Analysis of environmental carrying capacity with AHP in ArcGIS of Weh Island

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Abstract. Development of infrastructure will increase sporadic land use and tend to cause land degradation. This paper is intended to investigate the effects of land use and land cover (LULC) processes on Weh-Sabang Island, Indonesia. The duration of LULC changes is analyzed using Google Earth image and ArcGIS from 2008 to 2018. Through observations of satellite imagery detected protected area and green space area has been greatly reduced in area and transformed into built-in land which functions as a tourist area and urban built environment. The increase in land density since 2008 is due to the construction of tourist attractions in hilly areas to coastal areas around Weh-Sabang Island, and can cause changes in the morphology and typology of the city of Sabang. Through the method of calculating the Land Diversity Index, changes can be made in the number of areas that have changed in the period of the year being monitored. This paper focuses the development of an ArcGIS Weh Island map with the analytical hierarchy process (AHP). It is expected that efforts will be made to control land use changes in areas that have directly experienced land degradation, and analysis of water resources carrying capacity in Weh Island.

1. Introduction
Sabang is a port city that is very well known as a natural port on Weh Island. Cities must always have a distinctive identity and character. If the spatial planning of the city of Sabang as a tourist city is done well, it will be accepted by the community because it gives a real contribution to the development of the quality of life of the community. However, how the public responds if the structuring of the central area of Sabang that has been visited by many foreign tourists so far is not as beautiful as in design photos and drawings, and even eliminates elements of the city spatial structure and spatial patterns that have been formed for a long time and have been included in the City Planning Sabang in 2007-2027 (Sabang RTRW, 2007-2027). Spatial Planning has explained the function of space to obtain a safe, comfortable, productive and
sustainable environment that must be achieved in every region of the Republic of Indonesia in accordance with the mandate of the 1945 Constitution, namely to prosper the lives of Indonesian people.

2. Object and Research Location
Weh Island is geographically located between 95° 13' 02" and 95° 22' 36" East Longitude, and between 05° 46' 28" and 05° 28' 54" North Latitude. Geographically, this region is the westernmost administrative region in Indonesia, and is directly adjacent to three neighboring countries, namely Malaysia, Thailand and India. The city of Sabang consists of five islands, namely Pulau Weh (121 km²), Rubiah Island (0.357 km²), Seulako Island (0.055 km²), Pulau Klah (0.186 km²), and Pulau Rondo (0.650 km²).

Weh Island is a volcanic island, a coral island where the process experiences elevation from the sea surface. The process takes place in three distinct stages from the presence of three terraces located at different heights. Weh Island consists of two types of rocks, namely tuf marina and core rock. Tuf marina is found almost along the coast to a height of 40 to 50 meters. The widest tuff layer is around the city of Sabang (RTRW of Sabang City, 2012-2032).

Small islands are defined by the Decree of the Minister of Marine Affairs and Fisheries No. 41/2000 Jo Minister of Maritime Affairs and Fisheries No. 67/2002 is an island with a size or equal to 10,000 km², a population of less than 200,000 inhabitants. The characteristics of small islands are ecologically separate from the main islands, have clear physical boundaries and are far from mainland island habitats, so they have high environmental value; cannot affect the hydrocarbon climate; has a relatively small catchment area so that most surface flows and sediments enter the sea. [4,8,9].

![Figure 1. Map of the research area, Weh-Sabang Island](image-url)
Figure 2. Comparison of changes in the spatial layout of the city of Sabang between 1900 and 2018

3. Research Methodology and Discussion

As an island, geographically Weh Sabang Island limits land and natural resources, so it is very dependent and requires a supply of raw materials and food ingredients from outside the island, especially the city of Banda Aceh. As is known that the UN-21 agenda suggests many challenges faced in planning and implementing sustainable development on an island, limited natural resources, also geographically isolated and highly dependent on other regions [1].

Sustainable development of an island can be achieved by managing consumed resources and protecting ecosystems so as to minimize pollution. The waste produced, both liquid and solid waste, includes aspects that significantly affect the ecological degradation of the island, moreover the management of waste on an island is very limited. Based on the preliminary study in this study, the quantity of solid waste, especially the public consumption of waste from Pulau Weh, Sabang. Changes in land use in a certain period can be analyzed by changes in land use and land cover (LULC). Analysis of land use change on Weh - Sabang Island was carried out using satellite imagery obtained from Google Earth, which is an independent software program that provides satellite imagery. This method also follows from what some previous researchers have done, including [2,5,6,7].

The use of AHP begins with the problem solving process into the elements where accurate results are obtained through tiered problem solving. So that the problem solving process is called hierarchy. In relationships between variables sometimes appear in the simplest form, namely linear. The linear pattern can be in the form of relationships arranged in a hierarchy with main objectives, criteria, sub-criteria and alternatives that will be discussed through this study [14].

3.1 Processing of clean water data on Weh Island - Sabang

Based on data from the Regional Water Supply Company (PDAM) of Sabang City in 2015-2018, there is an increase in the need for clean water and the number of customers on Weh-Sabang Island. Especially in urban areas and tourism, then efforts are needed to preserve the catbhattan area of the lake aneuk laot.
Table 1. Clean water data in Weh Island – Sabang, Arif, AA (2018)

| Year | Number of Drinking Water produced | Number of Customers |
|------|-----------------------------------|---------------------|
| 2015 | 1,997,414                         | 5,729               |
| 2016 | 1,404,363                         | 5,668               |
| 2017 | 1,593,597                         | 5,857               |
| 2018 | 1,726,179                         | 6,176               |

Figure 3. Comparison of the availability of clean water and PDAM customers (Arif, A.A 2018)

Table 2. The number of people who are not served by clean water in Weh Island

| Year | Amount of Water (M3) | PDAM customers | Total Resident | Ideal Amount (150 M3/people/day) | Amount not get clean water services |
|------|----------------------|----------------|----------------|-----------------------------------|-----------------------------------|
| 2015 | 1,997,414            | 5,729          | 33,739         | 13,316                            | 20,423                            |
| 2016 | 1,404,363            | 5,668          | 33,215         | 9,362                             | 23,853                            |
| 2017 | 1,593,597            | 5,857          | 33,622         | 10,623                            | 22,999                            |
| 2018 | 1,726,179            | 6,176          | 33,978         | 11,507                            | 22,471                            |

Table 3. Land Use in the City of Sabang in 2008-2015

| No. | Land Use                      | Area (Ha) | %  |
|-----|-------------------------------|-----------|----|
| 1   | Forest                        | 6,814.78  | 41.7|
| 2   | Plantation / fields / paddy fields | 5,780.28 | 37.8|
| 3   | Lakes / ponds                 | 67.54     | 0.44|
| 4   | Grasslands / open fields      | 1,300.34  | 8.5 |
| 5   | Built Area                    | 1,554.23  | 10.16|
| 6   | special areas (Harbor / Airport) | 211.92   | 1.38|
|     | Total                         | 15,290.68 | 100 |

Source: BPS Data processing of Sabang City in 2008-2018, RTRW of Sabang City 2004-2014

Table 4. Land Use in Sabang City in 2015-2018

| No. | Land use | Area (Ha)% |
|-----|----------|------------|
| 1   | Forest   | 6,072.89   | 39.7 |
The most dominant changes in land use and land cover from 2008 to 2018 is an area that has increased by around 70% in the last five years, water bodies in Lake Aneuk Laot have decreased by 33% depreciation, agricultural land has decreased by 20% and forest area has decreased by 12%. Coverage of land around the lake has decreased, it will affect the condition of the availability of raw water in the lake. Based on the results of the LUC 2008-2018 analysis, the body area of water is rapidly decreasing.

### 4. Implementation of the AHP in ArcGIS of Weh Island

#### Criteria Level 1

| Variable | The characteristics of topography land | Natural resources and environment |
|----------|----------------------------------------|----------------------------------|
| Weighted Sum criteria | 0.25 | 0.75 |
| The characteristics of topography land | 1 | 0.333333333 |
| Natural resources and environment | 3 | 1 |
## The Calculation Of The Weighted Sum

| Variable                                      | The characteristics of topography land | Natural resources and environment | Weighted Sum |
|-----------------------------------------------|----------------------------------------|----------------------------------|--------------|
| The characteristics of topography land       | 0.25                                   | 0.25                             | 0.5          |
| Natural resources and environment             | 0.75                                   | 0.75                             | 1.5          |

### Criterion Level 2

Priorities as a factor Weighted Sum

| Variable                                      | Geology | Topography | Of natural resources | Environment | Weighted Sum |
|-----------------------------------------------|---------|------------|----------------------|-------------|--------------|
| Weighted Sum criteria                         | 0.272098516 | 0.119939271 | 0.607962213          | 0.25        |
| Geology                                       | 1       | 3          | 0.333333333          | 3           |
| Topography                                    | 0.333333333 | 1          | 0.25                | 3           |
| Of natural resources                          | 3       | 4          | 1                    | 2           |
| Environment                                   | 0.333333333 | 0.25       | 1                    | 1           |

## The Calculation Of The Weighted Sum

| Variable                                      | Geology | Topography | Of Natural Resources | Environment | Weighted Sum |
|-----------------------------------------------|---------|------------|----------------------|-------------|--------------|
| Geology                                       | 0.272098516 | 0.359817814 | 0.202654071          | 0.25        | 0.8345704    |
| Topography                                    | 0.090699505 | 0.119939271 | 0.151990553          | 0.333333333 | 0.362629329  |
| Of natural resources                          | 0.816295547 | 0.479757085 | 0.607962213          | 0.5         | 1.904014845  |
| Environment                                   | 0.75     | 0.75       | 0.25                 | 0.75        | 2.5          |

\[ \text{Lamdamax} = 3.074133934 \]
\[ \text{CI} = 0.037066967 \]
\[ \text{CR} = 0.063908564 \]

Value < CR 0.1 so this data is good to use (lamdamax = Value of Weighted Sum = criteria, eigen vectors eigen)

\[ \text{CR} = \frac{\text{CI}}{\text{RI}} \text{ RI (Satty and Vargas, 1991),[14] Satty, 2003.} \]

| n    | 2   | 3   | 4   | 5   | 6   | 7   | 8   |
|------|-----|-----|-----|-----|-----|-----|-----|
| RI   | 0.00| 0.52| 0.90| 1.12| 1.24| 1.32| 1.41|
5. ArcGIS simulation of Weh Island

![ArcGIS simulation of Weh Island](image)

**Figure 6. Art simulation of Weh island**

6. Conclusion

Research that will be carried out is expected to get an overview of development management on Weh Island which contributes to protecting the environment of the island ecosystem itself and preserving the environment that is inherited to future generations. As mandated in Environmental Law No. 32 of 2009 in which one of the instruments to protect the environment was a spatial plan. What has been stated in the RTRW (Urban Land use Plan) product is the result of research to be able to become a concept of land use and consider the carrying capacity of the environment in the small island region.

The essence of environmental carrying capacity is the comparison between supply and demand. Supply is usually limited, while demand is unlimited. The concept of environmental carrying capacity is usually developed based on many sectors. The population pressure towards the environment, considered the factors of physical land and water resources carrying capacity.

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