrunk from 2015 to 2019, as shown in Table 2.

| Year | Domestic | International | Total Visitors | Source |
|------|----------|---------------|----------------|--------|
| 2015 | 77,574   | 9,527         | 87,101         | [13]   |
| 2016 | 101,416  | 6,119         | 107,535        | [14]   |
| 2017 | 75,545   | 2,573         | 78,118         | [15]   |
| 2018 | 203,404  | 4,376         | 207,780        | [10]   |
| 2019 | 283,294  | 2,586         | 285,880        | [16]   |

Based on coastline analysis using the DSAS technique, coastal abrasion in Derawan Island mostly occurred on the eastern side due to the current and wave movement supported by strong wind and bathymetry characteristics [17]. Based on interviews with locals, that in 1995, there was a national level sports event held in East Kalimantan, and Derawan Island took part in a water sports event. Several infrastructures were built to support the venue and found broken, where most of the area has been lost due to massive abrasion, which is located in the western part of the island (Figure 3).

![Figure 3. Abrasion in eastern part of Derawan Island since 2000’s](image_url)
During the field observation, the wave in the eastern side of Derawan Island (seawards direction) were higher compared to the west and south (leewards direction), which more stable due to the location towards the mainland (Kalimantan Island), while the eastern side adjacent to the open sea and deep-sea (Sulawesi Waters and the mouth of Makassar Strait). Based on observation and desk study analysis through a high-resolution image taken from Google Earth, it was obvious that abrasion occurred massively from 2011 to 2018, shown by changes in the size and shape of the island [17].

The condition in the west and southern part of Derawan Islands relatively stable, which suitable for infrastructure development, especially for tourism purposes where the land use type in the region is fulfilled with a hotel, restaurant, and jetties. Some parts of the infrastructure located towards the sea without permission, which actually violates the regulation and can threaten the environment and adjacent ecosystem [18]. This kind of issue has not just occurred in Derawan Island only, but it was a common problem, especially in countries with small islands due to the economy and environment limitation that need more attention [19]. The infrastructure development related to tourism sector mostly occurred in the western side of Derawan Island, but not in the eastern part due to its wave-induced abrasion and hydrodynamic condition. Abrasion in Derawan Island reduce the land area and threaten the green sea turtle life cycle. Poor waste management as shown by the floating rubbish in the environment contributed in threatening the green sea turtle breeding [20].

Based on spatial analysis using high-resolution satellite imagery combined with remote sensing technology, it can be concluded that there were significant changes in the extent and shape of Derawan Island through the years. By comparing the island condition from 2003, 2011, 2015, and 2018, the land extent decreased significantly from 44.6 Ha in 2003 to 36.9 Ha in 2011. This trend continues in 2015, where the extent decreased to 36.6 Ha, while in 2018, about 35.9 Ha. The condition of shrinking Derawan Island is caused by several issues, such as abrasion as the impact of hydrodynamic factors (wave and currents) in the western and eastern side of the island, and land use and land-use change due to the infrastructure development to facilitate tourism sector. The increase in land use cover from 2003, 2011, 2015, and 2018, with the number of building units, reached 110 units in 2018 or rise to 40%, as shown in table 2.

Table 2. Derawan Island Land Cover Type

| Year | Public Jetty (Unit) | Navy Jetty (Unit) | Private Jetties (Unit) | Explanation |
|------|---------------------|------------------|-----------------------|-------------|
| 2003 | 1                   | 1                | 1                     | Before MPA Designation |
| 2011 | 1                   | 1                | 19                    | Before MPA Designation |
| 2015 | 1                   | 1                | 27                    | MPA Designation on progress |
| 2018 | 1                   | 1                | 45                    | After MPA Designation |

(Source: Field Data, 2019)

Beaches are one of the most attracted tourism objects globally, with more than 45% vote from tourists and visitors, which also contributed directly to the economic sector with 8.6% to the national GDP. Indonesian beaches are quite similar to Mexico, who admired due to its sun, sand, and sea (knowns 3S) and made sandy beaches as the national priority to take care of since 1950 [21]. However, the international hotel group's invasion and its association prioritize solely to the economic benefit than the quality of the natural resource, environment quality, and sustainability. When the coastal ecosystem is damaged or degraded, it will affect the water quality, natural condition, and the environment, and then the attractiveness will be lost and directly impacted the tourism sector. Therefore, strict regulation and supervision should be applied in order to minimize the impact on the environment.

Derawan Island land use and land cover change for the past 15 years has changed massively, where most of the inhabitants lived in the southern and western part of the island. This location known as the safest area, which has lesser effect from wind, waves and monsoon season through the year compared to the north and east side of the island and of course protected from the exposure towards the Sulawesi Sea and Makassar Strait directly. The population concentration also affecting the mobilization
activities both from the island and to the island, which shown by the density of housing and residential in the south and west of the island, including for tourism sector and its infrastructure as shown in figure 4.

![Figure 4. Derawan island land use and land cover in 2019 (Source: Google Earth Pro)](image)

### 3.2. Waterfront Building
Tourism infrastructures such as hotel, restaurant and jetties in Derawan Island mostly come in a package to support and facilitate the visitors. This tourism infrastructures increased significantly through the years towards the sea and occupy the adjacent beaches, which considered as a public space as shown in Table 3. Overexploitation on the coastal area due to the waterfront buildings in Derawan Island created another issue related to the natural condition, water quality and surely the aesthetic aspect as the main asset of Derawan Island.

| Year  | Waterfront Building (m²) | Explanation                      |
|-------|--------------------------|----------------------------------|
| 2003  | 6977.28                  | Before MPA Designation           |
| 2011  | 15362.04                 | Before MPA Designation           |
| 2015  | 25282.59                 | MPA Designation on progress      |
| 2018  | 66011.21                 | After MPA Designation            |

Source: Field Observation

The tourism infrastructures like jetties existence increased massively from 2003 to 2018 as shown by figure 5, where most of the infrastructure were built near to the population. Even though Derawan Island already have 3 Jetties in 2003 (1 for public, 1 for private and 1 for Navy) but more jetties (private ownership) were built by the hotel owner as a supporting infrastructure and facilities to their resort. This condition might threaten the coastal ecosystem and the adjacent environment and considered as an overexploited tourism sector in Derawan Island.

Spatial planning is an approach to socio-economic development that affects the community sector and economic, social, cultural, and ecological policies [22] as what had happened in Derawan Island. Therefore the growth of the tourism infrastructure, especially jetties in small islands, needs management from the government, following the assumptions from Yulianda and Atmadipoera [12] for boat-tours required a jetty with 500 meters in the distance. The distance reference used to manage the suitability of jetties of Derawan Islands, the exact location, and the length of jetties towards the
sea. The length of jetties measured from Phantom DJI 3 high-resolution photos, recorded in 2018, has an average length of 70 m. From the result of GIS analysis and development simulation, the ideal number of jetties is proposed for five units with a length of 70 m (Figure 6).

After conducting in-depth analysis dealing with the extent, the coastline and environmental condition resulting in the maximum number of ideal jetties in Derawan Island was five units, where three jetties already determined namely the public jetty build by the local government for island mobilization, and navy jetty built by the Navy for defense purpose since Derawan Island located in the outer area of Indonesia adjacent to Malaysia waters. The other three jetties considered to fulfill the distance requirements, but only two are regarded as a perfect location for jetties existence, while the other jetty located in the northeast is not recommended due to some issue with the abrasion. (Figure 6). Therefore, jetties management in Derawan Island should be restructured based on needs and sharing the jetties load not just for private interest but for public access to maintain its aesthetic and for a better and sustainable environment.

![Figure 5. Development of jetties in Derawan Island through years (2003, 2011, 2015 and 2018)](image)

![Figure 6. The ideal proposed jetties map with distance 500 m and 70 m length](image)
4. Conclusions and Suggestions
The development of jetties as infrastructure in Derawan Island, especially the private jetties has been developed massively. This raises aesthetic problems and the effectiveness of transportation service mobilization inside and outside the island. Based on spatial analysis and simulation results, which combined with the islands characteristics, resulted a recommendation of the maximum number and the suitability location for jetty distribution in Derawan Island. This recommendation is not in accordance with the reality in the island, which need more adjustment on jetties distribution to share the load and public interest in Derawan Island.

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