

Assessing coastal vulnerability index of tourism site: the case of Mataram Coast

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Abstract. Many coastal areas and infrastructure suffered from unprecedented hazards such as storms, flooding, and erosion. Thus, it is increasing the vulnerability of urban coastal areas aggravated with the absence of coastal green infrastructure. Given the state of coastal environments, there is a genuine need to appraise the vulnerability of coastal cities on the basis of the latest projected climate scenarios and existing condition. Hence, to assess, the vulnerability level of Mataram coastal, the Coastal Vulnerability Index (CVI) accompanied by pre-assessment of readiness to climate disruption. The CVI used to map coastal into five classes of using GIS. As a case study, this approach applied to Mataram City: one of the tourism destinations in Lombok. Two of sub-districts in Mataram City, Ampenan and Sekarbela, laying in the shorelines have undergone coastal flooding and erosion. One of them, Ampenan sub-district, experienced flooding due to river-discharge and became the most severe location during inundation. Results indicated that along ± 9000 meters of Mataram coast possess vulnerability level in moderate to very high-risk level. The assessment also showed that sea-level rise is not the only critical issue but also geomorphology and shoreline changes, the existence of green infrastructure, also human activity parameters took important part to be assessed.

1 Introduction

Since coastal are very complex and dynamic[1], it is very challenging to assess the changes on coastal zones. Numbers of social and economic activities take place on coastal. Thus, we need to delve the condition of the coastal itself. This also aggravated with threats that undergo the coastal come from climate change[2]. It is important to go over on coastal vulnerability, to anticipate the impact of climate disruption on coastal areas. There are oncoming to analyse the coastal vulnerability[2]–[5], mostly use physical characteristics to classify the coastal condition. In two decades, people had Coastal Vulnerability Index (CVI) for the estimation of vulnerability of the coastal region[6]–[8]. The CVI came as one of the simplistic and commonly used methods for appraising the rank of susceptibility to hazard and risk within the

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coastal zone[9], [10]. Giving rates to the physical variables in a quantifiable way to prove the dependent vulnerability of the coastal changes mainly due to climate disturbance. To succeed in the point of spatial scale, CVI assessment was implemented using a geographic information system (GIS).

Mataram city has been known as one of tourism destination. Unfortunately, some of the coast of West Lombok Regency and Mataram City are disaster-prone areas. In the last 10 years there has been an shoreline change, in 2007 a wave breakwater dike was built on a portion of the Ampenan coast [11]. Thus, in this paper, we try to convey the results of coastal vulnerability appraisalment at Mataram coast using six parameters of CVI [9]. Pre-assessment to coastal green infrastructure also carried on to reveal the condition of one readiness composing factor[12].

2 Method

2.1 Study Area

This study was part of research on Mapping of Coastal Vulnerability to Disaster. Research took place in two districts, Ampenan and Sekarbela, at Mataram, Lombok island, as shown in **Fig. 1**. Total length of the shorelines approximately 9000 m. Between two districts laying numbers of beaches as tourism attraction such as Loang Baloq, Ampenan, Gading, and Meninting.

1.1 Data

In coastal vulnerability assessment, defining coastal parameters is useful in describing physical conditions and changes. The parameters used are arranged out in **Table 1**. Various data sources are used to approach the condition of coastal vulnerability in the city of Mataram, Lombok. Time-series data were used in this study toward the dynamics of coastal conditions. For the scoring purpose, the vulnerability was divided into five class. Thus, each parameter could reveal various stage of vulnerability. The categories of vulnerability were (1) very low, (2) low, (3) moderate, (4) high, and (5) very high [9], [10].

Visualization of coastal vulnerability in Mataram started by creating grid cells along the shorelines. Each parameter meant vulnerability, measured within the 250 m*250 m cell which served as a mapping unit. An assumption made that the cell size was adequate for an identical scaling of the data. Consequently, 33 cells produced along the shorelines (**Fig.1**). These cells performed to structure a database of six parameters of Coastal Vulnerability Index which occupied i.e. mean significant wave height, coastal slope, shoreline change analysis, mean tidal range, sea-level rise rate (mm/year), and geomorphology.

Denoting added information for coastal vulnerability, we made a pre-assessment for readiness to sea-level rise due to climate disruption [12]. On the initial step, interview about green infrastructure data (i.e. artificial reefs, seagrass beds, coastal monuments, and mangroves) was delivered to the coastal residents. The questions were about to get an early description of one information on readiness.

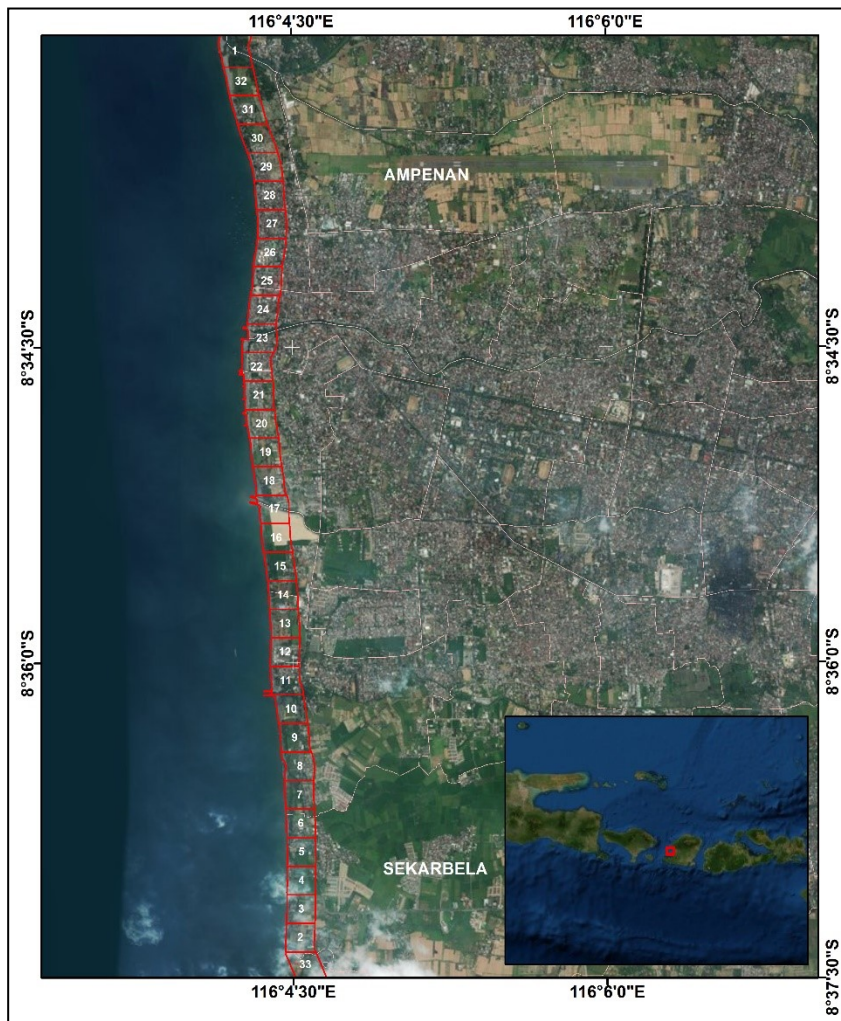


Fig. 1. Research location in Mataram, Lombok.

Table 1. Data sources and period of various parameters for CVI.

Parameters	Unit	Sources	Period	Resolution
Shoreline changes	m/year	Landsat 5 TM & Landsat 8	1996 & 2018	30 m
Coastal slope	%	National DEM (DEMNAS) by Indonesia Geospatial Information Agency	2018	7 m
Mean Significant Wave Height	m	ECMWF (European Centre for Medium-Range Weather Forecasts)	2010 – 2018	0.125°
Geomorphology	-	Land-use from Indonesia Topographic Map (RBI) scale 1:5000; Hi-res imagery (Worldview-2)	2017	0.5 m

		from Indonesia Geospatial Information Agency.		
Sea-level rise	mm/year	MDT and SLA from Altimetry Data (1993 – 2017) in Indonesia Geospatial Information Agency Research Report [13]	2018	0.5°
Mean Tidal Range	m	Accessed from Indonesia Geospatial Information Agency (BIG) via http://tides.big.go.id	2013 - 2017	-

1.2 Coastal Vulnerability Index

As the most regularly used to assess coastal vulnerability to sea-level rise or due to shoreline changes, we calculated the CVI as the square root of the ranked variable that divided by the total number of variables. In this case, six parameters were added to the calculation. Since there are no rules for weight assignment [14], should be noticed that the equal weight of the CVI was implied in this study. Each parameter had been addressed to the vulnerability rank (1-5) following the range described in **Table 2**. The highest and lowest values of the CVI were determined as in the following Eq.(1) [9], [10].

$$CVI_6 = \sqrt{\frac{SC*CS*Gm*Mtide*SLR*SWH}{6}} \quad (1)$$

Where:

- SC = shoreline change
- CS = coastal slope
- Gm = geomorphology
- Mtide = mean tidal range
- SLR = sea level rise rate
- SWH = mean significant wave height

The calculated CVI divided into five risk levels through percentiles classification. The CVI values assigned as very low-risk level (1) at the lowest value, low-risk level (2), moderate level (3), high-risk level (4), and the highest value addressed to a very high-risk level (5).

Table 2. Vulnerability rank for parameters of CVI[9], [10].

Parameters	Very Low	Low	Moderate	High	Very High
<i>Score</i>	1	2	3	4	5
Shoreline changes (m)	>2.0	1.0–2.0	-1.0 to 1.0	-2.0 to -1.0	<-2.0
Coastal slope (%)	>1.420	1.20–0.90	0.90–0.60	0.60–0.30	<0.30
Mean Significant Wave Height (m)	<0.55	0.55–0.85	0.85–1.05	1.05–1.25	>1.25
Geomorphology	Rocky cliffed coast, fjords	Medium cliffs, indented coasts	Low cliffs, glacial	Cobble beaches, estuary, lagoon	Barrier beaches, sand beaches,

			drift, alluvial plains		salt marsh, mud flats, deltas, mangrove, coral reefs
Sea-level rise (mm/year)	<1.8	1.8–2.5	2.5–3.0	3.0–3.4	>3.4
Mean Tidal Range (m)	<0.99	1.0–1.99	2.0–3.99	4.0–6.0	>0.6

3 Result and Discussion

3.1 Mataram coastal vulnerability index

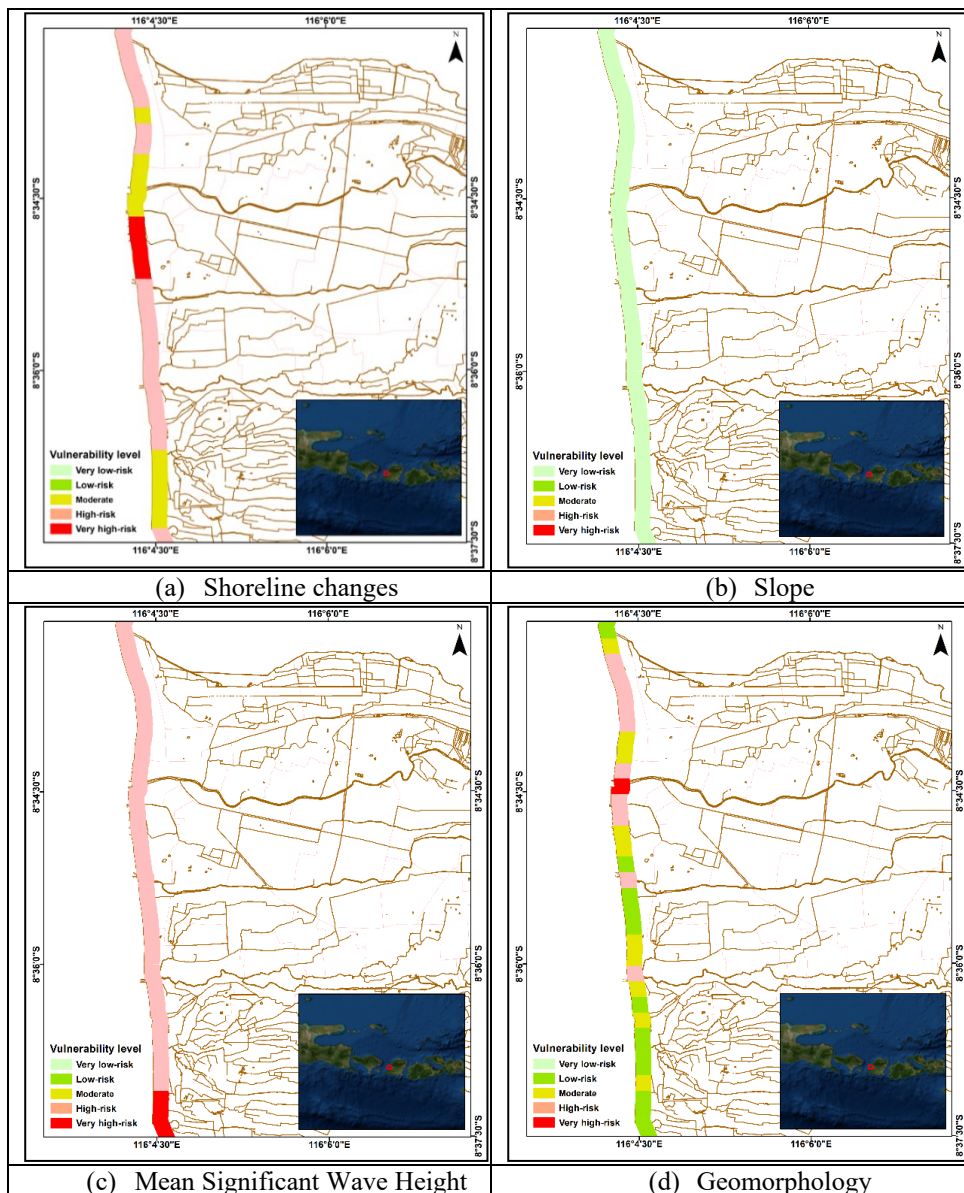
Six parameters used for CVI assessment shown at **Fig. 2.** respectively for shoreline changes (a), coastal slope (b), significant wave height (c), geomorphology (d), SLR (e), and tidal range (f). Those parameters are commonly used for CVI [1], [3]–[5]. Referring to the data in Table 1 and classification based on Table 2, the CVI level earned for Mataram city as attached in **Fig. 3.** Sequentially, the length of shorelines at Mataram city which classified into vulnerability level is 2793.696 m at a moderate level (3), 5251.174 m at high-risk level (4), and 1175.722 m at very high-risk level (5).

By assessing six parameters of CVI, Mataram coast are on moderate to high-risk level of vulnerability (Figure 3). Level of vulnerability of each parameter varied from very low to very high, in particular for geomorphology and shoreline change. Different from these following parameters, slope, sea-level rise, and mean tidal range only possess one class due to the same value at all grids along the shore. Meanwhile, parameter of significant wave height had two classes, very high and high level of vulnerability. Thus, the parameter that significantly affected the result of CVI in Mataram were geomorphology, shoreline changes, and significant wave height. It is known that shoreline changes influenced by physical processes, e.g., significant wave height, high tides and sea level rise. However, significant wave height and sea-level rate at Mataram coast sat on high-risk level give an impact to the shoreline changes. Refer to the previous study of [15] and [14] shoreline change was caused not only by physical processes but also by continuous usage through social and economic activities, such as happened in Semarang. In line with the survey result on August 2019, most of shoreline in Mataram experienced erosion. Interview with keypersons at Jempong Baru, Sekarbela district and Bintaro, Ampenan district revealed that in early 1990s the shorelines were at around 100 m forward to the sea. Meanwhile, accretion on Mataram coast happened at several point due to coastal infrastructure such as jetty or breakwater. In the term of geomorphology, sand beaches dominated the Mataram coast.

Using data Landsat 5 TM and Landsat 8 from 1996 and 2018 respectively, we found that shoreline change (erosion) at Mataram coast ranged from 0.25 – 2.99 m/year. Sea level rate used in this study was a research result from 2018. Altimetry data from RADS server along 1993 – 2017 were used to estimate the sea level rise through Indonesia waters which value ranged 2 – 7 mm/year[13]. For Mataram coast, the SLR was 4 mm/year for each grid at shoreline. Thus, the vulnerability class was very high vulnerability along the shore.

Slope (%) on the coastal zone of Mataram was delivered by the data of Indonesia Digital Elevation Model (DEMNAS) with 7 m of spatial resolution. The data was published by Indonesia Geospatial Information Agency. Using zonal statistical, we calculated average slope for each grid cell. As the result, we found slope in the coastal of Mataram ranged from 7% - 10% and classified as very low-risk (1) level of vulnerability (**Fig. 2**).

For readiness to climate disruption, we earned answer, from 30 respondents who are resident locally on Mataram coast, that coastal green infrastructure such as mangrove, artificial reefs, seagrass bed were very less existed. Thus, to enhance the readiness, the coastal green infrastructure should take precedence in order to adapt due to climate change [12].



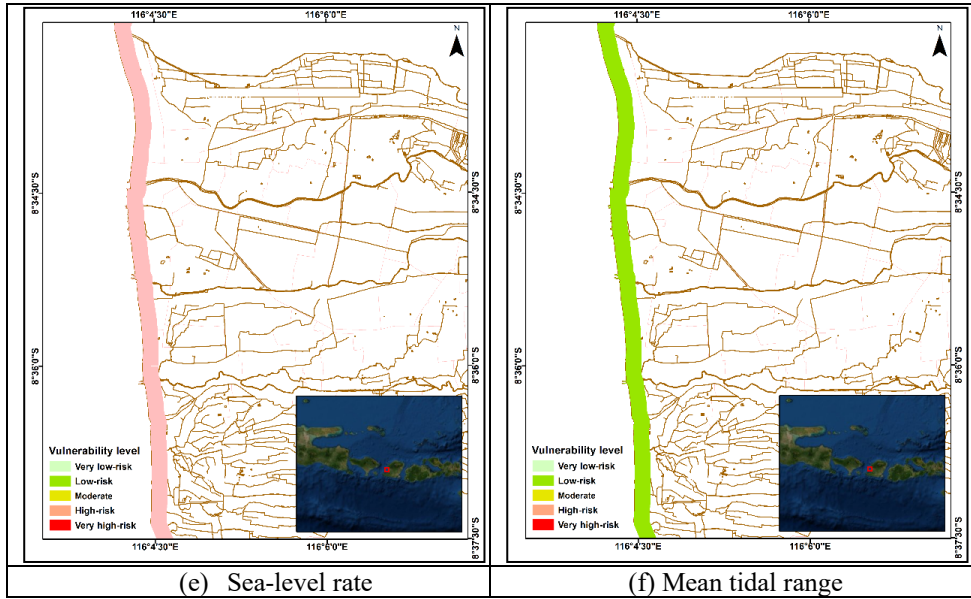


Fig. 2. Vulnerability level of each CVI parameters .

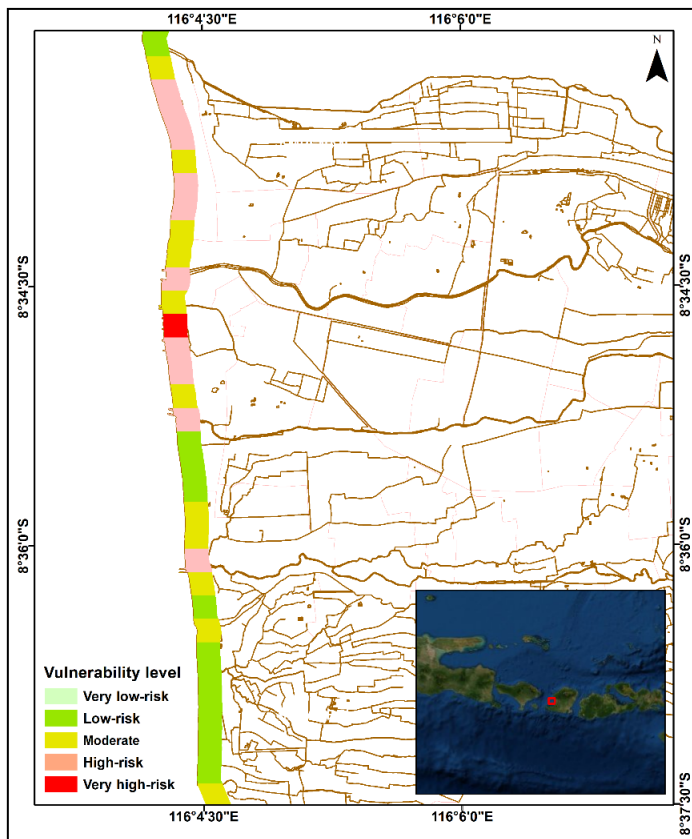


Fig. 3. CVI level of Mataram coastal.

4 Conclusion

Six parameters were occupied to assess CVI of Mataram coast. The moderate to high-risk level of vulnerability level found on Mataram coast were due to geomorphology and shoreline change factors. This condition aggravated with the less existence of coastal green infrastructure. Result of assessment on the vulnerability index is very depending on the matrix composition. The continuous study/research related to the weight composition of each parameter for vulnerability index assessment is needed. To accomplish the plausible level of vulnerability of different places.

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