INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE
ISSN: 2067-533X Volume 12, Issue 4, October-December 2021: 1515-1526 www.ijcs.ro

ASSESSMENT OF MANGROVE AS A NATURAL BEACH PROTECTION IN SURABAYA COAST, INDONESIA

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Abstract

Mangrove area in east coast of Surabaya region is becomes a fortress to protect the city from the threat of erosion and sea intrusion. According to its function, the development of mangrove areas will help this area in dealing with coastal erosion. This study presents a GIS model that aims to determine the effect of mangrove changes to coastal erosion risk. The method used Landsat satellite images during 2015-2019 to calculate mangrove changes. DSAS (Digital Shoreline Analysis System) is used to calculate shoreline changes. Finally, the model used CERA to analysis coastal erosion risk. The results showed that there is the dynamics change of shoreline (both accretion and abrasion) in the 2015-2019 period in each district. This change is influenced by the density of mangroves. Meanwhile, the analysis of CERA showed that the Kenjeran and Bulak Districts are classified as high risk of erosion. This condition is not only based on the extent of mangrove but is also caused by other parameters such as geomorphology, land cover, population density, and so on.

***Keywords**: CERA, DSAS, Risk, Mangrove, Coastal*

Introduction

Pamurbaya is an open space area that plays a major role in controlling the geographical situation of the city of Surabaya, East Java, Indonesia. It is because the mangrove area on the east coast of Surabaya is a stronghold of the city of Surabaya from the threat of abrasion, sea intrusion, and subsidence. Indonesia's mangrove ecosystem is the largest in the world and has the highest biodiversity. Traditional fisheries and aquaculture are also directly assisted by the presence of mangrove forests as breeding grounds and nurseries [1].

One of the mangrove areas in Indonesia that is indicated to be damaged is the east coast of Surabaya. Whereas according to the Surabaya City Spatial Plan and Region of 2014, this area is designated as a protected area.

As an area of green open space that remains and becomes a fortress to protect the city of Surabaya from the threat of erosion, sea intrusion, and subsidence, the mangrove area in Pamurbaya has begun to experience changes due to land development for housing. This happens because of the inconsistency of the Conservation Law and the housing permit that was issued [2].

However, there has been a degradation in the coastal area and the mangrove ecosystems due to human activities. If this situation continues, the city of Surabaya will be very dangerous and vulnerable to natural disasters [3-6].

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The objective of this research is to determine the effect of mangrove changes to coastal erosion risk using GIS model. The method analysis mangrove coastlines changes from 2015 to 2019 on the east coast of Surabaya using Landsat satellite images and DSAS. Also, CERA is combine in this study to analysis coastal erosion risk. The results of this study are expected to provide an overview of the condition of mangroves and changes in the shoreline in order to manage and to protect this area from erosion.

Material and Method

Study Location

This study is located in coastal area of Surabaya at coordinates 7° 14' - 7° 21' Latitute and 112° 37' - 112° 57' Longitude. Surabaya east coast or also called Pamurbaya is located in the eastern part of the city of Surabaya and is directly adjacent to the Madura Strait as seen in figure 1. This area has coastline length of 35.7km along. Pamurbaya is divided into six district as shown in Table 1. Surabaya features typical a tropical monsoon climate, with distinct dry and wet seasons. For average high temperature of 32 °C and average low temperatures about 25 °C.

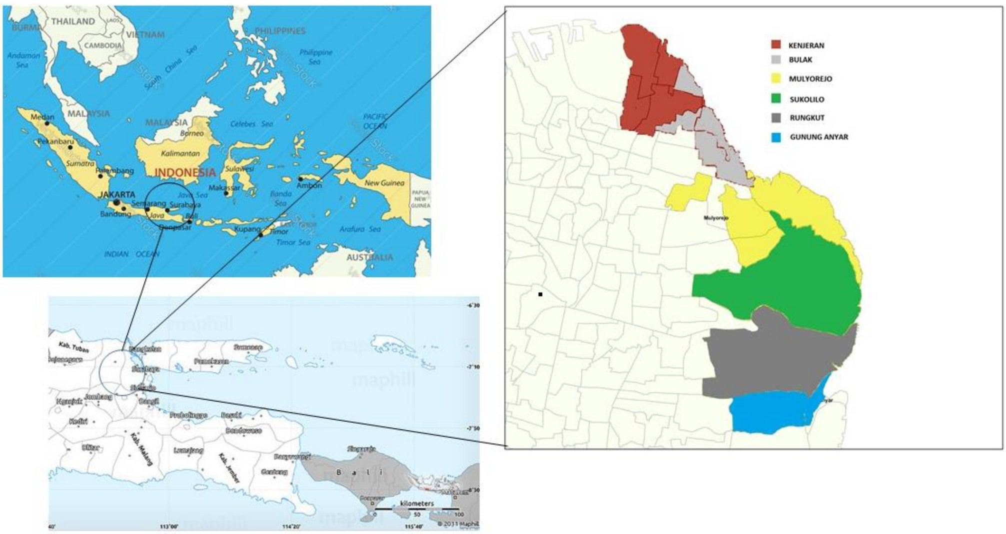


Fig. 1. The location of east coast Surabaya in east Java province, Indonesia

Table 1. East Coast of Surabaya Area

No	District	Sub-District
1	Gunung Anyar	Gunung Anyar
2	Rungkut	Medokan Ayu, Wonorejo
3	Sukolilo	Keputih
4	Mulyorejo	Dukuh Sutorejo, Kalisari, Kejawan
5	Bulak	Kedung Cowek, Bulak, Komp. Kenjeran, Kenjeran, Sukolilo
6	Kenjeran	Tambak Wedi, Bulak Banteng

Data

In the present study, we used Landsat 8 satellite image database which has a resolution of 30 x 30 meter of the east coast region of Surabaya from 2015 to 2019. The LANDSAT image data were downloaded from the United States Geological Survey homepages for free (http://earthexplorer.usgs.gov). Added, the high spatial resolution images, which were collected in 2015 and 2019 and derived from Google Earth, were used to validate the accuracy of the classification image. Data of this study also supported by Digital Elevation Model and Geological Map of Surabaya. Added, economic data, population density, ecological data, wave height and tidal data in the Surabaya region are collected to support risk analysis model.

Methods

Image Analysis

First preparation in image management is radiometric correction and geometric correction. Radiometric correction to correct pixel values from solar or atmospheric radiation variation, while geometric correction to obtain correct geometry of the image that matches the reference image with ground control points.

Then, composite image was carried out using ENVI 5.3 software. This process is done to classsify or to identification the mangrove vegetation. The RGB composite of 564 was used in Landsat 8 satellite imagery.

Next, to distinguish mangroves from other types of land use, image classification was implemented in this analysis. Image classification is sorting process by grouping pixels in several classes based on objective or category. Every pixel in each class is assumed to have similar characteristics. The classification method used in this paper is the supervised classification with the maximum likelihood classification [7].

Finally is the calculation of mangroves area during 5 years from 2015 to 2019. The calculation is done using the method of calculate geometric. Calculate geometrically method is an automatic calculation procedure on ArcMap based on the geometric shape or coordinate system used in GIS data. In this analysis, raster data will be converted into vector data to simplify the calculation of land cover change area from the image of the classification results. This data conversion uses one of tool in ENVI software (Fig. 2). Then, the area will be calculated by using calculate geometric method contained in ArcMap 10.5 software.In the present study, we used Landsat 8 satellite image database which has a resolution of 30-meter x 30 of the east coast region of Surabaya from 2015 to 2019. The LANDSAT image data were downloaded from the United States Geological Survey homepages for free (http://earthexplorer.usgs.gov). Added, the high spatial resolution images, which were collected in 2015 and 2019 and derived from Google Earth, were used to validate the accuracy of the classification image. Data of this study also supported by Digital Elevation Model and Geological Map of Surabaya. Added, economic data, population density, ecological data, wave height and tidal data in the Surabaya region are collected to support risk analysis model.

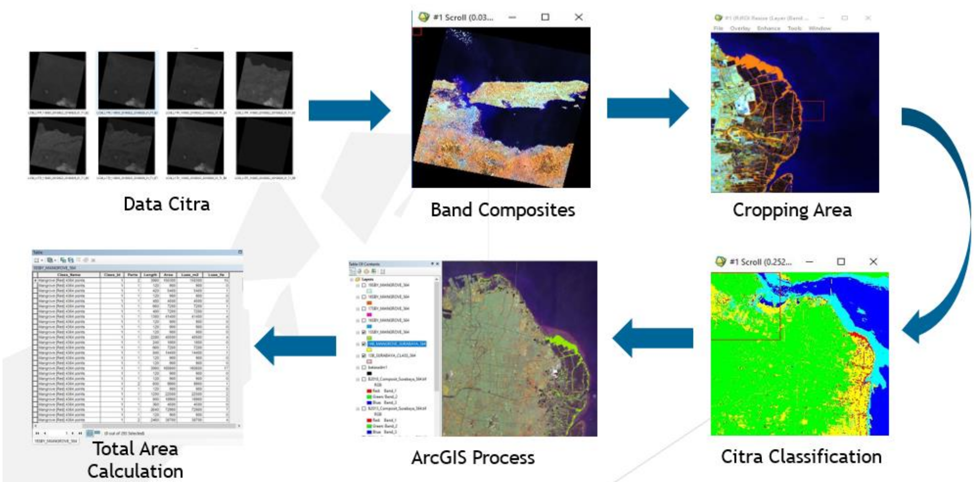


Fig. 2. Mangrove change analysis

Digital Shoreline Analysis System (DSAS)

In the analysis of shoreline changes, Digital Shoreline Analysis System (DSAS) was used in this study. DSAS is a GIS-based system invented and developed by USGS (the United States Geological Survey) [8-10]. Analysis of shoreline changes is done by three methods, namely SCE (Shoreline Change Enelope), NSM (Net Shoreline Movement), and EPR (End Point Rate). In this paper, the EPR was chosen the statistical parameters describing the spatial patterns of shoreline change [10]. EPR measures mangrove shoreline change by calculating the rate of shoreline change by dividing the distance of the mangrove shoreline between its initial (year 2015) and the last position of shoreline (year 2019).

Coastal Erosion Risk Assessment (CERA)

CERA is a tool based on geographic information systems, so it can be used in GIS software especially open source software like QGIS or it can be used on ArcGIS software [11]. CERA will help calculate vulnerability, consequences, and erosion risks that occur in an area by entering all the main parameters of vulnerability data, namely distance to shoreline, topographic maps, geological maps, geomorphological data, human activity data, waves, average tides, etc.

The CERA software will analyze the risk of erosion by looking at vulnerability assessments and assessing the consequences of existing parameters. A vulnerability map, a consequence map and a risk map are generated outputs from CERA [12].

In CERA, the risk assessment analysis is divided into 2 parts. First is the vulnerability assessment which estimates qualitatively the level of vulnerability of a coastal area to coastal erosion, where the assessment focuses on the physical characteristics of the coastal area and the potential threat to erosion. Second is an assessment of the consequences of hazard events by reviewing social, environmental, cultural and economic aspects in the work area.

For assessment weights on the consequence parameter classification tools are presented in Tables 2 and 3.

Table 2. Classification of vulnerability level parameters [13-16]

Parameters	Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
Distance to coastline (m)	>1000	200-1000	50-200	20-50	< 20
Topography (m)	>30	20-30	10-20	5-10	<5
Geology	Igneous rock	Metamorphic rocks	Sedimentary rocks	Coarse-textured sediment	Fine textured sediments
Geomorphology	mountains	Rocky cliffs	The eroded cliffs that extend along the beach	Beach tourism, plain fluvio marin	Sand dunes, river mouths, estuaries
Land cover	forest	Agricultural crops	Open field	Rural settlement	Urban settlements, industrial areas
Anthropogenic action	Coastal stabilization interventions	Intervention without reduction of sediment sources	Intervention with reduction of sediment sources	Without intervention or reduction of sediment sources	Without intervention, there is a reduction in sediment sources
Maximum significant wave height (m)	<3	3-5	5-6	6-6.9	>6.9
The maximum distance of tides (m)	<1	1-2	2-4	4-6	>6
Average level of beach erosion / accretion (m/tahun)	>0 (accretion)	(-1) – 0 (erosion)	(-3) – (-1) (erosion)	(-5) – (-3) (erosion)	< (-5) (erosion)

Table 3. Classification of the Level of Consequences [17, 18].

Parameters	Very low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
Population density (people/ km2)	500	500-1000	1000-2000	2000-4000	>4000
Economic Level (number of workers)	0	0-10	10-30	30-50	>50
Ekology	Not an ecological protection area	Strategic agricultural area	Ecological conservation area	Ecological protected area	National Parks
Historic Site	Not a historic site	There are several historic constructions	There are historic constructions and community activities therein	Regional-level historic construction	National Monument

Correlation of the level of vulnerability with the consequences according to CERA tools are given in Table 4**.**

Table 4. Matrix of erosion risk assessment using CERA [17].

		The consequences				
		I	**II**	**III**	**IV**	**V**
Vulnerability	**I**	I	I	I	II	III
	II	I	I	II	III	IV
	III	I	II	III	IV	V
	IV	II	III	IV	V	V
	V	III	IV	V	V	V

At the analysis stage using CERA, data from each parameter are classified according to tables 2-4, respectively. The data used is data collected from various sources. Furthermore, all parameters are inputted in the CERA tools for raster map operations according to the weight calculation algorithm presented by CERA.

Results and discussion

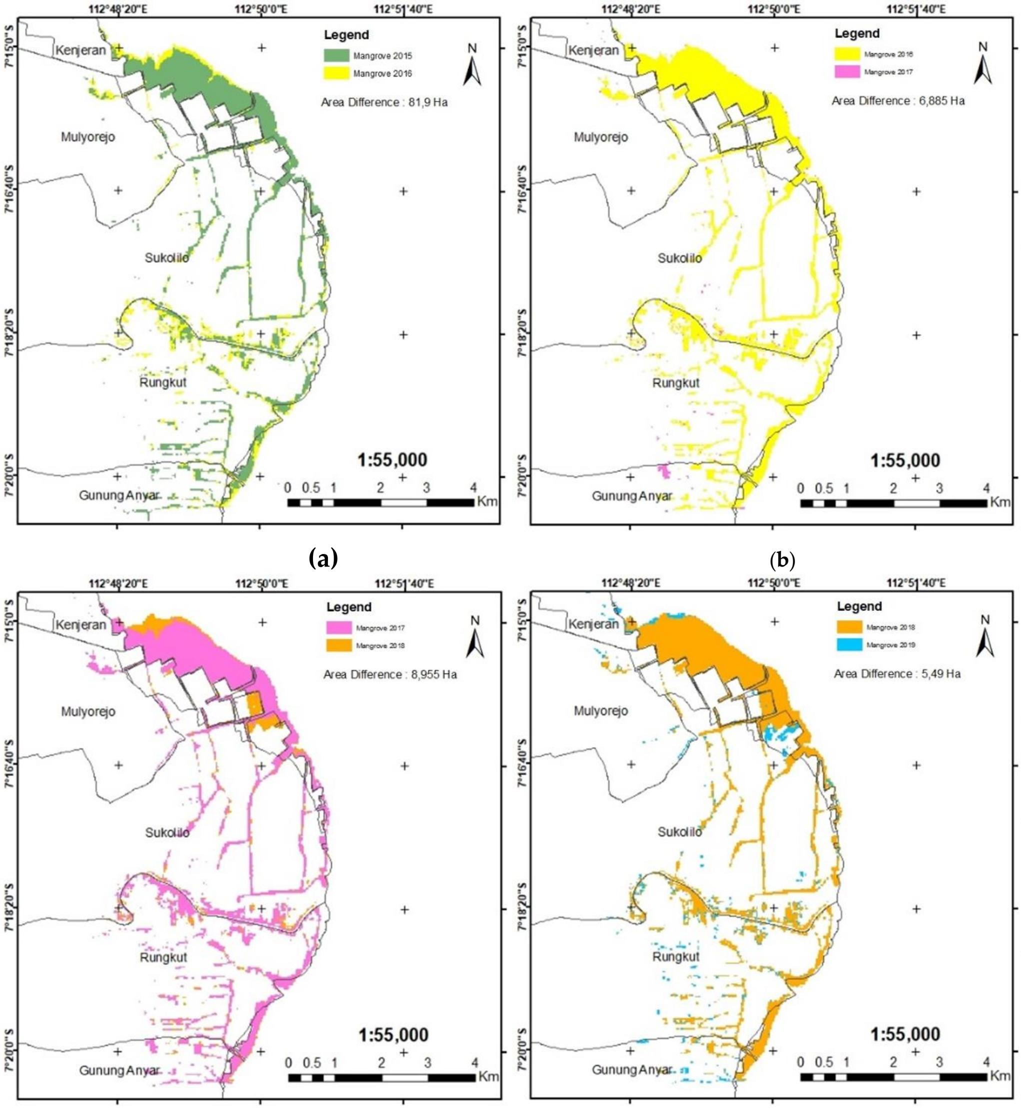
Mangrove and Coastline Change

Figure 3 presents the distribution of mangrove area in Surabaya east coast during 2015-2019. Figure 4 presents change in mangrove area based on Google Earth satellite during 2010-2019. After the results of the digitization process are formed, the mangrove area is calculated using the image processing software that produces the data in Table 5 as follows:

Table 5. Total area of mangrove for 2015-2019

No	Year	Area (Ha)
1	2015	475,40
2	2016	496,96
3	2017	490,04
4	2018	555,60
5	2019	609,88

Based on field survey [15], mangrove type in the study area are dominated by several species, including Rhizophora sp., Avicennia sp., Exoecaria sp., Sonneratia sp., Xylocarpus sp. and Bruguiera sp. as shown in figure 5.



(a) (b)

(c) (d)

Fig. 3. Figures of mangrove area distribution; (**a**) 2015 to 2016; (**b**) 2016 to 2017; (**c**) 2017 to 2018; (**d**) 2018 to 2019.

(**a**) (**b**) (**c**)

Fig. 4. Figures of change in mangrove area; (**a**) 2010; (**b**) 2015; (**c**) 2019.

In Tables 6 and 7 shows the data for total area of mangrove and shoreline changes for every district.

Table 6. Total area of mangrove for every district

No	District	2015 (ha)	2016 (ha)	2017 (ha)	2018 (ha)	2019 (ha)
1	Kenjeran	25.28	35.41	32.59	38.38	44.77
2	Bulak	68.47	49.62	25.85	36.14	61.62
3	Mulyorejo	232.52	248.64	268.12	289.69	293.6
4	Sukolilo	62.54	71.53	71.15	96.05	111.46
5	Wonorejo	62.88	66.32	62.18	69.4	72.64
6	Gunung Anyar	23.65	25.43	22.16	25.93	25.8

Table 7. Shoreline changes for every district

No	District	2015 (m)	2016 (m)	2017 (m)	2018 (m)	2019 (m)
1	Kenjeran	-	46.72	24.4	27.83	29.4
2	Bulak	-	36.16	33.98	27.61	31.85
3	Mulyorejo	-	33.3	36.53	68.96	99.84
4	Sukolilo	-	61.54	14.81	29.18	41.05
5	Wonorejo	-	45.37	18.55	25.56	32.91
6	Gunung Anyar	-	38.41	18.35	21.2	21.22

Fig. 5. Mangrove species in eastern Surabaya

The results of changes in coastline and mangrove area in Surabaya east coast from 2015 to 2019 can be seen in figure 6. In figure 6, it can be seen that the change in coastline is in line or have similar trend with the change in mangrove area. If mangrove area is decrease, the shoreline also will be retreat.

Mostly, in every district such as Kenjeran, Sukolilo, Rungkut and Gunung Anyar, the mangrove area was a decrease in 2017. In the next following year, the area was increasing again. Logging activies from local fisherman is thought to have caused this decline

But in Mulyorejo, mangrove in this area increase every year. Based on the field investigation, in this region there are mangrove planting activities were carried out by many communities in large- or small-scale group. So, it can be assumed that this can affect the addition of mangroves area at all times. Added, start 2017, the mangrove area in every district in east coast Surabaya was become an eco-tourism area and botanical garden.

Based on the analysis of the net shoreline movement on the East Coast of Surabaya using DSAS software, it is known that from 2015-2019 the largest progression was 677.64m, which was known to be in the Mulyorejo district, and the largest setback was 36.76m which was known to be at Sukolilo district. Overall, along the East Coast of Surabaya, the average coastline progress has been 27.79m.

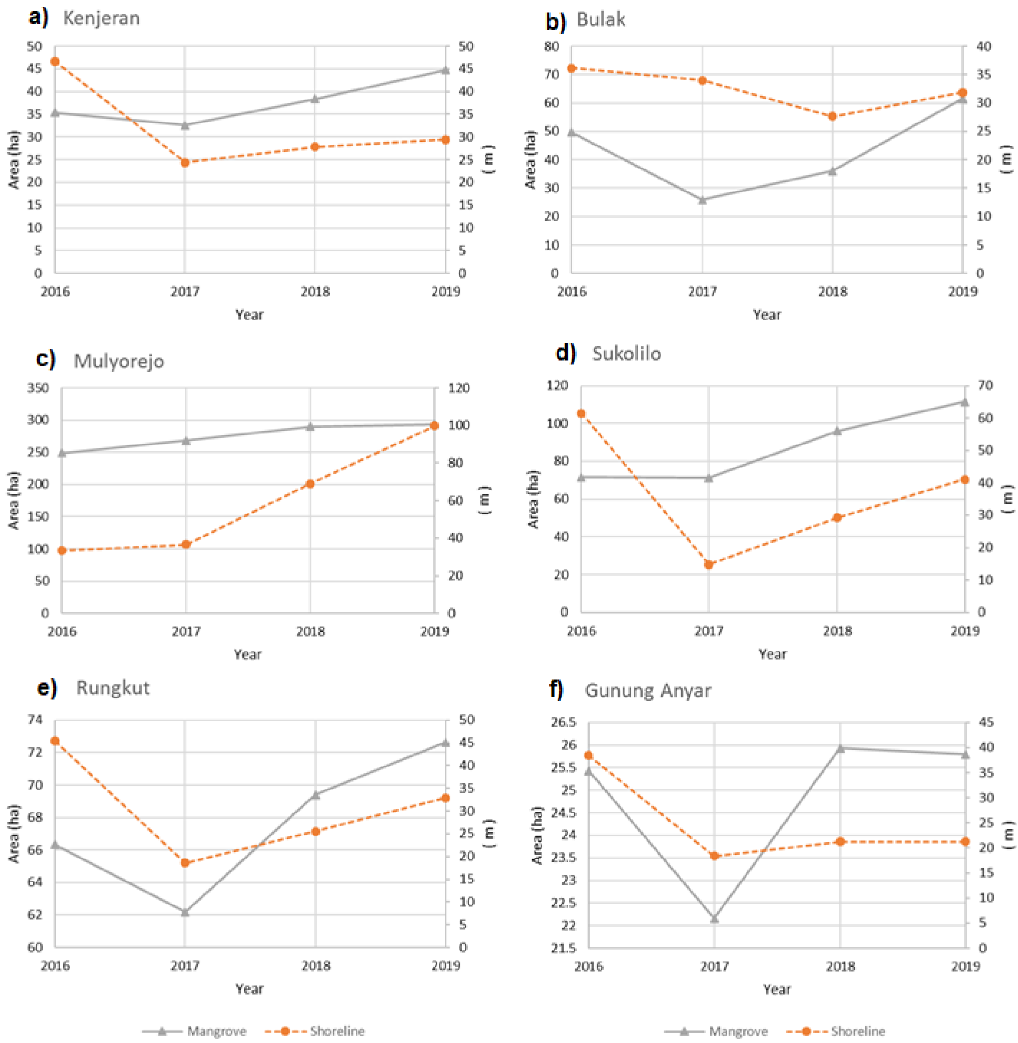


Fig. 6. Changes in Coastline and Mangrove in eastern Surabaya; (**a**) Kenjeran; (**b**) Bulak; (**c**) Mulyorejo; (**d**) Sukolilo; (**e**) Rungkut; (**f**) Gunung Anyar.

Vulnerability Analysis

The data in the analysis of vulnerability levels are first classified based on predetermined classification rules. Furthermore, all parameters can be input into the CERA application. The following parameters are used in the analysis of vulnerability levels.

Based on the results of data from the Geospatial Information Agency it is known that the highest tide distance in the East Coast of Surabaya is 2.36m in Kenjeran sub-district, 2.36m in Bulak sub-district, 2.68m in Mulyerojo sub-district, 2.70m in Sukolilo sub-district, 2.71m in Rungkut sub-district, and 2.70m in Gunung sub-district Anyar. The maximum wave height on the east coast of Surabaya is included in the very low category because the average wave height is 0.16m. Wave height data was obtained from the Geospatial Information Agency during 2015-2019 in the east coast region of Surabaya.

Topographic characteristics or land elevation in the East Coast region of Surabaya have the same characteristics because it has a land height of 2m. Topographic altitude data were obtained from the Digital Elevation Model from the Shuttle Radar Topography Mission website. Based on the analysis of shoreline changes through DSAS software, it is known that in the east coast of Surabaya it has an erosion rate of> 5m in each district. In general, the east coast of Surabaya is dominated by urbanization in the Kenjeran sub-district and Bulak sub-district. For the districts of Mulyorejo, Sukolilo, Rungkut, and Gunung Anyar are forest/pond areas. Land cover data can be seen from Google Earth.

Anthropogenic actions are actions in an effort to reduce the level of erosion and beach accretion. Google earth from Kenjeran and Bulak sub-districts is a coastline stabilization intervention area, but for Mulyorejo sub-district, Sukolilo sub-district, Rungkut sub-district, and Gunung Anyar sub-district are areas without intervention or reduction of sediment sources.

The distance to the coastline is calculated by drawing a line in the study area to the coastline using the Google Earth software. From the analysis results it is known that parameters of the coastline are classified as very low.

In general, the Surabaya east coast region is an area detected as land with fine sediments based on geological maps in Indonesia. Therefore, the geology of the research area is classified as very high. In geomorphological parameters, the study area has a different classification. In Kenjeran and Bulak sub-districts are areas directly adjacent to the coast, while the sub-districts of Mulyorejo, Sukolilo, Rungkut and Gunung Anyar do not directly border the coast.

Based on the results of the vulnerability level analysis as shown in figure 7 (left), it was found that the zones with a medium level of vulnerability in the Mulyorejo sub-district, Sukolilo sub-district, Rungkut sub-district, and Gunung Anyar sub-district. Whereas in Kenjeran and Bulak sub-districts they have a high level of vulnerability.

Consequence Analysis

The level of consequences is based on the estimated impact caused by erosion hazards in the Surabaya east coast region. The more important an area will be marked by population density, the distribution of ecological zones, the distribution of historic buildings, and economic level activities, the area has consequences for coastal erosion that will occur because it will affect the economic, social, and environmental structure in the region. The following parameters are used in assessing the level of consequences for coastal erosion in the east coast of Surabaya.

The economic level is measured based on the number of workers in a unit of land or in this analysis is the district area. Therefore, all sub-districts are classified as very high economic levels because they have an economic level of more than 480 workers/sub-districts. Where in Kenjeran sub-district has 2400 workers, in Bulak sub-district has 2276 workers, in Mulyorejo sub-district has 524 workers, in Sukolilo sub-district has 1172 workers, in Rungkut sub-district has 9272 workers, and in Gunung Anyar sub-district has 9369 workers. All data are obtained from data from BPS Surabaya City in 2018.

The level of population density is generally classified as very high in each district on the East Coast of Surabaya because the population is more than 1000 people. It is known from BPS data that in Kenjeran sub-district there are 21,034 inhabitants, in Bulak sub-district there are 5538 inhabitants, in Mulyorejo sub-district there are 6666 inhabitants, in Sukolilo sub-district there are 5062 residents, in Rungkut sub-district there are 5744 residents, and in Anyar sub-district there are 6398 residents.

High classified historical sites are found in Kenjeran sub-district, namely the Kedung Cowek Fortress historic building. In addition, in other districts classified as very low because there are no historic sites.

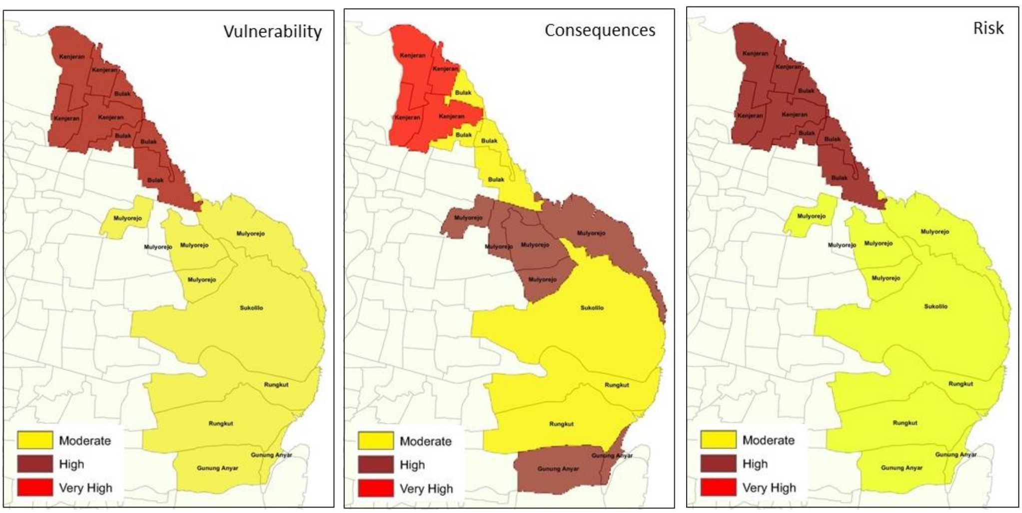
Ecological zone protection areas based on the Surabaya BLH [19] document show that in Rungkut sub-district are classified as high because the ecological protection area, in Kenjeran sub-district, Sukolilo is classified high because there are ponds and beaches, and in Mulyorejo sub-district and Gunung Anyar sub-district classified as very high due to natural zones.

Based on the analysis results as presented in Figure 7 (middle), it is known that the consequence level map has a different value distribution from the level of vulnerability because in this analysis has different parameters and different weights. The level of secondary consequences is found in the districts of Bulak, Sukolilo and Rungkut. Whereas the high level of consequences is found in Mulyorejo and Gunung Anyar sub-districts. High levels of consequence are found in Kenjeran sub-district.

Risk Analysis

Risk level analysis is the relationship between the results of the analysis of the level of vulnerability and analysis of the level of consequences to erosion in the study area. This analysis relationship is arranged in a matrix in the previous erosion matrix table. From the results of this analysis is the final result of the erosion risk assessment in the east coast of Surabaya and it will be seen that the zone or district that has a high level of erosion risk requires special attention by making it a priority area for erosion risk management.

Based on the analysis it can be seen that the level of risk of middle-class erosion erosion is found in Mulyorejo sub-district, in Sukolilo sub-district, in Rungkut sub-district, and Gunung Anyar sub-district as seen in figure 7 (right). Whereas the high classified areas are in Kenjeran sub-district and Bulak sub-district. High risk assessment in Kenjeran and Bulak Districts is due to the geomorphological parameters of the tourist beach area, land cover is rural settlements that have a very high population density, has historic construction and has a natural mangrove area so it does not have special treatment programs by the local government.



(**a**) (**b**) (**c**)

Fig. 7. Map Results; (**a**) vulnerability; (**b**) consequences; (**c**) risk

Conclusions

Based on the analysis it is known that the extent of mangroves in the period of 2015-2019 has changed every year which affects changes in coastline in the study area. From 2015-2016 there was an increase in mangrove area, but there was a decrease in mangrove area in

2017 and again experiencing mangrove area expansion in 2018 and 2019 in the east coast region of Surabaya.

Based on the analysis using CERA, the level of vulnerability and consequence indicate that the Kenjeran sub-district and the Bulak sub-district have a high risk of erosion. This condition is not only based on the extent of mangroves but is also influenced by the parameters of vulnerability and consequences used in the analysis.

Acknowledgments

The authors are grateful to RISTEK BRIN and DRPM ITS for supporting this project. This research was funded by grant number 925/PKS/ITS/2020.

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Received: October 11, 2021
Accepted: November 10, 2021