IOP Conf. Series: Earth and Environmental Science **216** (2018) 012010 doi:10.1088/1755-1315/216/1/012010

Coastline alteration rate of Weh Island, Aceh Province, Indonesia

R Dhiauddin[1] and **W A Gemilang**[2]
[1,2]Research Institute for Coastal Resources and Vulnerability, Ministry of Marine Affairs and Fisheries, West Sumatera (25245), Indonesia
E-mail: ruzanadhiauddin@yahoo.com

Abstract. Weh Island, Aceh Province, located in the Western-most of Indonesia, is one of the most popular tourism destinations among domestic and international tourists. The tourism sectors in this island might be endangered by nature dynamics that continuously changes to remain balance, either of the noticeable changes is the coastline shape and position alteration. This manuscript aims to examine Weh Island coastline alteration by mapping it through the satellite imageries of Landsat-7 ETM+ of year 2002 and 2009, and Landsat-8 OLI TIRS of year 2015 then calculate the rate by employing DSAS (Digital Shoreline Analysis System) 4.3. The used statistical method, called EPR (End Point Rate), showed that the coastline alteration rate in the area were classified into 5 categories; 1) stable, 2) accretion, 3) low erosion, 4) moderate erosion, and 5) high erosion. In general, Weh Island were encountered erosion for period 2002 – 2009 and accretion for period 2009 – 2015, which distributed over the island. Moreover, the alteration was found around the tourism sites such as Gapang, Iboih and Jaboi coastal area, also Sabang and Balohan port area.

1. Introduction

Weh Island is the biggest and the only reside in area of 12.066,56 ha among another small islands, Klah, Rubiah, Seulako dan Rondo, which geographically part of Sabang City that directly adjacent with Malaka Strait, Benggala Strait and Indian Ocean. Its position is very strategic as the international voyage entrance from the west part of Indonesia, since it is neighbouring with Malaysia, India and Thailand [1]. In 2014, Sabang government utilized about 37% of the total area to be the tourism sites that significantly developed and gave great contribution to the regional income which in 2013 there were ±4,622 international and ±400,000 domestic tourists [2].

As it was struck by the shocking tsunami in the early morning on 24th December 2004 which affected the coastal ecosystem such as coral reefs damages [3], [4], coastal vegetation and coastline alteration in Iboih Beach, Sabang Fair Beach, and Jaboi Beach with sand to sandy silt material size [2]. Other upshots of tsunami in this area were the buildings decay, casualties, prosperity losses, and left the long-term trauma particularly to the children.

By the fact that the tsunami outcomes found in the Weh Island coastal area, the tourism sites especially the marine related tourism (underwater, white sandy beaches, and 0 kilometres monument) are very popular, and that it is becoming the main target of the Sabang government development plans, we decide to examine the coastline alteration as the preliminary study of the coastal vulnerability.

2. Materials and Methods

The study started by collecting 3 satellite imageries acquired from different times; Landsat 7 ETM+ of year 2002 and 2009, and Landsat 8 OLI TIRS of year 2015. The images were chosen by its clearness, free of clouds and strips. Each image was displayed as composite band of 432 to ease the coastline digitation process, which result in 2 period coastline alteration, 2002 and 2009 (7 years different) and 2009 and 2015 (6 years different). The coastlines of every period were overlaid together to provide the brief depiction of the alteration occurrence locations. The numerical calculation was completed through DSAS (Digital Shoreline Analysis System), the free application that works as the extension within the ArcGIS software ([5]).

DSAS was applied in many research sites such as in Puerto Rico ([6]), Nam Dinh coastal area-Vietnam ([7]), Ramsar wetland-Turkey ([8]), coastal area between Kanyakumari and Tuticorin-India ([9]), Wotje Atoll-Marshal Island, Pacific Ocean ([10]), South-West coast of Kanyakumari-Tamil Nadu ([11]), West Pasaman-West Sumatra, Indonesia ([12]), Simeulue Island-Indonesia ([13]), and Shabla Municipality-Northeast Bulgaria ([14]).

There are two main inputs in the DSAS system, coastline (at least from two different times) and baseline, which both may manually digitized or automatically generated. Baseline is used by DSAS as the base where the transect lines, consist of distances between the baseline to each of coastline, are created by command. The transect itself is the adjustable component that divides the coastline into segments, where the length and spacing may be set suit to the user needs. It must be noted that transect should pass all the employed coastlines to produce the accurate computation (Figure 1).

In this study, we employed DSAS 4.3 under ArcGIS 10.0 to calculate the alteration rate of Weh Island's coastline. The baseline was digitized on the offshore part, transects lines were set 1000 meters (for both spacing and length) and casted landward (Figure 2), and EPR (End Point Rate) was chosen as the statistical method defines by the following formula:

$$\text{EPR} = \frac{distance\ in\ meters}{time\ between\ oldest\ and\ most\ recent\ shoreline} \qquad (1)$$

3. Result and Discussion

The calculation showed there were many places in the study area happened to be shifted, in landward or seaward direction. The shifted areas were revealed during the calculation session that came up with area difference between two times. The EPR for all coastline segments was also calculated automatically by DSAS. The results were either in positive or negative sign which indicates accretion, stable or erosion. Moreover, to understand the level of each events, the coastline alteration rate classification proposed by [15] was used.

1. ≥ +2.1 m/y: accretion
2. 1.0 – 2.0 m/y: stable
3. -1.0 – +1.0 m/y: low erosion
4. -1.1 – -2.0 m/y: moderate erosion
5. ≤-2.1 m/y: severe erosion

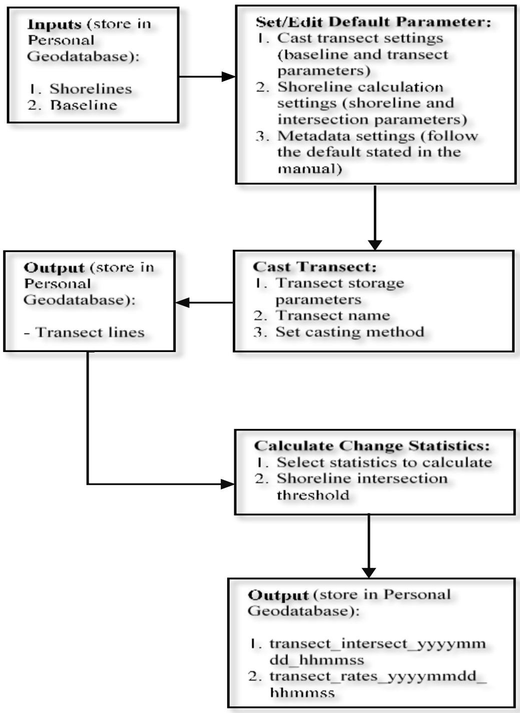

Figure 1. Coastline alteration rate calculation (after [5])

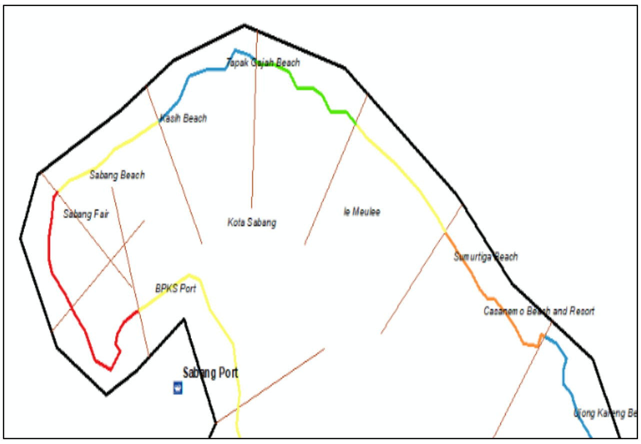

Figure 2. Offshore baseline (black line) and landward transect lines (brown).

3.1. Coastline alteration rate of 2002 – 2009

By stacking the two coastlines, there were noticeable contrasts of coastal area around Iboih, Marina, Gapang and Jaboi Beach. The satellite images showed that the coastline experienced significant retreat (Figure 3), that might be caused by tsunami 2004 and other factors during the period.

The alteration ranged between -495m (around Iboih to Gapang) to 201m (around Krueng Raya Port). In general, the negative sign always indicates erosion, which was formed as coastal vegetation decays in Iboih and Gapang Beaches. Meanwhile, the positive directs to the accretion event that in Krueng Raya Port a new construction was established.

EPR shows the coastline alteration rate during 2002 to 2009. With 1000m transect spacing, there were 81 coastline segments that were classified into 5 classes; accretion (2.26 – 28.72 m/y), stable (1.04 – 1.89 m/y), low erosion (0.93 – -0.98 m/y), moderate erosion (-1.17 – -1.96 m/y) and severe erosion (-2.18 – -70.82 m/y). The most common occurrence for this period was severe erosion that were experienced by 35 transect lines with the mean rate of -11.80 m/y. This class was distributed along 39.37 km from Sabang Fair Beach, Bateedua Beach, Jaboi Beach, Gua Sarang Beach, Iboih, Gapang and beaches around Sabang Bay. In contrast, it was only 9.14 Km of 89.46 Km experiencing moderate erosion. The rest of 10.91 Km, 12.74 Km, and 17.27 Km were respectively stable, accreted and moderately eroded as shown by Figure 4.

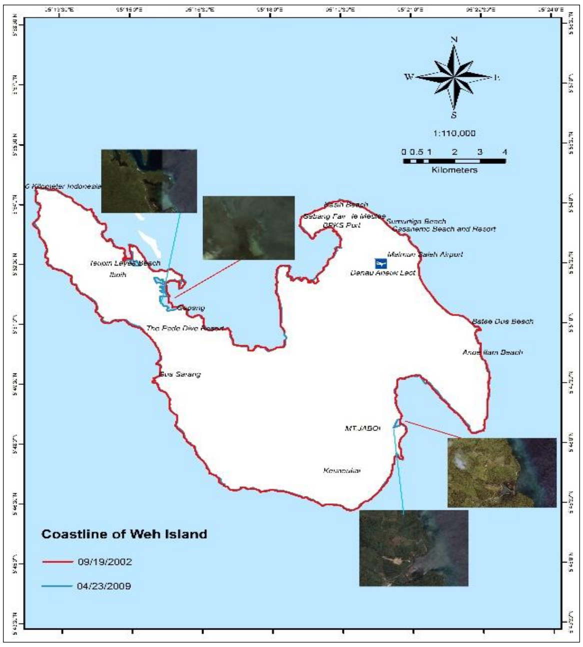

Figure 3. Comparison between two coastlines.

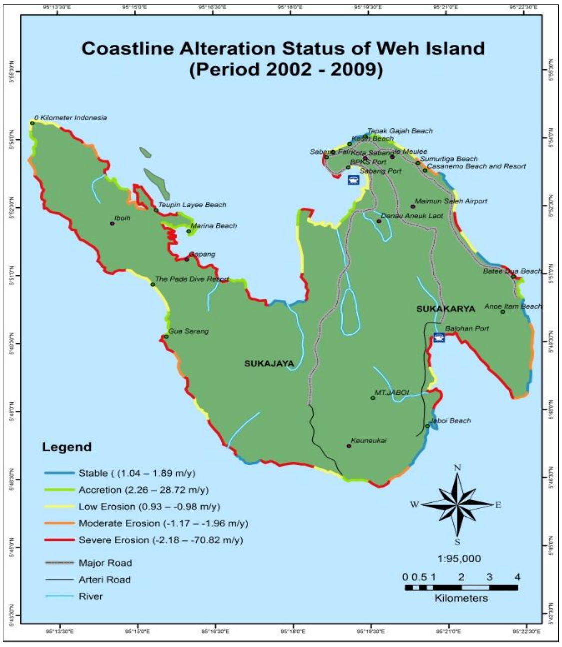

Figure 4. Coastal alteration rate of year 2002 to 2009.

3.2. Coastline alteration rate of 2009 – 2015

At a glance, the significant changes found near the Sabang Port, and around Gapang Beach coastal area (Figure 5). Based on the coastline distance between 2009 and 2015, it is known that most of the coastline were moving seaward for 1.38 Km, while the rest 763 m were landward.

The coastline alteration rate was ranged between -7.03 – 26.85 m/y that according to the classification by Aboudha and Woodroffe (2006) can be classified into the 5 classes; accretion (2.22 – 26.85 m/y), stable (1.07 – 1.89 m/y), low erosion (0.87 – -0.96 m/y), moderate erosion (-1.16 – -1.97 m/y) and severe erosion (-2.11 – -7.03 m/y).

Around 27.40 Km out of 89.46 Km Weh Island were accreted, commonly found from the north part at Gua Sarang Beach, to the west part around Sabang Port. Based on the investigation through the satellite images, there was a new man-made structure where the biggest accretion occurred as showed by Figure 6.

The 25.97 Km severe erosion evenly distributed all over the island included the most visited area like Sabang Fair, Iboih Beach, and The Pade Dive Resort. This event followed by 13.4 Km moderate erosion found around the activity center such as Sabang Port, Maimun Saleh Airport, and Balohan Port. Moreover, the tourist favourite places (Cassanemo, Sumurtiga dan 0 Kilometres Monument) were counted in 13.1 Km of low erosion, while the rest of 9.89 Km coastline were classified as stable (Figure 7).

The coastline alteration rate for all periods displayed in Table 1 were clearly summarized each result. In general, the mean rate for all events was slightly similar for both periods, except the severe erosion decreased from -11.80 m/y (2002 – 2009) to -4.05 m/y (2009 – 2015).

As the transect lines were placed exactly in the same position for both periods made the events fluctuation can be easily compared. Figure 8 illustrates where the significant dissimilarity occurred, which obviously happened for the Transect Id 1, 27, 62, 67, 68, 69 and 80, located around Sabang Port, Jaboi, Iboih, Marina, and Gapang Beach.

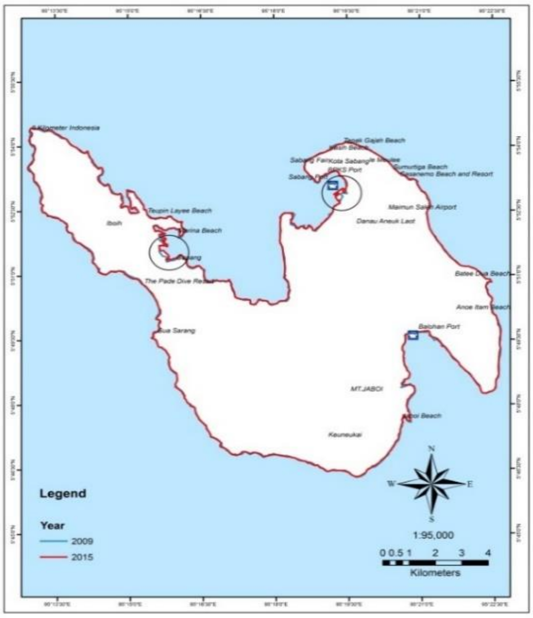

Figure 5. Coastline difference of year 2009 and 2015.

Figure 6. Man-made structure appears in the image of 2015.

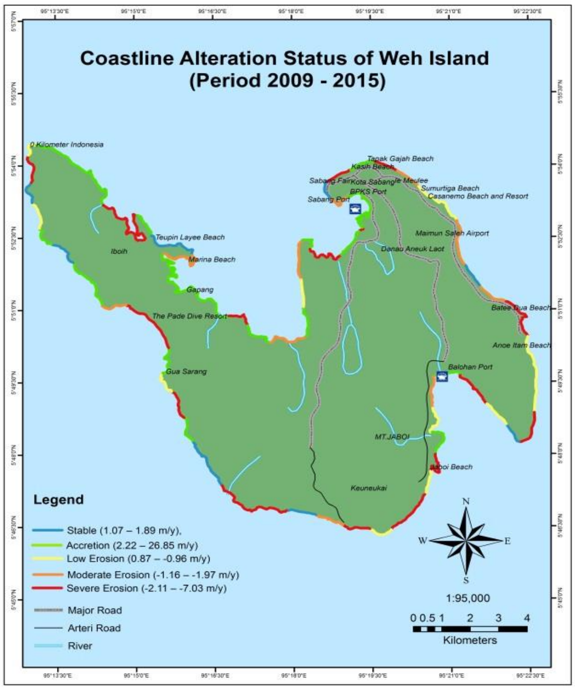

Figure 7. Coastline alteration rate of year 2009 to 2015.

Table 1. Coastal alteration rate using EPR derived from three available shorelines.

Period (Year)	Accretion Rate (m/y)		Stable Rate (m/y)		Low Erosion Rate (m/y)		Moderate Erosion Rate (m/y)		Severe Erosion Rate (m/y)	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
2002 - 2009	4.08	7.92	1.52	1.89	-0.19	-0.99	-1.53	-1.96	-11.80	-70.83
2009 - 2015	8.34	26.85	1.52	1.89	-0.14	-0.96	-1.52	-1.97	-4.05	-7.03

IOP Conf. Series: Earth and Environmental Science **216** (2018) 012010 doi:10.1088/1755-1315/216/1/012010

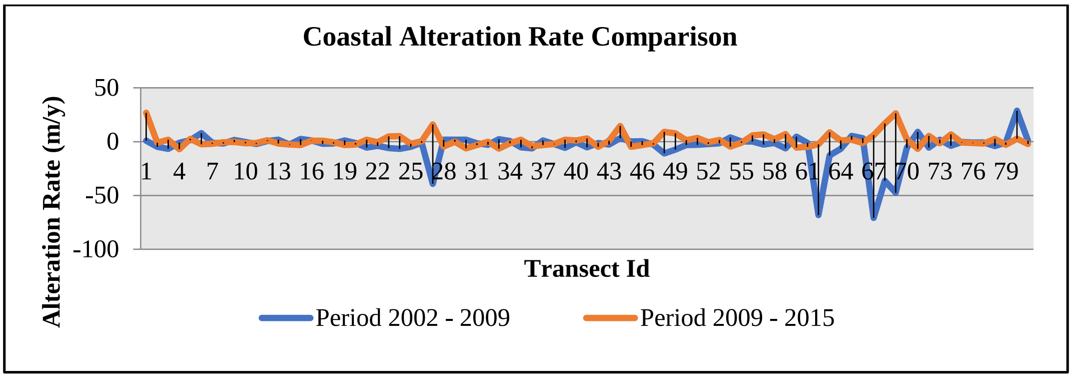

Figure 8. Alteration fluctuation between two periods.

4. Conclusion

Each period experienced different rate of coastal alteration, which severe erosion has the biggest value (-70.83 m/y) of all events in the period 2002 – 2009 and accretion of 26.85 m/y in the period 2009 – 2015. This phenomenon assumed to be related with tsunami event, which happened in between the first period that certain places noticed to have high erosion rate. On the other hand, in the second period Weh Island experienced accretions in many popular tourism areas, such as Sabang and Balohan Port, Jaboi Beach, Gua Sarang, 0 Kilometres Monument, Iboih and Gapang Beach. This preliminary result is one of the important aspects to assess the coastal vulnerability in the study area.

It is necessary to perform further study to understand the exact causes of coastal alteration by analysing related factors; wave, tide, current, wind, geomorphology, etc.

5. Acknowledgements

This present study was undertaken during the research supervised by Mrs. Nia Naelul Hasanah Ridwan and funded by the Institute for Coastal Resources and Vulnerability under Ministry of Marine Affairs and Fisheries.

References

[1] Sabang Government 2018 http://www.sabangkota.go.id/index.php/page/4/geografis
[2] Sabang Government 2014 283p
[3] Umam A H, Maryanto S D, Frediansyah A, Shalihatunnisa M, Izzati R, Hulwani Y R, and Handayani M T 2011 *Annual International Workshop & Expo on Sumatra Tsunami Disaster & Recovery 2011* **6** 6p
[4] Stoddart D R (Ed.) 2007 *Atoll Research Bulletin* **544** 37–54
[5] Thieler E R, Himmelstoss E A, Zichichi J L and Ergul A 2011 *US Geological Survey Open File Report* 1–79
[6] Thieler E R and Danforth W W 1994 *Journal of Coastal Research* **1** 600-620
[7] Van T D and Thao P T P 2008 *International Journal of Geoinformatics* **4(1)** 37-42
[8] Kuleli T, Guneroglu A, Karsli, F and Dihkan M 2011 *Ocean Engineering* **38(10)** 1141-1149
[9] Sheik M 2011 *Geo-spatial information Science* **14(4)** 282-293
[10] Ford M 2013 Remote Sensing of Environment 135 130–140
[11] Kaliraj S, Chandrasekar N and Magesh N S 2014 *Environmental Earth Sciences* **71(10)** 4523–4542
[12] Dhiauddin R and Husrin S 2016 Jurnal Segara 12(2) 91–98
[13] Dhiauddin R, Gemilang W A, Wisha U J, Rahmawan G A and Kusumah G 2017 EnviroScienteae 13(2) 157–170
[14] Stanchev H, Stancheva M, Young R and Palazov A 2018 Ocean & Coastal Management 156 127–140
[15] Aboudha P A and Woodroffe C D 2007 *CoastGIS 2006* 458p