Socio-Physical Assessment of Coastal Vulnerability Index in a Tourism Island Bali Using Multisatellite Data

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Abstract. The management of coastal areas in the Lovina area, Buleleng Bali, is currently faced with the threat of sea level rise. To keep tourism steady, disaster mitigation planning is needed that is sourced from the vulnerability data of coastal areas. Lovina coastal area vulnerability data from 2015-2020 were analyzed using physical and social indicators consisting of 7 types, namely land use, road network and elevation obtained from RBI map data; sea level rise obtained from Envisat altimetry satellite data; shoreline changes obtained from interpretation of satellite imagery; population density is obtained from data from the Central Statistics Agency; and cultural locations were obtained from field surveys. These indicators were then analyzed using the CVI method, and the results showed that the Lovina area's coastal vulnerability was in a low category. Detailed information on the vulnerability category of coastal areas, based on 14 grid areas with a grid width of 500 meters, it is known that ten grids are at a very low vulnerability index, 1 grid is low, two grids are medium, and one is very high. Grid areas with very high criteria are in the Kaliasem and Kalibukbuk areas nearest to the Lovina tourism center. The highest indicators causing variations in the vulnerability index are land use, road networks, and temples as part of religious tourism.

Keywords : sea level rise, tourism, coastal, vulnerability

1 Introduction

Indonesia's coastal resource management policy is a National Priority in the RPJMN, especially to support equitable and sustainable economic resilience (ICCTF). The coastal area management program in Indonesia is also contained in the Indonesian Government's vision in the maritime sector which focuses on five main policy groups and programs that must be carried out, namely: (a) enforcement of the sovereignty of the Unitary State of the Republic of Indonesia including completion of maritime boundaries, eradication of illegal fishing and various activities other illegal; (b) marine economic development; (c) maintain the sustainability of marine resources; (d) development of marine science and technology capacity and (e) improvement of the nation's maritime culture.

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Expectations for conservation, sustainable rehabilitation of coastal resources and minimization of disaster risk in coastal areas are increasingly far from reality. The phenomenon that appears is in the form of threats, not only political and economic, but also environmental problems, one of which is the impact of the global warming phenomenon. Various threats in coastal areas will experience dynamics that lead to disaster events [1]. Today, the threat in coastal areas that is in the world's spotlight is the threat of sea levels rise that threatens all coastal areas. The IPCC carries out a scenario of sea level rise around the world reaching 110 cm by 2100. Asian Development Bank [2] also predicts an increase in sea level in Indonesia to reach 15-90 cm in 2100. Sea level rise will have an impact negative on coastal areas such as shoreline erosion, inundation of land areas near the coast, increased risk of flooding, and seawater intrusion [3] [4].

Notice into account the impact of an increase in sea level, sea level rise is seen as one of the fundamental problems in efforts to manage coastal areas [1]. So is, from the results of research on disaster threats in coastal areas, it was found that there were potential hazards such as inundation of land, coastal erosion, sea water intrusion, tsunamis, tropical storms [3] [4] [5]. The results of research in the coastal area of Semarang explain that the phenomenon of inundation of coastal areas is the result of various processes, including: changes in land use in coastal areas, land subsidence in coastal areas, and sea level rise as an effect global warming [6].

One area in Indonesia that currently has the potential have a threat from sea levels rise is the coastal area of the Lovina area in Buleleng Regency in Bali Province. The Lovina area is one of the tourist destinations in Buleleng Regency, has physical and social characteristics as a tourist area. Along the coast of the Lovina area there are residential areas and places of worship as social indicators that must be considered because they are very vulnerable to impacting sea level rise. This is intended as a mitigation effort for the sustainability of tourism in the Lovina area. For information, explains that the percentage of coastal areas in the western part of Buleleng Regency that are potentially inundated, namely: in 2015 it reached 2.254%, in 2020 it reached 7.396%, in 2025 it reached 12.294%, in 2030 it reached 16.920%, and in 2035 it reached 21.636%. Of course, there are indications that this sea level rise must be balanced by policies that consider disaster mitigation efforts [1].

As an effort to mitigate disasters in coastal areas, it can be done through the provision of data on potential vulnerability of coastal areas. One method that is considered qualified is through the assessment of the coastal vulnerability index or known as the Coastal Vulnerability Index (CVI). Currently, the CVI method that has been carried out by previous researchers is limited to the limits of physical vulnerability indicators that use data : geomorphology, land use/land cover, bathymetry, slope, shoreline change and mean tidal range [7]. However, the social component indicators have not been accommodated, even though in terms of disaster management policies, according to Regulation BNPB No. 2 of 2012, social vulnerability is also one of the indicators analyzed when assessing regional vulnerability [8]. The involvement of social indicators in assessing vulnerability certainly requires a method that must be used considering that social indicators in this case are dominantly non-spatial data which must be approached with spatial-based data. The use of social indicators in the CVI method has been carried out [9], so this study accommodates this method in order to assess coastal vulnerability in Buleleng Regency. The difference with previous studies in this study is that the data used are mostly sourced from high-resolution image data obtained from manual interpretation methods.

2 Methods

2.1 Study Area

Geographically, the Lovina-Bali area is located in 8.165 S, 115.021 E – 8.134 S, 115.057 E. The physical condition of the coastal area of Lovina-Bali is a lowland area that is very much affected by the pressure of sea levels rise. The changes in the coastline visually from observations in the field show that the Lovina-Bali area has a vulnerability to sea levels rise, as well as settlements on the coast and places of prayer which have also experienced erosion on their buffer parts. This phenomenon is also corroborated by the results of the son's research which estimates an increase in sea level of 5.1 cm/year. The map of the research location is presented in Figure 1 which consists of 14 grids.

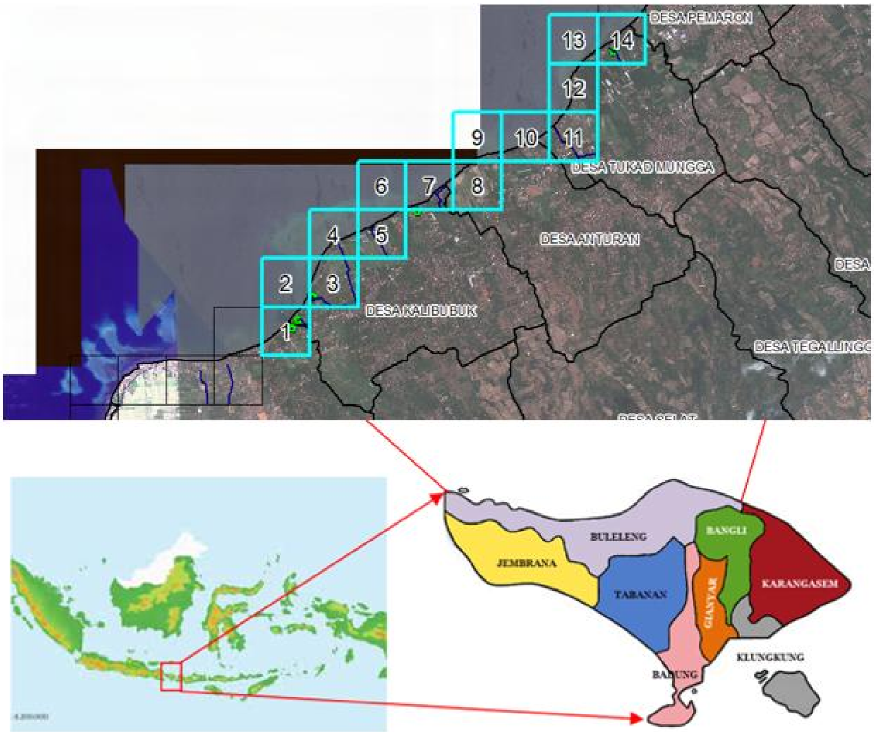

Fig 1. Location map of the study area

2.2 Data Sources

The data sources used in this study adopted the research variables conducted which consisted of the following variables: (a) shoreline changes, (b) land use, (c) road network, (d) elevation, (e) sea level rise, (f) temple/culture and (g) population density [9]. The recapitulation of the data used is presented along with its sources in the following table.

Table 1. Parameter, Indicator and Source of Data Research

Parameter	Indicator	Source	Year of data Release
Physic	Shoreline changes	Interpretation of satellite imagery	2000 – 2021
	Land use	Interpretation of satellite imagery / RBI Map	2022
	Road network	RBI Map	2019
	Elevation	SRTM/ RBI Map	2019
	Sea level rise	Envisat altimetry satellite data	2020*
Social	Temple/culture	Field surveys	2022
	Population density	Central Statistics Agency	2021

* Forcasting from analysis Envisat altimetry satellite data

The CVI method is a concept to assess the risk of sea level rise on the east coast of the United States. Gornitz created a database for coastal disaster analysis. Then in 1999, Thieler and Hammer-Klose developed a new application of CVI Gornitz, by modifying and reducing the number of variables. Until recently, many researchers have adopted the CVI method to assess the vulnerability of coastal areas. In this study, the CVI method is used to assess the vulnerability of coastal areas in the Lovina-Bali area which adopts physical and social variables consisting of 7 indicators. Each indicator is then classified using 5 class intervals, namely very low, low, medium, high and very high. The criteria are presented in table 2.

Table 2. Vulnerability Classes and Scores Defined for Each Selected Indicator

Indicator	Criteria				
	very low	low	medium	high	very high
Shoreline changes (m/y)	> 4.808	-6.535 to 4.808	-20.266 to – 4.808	-40.565 to -20.266	< -40.565
Land use	Water	Meadow	Mangrove	Agriculture	Settlement
Road network	Absent	-	-	-	Present
Elevation (m)	> 3.646	2.942-3.646	2.163-2.943	1.509-2.162	< 1.509
Sea level rise (mm/y)	< 3.56	3.56-3.91	3.91-4.29	4.29-4.79	> 4.79
Temple/culture	Absent	-	-	-	Present
Population density	Uninhabited	< 185	185-803	803-1.350	>1.350

Furthermore, the vulnerability criteria from the combination of these indicators are calculated using the following formula, which will later obtain 5 criteria as presented in table 3.

$$CVI = \sqrt{\frac{a*b*c*d*e*f*g}{7}} \quad \ldots\ldots (1)$$

where : a, b, c, d, e, f, g are each the coastline, land use, road network, elevation, sea level rise, temple/culture, and population density.

Table 3. Criteria of Interval CVI

Interval CVI	**Criteria**
< 12.6	Very low
12.6 – 18.2	Low
18.2 – 23.8	Medium
23.8 – 29.4	High
> 29.4	Very high

3 Result and Discussion

Vulnerability is a condition of the inability of an area to face the potential threat of disasters that occur. Assessment of the level of vulnerability of an area includes various indicators such as what has been done [9], [10], [11] including in Indonesia, vulnerability assessment guidelines have been released through regulation of the head of BNPB No. 2 Year 2012 [8]. This study analyzes the level of vulnerability in the coastal area of the Lovina area which is focused on social and physical indicators of the area. Based on the results of the research that has been done, the results can be recapitulated as shown in the following table.

Table 4. Recapitulation of Research Results

No Grid Area	Landuse	Road Network	Temple/ Culture	Shorline Change	Elevation	Sea Level Rise	Population Density	CVI	Criteria
1	5	5	5	3	5	5	3	24,0	Very High
2	1	1	1	2	5	5	3	1,7	Very Low
3	5	5	5	2	5	5	3	19,6	Medium
4	4	5	1	2	5	5	3	7,8	Very Low
5	5	5	1	2	5	5	3	8,7	Very Low
6	1	1	1	2	5	5	3	1,7	Very Low
7	4	5	5	2	5	5	3	17,5	Low
8	4	1	1	2	5	5	3	3,5	Very Low
9	1	1	1	2	5	5	3	1,7	Very Low
10	4	1	1	2	5	5	3	3,5	Very Low
11	5	5	1	2	5	5	3	8,7	Very Low
12	4	1	1	2	5	5	3	3,5	Very Low
13	1	1	1	2	5	5	3	1,7	Very Low
14	5	5	5	2	5	5	3	19,6	Medium

Source : Research results (2022)

Based on Table 4, it is known that the variation in the criteria for the level of vulnerability of the research area is in the very low criteria to the very high criteria based on distribution of index CVI. This variation in the level of vulnerability is caused by variations in the distribution of vulnerability indicators that exist in each grid area that is used as the unit of analysis. For example, in grid area no. 1, it is known to have very high criteria due to the high vulnerability indicators, namely land use, road network, temples, while other indicators are almost the same as other grid areas. This means that in grid area no. 1 there are temples, a road network that has the potential to be affected by sea levels rise, as well as in terms of land use in general in the area, most of which are built spaces that are very vulnerable. If the spatial distribution of the vulnerability index of the research results as shown in table 4 is visualized through a map, the following results will be obtained.

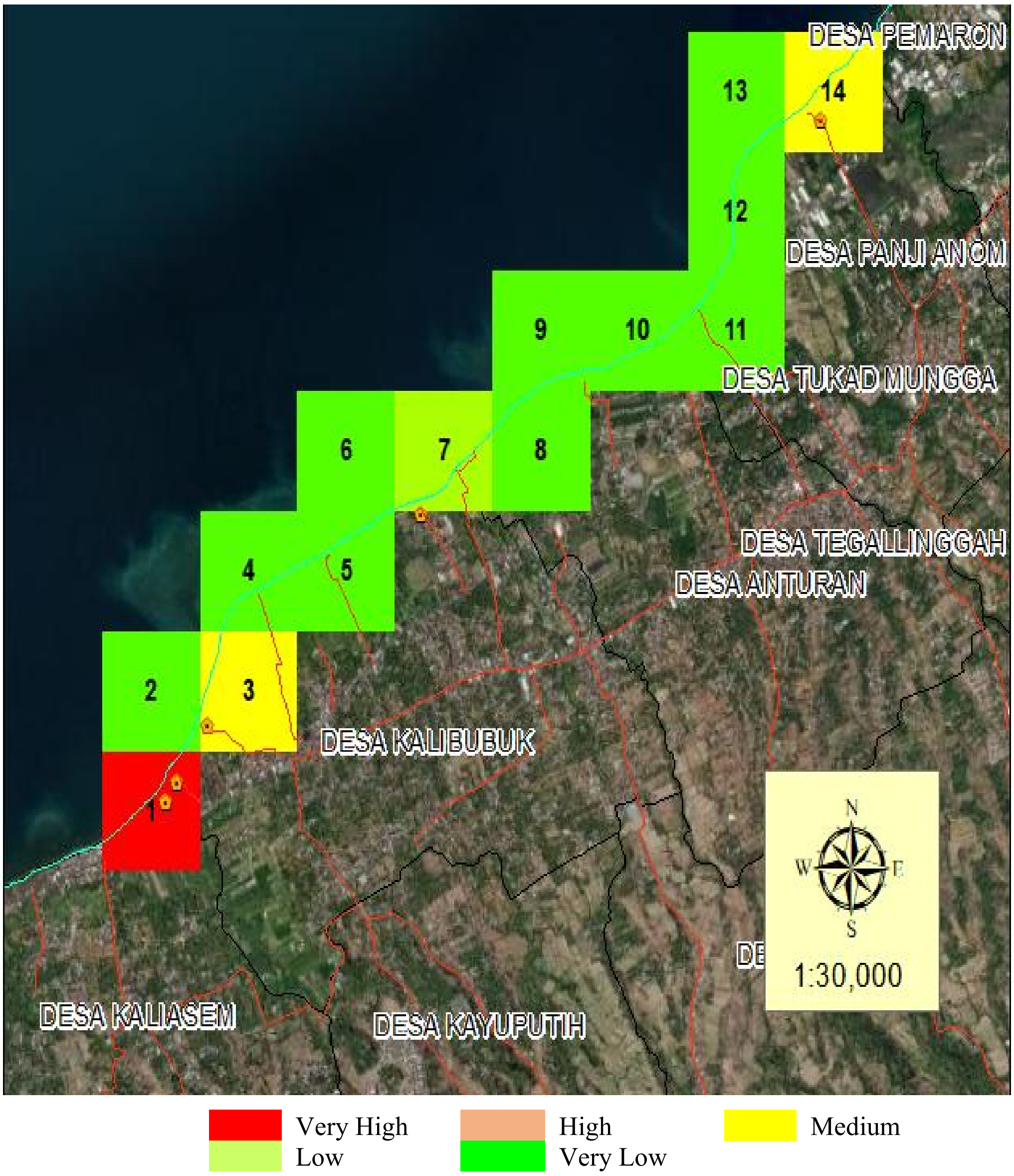

Fig 2. Spatial Visualization of the Coastal Area Vulnerability Index

Based on Figure 2, the distribution of the vulnerability index in the study area is in the very low to very high criteria. This variation is caused by variations in both physical and social indicators that are in the research area which is generally a tourism area so that it has an impact on the development of residential land use supported by road network access and the existence of several temples as religious tourism. This is in line with the research conducted which states that variations in land use are closely related to an increase in the regional vulnerability index [11].

In general, from the results of this study, it is known that the highest vulnerability index is found in Kaliasem and Kalibukbuk villages which are on grid area no 1 which is one of the centers for the development of the Lovina tourism area which has an influence on the development of built space including road access, and in that area there is a Segara Temple. And than in grid area no 3, there is the Dalem Temple, Desa Pakraman Kalibukbuk and there is an access road to Lovina Beach. In addition, in grid area no 4 there is also the Puseh Temple, Desa Pakraman Dharmajati Tukadmungga and the object of the Happy Tukadmungga Beach Tourism Park which is also supported by road network access so that it has an impact on the vulnerability index in the medium category. The visualization of several indicators that cause a high regional vulnerability index is as follows.

Build up area in Lovina Beach

Puseh Temple Desa Pakraman Dharmajati Tukadmungga in Coastal Area

Dalem Temple Desa Pakraman Kalibukbuk in

Segara Temple in Coastal Area

Coastal Area

Fig 3. Indicators that Cause the High Vulnerability Index of Coastal Areas

Based on Figure 3, that the variation in the distribution of the vulnerability index requires attention from policy makers, especially to suppress the vulnerability index which is still high so that it will reduce disaster risk. However, it should be noted that not all vulnerability indices can be minimize because the area is physically needed. For example, in grid area no 1 which has a high vulnerability index due to the presence of temples, road networks and land use for settlements, the government must take other steps to reduce disaster risk, namely by increasing capacity both structurally such as embankment construction and non-structural such as increasing understanding communities to respond to disasters. Thus the risk of disasters that will occur can be minimized according to the concept of disaster risk reduction [12] [13].

4 Conclusion

Socio-Physical Assessment of Coastal Vulnerability Index in a Tourism Island Bali that located in Lovina Area, Buleleng Regency that shown the distribution variation in the criteria for the level of vulnerability of the research area is in the very low criteria to the very high criteria. Based on 14 grid areas with a grid width of 500 meters, it is known that 10 grids are at very low vulnerability index, 1 grid is low, 2 grids are medium, and 1 is very high. Grid areas that have very high criteria are in the Kaliasem and Kalibukbuk areas which are nearst to the Lovina tourism center. The highest indicators causing variations in the regional vulnerability index are land use, road networks and temples as part of religious tourism.

5 Reference

[1] Putra, I Wayan Krisna Eka.2013. Evaluasi Hasil Post Processing Data Satalit Altimetri Envisat Sebagai Data Prediksi Ancaman Peningkatan Muka Air Laut untuk Pemetaan Genangan Wilayah Pesisir. *Tesis.* Yogyakarta : Universitas Gadjah Mada.

[2] Asian Development Bank. 2007. *The Economic of Climate Change in Southeast Asia.* A Report of Regional Meeting on Climate Change.

[3] Nicholls, R.J. 2003. *Case Study on Sea Level Rise Impact.* Organisation for Economic Co-operation and Development.

[4] Hopkinson, C.S., Ariel E.L., Merryl A., Alan P.C., dan Skip J.V.B. 2008. Forcasting Effects of Sea Level Rise and Windstroms on Coastal and Inland Ecosystems. *Journal* Front Ecol Environ. hal 255-263 : The Ecological Society of America.

[5] Marfai, M.A., Nursakti A.P., Taufik H., Anang W.N., dan Muammar G. 2011. *Model Kerentanan Wilayah Pesisir Berdasarkan Garis Pantai dan Banjir Pasang.* Yogyakarta: Magister Perencanaan Pengelolaan Pesisir dan Daerah Aliran Sungai, Fakultas Geografi Universitas Gadjah Mada Yogyakarta.

[6] Suryanti, E.D. dan Muh A.M. 2008. Adaptasi Masyarakat Kawasan Pesisir Semarang Terhadap Bahaya Banjir Pasang Air Laut (Rob). *Jurnal* Kebencanaan Indonesia Vol. 1. No. 5, ISSN 1978-3450.

[7] Baig, Mirza R.I., Shahfahad.,Ishita A.A.,Mohammad Tayyab.,Md Sarfaraz A.,& Atiqur R. *Coastal Vulnerability Mapping by Integrating Geospatial Techniquesand*

Analytical Hierarchy Process (AHP) along the VishakhapatnamCoastal Tract, Andhra Pradesh, India. Journal of the Indian Society of Remote Sensing.
[8] BNPB. 2012, Pedoman Umum Pengkajian Risiko Bencana. *Peraturan Kepala Badan Nasional Penanggulangan Bencana No. 2 Tahun 2012.*
[9] Duriyapong, F., & Nakhapakorn, K. (n.d.). Coastal vulnerability assessment: a case study of Samut Sakhon coastal zone. *J. Sci. Technol*, *33*(4), 469–476. Retrieved May 24, 2022, from http://www.sjst.psu.ac.th.
[10] Vieira, L.R. et al. (2021) 'GIS models for vulnerability of coastal erosion assessment in a tropical protected area', *ISPRS International Journal of Geo-Information*, 10(9). Available at: https://doi.org/10.3390/ijgi10090598.
[11] Furlan, E. et al. (2021) 'Development of a Multi-Dimensional Coastal Vulnerability Index: Assessing vulnerability to inundation scenarios in the Italian coast', Science of the Total Environment, 772, p. 144650. Available at: https://doi.org/10.1016/j.scitotenv.2020.144650.
[12] Rahma, Aldila. 2018. *Implementasi Program Pengurangan Risiko Bencana (PRB) Melalui Pendidikan Formal.* Jurnal Varia Pendidikan. Vol.30 No.1, ISSN:0852-0976.
[13] Hadi, Hasrul, Sri Agustina, dan Armin Subhani. 2019. *Penguatan Kesiapsiagaan Stakeholder Dalam Pengurangan Risiko Bencana Gempa Bumi.* Jurnal Geodika. Vol. 3. No 1, e-ISSN 2549-1830.