Study of coastline changes and land use change in marine protected area (Case study: Derawan Island, East Kalimantan Province)

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Abstract. Derawan Island is an island with an area of 45 ha, it categorized as a small island and part of Derawan Islands archipelago located in East Kalimantan province. It designated as a conservation area by the decision of Berau District Head No. 516 of 2013 concerning the Reservation of Coastal Conservation Areas and Small Islands. Derawan Island, also known as the National Tourism Destination (DPN) based on its coral reefs diversity that considered adjacent to the Coral Triangle Initiative (CTI). The increase of Tourist visit to Derawan Islands since 2000, which affected land cover changes in Derawan Island coast such as for lodging, jetty and other infrastructure. Changes in land cover together with natural coastal processes causing abrasion in the west, and east sides, while accretion in the southeast side of the island. Land cover change especially built-up area from 2003 to 2018 is 6.25% per year. Observations and analyzes using DSAS (Digital Coastline Analysis System) conducted in 2003, 2011 and 2018 illustrates coastline change which shown by abrasion an accretion along Derawan Island. Abrasion trends increased from 2003, 2011 and 2018 with the highest abrasion rate up to 12.4 m / year, which occurred on the west side, while the highest accretion rate was 2.46 m / year on the southeast side. Based on several considerations and conditions, it is highly recommended that the coastal border for utilization in the islands is around 15 m.

1. Introduction

Derawan Islands is a group of islands located to the east of Borneo Island and administratively part of Berau Regency, and under the authority of East Borneo Province [1]. Geographically, Derawan Islands located separately from Borneo main island and situated in the northern part of the Makassar Strait which connected with Sulawesi and Java waters [2]. Derawan Islands become an area for marine tourism objects as the establishment of Derawan Marine Protected Area, which is part of the Sulu-Sulawesi Sea Ecoregion that crosses Indonesia, Malaysia, and the Philippines [3]. The ecoregion located in the center of the world's triangle coral region with the highest coral biodiversity in the world, which known as “The Coral Triangle” because it is the epicenter of marine life in the area [4]. More than 75% of coral species from 600 coral species around the world are found in this region with more than 3,000 species of fish [5], as well as an important biodiversity in the region which covers 13% of the total area [6]. Based on research developed by Berau Department of Tourism (disbudpar.beraukab.go.id/kepulauan-derawan/), Derawan Islands is one of the most important multi countries feeding ground in the world which is known as the Amazone of the Seas region dubbed as the center of life at sea and high biodiversity [7].
Besides the beauty of its coral reefs, Derawan Island also has other unique marine biota, green turtles (*Chelonia mydas*) which depend on the distribution of the seagrass beds as its main food. [8].

Considering the potential that exists on Derawan Island with the diversity of biological resources such as coral reefs, reef fish, turtles and the beauty of white sand beaches so that Derawan Island is a tourist destination that is favored by both domestic and foreign tourists. Based on the annual statistical data, the number of visits to Berau District was the most in December of 16,890, and the lowest was in June 8,837 foreign and domestic tourists [2].

Along with developments in the Derawan Islands, especially Derawan Island, which has the potential for tourism, natural resources are starting to attract tourists and make the area as a tourism/natural tourist attraction (ODTWA) object. Regional Government Support through the Regional Regulation of East Kalimantan Province Number 14 of 2008 concerning the Master Plan for Regional Tourism Development in East Kalimantan Province as a reference in developing regions that have tourism potential, as well as mandating Law Number 10 of 2009 concerning Tourism that allows development, and tourism management in promoting equity, utilization and development in the region. The tourism potential with the support of the Regional Government and the mandate of the Law increasingly brings real changes on Derawan Island which is the 5th priority as Berau District tourism industry in the economic development and strengthening the program of the Berau community in 2018 (Figure 1).

![Figure 1. The Concept of Regional and Central Development to accelerate the equity of Economic Growth. (Source: Head of Research and Development Agency of East Kalimantan Province, 2017)](image)

The issuance of Law No. 10 of 2009 concerning Tourism which was later strengthened by the Regional Regulation of the Province of East Kalimantan No. 14 of 2008 concerning the Master Plan for Regional Tourism Development used as the legal basis to develop and manage Derawan Island become a tourist destination. The implementation of these regulation increase the number of tourists both from domestic and overseas visiting Derawan Island in 2009 to 2016 (Table 1).
Table 1. Tourists visit in Berau Regency year 2009-2016

| No | Year | Overseas | Domestic | Total |
|----|------|----------|----------|-------|
| 1  | 2009 | 1.401    | 2.025    | 3.426 |
| 2  | 2010 | 3.111    | 15.024   | 18.135|
| 3  | 2011 | 3.300    | 24.253   | 27.553|
| 4  | 2012 | 837      | 66.024   | 66.861|
| 5  | 2013 | 4.026    | 80.753   | 84.779|
| 6  | 2014 | 10.728   | 77.574   | 88.302|
| 7  | 2015 | 6.119    | 99.146   | 105.535|
| 8  | 2016 | 2.573    | 127.450  | 130.023|
|    | Total| 33.206   | 512.750  | 545.956|

The high interest of tourists to Berau Regency where one of its objectives is Derawan Island affects investor and local residents to provide tourism supporting infrastructures such as homestays, hotels and jetties. The development of these infrastructures massively changed the land cover directly and indirectly. Significant changes in land cover occurred on the coastal region with so many resorts, or homestays built around the shore facing the sea, thus potentially disturbing the balance of the coastal ecosystem environment.

The real impact that can be observed directly is water quality degradation, where the physical properties become turbid, and marine debris existence found around the region. The construction of resorts on Derawan Island generally violates the provisions of Law No. 1. 2014 concerning Amendments to Law Number 27 of 2007 concerning Management of Coastal Areas and Small Islands in Coastal Management where the Conservation Areas in Coastal Areas and Small Islands should be protected for coastal zone and small island sustainability [9]. Another rule violated by infrastructure construction is article 21 concerning coastal borders for development, where the proportional distance for built-up infrastructure at least 100 (one hundred) meters from the highest tide towards land.

Based on several problems existed in Derawan Island, there are things that need to be address in line with the research objectives, such as:

1. Examine the coastline changes from 2003, 2011 and 2018.
2. Mapping the coastline changes that year.
3. Mapping land cover in 2003, 2011 and 2018.
4. Moratorium on infrastructure development, and restructuring the region.

2. Metodology

2.1 Study Area and Time Observation

Derawan Island is one of the islands in the Derawan Islands Archipelago, which located at the gate of the Makassar Strait next to the Sulawesi Sea. The area of Derawan Island is 44.60 ha with a population reaching 1,491 inhabitants and the rate of population growth of 1.18 people per year from 2010-2017 [2].

In addition to the existence of Derawan Island, there are several islands around Derawan Island which have the attraction of marine tourism, including Maratua Island, Sangalaki, Semama and Kakaban, where all of the islands are included in the Derawan Islands Archipelago [10]. Observation carried out in early September 2018, proceeded with desk study and data processing until January 2019 (Figure 2).
2.2 Research Methods
Several studies on coastline changes, changes in land cover, and changes in land use using remote sensing techniques combined with geographic information systems have been carried out. Coastline change, land cover and land use were examined using satellite imagery from Landsat TM, ETM, and OLI by combining several geoinformatics techniques such as comparison of the band ratio, the combination of non-guided classification with guided classification and calculation its accuracy reaches 90-95% [11].

This research was conducted by analyzing several satellite images in different time frames, namely in 2003, 2011 and 2018 with an interval of around 7 and 8 years, which in 2003 and 2011 used high resolution World View 2 satellite imagery (0.5 meters), while the 2018 image obtained by combining photos obtained from Unmanned Aerial Vehicle (UAV) from DJI Phantom 3. Drone analysis conducted in assessing coastline changes on Derawan Island using the Digital Coastline Analysis System (DSAS) by comparing coastlines of the three available images.

| No | Acquisition Time | Satellite       | Source            | Resolution (m) |
|----|------------------|-----------------|-------------------|----------------|
| 1  | 2003             | Worldview 2     | Digital Globe     | 1.84           |
| 2  | 2011             | Worldview 2     | Digital Globe     | 1.84           |
| 3  | 2018             | UAV             | Phantom DJI 3     | 0.5            |

After obtaining the images form 2003, 2011, and 2018, Land cover analysis executed using Geographic Information System to separate the built-up area including tourism infrastructure with open space (Figure 3), resulted as changes in extent between built-up area and open space, while coastline change analysis carried out using the Digital Coastline Analysis System (DSAS) by comparing the coastline of the three available images (Figure 4) resulted with location of abrasion, accretion in the region.
3. Result and Discussion

Condition of Derawan Island in 2003 still appeared natural, with a normal demographic as a small island, where there were two private jets and one public dock as access for public transportation and mobility, while the settlement centered in the middle of the island. Since 2009 the tourist visits to Derawan Island increasing, which affect the development and infrastructure construction in the island, especially in the
coastal area. This phenomena happened due to the regulation issued by the central government No. 10 Year 2009 regarding Tourism then strengthened by the East Borneo Provincial Government No 14 Year 2008 regarding Master Plan of Regional Tourism Development, which stimulate the island to accommodate the visitor with massive tourism supporting construction.

The impact of unsynchronized, weak of planning and unorganized development in this coastal area causing negative effect, especially in the surrounding environment such as water turbidity, marine debris etc. These activities focused on the comparison between three different time frames, which are 2003, 2011 and 2018, where the build-up area increased significantly compared to open space area (table 3 and Figure 5). Based on linear regression assessment, the algorithm for built-up area resulted $y = 18413 + 61292$, which showed the trend of built-up construction growth increased annually with average 6.25%.

**Table 3. Land cover change**

| No | Land cover   | Area (m²) 2003 | Area (m²) 2011 | Area (m²) 2018 | Total (m²) | Persen (%) 2003 | Persen (%) 2011 | Persen (%) 2018 |
|----|--------------|----------------|----------------|----------------|------------|-----------------|-----------------|-----------------|
| 1  | Open Area    | 286442.25      | 290896.16      | 282421.94      | 859760.35  | 33.32           | 33.83           | 32.85           |
| 2  | Built Area   | 80516.76       | 96493.25       | 117342.82      | 294352.83  | 27.35           | 32.78           | 39.86           |

Source: Data analysis

**Figure 5.** Graphic of open space dan built up area 2003, 2011 and 2018

The proportion of built-up area between 2003 to 2011 and 2011 to 2018 increased gradually (Figure 6), where most of the construction towards eastern side based on its stability compared to the west where the abrasion took place. Based on DSAS analysis, abrasion in the western side reached up to 12.4 m, where the east side accretion occurred and reached up to 2.46 m (Figure 7, and Figure 8).
Figure 6. Built-up area changes compared to open space in 2003, 2011, and 2018

Figure 7. Coastline changes in Derawan Island in 2003, 2011, and 2018
Due to the level of abrasion up to 12.4 m and level of accretion up to 2.46 m, which concluded the coastline changes in Derawan Island, suggested the minimum requirement for the coastal border as consideration to develop or constructs the tourism supporting infrastructure as far as 15 m from the coastline.

4. Conclusions and Recommendations

Considering the development, development, and management of Derawan Island, it can be concluded that development has led to over-exploitation on Derawan Island which does not adhere to the principles of sustainable and environmentally friendly sustainable development as well as the following:

• Infrastructure development in Derawan Island is not well organized and violates several rules that apply in terms of coastal area management.
• The impact of this disorder also exacerbated by the natural processes of the waters which cause abrasion in most areas around Derawan Island, although there are areas that experience accretion.
• In addition, many migrants, both residents and tourists who visit, also affect the environment around the island such as the carrying capacity of the island in the form of clean water, waste management, and cleanliness of the environment around the island

Based on the conclusions above, several actions are needed in overcoming the problem, preventing the enlargement of the problem, and fixing the problems that arise as follows:

• Strengthening the application of regulations related to the development and management of coastal areas on Derawan Island.
• Restore the function of Derawan Island coast for public purposes, so that the beach is open to the public and enjoyed by everyone.
• Rearranging management areas based on their designation, especially areas that have the potential for abrasion to become areas that are free from infrastructure development in the form of lodgings, and the like become open coastal areas and become joint recreation zones.
• Development of recreational facilities on the coast that have the potential for abrasion with beach modification and protection that retain beaches from abrasion.
• Increasing the status of Derawan Island to a closed island or semi-closed island with restrictions on the number of tourists visit to reduce pressure on the island.

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Acknowledgement
This research was funded by the government of the Republic of Indonesia under the Marine Research Center, Ministry of Marine Affairs and Fisheries, the Republic of Indonesia, as part of joint research with Japan government under Science and Technology Research Partnerships for Sustainable Development (SATREPS). Thanks to Novi Susetyo Adi, Ph.D as principal investigator and Yusmiana Puspitaningsih Rahayu, M.I.L as coordinator for their support.