

COASTAL VULNERABILITY ASSESMENT OF TOURISM AREA AND MANAGEMENT STRATEGY FOR SUSTAINABLE ENVIRONMENTAL RESILIENCE: CASE OF MANDEH COAST, WEST SUMATERA

(Kerentanan Pesisir Kawasan Wisata Mandeh, Sumatera Barat dan Upaya Pengelolaan Ketahanan Lingkungan yang Berkelanjutan: Studi Kasus Pulau Mandeh, Sumatera Barat)

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ABSTRACT

Mandeh area located in Pesisir Selatan Regency is a beautiful coastal bay that is why the local governments focus on its tourism development. However, this coastal bay region is potentially affected by the disaster, thus sustainable coastal management is essential to be applied. To assess the vulnerability of Mandeh Bay, CVI method and the Smartline mapping approach are utilized by applying several physical parameters. The aforementioned parameters encompassed beach materials, wave exposure, hinterland formation, berm features, beach-face features, coastline changes, and land-use patterns. The results show that several regions within Mandeh Bay categorized into very low vulnerability 10%, low vulnerability 27%, moderate vulnerability 18%, high vulnerability 31%, and very high vulnerability 14%, respectively. Most of the northern coastal areas of the XI Koto Tarusan Sub-District predominated by the high vulnerability. Therefore, the development of coastal building in the forms of hard and soft structures, as well as the establishment of regional regulation regarding coastal zone utilization to prevent further environmental degradations and coastal hazards are necessary as a part of coastal management of this study area.

Abstract: *Vulnerability, coastal, Mandeh, environmental, tourism*

ABSTRAK

Kawasan Mandeh yang berada di Kabupaten Pesisir Selatan merupakan kawasan teluk yang sangat menawan, sehingga pemerintah lokal fokus pada pengembangan pariwisata. Namun, kawasan Mandeh mempunyai potensi terdampak bencana alam, sehingga manajemen pantai yang berkelanjutan sangat penting untuk diterapkan salah satunya dengan melakukan penilaian tingkat kerentanan. Penilaian tingkat kerentanan di Kawasan Mandeh memanfaatkan metode CVI dan *Smartline mapping approach* dengan mempertimbangkan beberapa parameter fisik yakni material pantai, paparan gelombang, bentuk daratan, fitur *berm*, fitur *beachface*, perubahan garis pantai, dan pola tata guna lahan. Hasil penilaian menunjukkan bahwa beberapa area di dalam teluk sebanyak 10% tergolong kerentanan sangat rendah, 27% kerentanan rendah, 18% kerentanan sedang, 31% kerentanan tinggi, dan 14% kerentanan sangat tinggi yang mana sebagian besar kawasan Pantai Utara Kecamatan XI Koto Tarusan didominasi oleh kerentanan tinggi. Oleh karena itu, pembangunan pelindung pantai baik secara struktur alami maupun buatan serta pembuatan regulasi regional terkait dengan pemanfaatan kawasan pesisir untuk mencegah terjadinya degradasi lingkungan dan bahaya pesisir dibutuhkan sebagai bagian dari manajemen pesisir pada area studi.

Kata kunci: Kerentanan, pesisir, Mandeh, lingkungan, pariwisata

INTRODUCTION

During several last decades, disasters such as tsunami and cyclones threaten tourism areas. At the same time, marine tourism around the world grows globally reaching one billion international visits in 2011 (Becken et al., 2014). One of the impacts of coastal hazards (such as abrasion, tidal flood) and mass-tourism is environmental degradation as a result of natural and anthropogenic influences, inducing highly vulnerable area (Alexandrakis et al., 2015). Moreover, the threats of disaster in the coastal area are undoubtedly avoided that may cause human

casualties (Becken et al., 2014). Significant relation among remote areas, surrounding neighborhood, tourism interest, and land management agencies creates a complex combination of coastal management interests that are supporting each other (Espiner & Becken, 2014).

A coherence framework systematically analyzing the vulnerable factors of the tourism area is necessary to be conducted. The first point of that framework is creating a tourism destination as a human environment system in which social, economic, and environmental factors interact (Becken & Hughey, 2013).

During several last years, the vulnerability concept was studied and applied to different spatial scales and many disciplines such as the economy and social welfare study (Abson et al., 2012). The way to determine the clearer vulnerability is to determine vulnerability as a function of three-element interactions, namely exposure, sensitivity, and adaptive capacity (Marshall et al., 2009; Bennett et al., 2015). In this age, while the sustainability of coastal ecosystems depends on the local government and the impacts of exogeny hazards in the form of global warming and sea-level rise (Berry et al., 2014).

In the coastal area, the economic aspect depends on tourism activities. Coastal resorts, for example, can be considered as the dynamic natural resources (Phillips & Jones, 2006). Therefore, to develop the tourism industry in the coastal area is very important, since it can automatically generate and increase the social livelihood and income of local communities (Semeoshenkova & Newton, 2015). One of the examples of successful tourism developments in West Sumatera is Mandeh Bay (Mukhtar et al., 2017).

Mandeh area is well-known as “the paradise in the south”, which consists of several small islands such as Cubadak, Pagang, Sironjong, Setan, Marai, Pasumpahan, Pamutusan, Suwarnadwipa, Sikulo Bay, etc. (Ridwan, 2013). The development of the Mandeh area had been initiated since 2012, however, the tourism area regulation to restrain coastal exploitation has not established yet (Fuadi & Yoswaty, 2016).

Nowadays, coastal degradation has been occurring resulted from overdevelopment in the tourism aspect in the Mandeh region. The Mangrove forest is clear-cut to build a resort and tourism objects (DPR, 2017). The building of the connecting road between Mandeh and Padang City results in surrounding degradation that discarded sands pollute the coral ecosystem. The development that has been occurring plays a significant role in changing land-use and evoking vulnerability in the coastal Bay of Mandeh.

Coastal zone management is essential to be applied to reduce coastal vulnerability from hazards and disasters (Phillips & Jones, 2006). The management must be directed to reach optimal physical development but still consider the susceptible area and socio-cultural aspect (Zacarias et al., 2011). Efforts to manage and to anticipate the influence of coastal hazards on marine tourism are necessary. This study aimed to determine the vulnerability level of Mandeh coastal bay according to physical parameters that potentially threaten to coastal degradation.

METHOD

Study area located in Koto XI Tarusan Sub-District, Pesisir Selatan Regency that situated at 100° 20' 0" – 100° 26' 40" E dan 1° 8' 20" – 1° 16'

40" S (Figure 1). Mostly, this Sub-District consists of the forest areas where the rain intensity is relatively high reached 4,255 mm/year. The study area is bordered by several small islands that become the center of marine tourism in Mandeh (BPS, 2018).



Figure 1. The study area in the XI Koto Tarusan Sub-District, Pesisir Selatan Regency.

This study employs the Smartline method to describe coastal vulnerability (Sharples et al., 2009) by considering parameters that needed to observe through four steps: 1. indicative mapping (to identify geological coastal areas as a fundamental factor); 2. regional assessments (to map geomorphic integration of beaches and vulnerability variables such as climate, sea waves, tidal range, and vertical tectonic movements); 3. site-specific assessment (to identify geological, geomorphic, topographic, oceanographic and climate elements affecting coastal systems); and 4. social vulnerability and risk assessment (to map socio-economic elements) see **Table 1**.

Table 1 shows some parameters needed to collect through the four steps of observation to reveal the vulnerability of the coast. During data collection, some modification applied to those parameters, obtained from field survey (in situ) through direct observation such as beach materials, wave exposure, hinterland formation, berm feature, beachface, and land use pattern, while, coastline changes caused by erosion and accretion were identified through Google Earth Image digitation by comparing two images with different periods from 2007 to 2015 (14 years).

Figure 2 displays a cross-section of the coastal profile with various terms used in this study. The measured parameters in **Table 1** are carried out both perpendicularly and parallel to the coastline. From analyzed parameters, we interpreted the values obtained by using a scoring method to produce the coastal vulnerability criteria. The procedure of vulnerability mapping using the Smartline method is a representation of a simple line without any calculation of vulnerability level. That is why in this study, we employed the CVI (Coastal Vulnerability Index) approach to assess the level of vulnerability as shown by **Formula 1** (Gornitz et al., 1992):

$$CVI = \sqrt{\frac{x_1 * x_2 * x_3 * x_4 * \dots * x_n}{n}} \dots \dots \dots (1)$$

Where x is the score of the parameter used and n is the total value of the parameter used.

CVI can be calculated after the thirteen parameters are scored by applying interval value from 1 to 5. Score 1 is representing the very low

category and score 5 is representing the very high category.

RESULT AND DISCUSSION

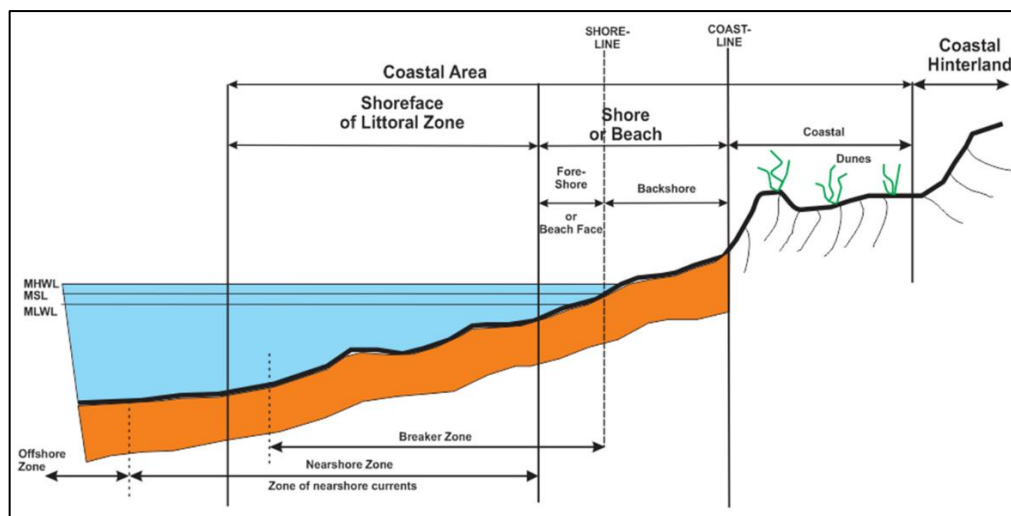
Indicative Mapping

Beach Materials

Pesisir Selatan Regency geologically is formed by 2 rock formations namely volcanic rock Oligo-Miosen (Tomp) and youngest formation of Alluvium (Qa). Volcanic rock Oligo-Miosen consists of several sediment rocks, lava, breccia, tuff breccia, crystal tuff, ignimbrite, and lithic tuff, which generally is formed by andesitic and dacitic. Meanwhile, alluvium formation (Qa) consists of clay, sand, and gravel (Rosidi et al., 1996). The beach materials are related to host rock located inland so that the sediment deposit in the coastal area is not different from its provenance. We identified two constituent materials namely the rocky beach (8%) and sandy beach (92%) (**Figure 3**).

Table 1. Parameters.

Steps	Parameters that needed to observe	Data source
<i>Indicative Mapping</i>	Beach materials, Wave exposure, and hinterland formation	Field measurement
<i>Regional Assessment</i>	Berm feature	Field measurement
<i>Site-specific Assessment</i>	Beach face feature and shoreline changes	Field measurement and google earth image digitation (Terrametrics Image) with a spatial resolution of 14.53 meters and resolution 7,200 pixels per degree/0.5 arcsecond per pixel
<i>Social-economic Assessment</i>	Land use pattern	Field measurement



Source: Short & Woodroffe (2009) modified by authors

Figure 2. Coastal cross-section profile.

Mandeh Bay is a transitional deposition area resulted from river-ocean interactions in the form of the delta. This will influence the distribution pattern of sediment grain size which reflects fluidity factor and deposition energy (Ruzamuri & Hidayat, 2016). So that the Mandeh coastal bay is dominated by sand-clay sediments. Beach constituent materials for the rocky beach has a low level of vulnerability (score 1), while for sand materials are categorized into high vulnerability (score 5) (Lins-de-Barros & Muehe, 2013). Based on its beach materials, Mandeh area is categorized into a high vulnerability coastal area.

Ocean Wave Exposure

The assessment of this parameter divided into 5 categories, fully exposed, semi-exposed, exposed, sheltered, and no data, respectively (Figure 4). The highest vulnerability level belongs to the full exposure category (score 5) and the lowest one belongs to the sheltered category (score 1) (Gornitz, White & Daniels, 1992). Of 51 observation points, we calculated the percentage of the wave-exposed area which is 2% on the sheltered, 6% on the semi-exposed, 14% on the exposed, and 78% on the fully exposed category. Groin as coastal protection has been built in Mandeh which serves to protect the coastal area from wave exposure.

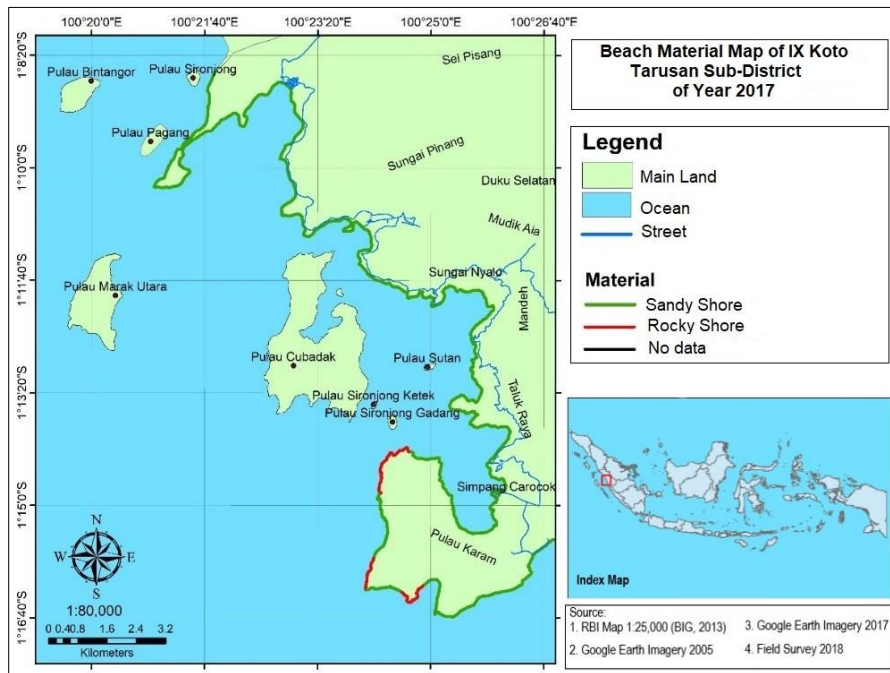


Figure 3. Beaches material types on Mandeh coastal.

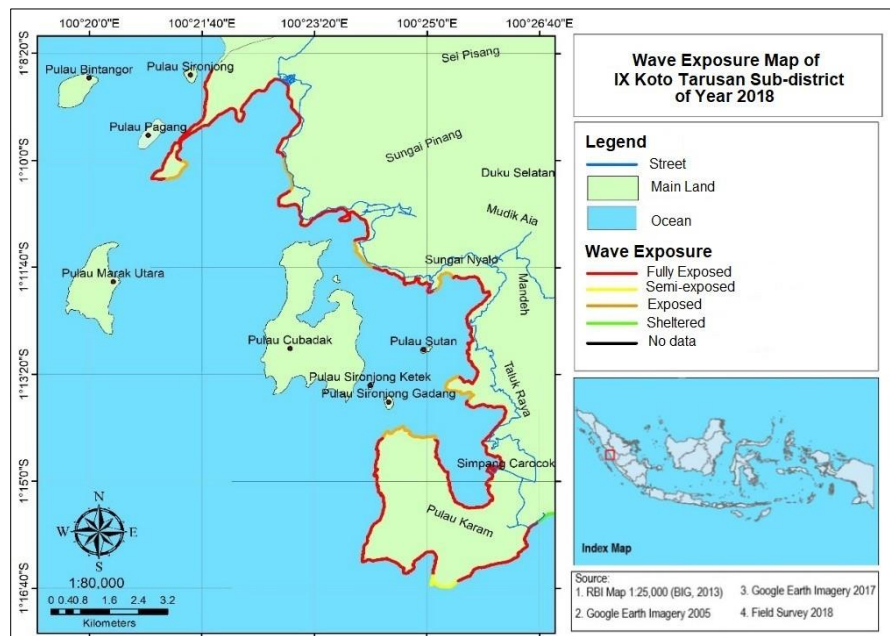


Figure 4. Wave exposure on the Mandeh coastal bay.

Hinterland Formation

Geology and geomorphology are the main factors in tourism because a certain tourist attraction can be developed by utilizing geology and geomorphology certain formations (Irawan & Mulyadi, 2014). Pesisir Selatan Regency surface conditions mostly covered by forest area consist of 70.54% dense forest, 13.37% bushes, 6.07% rice field, 2.30% plantation area, and the rest are villages, mixed gardens and other community gardens (BPS, 2018). Based on the hinterland formation, Koto XI Tarusan Sub-District coastal area is arranged by 94% hills and 6% settlement. Geologically, the study area is included in Semangko fault that is lengthwise from north to south. The area with steep hill and swamp along the coastline are dominating this area (KLH, 2010). Therefore the hinterland formations in Pesisir Selatan are mostly hilly hinterland which is influenced by the geological factor of Sumatera.

Regional Assessment

Berm Features

Berm morphology is responsible for covering the lagoon in the coastal area, formed through sedimentary processes in the land due to wave propagation, resulting in the seaward vertical and horizontal beach face formation (Carling et al., 2018). Berm features of Koto Xi Tarusan Sub-District are divided into 3 categories including 24% for the forest, 72% vegetation area, and 4% for an urban area (**Figure 6**). Berm feature in the study area is predominated by vegetation areas and settlement (only 4%) including the centre of fisheries activity and tourism as well. Several berms used as the settlement area are not well-propagated in the Mandeh coast which is centered in the Carocok Harbor well-known as the area of fishing activities. Berm morphology that changes to be a settlement area has a high vulnerability level (Jadidi et al., 2013). Meanwhile, overall berm conditions in Mandeh coastal bay are categorized into low vulnerability because it is dominated by forest and vegetation area features.

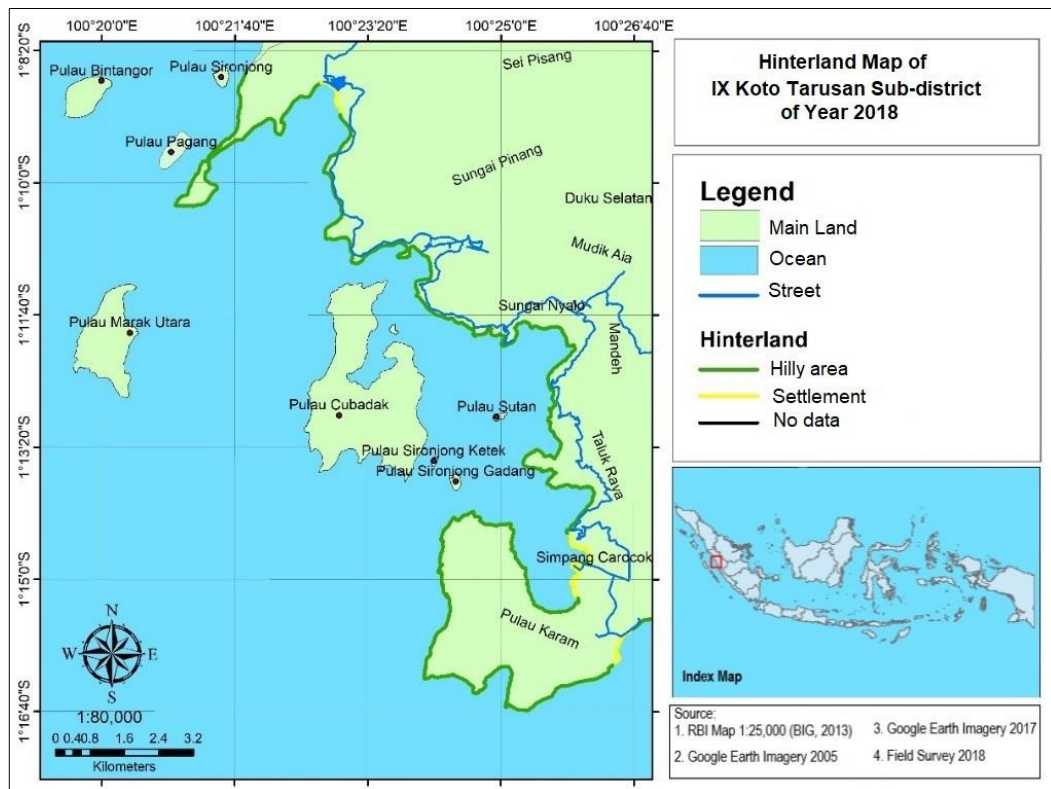


Figure 5. Hinterland formation map of Mandeh coastal bay.

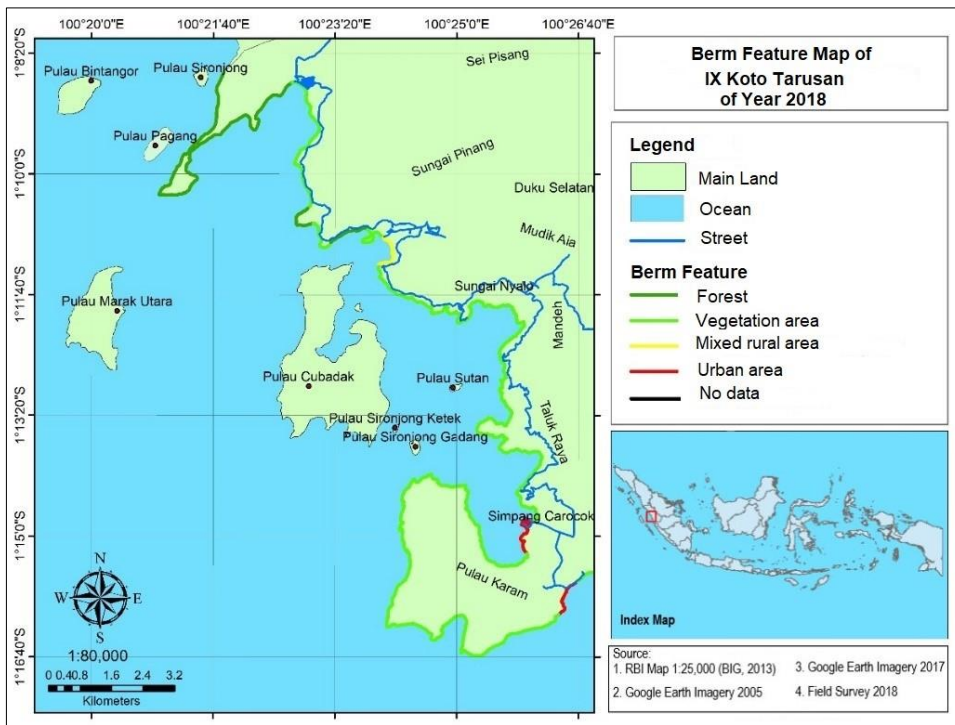


Figure 6. Berm features on Mandeh coastal bay.

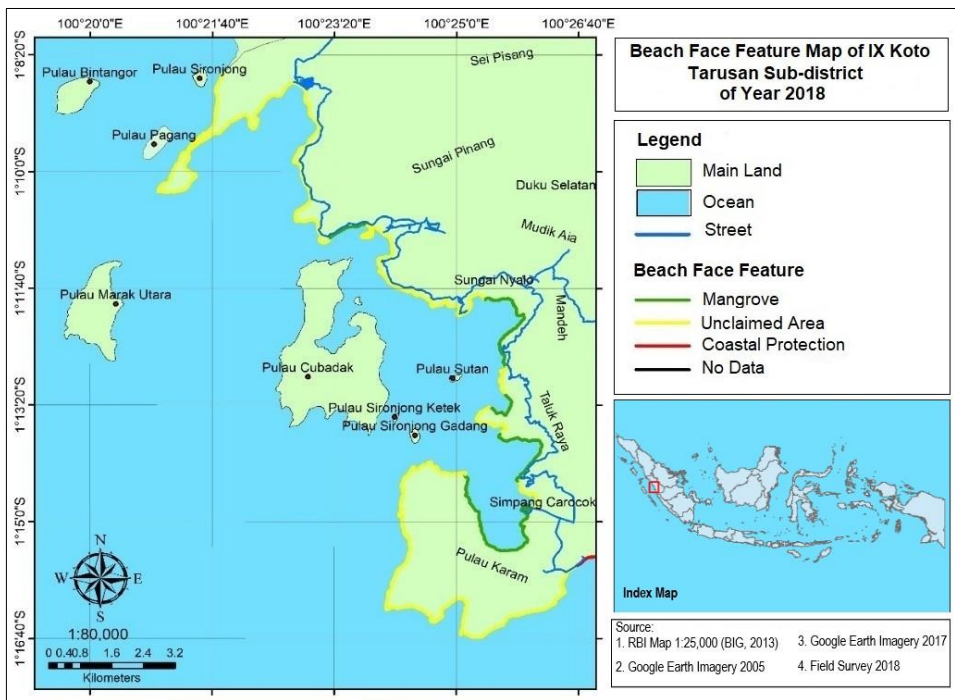


Figure 7. Beach-face feature on Mandeh coastal bay.

Site-Specific Assessment

Beachface features

Beachface features in Koto XI Tarusan consists of 4% coastal protections, 22% green belt (mangrove), and 75% vacant space (Figure 7). Beachface is a part of the coastal area that existed beneath berm morphology with a steep slope. This feature is still influenced by wave swash that has a role in sediment transport (Reis & Gama, 2010). Beachface feature in Mandeh has been changed from its first formation. The dynamic of the coastal

area and unreliable coastal protection affect the changes of beach-face in Mandeh coastal bay.

Shoreline changes, Erosion, and Accretion

Shoreline changes in Koto XI Tarusan Sub-District between 2005 – 2017 described as followed: 22% area run into accretion resulted from the sedimentary process, while 26% of the coastal area remained stable, 27% suffered low erosion, 6% experienced moderate erosion, and the last 2% represented as the area with high erosion (Figure 8).

Shoreline change is one of the parameters that are difficult to determine because the erosion or abrasion happens periodically, furthermore, it only can be interpreted by using a temporal satellite data (Abuodha & Woodroffe, 2010). Comparison between two different images is possible to predict the shoreline change which the shoreline data can be changed as the scales, spaces, and times.

Social-Economic Assessment

Land-Use Pattern

Koto XI Tarusan Sub-District is vastly predominated by forest area reached 185.87 km² (43.67%). The 9,497 Ha area of agriculture (22.31% from the total area) consists of rice-field (1,863 Ha), moor area (4,102 Ha), unclaimed (55 Ha), pasture (30 ha), and 3,447 Ha of plantation area (BPS, 2018). Based on the collected land-use data, it is known that 84% area is unclaimed, 10% of it is the settlement area, and the rest is the industrial area (6%). The assessment of land-use pattern is not only analyzing the berm morphology but also determining the utilization of coastal areas widely and perpendicularly coastline-ward. Only 10% of the Mandeh coastal area utilizes as a settlement area, fisheries activity, and tourism. The vulnerability level based on land-use data is determined using groundwater pollution indicators in the coastal area.

Anthropogenic activities such as agriculture, industry, as well as settlements pollute the

groundwater sources. Agriculture is the main factor of groundwater utilization where if it is developed in the coastal area, the land will be burdened, and tidal flood takes place. Those conditions are caused by groundwater over-exploitation which eventually pushes the sediment budget intake and seawater intrusion (Bonaldo et al., 2018). The study area is mostly utilized as marine tourism and settlement area, significantly resulting in over-explored groundwater. Nowadays, the undeniable development of the Mandeh Coastal area causes forest utilization change which potentially might disrupt the availability of groundwater.

The area of highly eroded must be highlighted that located in the Sungai Nyalo coast. This area becomes tremendously prone caused by the high water mass movement in the narrowed area between Sungai Nyalo Region and Cubadak Island. Mandeh Bay is slightly related to the Indian Ocean wind trades and current circulation because of its semi-enclosed water area characteristic. Thus, it is predominantly influenced by the local tidal current that the longshore current regime takes place in the semi-enclosed water area (Bayhaqi et al., 2018; Wisha et al., 2018). The erosion emergence is also induced by the erratic sediment transportation which is more deposited within Mandeh Bay. Consequently, the other areas will be eroded, induced by both extreme current speed and unstable sedimentation (Hidayat & Rozamuri, 2016).

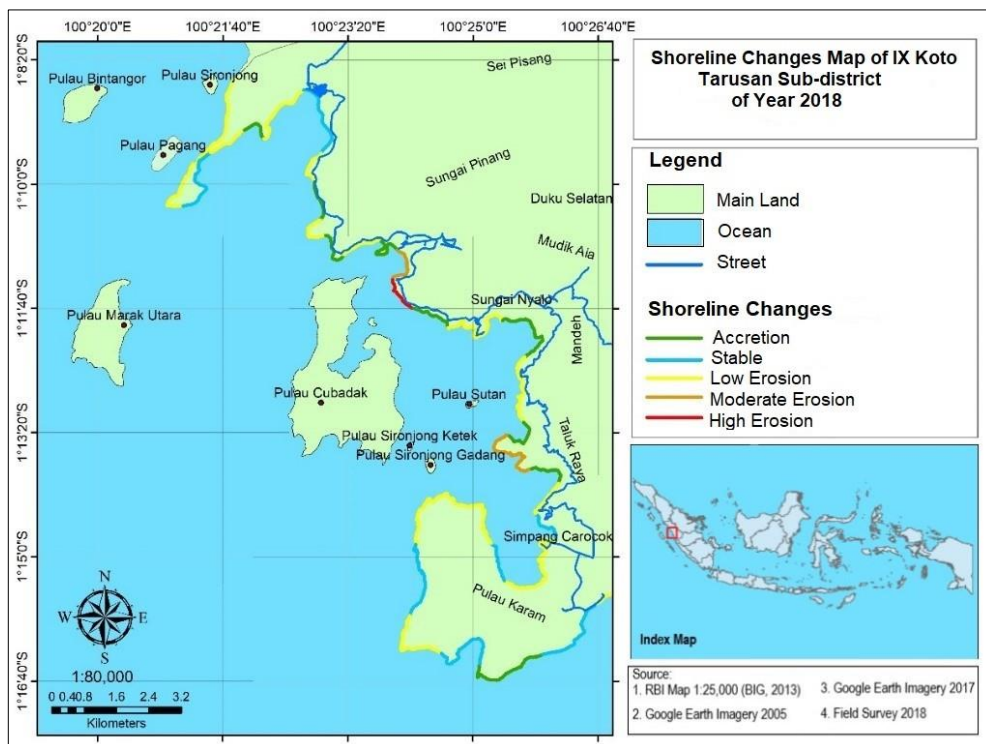


Figure 8. Shoreline changes map on Mandeh coastal bay.

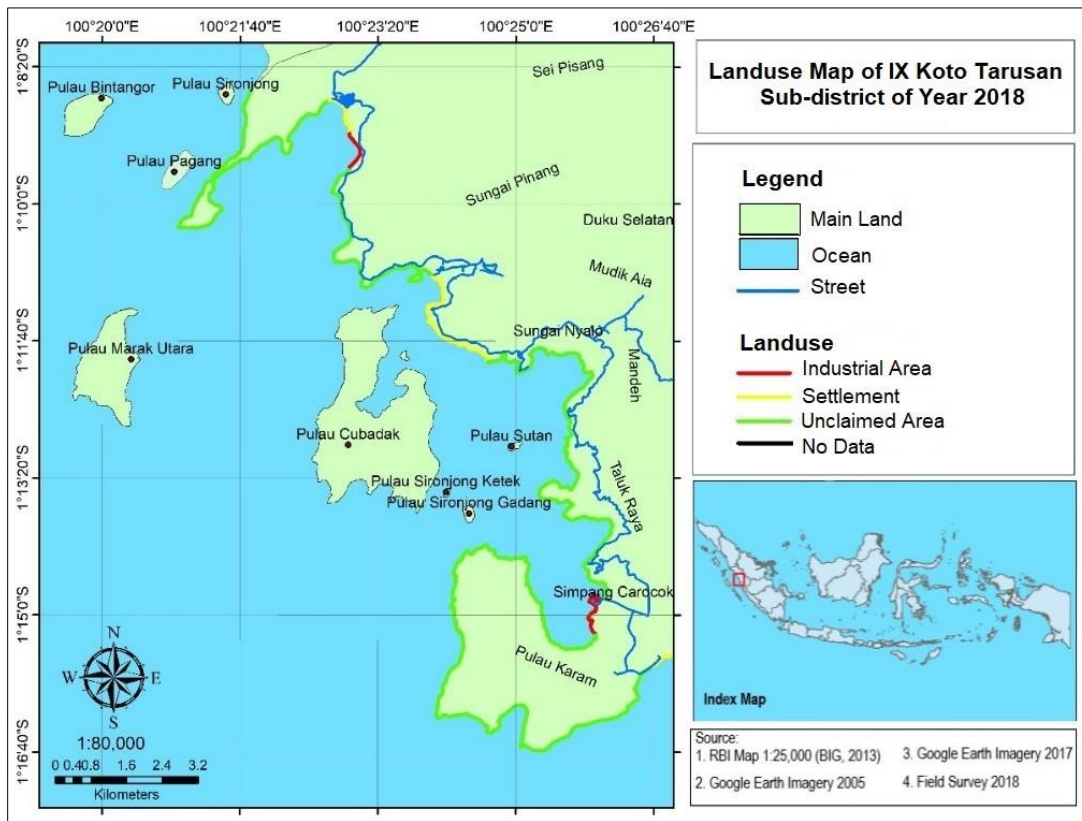


Figure 9. Coastal land-use pattern on Mandeh coastal bay.

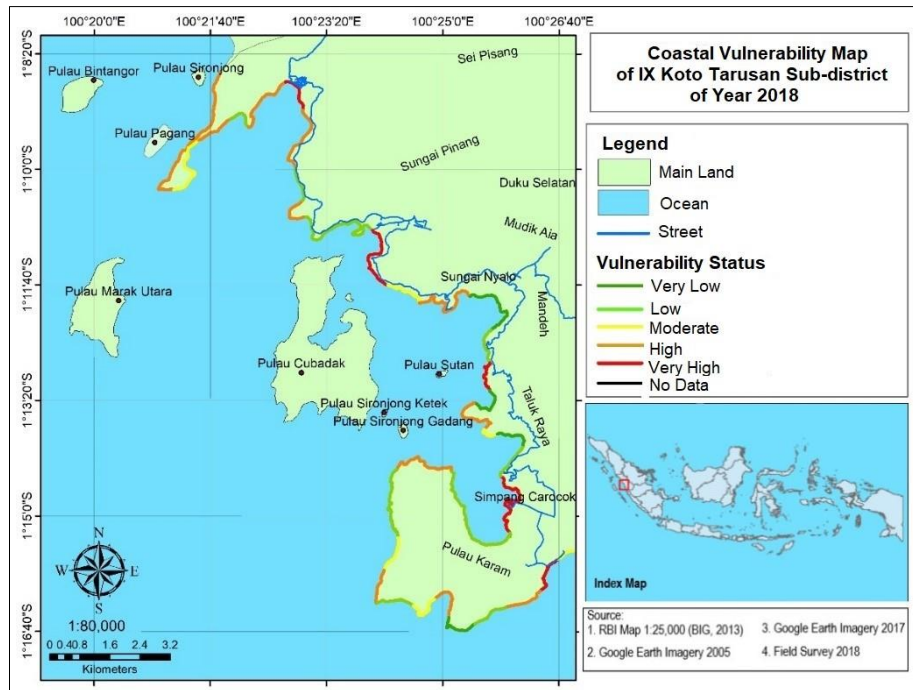
Coastal Vulnerability Index (CVI) calculation

The assessment of CVI in the study area is based on the approaches used by (Gornitz and Daniels, 1992). We applied seven parameters which are respectively representing the level of

vulnerability (Table 2). The CVI value ranged 5.07-23.15 for 51 observation points in the north and south coast of Koto XI Tarusan. Then the value of CVI obtained is grouped into 5 classes of vulnerability that are very low, low, moderate, high, and very high. Results are then classified spatially.

Table 2. CVI parameters.

Parameters	The scale of vulnerability parameters				
	Very low 1	Low 2	Moderate 3	High 4	Very high 5
Beach materials	Ice (Pure ice glacier and ice-sheet margin)	Coral (Primary hard biogenic carbonate substrates)	Hard rock (hard lithified bedrock or coastal precipitates dominant, not deeply weathered)	Soft rock (semi-lithified or inherently soft-sediment rock)	Soft sediment (dominantly muddy, dominantly coarse (pebble to boulder grade), undifferentiated soft sediment)
Wave exposure		Sheltered Hills	Semi-Exposed	Exposed	Fully Exposed
Hinterland formation					Settlements
Berm feature	Park, forest, marsh, vegetation land	Rural zone	Mixed rural zone	Urban zone	Mixed Urban Zone
Beachface feature	Coastal protection (permanent)	Green belt (mangrove)			Empty space
Shoreline changes	Accretion ($\geq +2.1$ m/year)	Stable (1.0 - 2.0 m/year)	Low erosion (-1 - +1 m/year)	Moderate erosion (-1.0 - 2.0 m/year)	High erosion (≤ -2.0 m/year)
Land-use pattern	Protected area	Unclaimed	Settlement	Industrial	Agricultural



Gambar 10. CVI map of Mandeh coastal bay.

Results show that the north coast of Koto XI Tarusan is mostly predominated by high vulnerability criteria covering 30% Sub-district area, while the rest such as the area categorized very low, low, moderate, and very high is respectively covering 10%, 27%, 18%, and 14%. One of the areas categorized into very high vulnerability is Carocok Harbor and surrounding. The variables of CVI is depended on the contribution level of damage impacted. Socio-economic variable, which is strongly related to human and society, is the most significant variable determining the risk level and vulnerability as well (Mujabar & Chandrasekar, 2013). The area categorized into very high and moderate vulnerability located in the tourism area, settlement, and human activity. Efforts to manage Mandeh coastal bay in the form of coastal protection using both natural and hard structures are necessary. Due to the sedimentary problem observed in the study area, it is tremendously essential to establish regulations regarding coastal area utilization which will limit the over-development occurred in Mandeh. The rapid degradation in Mandeh will get worse if it is not managed properly in terms of hazard and disaster threats. Moreover, over-exploration will induce the degradation of the environment as well. Local people and governments are the key roles in minimizing the impact of the vulnerability in the coastal area by which they together can control the development in the coastal area and initiate coastal protections.

CONCLUSION

The assessment of coastal vulnerability in Mandeh using the CVI and Smartline method

shows that the most prone area covers 31 % of the total area. Mandeh coastal bay that is used as a tourism area, commercial settlements, and fisheries activities are categorized into very high and high vulnerability. The socio-economic parameter is severely related to humans and society becoming the main factor determining the level of vulnerability in Mandeh. Berm features have a role in reducing the impact of the vulnerable area in the form of a green belt (mangrove forest) and permanent coastal building. Coastal zone management is tremendously essential to prevent environmental degradation resulted from tourism development and to reduce the threats of coastal hazards and disasters.

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