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ScienceDirect

Procedia - Social and Behavioral Sciences 135 (2014) 123 – 129

Procedia
Social and Behavioral Sciences

CITIES 2013

Sea Level Rise Flood Zones: Mitigating Floods in Surabaya Coastal Area

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Abstract

Sea level rise (SLR) brings with it a negative impact towards Surabaya's coastal area as this particular part of the city is situated only 0-3 meters above sea level. The amount of damage due to the floods indicates the city's level of readiness in facing threats from the flood. With flood height up to 90 centimeters, it is necessary to classify flood risk levels in an attempt to reduce the impact that will occur.

This paper identify sea level rise by using least square regression, which generates the trend and prediction of sea level rise. The next analysis is the identification of a potentially disaster due to sea level rise by using multinomial logistic regression. Identification of flood hazard characteristics through weighted-overlay analysis using flood height and duration as variables. It also identifies factors influencing vulnerability using Delphi analysis. AHP Expert is then employed to calculate the weight of each factor. Vulnerable zones are determined using overlay-weighted-sum on each vulnerable factor. These results are then mapped using Raster Calculator method, placing emphasis on risk functions influenced by hazard and vulnerability.

The final result is a flood risk zone map which identifies 5 risk levels according to the National Disaster Mitigation Guidance.

Peer-review under responsibility of the Cities International Seminar Committee.

*Keywords:*Sea level rise, Mitigation, Risk zone.

1. Introduction

The increase of human activity, especially in the transportation, industry, building construction and human activities affect global climate change marked with an increase in Earth's average temperature from year to year.

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Peer-review under responsibility of the Cities International Seminar Committee.
doi:10.1016/j.sbspro.2014.07.335

Based on research by WWF, Indonesia has an increase in temperature by 0.3 ° C since 1990 and climate change scenarios conducted by WWF Indonesia and the IPCC reported that the temperature will increase by 1.3 ° C to 4.6 ° C in 2100 with the rate by 0.1 ° C to 0.4 ° C that will lead to the sea level rise by 20 - 100 cm in 100 years. The rising of sea level (sea level rise) causes some islands and places lower than sea level in potentiall disaster, which is the fact that in coastal areas.

Surabaya, the second largest city in Indonesia as well as the capital of East Java province, is coastal city that has a delta system in coastal morphology and topography is located on low (average 0-6 meters above sea level) with an average slope <3 % (RTRW Surabaya). P3O-LIPI investigators (1991), meiviana et al (2004) in Proceedings of the National Seminar on Serealia (2009) and workshop proceedings (2010) showed the rate of sea level rise on coastal Surabaya as high as 5.47 mm per year, calculated in the period of 64 years (1925-1989), where the presence of sea level rise brings up the height of tide gauges. Based on data BMKG Maritim Tanjung Perak, Surabaya city was flooded due to the tide height between 150-170 cm above sea level. The followig impact due to sea level rise are the changes of coastal conditions, the increased erosion, the faster the damage to the buildings and the disruption of people's activities such as housing, industry, agriculture and others. Generally the extent of the damage occured will depend on the level and type of area edge of water used (UNDP, 2007).

2. Overview of Floods in Surabaya Coastal Area

Surabaya is located in south latitude and east longitude between 7°12' s.d 7°21' South latitude dan 112°36' s.d 127°54' east longitude. The study area is sub-districts located in the Coastal city of Surabaya. Based on data from the Maritime BMKG Surabaya, 2011 The average maximum height of tide in coastal areas Surabaya is 150-170 cm above sea level and shows a significant rise of sea level rise in surabaya approximately 4.8 mm / year. Here is portraits of flooding due to tides in coastal areas Surabaya.

3. Analysis

Preparation of the risk zone map is one of the mitigation as a result of non structural sea level rise so as to position the community at different levels of risk. here are the steps in the formulation of the risk zone.

3.1. Identification of Sea Level Rise

From the results of tidal analysis based on data per hour tidal Bakosurtanal of 20 years, with a datum Tanjung Perak Surabaya, dated January 1, 1984 to 31 December 2004 Surabaya tidal conditions are included tidal mix-leaning daily double (mixed tide prevelailing semidiurnal tide) which occurs twice a day ,twice as a high tide and twice as a low tide, but has a different height and periods. This type of tidal maters occurs a lot in the eastern Indonesiaobtained predictions of sea level rise trend,as follows:

Table 1. Prediction of Trend Sea Level Rise

No	Tides	Trend of Sea Level Rise	Sea Level Rise (mm/years)	Positions of Sea Level Rise (m)			
				2010	2050	2080	2100
1.	MSL	Y= 1.49737+0.0003x	4 mm/th	1.558	1.732	1.84	1.912
2.	M2	Y = 0.3158+0.0001x	1 mm/th	0.3471	0.3962	0.4311	0.455
3.	S2	Y= 0.3158+0.0001x	4.8 mm/th	0.325	0.515	0.659	1.038
4.	HHWL	Y=2.8308+0.0004x	4.8 mm/th	2.956	3.148	3.292	3.388

Source : analysis result, 2012

Table 2. Prediction of Sea Level Rise until 2100

No	Tides	Trend of Sea Level Rise	Sea Level Rise (mm/years)	Positions of Sea Level Rise (m)			
				2010	2050	2080	2100
1.	MSL	Y= 1.49737+0.0003x	4 mm/th	0.094	0.238	0.346	0.418
2.	M2	Y = 0.3158+0.0001x	1 mm/th	0.031	0.080	0.115	0.139
3.	S2	Y= 0.3158+0.0001x	4.8 mm/th	0.125	0.317	0.461	0.840
4.	HHWL	Y=2.8308+0.0004x	4.8 mm/th	0.125	0.317	0.461	0.557

Source : analysis result, 2012

The trend of sea level rise above, shows an increase in sea level rise of 4.8mm / year. This can result in a serious danger because the topography is quite low in ranges from 0-3m above sea level.

3.2. Identification of a disaster due to sea level rise

The analysis phase is aimed to look at the influence of sea level rise on society and explain whether the disasters arereally occurred or not in the study area. This analysis uses the research variables consisting of two variables, namely the response variable (Y) is the flood due to sea level rise, sea water intrusion, and erosion caused by waves piling up water. and the predictor variable (X), the drainage network disruptions, the damage to the coastal environment, and an increase in mass of sea water. Here are the steps to find out the disasters caused by sea level rise on coastal areas Surabaya:

Validity test is used to test the suitability of the variable with the attributes of the questionnaire prior to analysis, data are grouped based on the criteria of each question. Here is a validity test result data:

H0: The data has a relationship

H1: Data not related (independent)

H0 is rejected if the correlation is less than 70%

Table 3. Output Validity Test

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
Factors Correlation	0.92	0.88	0.83	0.76	0.76	0.78	0.74	0.85	0.93	0.94	0.73	0.78	0.75	0.89

Source : analysis result, 2012

Reliability test is a test to determine the reliability of the data can be trusted in order to detect any manipulation of the observer. In this study, the reliability of test used is the spearman born. Data is said to be reliable if R obtained R is greater than 80%. Because of the R value above 80%, then it can be stated that the data reliably in accordance with the historical because it shows the confidence level of 97.7%. So that could be done further analysis.

Multinomial logistic regression analysis is used to determine the effect of predictor variables on the response variable. Multinomial regression is used because there are three kinds of response variables, but the response variable does not have different level.

Hypothesis :

H0 : $\beta x_1 = 0$, drainage disturbance variables has no effect on the incidence of disaster due to sea level rise

H1 : $\beta x_1 \neq 0$, drainage disruption variable effects on the incidence of due to disaster sea level rise.

significance level:: $\alpha = 0.05$

Critical areas: Reject H0 if the values W2 (Wald) > $\chi^2_{(df,\alpha)}$ or P-value < α

From theabove tableit can be seenthattheP-value valued at0.018. The valueP-value <0.05 alphathenrejectH0, so thatit can be concludedthat theeffectof drainagedisruptiondue tothe disasterdue tosea level rise.

3.3. Identification of a disaster due to sea level rise

Flood hazard zones due to sea level rise illustrates the level of flood hazard zone in accordiance with the level of hazard from highest to lowest. Flood hazard zones derived from the overlay pool of variable height and duration of inundation. The method of analysis used in determining the level of flood hazard due to sea level rise that is by using Weighted Overlay. Each variable will be made in accordance with the hazard map data already existed and are regrouped into 5 classes. From both of these variables will be found each map and then overlay with weights on each map is 1.

3.4. Determining of influential factors of vulnerability

In analyzing the factors that influence vulnerability to floods due to sea level rise on coastal areas Surabaya analyzer using Delphi as a fixation of the factors that affect vulnerabilityand then weight factor will be determined using the AHP. where the weights are used to pmbuatan vulnerability zone maps.

With the acquisition of the weighting in each of the determinants of vulnerability assessment of flooding due to sea level rise, the next stage wighted overlay analysis using ArcGIS 9.3 sum to determine the zoning on the level of vulnerability of coastal areas Surabaya. Here is a map-making stage Vulnerability Zone.

Making a map based on sub factors affecting vulnerability of flooding due to sea level rise. wherein each of these maps will be classified into five classifications based on the Guidelines on Control of Flood Prone Areas is

- Not vulnerable
- Slightly Vulnerable
- Quite Vulnerable
- Vulnerable
- Highly Vulnerable

for such classification, the data will be compared between each existing Sub factor with the applicable standards or Surabaya in Indonesia. For example, for Sub topographic factors:

Table 4. Clasification Class of Topograpgy Based on Vulnerability Level

Factors	Scale	Classification		Explanation
Topography of the land	>15m	Not vulnerable	1	Description of scale using the standard issue by the department of marine and fisheries, 2004
	10m-15m	Less vulnerable	2	
	5m-10m	Quite vulnerable	3	
	2m-5m	Vulnerable	4	
	0m-2m	Highly vulnerable	5	

Source : analysis result. 2012

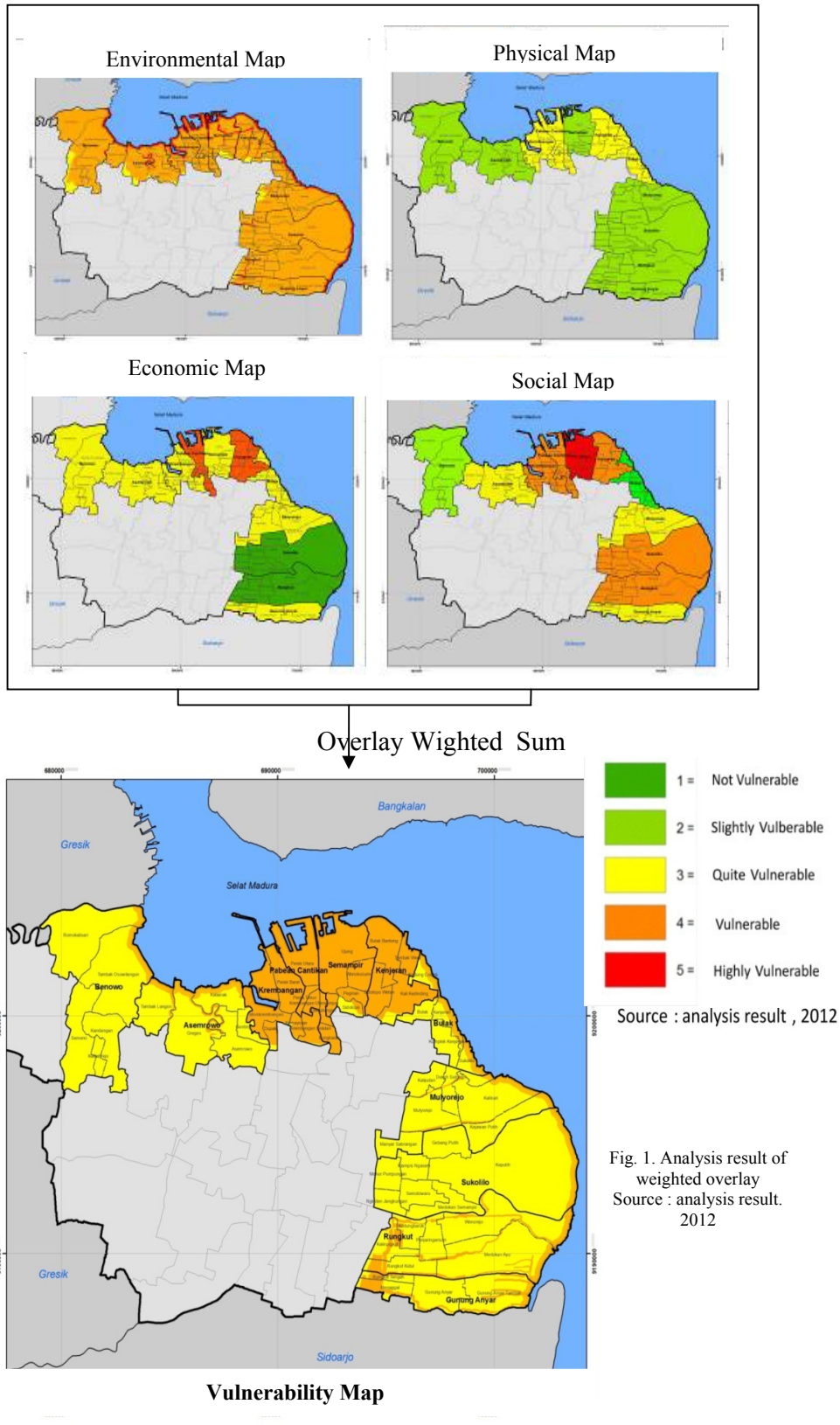
Based onexistingdata, SurabayaCoastal Zoneis Locatedon the topographywith a height of0-6meters. Therefore, whenit is comparedwiththe tableit was found thatthe topographyinSurabayaCoastal Zoneis divided intothreeclasses, namely:

- 0-2 meters (5 Classification or highly vulnerable)
- 2.1 to 5 meters (classification 4 or Vulnerable)
- 5.1 to 10 Meters (3 or fairly susceptible of classification)

From the division it will be created maps using ArcGIS 9.3. From this stage we will get a map of each sub factor. The following are the results topographic factor maps

- Having obtained a map of each sub-factor, then create a map Based on factors that influence susceptibility flooding due to Sea level rise using the overlay ArcGIS 9.3 and the weights of the AHP. Where there are 4 flood vulnerability factor (Guide Introduction Characteristics of Disasters in Indonesia and mitigation, 2005) that environmental factors, physical factors, social factors and economic factors. For example, to physical factors.

- Having found each of the four maps, all four maps will be in use arc gis overlay with weights that have been obtained from the analysis of AHP to obtain Flood Vulnerability Due to Sea Level Rise map. The following is a formulation of the vulnerability map.



Vulnerability Map

Fig. 1. Analysis result of weighted overlay
Source : analysis result. 2012

Conclusion

Spatial distribution of the hazard rate (hazard) of floods due to sea level rise on coastal areas Surabaya is a whole sub-districts which are along the coast. Districts that have the highest level of flood hazard area due to sea level rise sre Mulyorejo District, Kenjeran District ,Bulak District.

Spatial distribution of zones level of floods vulnerability due to sea level rise on coastal areas along the coast of Surabaya, the areas at the highest level of vulnerability are the District Krembangan, Pabenancantikan, Semampir and Kenjeran.

Spatial distribution of zones of of floods risk level due to sea level rise on coastal areas along the coast of Surabaya in Surabaya, the areas at highest risk are Krembangan District, District and Sub Asemrowo Bulak.

Influential factor in the formulation of of floods risk zones due to sea level rise in coastal areas Surabaya is the height of the flood, flood duration, Replace sea water, rainfall, distance to the river Proximity, Proximity distance to the coastline, the height of topography, soil type, Tata order land, density of buildings, road networks, population density, population growth rate, elderly + toddler (aged vulnerable), household sector working farms and the number of poor households.