Prediction Of Sea Level Rise Impacts On The Coastal Areas Of Surabaya Using GIS

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---ABSTRACT---
This research was conducted to predict the impact of sea level rise in coastal areas of Surabaya. The method used is the field survey and methods of Geographical Information Systems (GIS). The results indicate that the impacts of sea level rise of 1 m is going to inundate coastal areas in Surabaya area of 4,902.06 ha (15.02 %), in ten coastal districts. The largest impact is in the district of Gunung Anyar which is expected to inundate the tourist areas of mangroves.

KEYWORDS: *coastal zone, GIS, inundation, impact, sea level rise.*

I. INTRODUCTION

Coastal Zone is an area of transition between terrestrial and marine ecosystems are affected by changes in land and sea [1]. This region is highly vulnerable to environmental pressures from land and sea. One of the pressure that slowly but surely in all parts of the world is the existence of sea level rise in coastal areas.Sea level rise is one that definitely impacts the process of global warming. Based on the IPCC (Intergovernmental Panel On Climate Change) report that - average global surface temperatures increased from 0.3 to 0.6 $^{\circ}$C since the late 19th century and until the year 2100 the earth's temperature is expected to rise about 1.4 to 5.8 $^{\circ}$C [2,3]. Rising global surface temperature causes melting of ice in the north and south poles of the earth and become involved in sea level rise. It is estimated that from 1999-2100 the next year sea level rise of about 1.4 - 5.8 m [3].. Some indications of the rising sea level include rising coastlines, coastal areas are increasingly reduced, the loss of mangrove forests and the erosion and sedimentation.

Currently, sea level rise is very interesting to be discussed because of its potential impact on existing residents in coastal areas and islands. In Indonesia, about 65% of the population live on the beach. Therefore, the impact of sea level rise is very influential on housing and livelihoods. Livelihood is related to several sectors, including: fisheries and marine, transportation / seaport, marine tourism.Regional Municipality of Surabaya is in a part of low-lying areas with an average height of 3-6 meters above sea level [4]. Hilly area in the southwestern part of town that is at Bukit Lidah and Bukit Gayungan with a height of 25-50 meters above sea level. The total area of Surabaya Municipality is 32,639 hectares which is divided 28 districts (kecamatan) and 163 villages (kelurahan).

By looking at the topographical conditions in Surabaya, the impacts of sea level rise in the city of Surabaya will directly affect the low-lying areas located in those coastal areas. Therefore restriction area which will be further reviewed focused on those coastal areas. The purpose of this study was to (1). determine the extent of coastal areas of Surabaya are affected by the rising sea level using GIS technology and the projected impacts, (2). identification of coastal resources that will be affected.
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II. RESEARCH ELABORATIONS

Research carried out for 6 months. Location of the study is the Coastal region of Surabaya in East Java in position 7°12' - 7°21' South Lattitude and 112°36'- 127°54' East Longitude. Materials or data used in this study include: (1). Topographic maps scale 1: 25.000, (2). Thematic Mapper satellite imagery of Surabaya 29 - 03 – 2004, (3). HGT-SRTM (Shuttle Radar Topography Mission) data, dated 23-11-2004 at 2:58 with WGS84 projection.

The instrument used in data processing are: GPS (Global Positioning System) Garmin equipment, A set of tidal measurement tools, Computer/laptop Toshiba, Software, among others: Arc view 3.3., Global Mapper 7.0 and Image Analysis 1.1. The research method used in this study included a survey method and GIS analysis. In summary, this study flow diagram is presented in Fig (1).

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│            Sea Level Rise            │
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                   ▼
┌─────────────────────────────────────┐
│  Data :                             │
│      -   Tidal, Satellite Image,    │
│      -   Map of Topography          │
│      -   Shorelines, Contours       │
│      -   Landuses                   │
│      -   Coastal resources which are│
│          affected                   │
└─────────────────────────────────────┘
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│  Digitation, Data Analysis using GIS │
│              technology              │
└─────────────────────────────────────┘
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┌─────────────────────────────────────┐
│   Map of Coastal Zones which are    │
│     affected by Sea Level Rise      │
└─────────────────────────────────────┘
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┌─────────────────────────────────────┐
│  Prediction of the SLR impacts on The │
│            CZ of Surabaya            │
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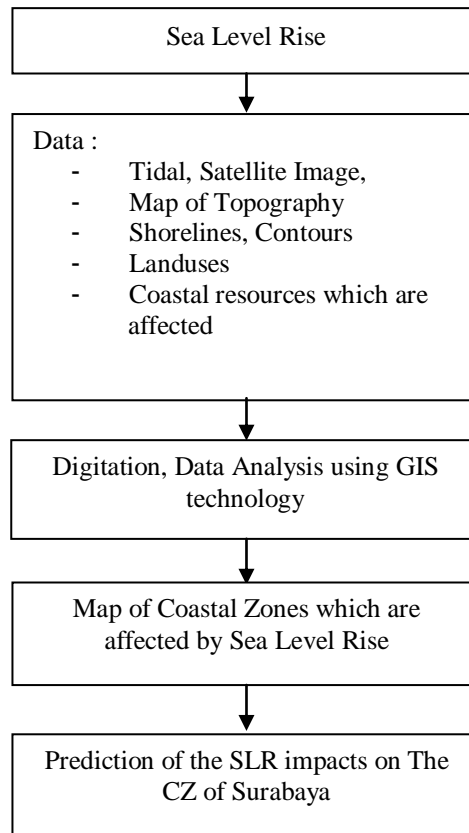
Fig (1) : Flowchart of Research Methods

2.1. Tidal analysis method

The material examined in this study includes the tidal data in waters of Surabaya for 20 years. Tidal data collection aims to obtain information about the development of mean sea level position on the waters of Surabaya. Tidal data collected are secondary data. The data are daily tidal data in the waters of Surabaya in December 2010.

Method of tidal observations carried out with direct observation. Reading the scale on the exposed tidal signs or coincide with sea level at any given time period.Calculation method used for ocean tides closely related to the purpose of observation, namely to determine the Mean Sea Level (MSL) daily, monthly, yearly or other. In general, known as two ways for calculating the tidal data, namely: (1). Conventional ways, namely by taking the average value of all observation data, where the value is stated position of MSL, (2). Methods Admiralty, where sea surface average is obtained by calculating the tidal constants. The data are analyzed by using the method of Admiralty 29 days so that the end result will be known the components of the induced tidal in Surabaya waters that can be used to determine MSL, LLW, HHW values and types of tides.

2.2. Analysis Method of Geographical Information Systems (GIS)

Spatial data / spatial processed using the software Arcview 3.3 and Global Mapper 7.0. In principle, processing of data with geographic information system (GIS) are data entry, data analysis and data display. Data entry associated with spatial data and tabular (textual) data. Spatial data is created through the scanning, digitization, or import data from existing digital maps. Textual data entry will follow the spatial data. After data entry, the next step is to process the spatial data as needed, for example: overlaying, buffering, computation of area. The last step is to view data. Display the data could be maps, graphs, tables or storage into electronic media, such as multimedia.

Some of the important spatial data processing operations used in this research is the process of digitizing maps, the process of overlaying, area calculation, the determination of slope of the beach and creating maps. For the determination of contours and bathymetry is used Global Mapper 7.0 software with the stages of the process as follows: (1). Opening the Global Mapper 7.0 software by executing the file Global Mapper 7 on windows start menu (with notes software Global Mapper 7 already installed), (2). Open a file by selecting "Open Your Own Data Files" and select the data files in the appropriate directory, eg: SRTMPlus directory, (3). Determining the file to be opened, in this case and e100n40 indonesia.bil file and choose the type of overlay (select an overlay type) are appropriate, namely: HGT-SRTM (Shuttle Radar Topography Mission) and the computer will open the grid elevation, (4). Using the tool bar zoom-in and pan to get the appropriate area, in this study area, (5). Using the tool bar Path Profile / LOS (line of site) to make the trajectory slope pantai.dengan place mouse point on the map and draw a line, (6). Right Click, beach slope profile will be demonstrated at the designated position and then the slope of the beach can be determined based on the profile slope of the beach, which is tan θ, (7). Contour is determined by "Generate Contours" from the File menu. "Contour Interval" is set 1 meter Contour Bound and determined "All Visible on Screen". The results will be obtained on the screen by pressing the OK button, (8). Results contours shapefile exported to a file to be processed into ArcView 3.3. Furthermore shapefile file is ready to be combined with another shapefile files, such as roads, rivers, sub-district boundary.

III. RESULTS AND DISCUSSION
3.1. Mean Sea Level and Tidal Type in Surabaya

Measurement of tidal sea conducted in the Village Nambangan, Kenjeran Surabaya, Location of the geography and topography profiles in Surabaya waters transversely from the shoreline towards the sea is relatively very gentle slope with a ratio of 1:277 meters and it is 0,206 degree. Fig (2) displays the location of the position beacon tidal sea.Water level observation data every hour for 15 days, producing a sea tidal graph shown in Fig (3). Judging from the graph, then the type of sea tides in Surabaya area is a mixture tends to double daily.
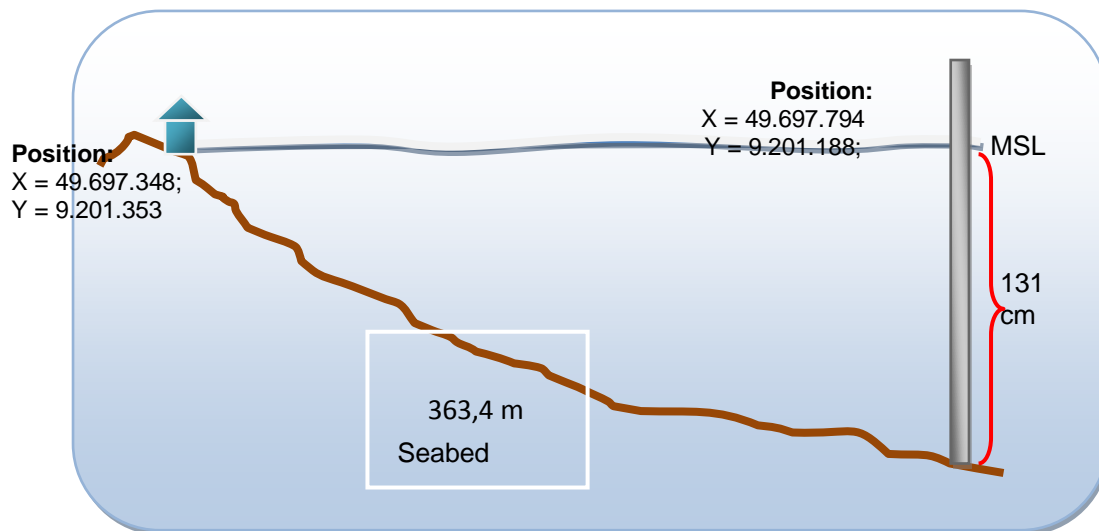

Fig (2) : Ilustration for determining Mean Sea Level

Sea tidal data processing to obtain constant (constant) harmonic tidal sea based Admiralthy Method has been done with the following results:

Table (1) : Harmonic Constants of Tides

Constants	S_0	M_2	S_2	N_2	K_1	O_1	M_4	MS_4	K_2	P_1
A (cm)	131	68	24	73	54	4	4	1	6	18
g^0	-	356	118	279	124	55	63	279	118	124

Based on Table (1), the calculation result of Formzhal value is 0.62. This value means that the type of sea tides indicates the category of a mixed semi-diurnal. This shows the correspondence between the calculations and the

graphs. Calculation of Mean Sea Level in the range of 129.5 cm, whereas from Table (1) obtained information on the calculation of mean sea level is 131 cm and its tidal range is 271 cm.

3.2. Global Sea Level Rise, Causes and Effects

Due to various human activities, carbon dioxide (CO_2) and greenhouse gases accumulating in Earth's atmosphere, resulting in climate change. Increase the volume of sea temperature rise in two ways. First, melting of polar ice mass in the region and secondly, it causes thermal expansion of sea water. Wigley and Raper [5] *in* [6] states that the relative contribution of thermal expansion and melting ice caused sea level rise is uncertain and estimates vary widely.
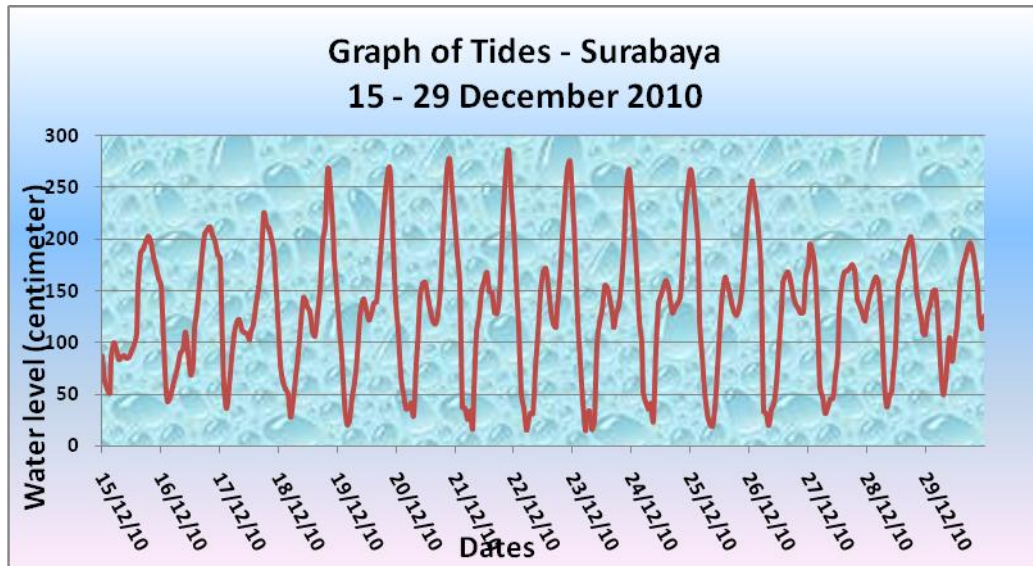
Fig (3) : Graph of Tides

Human factors that cause global warming and sea level rise is the burning of fossil fuels. Forest logging is a human activity. Miller [7] states that, 75% of human-caused CO_2 emissions since 1980 is due to burning of fossil fuels and the rest is the result of logging, agriculture and other human changes in land use. The two biggest contributors to CO_2 emissions currently are burning coal and industrial plants and more than 700 million gasoline vehicles (555 million out of the car). CO_2 emissions from U.S. coal burning and industrial plants alone exceeds the combined CO_2 emissions of 146 countries, which contain 75% of the world's population [7]. Predicted impact of global warming by the IPCC (Intergovernmental Panel on Climate Change) by using several approaches, such as: models, scenarios. Scenarios are used to illustrate the impacts that would occur if certain assumptions are used.

The IPCC has two main scenarios, namely: (1) CO_2 emissions will continue to increase until two times in 2030. Increasing world population will also increase emissions dinitroksida and methane, (2). Specification of each scenario. The specification has resulted in rapid sea level rise scenario, medium and slow.

Predicted sea level rise for the future based on the condition of sea level rise at this time. Fig (4) shows the sea level change are taken from the tidal record annual 23 [8].
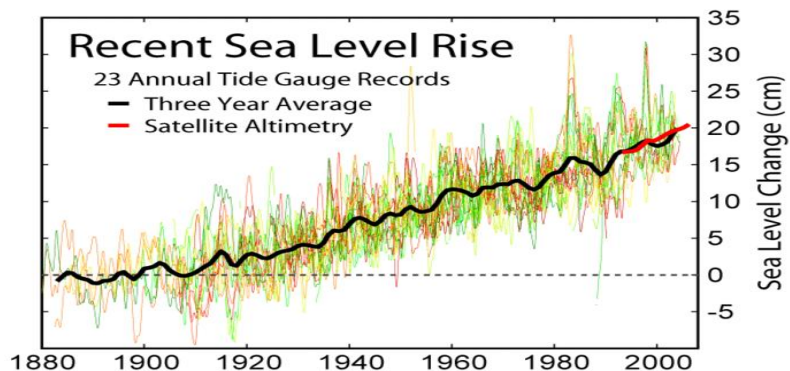

Fig (4) : Record result in Sea Level Rise (Source : Susandi A. [8])

In 1990, the Intergovernmental Panel on Climate Change (IPCC) estimates that 3.3 ° C rise in global temperatures in 2100 with the uncertainty of 2.2 to 4.9 ° C. Changes in global temperatures like that, occurs naturally during the 10,000 years. IPCC estimate of global sea level rise from 1.0 to 2.0 mm / year over the last century. With high global temperatures increase, sea level will rise at a faster rate 2-6 times that of current conditions [9]. Wigley and Raper [5] estimates that greenhouse gases contribute to the thermal expansion of sea level rise between 1880 and 1985 is 2 - 5 cm and for the period 1985 to 2025 estimates of greenhouse gas warming is estimated to 0.6 to 1.0 °C. The resulting thermal expansion would raise sea level by 4-8 cm. Nicholls *et al.* [10] estimates that by 2080's, sea level rise can cause loss of up to 22% of coastal wetlands in the world. When combined with other losses due to direct human action, up to 70% of the world's coastal wetlands could disappear by 2080's. The IPCC estimates that sea level rise would be 66 cm in normal conditions in 2100 with various uncertainties of 13 to 110 cm (Table (2)). Several scenarios [11], the mean global sea level rise in 1990 to 2100, including a direct effect of sulphate aerosols are shown in Fig (5).

Table (2) : Scenario of Global Warming (GW) and Sea Level Rise (SLR)
(Source : Sarwar, G.M. [6])

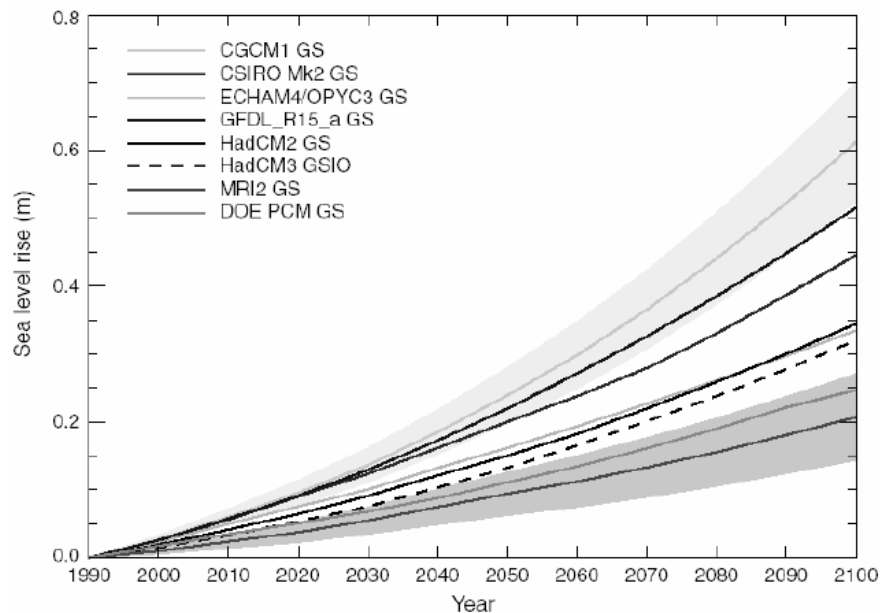| Model Assumption	GW Scenario by year (^{0}C)				SLR Scenario by year (cm)			
	2010	*2030*	*2050*	*2100*	*2010*	*2030*	*2050*	*2100*
Low	0.3	0.7	1.2	2.2	4	8	15	31
Business-as-usual	0.5	1.1	1.7	3.3	8	18	30	66
High	0.7	1.5	2.5	4.9	13	29	48	110
Source	Bretherton et al., 1990; Cited in Warrick et al., 1993				Warrick and Oerlemans, 1990; Cited in Warrick et al., 1993			

Fig (5). Global sea level rise in 1990 to 2100 (IPCC, 2001).

The impacts of sea level rise experienced by each country differ. Broadly speaking, the impact is illustrated in Fig (6) below. Impact on loss of dry land and wetlands and greater transfer of population would be experienced in developing countries than in developed countries so that the costs required to overcome this is also comparable with the impacts.

3.3. National and Regional Sea Level Rise

Projected sea level rise in Indonesia have been done by Susandi [8]. The projection shows the Indonesian territory experiencing loss of lands due to sea level rise. For the years 2010, 2050, and 2100, the projected land area lost consecutive area of 7408 km2, 30,120 km^2 and 90,260 km^2.
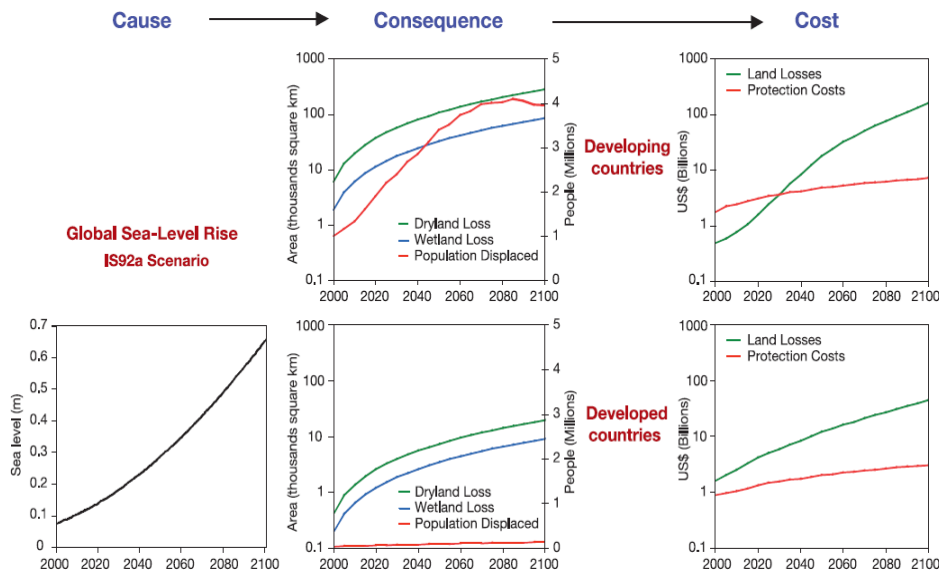

Fig (6) : Cause, consequnece, and cost of the impact of sea level rise.

In the Asia Pacific region, sea level rise as high as 5 meters is presented in Fig (7) by CRESIS Haskell Indian Nations University. Inudated areas are expressed in red. Indonesia is wide enough affected by sea level rise as high as 5 meters, especially Papua, Sumatra and Kalimantan. In Java, the Surabaya areas of SLR impacts look obvious.

3.3. Impacts of Sea Level Rise in the Coastal Zone of Surabaya

Assuming there is an increase of 1 meter sea level, coastal areas of Surabaya will be affected directly on the ten sub-districts, namely: Benowo, Asem Rowo, Krembangan, Semampir, Pabean Cantikan, Kenjeran, Mulyorejo, Sukolilo, Rungkut and Gunung Anyar. These sub-districts will be affected because they are directly in contact with the sea.
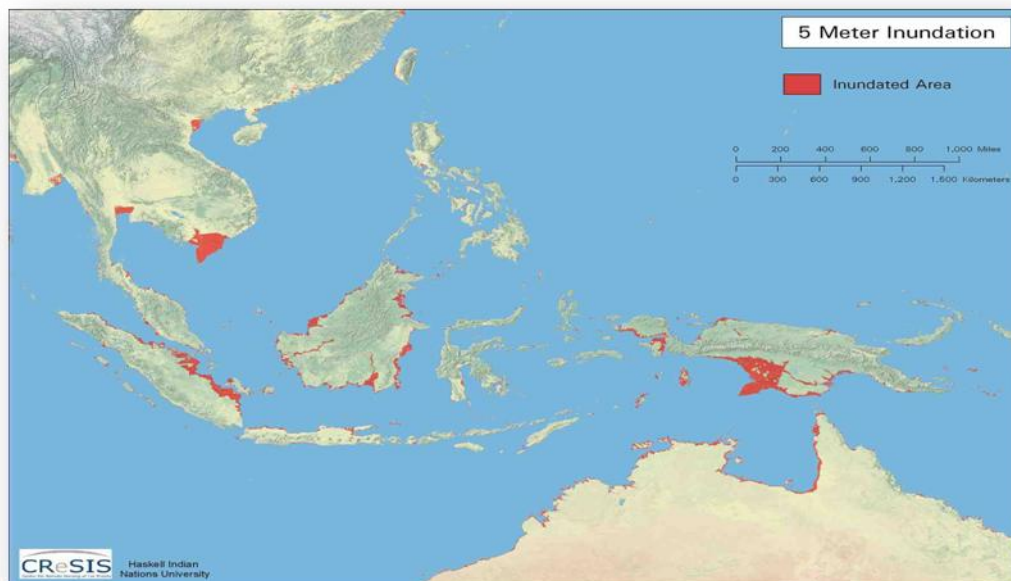

Fig (7) : Sea level rise for 5 meters in the Asia Pasifik zones
(Source : CRESIS Haskell Indian Nation University).

Risk areas to the effects of sea level rise can be seen in the satellite images presented in Fig (8). The area was determined based on the contour map that is derived from SRTM data in 2004 are presented in Fig (9). The impact-risk areas are part of the coastal district.

The population of Surabaya from the registration of December 2007 approximately 2,861,928 inhabitants [13]. Average population growth is 1.2% per year. Districts in the coastal region has a low enough density, the lowest is 8 people / Ha. Coastal districts have a relatively high growth compared to other districts in the region. As an illustration, the number of residents in the coastal district of Surabaya in 2010 amounted to 960,714 people, with details of the districts (kecamatan) : Benowo, Asemrowo, Krembangan, Semampir, Pabean Cantikan, Kenjeran, Mulyorejo, Sukolilo, Rungkut, Gunung Anyar respectively are as follows: 47,686 people ; 39,082 people; 123,017 people; 195,137 people; 91,308 people; 131,723 people, 103,217 people, 81,663 people, 98,457 people, 49,424 people [13].
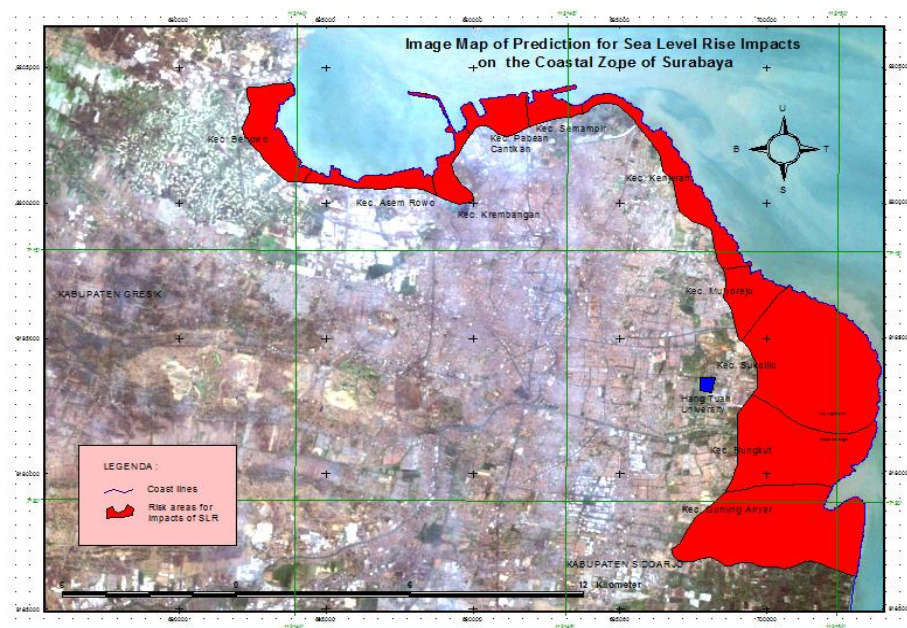

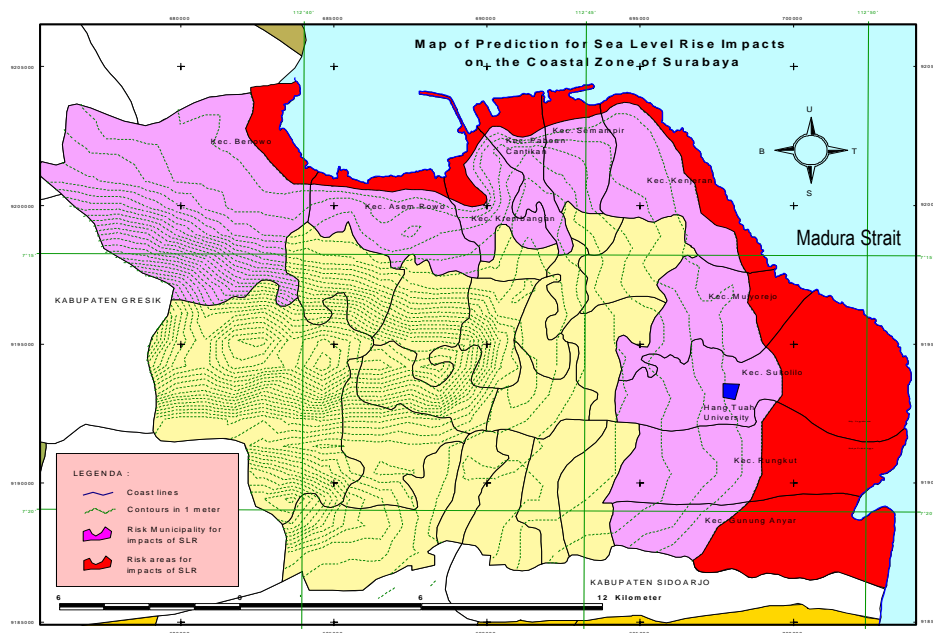Fig (8) : Map of satellite image and impact risk areas of sea level rise.

Fig (9) : Map of contours and risk areas of the sea level rise impacts

Coastal villages potentially affected directly is Romo Kalisari and Tambak Oso Wilangun (District of Benowo), Tambak Langen, Greges and Kalianget (District of Asemrowo), Morokrembangan and Perak Barat (District of Krembangan), Perak Utara dan Perak Timur (Kecamatan Pabean Cantikan), Kedung Cowek (District of Kenjeran), Dukuh Sutorejo, Kalisari and Kejawen Putih Tambak (District of Mulyorejo), Keputih (District of Sukolilo), Medokan Ayu and Wonorejo (District of Rungkut), Gunung Anyar Tambak (District of Gunung Anyar).

Livelihoods in coastal areas have the main livelihood in the marine fisheries sector, namely as sea fishing, fish ponds / shrimp farms, salt production and boat rentals. The limited capital and skill factors are constraints in developing business. In addition, narrower pond lands are also constrain for business of some communities. These communities are classified as low-income communities where the average income per month of about 150,000, - sd Rp. 450.000, - [4] is only sufficient for basic needs of clothing, food, shelter and educational needs and family health.

The condition of this population to be exposed to direct impact on sea level rise. These impacts ranging from where he lived up to his livelihood because of life and the workings are very dependent coastal areas.Some coastal resources (objects) which affected the sea level rise is the tourist area of mangrove, coastal resorts, Tanjung Perak cape harbor, salt ponds, industrial and residential areas. In detail, the object affected is presented in Table (3).

Table (3) : Coastal resources which are in risk of 1 meter SLR impacts.

No	Sub District (Kecamatan)	Coastal resources	Impact Areas (Ha)
1.	Benowo	Salt ponds, Industry areas	427.89
2.	Asemrowo	Salt ponds, Settlements	216.17
3.	Krembangan	Ports, Settlements	206.74
4.	Semampir	Settlements	249.75
5.	Pabean Cantikan	Settlements	163.85
6.	Kenjeran	Tourism regions, Settlements	505.61
7.	Sukolilo	Mangrove regions, Settlements	313.38
8.	Mulyorejo	Settlements	177.03
9.	Rungkut	Mangrove tourism regions and Settlements	1054.78
10.	Gunung Anyar	Mangrove tourism regions and Settlements	1587.40
		Total	4902.60

Effect of sea level rise in Surabaya will also result in impacts on socio-economic conditions, among others, ie.: (1) Loss of property, especially in densely populated northern section, as in the Districts of Asem Rowo, Krembangan, and Semampir; (2) Lost and coastal habitats in the eastern part, especially in particular mangrove conservation area, in the District of Gunung Anyar Rungkut; (3) The risk of increased flooding in the Districts of Krembangan, Kenjeran, and Sukolilo; (4) Loss of coastal resources, such as mangroves, ponds in the Districts of Rungkut and Gunung Anyar; (5) Loss of function of tourism and recreation in the Districts of Kenjeran and Rungkut and Gunung Anyar; and (6) Impact on agriculture and fish farming as a result of land degradation and water.

IV. CONCLUSION

From this research, it can be concluded and recomended, as follows : (1) The impact of sea level rise of 1 m is predicted to inundate coastal areas of 4902.06 hectares (15.02%) in ten coastal districts of Surabaya. Floods will occur mainly at high tide. Type in the tidal waters of Surabaya is a mixed semi-diurnal, which means in a day there is twice high tide and twice low tide but different in height and time; (2) The use of coastal land that will be affected mostly mangrove conservation area, residential, tourist areas of Kenjeran, ports, and salt ponds; (3) Each sector or regional/sub-region should predict the impact of sea level rise and seek ways to adapt or mitigate these impacts.

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