Identification of element at risk due to tidal flood hazard in Genuk Sub-District coastal area

A G H Yoga¹, M A Marfai² and D R Hizbaron²

¹Master Program on Planning and Management of Coastal and Watershed, Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, Indonesia, 55281
²Department of Environmental Geography, Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, Indonesia, 55281

*Corresponding author: dyah.hizbaron@ugm.ac.id

Abstract. The coastal area is a meeting point and a transition zone between land and sea. The morphology of the coastal areas, which is relatively flat and rich in the quality and quantity of natural resources makes the coastal area become centre of population growth. Population growth in coastal areas occurs rapidly and accompanied by potential coastal hazards alongside. Population growth is one factor that many elements at risk will be affected. The Semarang-Demak coastal area, especially at the downstream of Babon River, Genuk Sub-District, experienced the potential of tidal flood. The purposes of this study are to examine the distribution of element at risk due to tidal flood hazards. This research employed satellite image data processing and field surveys methods. First, the research analyzed tidal flood hazard using ArcGIS software and map algebra with a raster calculation tool. Second, it elaborated several elements at risk in the research area. The result of the study showed that the flood hazard index resulted in the distribution of areas affected by tidal floods covering the areas of Terboyo Kulon, Terboyo Wetan, Trimulyo, Banjardowo and Muktiharjo Lor. The largest area which affected by the tidal floods is in the Trimulyo Village (176,820 Ha with the number of hazard index 0.2; 185,364 Ha at the hazard index 0.4; 195,931 Ha at the hazard index 0.6; 205,393 Ha at the hazard index 0.8; and 210,361 Ha on the hazard index 1). While the smallest area which affected by the tidal floods is in Banjardowo and Muktiharjo Lor Sub-Districts. Then the research area the most exposed element at risk are population and its built-up environment, while active productive agriculture land also prominent.

1. Introduction
The coastal area is a transition zone between land and sea. In coastal areas, it can also be said to be a meeting of activities that take place inland and sea areas. The activities are in the form of transportation, trade, fisheries and rapid settlement. The morphological condition of the coastal area, which is relatively flat and rich in the quality and quantity of natural resources makes the coastal area the centre of population growth activities [1]. Unfortunately, the coastal areas exposed to many natural hazards, which by no time increase disaster risk potentials for the area.

The coastal cities such as Semarang-Demak, which located at the downstream of Babon River presents very interesting phenomena relevant to the subjects. In particular at Genuk Sub-district, whereas potential tidal flood existed through time [2]. Derived from several literature reviews, found in print, electronic media and some data from related agencies, it stated that the research location often
experiences tidal floods from year to year. At least in February 2018, there were 119 tidal flood incidents at the study location including the events in Genuksari, Trimulyo, Muktiharjo Lor and Gebangsari villages with a height of 10-50 cm. Then in May 2018, there was also a tidal flood event in Trimulyo Village with a height of 20-40 cm. In April 2019, there was also an incident of tidal flooding that occurred in Gebangsari Trimulyo Urban Village with varying heights of 10-50 cm [3]. The incidence of tidal floods in April 2019 at the study location presented in Figure 1.

Abundant research has been carried out to analyze tidal flood potentials at Semarang, which commonly conducted at large scale of 1:25,000. This research aims to (1) analyze the index and distribution of tidal flood hazards and (2) identify element at risk due to tidal flood hazards.

2. Theoretical Background
Natural disasters are a series of events caused by nature, including earthquakes, tsunamis, volcanic eruptions, floods, droughts, hurricanes and landslides [4]. According to [4], disasters are divided into three types, namely natural disasters, non-natural disasters and social disasters. Most disasters reflect characteristics in the form of disruption to normal life, effects on humans, social structure and community needs [5].

The main cause of disaster has significant correlation with physical and social characteristics of the region. If any potential threat due to its physical and social characteristic, it presented in a risk index. The risk index is a convolution of hazard and vulnerability. The hazard analysis comprises from any endogenous and or exogeneous energy that reflected in particular temporal span. The hazard index is a number to indicate potential probability of future threat, and once it occurred it turn as disaster if it impacted human and it’s any relevant valuable assets [6]. Hazard is also interpreting as a condition or event originating from nature or human-made or both, which have the potential to cause injury or damage to life in terms of the environment or property [7]. The level of coastal hazard is presumably very dynamic due to its rapid human induced activities [8].

Coastal areas are confluence areas and transitional areas between land and sea affected by changes on land and sea [9]. The processes and impacts that take place in coastal areas are, of course, a result of the meeting of two terrestrial and marine ecosystems which lead to other processes taking place and being able to form other ecosystems.

Tidal flood is a phenomenon of flooding that occurs as a result of seawater activity in coastal areas. In some other coastal areas, tidal floods also refer to as rob floods. Tidal floods or rob floods occur due to changes in tide and tide elevation and are a normal cycle in coastal areas. However, this can have a negative impact, namely inundation on land use in coastal areas [10] [11]. Factors causing rob among other are:
1. Sea level rise due to the effects of global warming and climate change accompanied by land subsidence. The increase in global sea levels is slow but ongoing and progressive
2. Land subsidence occurs as a result of excessive groundwater extraction. Land use factors such as settlements, buildings, industrial zones contribute to excessive groundwater extraction.

Geographic Information System or GIS is a computer-based information system that enable scholars to add, store, manage and analyze geographic relevant data [12] [13]. Additionally, Geographic Information System or GIS is a combination of three elements, namely systems, information and geography [12]. The system is an interconnected network and gathered to carry out activities to accomplish specific goals or objectives [14]. The information has a meaning that is a data that has been processed in such a way that is meaningful to users and useful for decision making and supporting other sources of information [12]. While geography is part of spatial (spatial) which contains an understanding of the places that exist on the surface of the earth, its position on the surface of the earth and some other information (attributes) that accompany it [12]. The research applied GIS to ensure spatial entity as an expected outcome. The application of GIS to hazards in the coastal areas of the study location focuses on the use of modelling functions to determine the hazards.

Tidal flood modelling is done using algebra map. Algebra map is one of the functions in ArcGIS that functions to perform spatial analysis or geographic analysis [15]. Algebra maps use raster data in their processing and combine cells from raster data to be processed by mathematical operations. A mathematical operation can be in the form of addition, subtraction, division, maximum value, minimum value and some other mathematical operations [16].

Algebra map operations use the raster calculator to perform the mathematical operations. In the tidal flood modelling the use of algebra map is done through the DEM (Digital Elevation Model) raster data processing on the raster calculator and given an order to analyse the area of the DEM which has a certain height identified as a flooded and not flooded area. Examples of operations in the raster calculator shown in Figure 2.

![Figure 2. Operation in the raster calculator (ArcGIS Desktop Help)](image)

Output resulted after DEM processing through raster calculator is area having two values: null and one that will be identified as inundated area and non-inundated area. Partaking to the idea of putting tidal flood hazard of Babon Watershed, it is also essential to take a closer look upon the element at risk distribution. This research emphasized the observation towards three existing elements at risk, such as
people (demographic distribution), active asset of productive land, and built up environment. The research argued that the area with strong accumulation of element at risk also an area with high probability of hazard occurrence.

3. Method

The research extracted geomorphological and built up environment expression using GIS. The geomorphological explains physical processes that occur at the study location, the built-up environment express the potential impacted areas and its development investment as well as other valuable assets. While the GIS approach is used to compile and model the distribution of tidal floods in the study location which is subsequently link to the hazard of tidal flooding.

3.1. Data Collection

Data collecting is collected important and carried out step to obtain data related to the research objectives. The data obtained can be either primary or secondary data. This study uses these two data, and the data used present in Table 1.

| No | Data Name                                      | Data Type      | Scale    | Data Source                                                                 |
|----|-----------------------------------------------|----------------|----------|----------------------------------------------------------------------------|
| 1  | ArcGIS imagery                                | Secondary data | 1: 400   | Geospatial Information Agency (BIG), National Institute of Aeronautics and Space (Lapan), Centre for Remote Sensing and Geographical Information System (Puspics), Development Planning Agency at Sub-National Level (Bappeda) |
| 2  | RBI map                                       | Secondary data | 1: 25000 | Geospatial Information Agency (BIG)                                          |
| 3  | Districts/Sub-districts in number             | Secondary data | -        | Central Bureau of Statistics (BPS)                                            |
| 4  | Spot height data                              | Secondary data | 1: 2000  | Development Planning Agency at Sub-National Level (Bappeda)                    |
| 5  | DEM data (Digital Elevation Model)            | Secondary data | 1: 2000  | Geospatial Information Agency (BIG)                                          |
| 6  | Tidal flood historical event and impact data  | Secondary data | -        | Field observation                                                            |

3.2. Data Processing

Data processing is step intended to process data obtained with certain approach to reach research goal. The stages of tidal flood data processing activities are carried out using the Algebra Raster Calculation Map. The stages of tidal flood data processing are as follows:

a. Preparation of altitude data and coastline data which will process into a DEM (Digital Elevation Model).

b. Determine each of the projections from the altitude point data and coastline data.

c. Adjust to the administrative data and coastline digitization.

d. Scenario calculations adjusted with historical data on tidal flood events and previous literature studies and research. The data obtained from Semarang City BPBD in 2018. The scenario used is starting from the inundation scenario height of 0.5 m, 0.75 m, 1 m, 1.25 m, and 1.5 m.
The 3rd Environmental Resources Management in Global Region

IOP Conf. Series: Earth and Environmental Science 451 (2020) 012008
doi:10.1088/1755-1315/451/1/012008

5

e. Tidal flood modelling did by preparing elevation point data, coastline data, inundation height scenarios and administrative boundaries of research locations.

f. The data that has prepared is processing with spatial analysis tools and algebra maps, namely raster calculations.

g. Enter DEM data and administrative boundaries of the study location then adjust to the desired scenario that is 0.5 m to 1.5 m.

h. The results of processing with the raster calculator are inundated and not inundated areas.

i. The results are in the form of raster data, and then the data is converted into vector data.

j. Conversions are performed using super-imposed techniques in each scenario.

k. The results are exported into new shapefile data.

l. The new shapefile data results classified into an index by dividing the class with the maximum number of classes.

m. These results can reprocess for further analysis. Calculation of the total area of inundation in each scenario done by calculating geometry. Data processing flow chart is presented in Figure 3.

3.3. Data Analysis

Data analysis in this research was carried out using GIS (Geographic Information System) approach. Data analysis using GIS (Geographic Information System) approach uses integrated and spatial or spatial tools. Determination of tidal flood hazard using the map algebra with raster calculation map modelling in ArcGIS software. The results of the modelling are then given a class and given a hazard index. The

![Data processing flow chart](image-url)

**Figure 3.** Data processing flow chart.
output from the process is presented in the form of a map and will validate in the field. Ways of analysing data in this study presented in Table 2.

**Table 2. Data analysis methods used in research**

| No | Purpose | Analysis Phase | Data Requirements | Analysis Technique |
|----|---------|----------------|-------------------|--------------------|
| 1  | Examine the distribution of tidal flood hazards and their hazard index | Tidal flood modelling | DEM data, tidal flood historical event and impact data, remote sensing imagery | Analysis of GIS approaches with algebra raster calculation map |
|    |         |                | Compilation of tidal flood index | |
|    |         |                | Tidal flood modelling results | Welding the results of tidal flood modelling into an index by dividing the class value with the maximum class value |
| 2  | Elaborate element at risk distribution in the research area | Distribution of productive land and built up area (active asset) | Distribution of productive land and built up area | Distribution of element at risk |
|    |         | Distribution of demographic feature | Distribution of demographic feature | |

4. Results and Discussion

Genuk Sub-district is one of the sub-districts in Semarang City among 15 other sub-districts. Geographically, the Genuk Subdistrict area is in the form of lowlands with an altitude of 0-2.5 meters above sea level, with rainfall ± 2000-3000 mm / year and an average air temperature of ± 29-36°C with natural conditions in several urban villages (Terboyo Kulon, Terboyo Wetan, Trimulyo, Muktiharo Lor, Gebangsari and Genuksari in the north) often flooded by tides (tidal) and floods [17]. The Genuk Subdistrict with an area of ± 28 km2 / 2798,442 ha administratively divided into 13 Sub-districts which presented in Figure 4.
Figure 4. Research location.

The location of the Genuk Subdistrict, which directly neighboring with the Java Sea to the north caused this area prone to flooding [18]. Therefore, the selection of research locations in Genuk Subdistrict is considered suitable for research on tidal flood hazards.

The Genuk Subdistrict, which has a low-lying area with an altitude of 0-2.5 meters above sea level and directly adjacent to the Java Sea, allows for the dynamics of the coastal process. One of these dynamics is the hazard of tidal floods which from year to year threaten this region. Based on the results of the processing of 2014 altitude data points and the 2016 coastline, DEM (Digital Elevation Model) data will produce, which will be used for the treatment of tidal flood hazards. The hazard of tidal flooding is processed with the help of DEM data and inundation scenarios, namely inundation of 0.5 m, 0.75 m,
1 m, 1.25 m, and 1.5 m. The determination of this scenario is based on historical data from the Semarang City BPBD, literature studies and previous research. The final result of data processing is a map of the tidal flood hazard index at the research location which will discuss further.

Tidal flood hazard index maps produce tidal flood distribution. The distribution of areas affected by tidal floods includes the areas of Terboyo Kulon, Terboyo Wetan, Trimulyo, Banjardowo and Muktiharjo Lor. Dominance areas affected by tidal floods are the areas of Terboyo Kulon, Terboyo Wetan and Trimulyo. Some parts of Muktiharjo Lor and Banjardowo are also affected by the tidal flood hazard. The distribution of tidal flood hazards presented in Figure 5.

![Map of Tidal Flood Hazard Index of Genuk Coastal Areas](image)

**Figure 5.** Distribution and index of tidal flood hazard.

A further result from the tidal flood index map is the extent of the tidal flood in each hazard index. Tidal flood hazard index includes values from 0 to 1. Value 0 is not inundated, and value 1 is inundation with the highest scenario is 1.5 m. The extent of the tidal flood at each hazard index presented in Table 3.

**Table 3.** Table of tidal flood area per hazard index

| No. | Hazard Index | Trimulyo | Terboyo Wetan | Terboyo Kulon | Banjardowo | Muktiharjo Lor | Total Area (Ha) |
|-----|--------------|----------|---------------|---------------|------------|----------------|-----------------|
| 1   | 0.2          | 176.820  | 59.537        | 59.496        | 3.174      | 3.226          | 302.253         |
| 2   | 0.4          | 185.364  | 62.955        | 69.706        | 11.521     | 9.278          | 338.824         |
| 3   | 0.6          | 195.931  | 67.758        | 79.761        | 19.910     | 14.263         | 377.622         |
| 4   | 0.8          | 205.393  | 74.285        | 86.436        | 21.680     | 22.605         | 410.399         |
| 5   | 1            | 210.361  | 79.929        | 90.604        | 29.896     | 30.346         | 441.136         |
The results from Table 3 show that the village in coastal area of Genuk Subdistrict experienced large areas of inundation including Trimulyo, Terboyo Wetan and Terboyo Kulon. Whereas in Banjardowo and Muktiharjo Lor Sub-Districts experienced relatively small inundation. The biggest village that experienced inundation was Trimulyo Village. The result will be in huge losses because, in Trimulyo, most of it consists of industrial areas. Whereas in the Village of Terboyo Wetan and Terboyo Kulon also experienced a large inundation but not as large as the Trimulyo Village. The result caused by the area of Terboyo Wetan and Terboyo Kulon consisting of ponds that already flooded.

Based on the hazard map that has been combined with population density, agricultural land, and the built environment, it can be analyzed elements that are at risk of being affected by the risk of tidal floods on the coast of the sub-district of Genuk. In Figure 6 the hazard map combined with population density shows that areas affected by tidal flooding include Trimulyo, Terboyo Wetan, Terboyo Kulon, Banjardowo and Muktiharjo Lor, each of which has a population density of 1028, 553, 343, 2713 and 3813 persons/km$^2$. The most dominant affected village are Trimulyo, Terboyo Wetan and Terboyo Kulon.

![Image: Map of Population Density Affected by Tidal Flood Hazard in Genuk Coastal Areas](image)

**Figure 6.** Population density affected by tidal flood hazard.

The next element of risk analysis is on agricultural land, which is one of the assets owned by the local community. The combined results of the map revealed that there is small area of agricultural land affected by tidal flooding. This is because the dominant agricultural land is far from the coastal areas of the subdistrict of Genuk, which is located in the villages are Gebangsari, Genuksari, Banjardowo, and Karangroto. Map of agricultural land affected by tidal flood hazard is presented in Figure 7.
Figure 7. Agricultural land affected by tidal flood hazard.

The last risk element is the built environment that is affected by the tidal flood hazard. The built environment is a very important asset of the community, the government, and the private sector. In the study area the results of the map show that the built environment that is affected is quite extensive. The affected areas are in the Trimulyo village, Terboyo Wetan, Terboyo Kulon, Mukthiargjo Lor, and Banjardowo. Areas that were significantly affected by the impact of tidal floods were the Trimulyo Village, Terboyo Wetan and Terboyo Kulon which consisted of a built environment in the form of industry, universities, bus terminals and places of worship. The built environment of industry is the most dominant. A map of the built environment affected by tidal flooding is presented in Figure 8.
Coastal area has complex dynamic. It is caused process pressured from land and sea [19]. Coastal of Semarang City, especially in the area of Genuk Subdistrict which borders directly with the Java Sea has the potential to get the process. Process in the form of tidal flood is a problem that often encountered when there are developments that occur in areas that are close to the coastal system [20].

The results of research conducted in the study area show that the Genuk Subdistrict region experienced a significant impact of tidal floods in its coastal areas. Based on the analysis of the elevation point data and coastline data, the coastal areas of Genuk District, namely Trimulyo, Terboyo Wetan and Terboyo Kulon, were directly affected by the tidal flood.

Based on the results that have been made, these villages also have several elements that are at risk of being affected by tidal floods. The affected population in the Trimulyo Village, Terboyo Wetan, Terboyo Kulon, Banjardowo and Muktiharjo Lor for 1028, 553, 343, 2713 and 3813 persons / km² [21]. In the most directly affected village that is most affected by tidal floods, namely Trimulyo, Terboyo Wetan and Terboyo Kulon, have a relatively higher population density compared to the Banjardowo village and Muktiharjo wards for those also affected by tidal flood hazards. This is caused by the dominance of land use in the region is industry. Then the agricultural land affected on the coast is also relatively small because the agricultural land in a location far from the coast is in the villages of Gebangsari, Genuksari, Banjardowo, and Karangroto. In the analysis of a predominantly built environment, of course, the dominant is in the Trimulyo village, Terboyo Wetan the dominant form of industry and several other built environments such as universities, bus terminals, and places of worship.

Overall, the Genuk District is indeed quite significantly affected by the impact of tidal floods. Because by abrasion and the coastal area of Genuk Subdistrict which is an area of abrasion of 153.47 Ha which makes the phenomenon of shoreline changes [22]. In addition, when compared with existing data and research, the coastal area of Semarang City has experienced significant coastline changes.

![Map of Built-Up Area Affected by Tidal Flood Hazard in Genuk Coastal Areas](image)

**Figure 8.** Built-up area affected by tidal flood hazard.
Based on research [23] the area of Semarang City has experienced various coastline changes. In the western part of Semarang City experienced abrasion, the middle part of Semarang City experienced accretion, and the eastern part of Semarang City experienced abrasion [23]. Especially in the eastern part of Semarang City that experienced abrasion, this occurred due to the growth of industrial areas and settlements that caused land subsidence and coastlines to change [24]. This change makes the impact of tides increase, which is the greater land and land use affected.

The phenomenon of the change in the coastline is what causes the impact of tidal floods in the coastal areas of Genuk Subdistrict increasingly significant. The withdrawal of the coastline makes the land that has a variety of land uses the greater. The change is caused by the wave energy entering the region [22]. In addition, coastal area of Genuk subdistrict also underwent decrease in land surface causing more significant impact of tidal flood. According to [25], factor triggering tidal flood is increase in water sea surface and decrease in land surface. Decrease in land surface caused land elevation low that make sea water enter easily to land. Decrease in land surface in coastal area of Genuk subdistrict reached 6-15 cm/year [26].

This land subsidence is caused by a layer of soil in the coastal area of the Genuk District in the form of a layer of soft sand and silt clay to cause compression. This compression occurs due to the addition of loads on the soil layer by buildings. Acceleration is also possible with excessive groundwater uptake [26].

There have been many studies on the mapping of tidal flood hazards in the Semarang coastal area, as previously done by researchers. As research [27] [28] [29] that discusses the mapping of tidal flooding in the Semarang coastal area with neighborhood methods using scientific software. However, in this study the mapping of tidal flood hazard was carried out more specifically in the sub-district of genuk with the neighborhood method but with the use of ArcGIS software (map algebra). Then the use of data sources for mapping the tidal flood hazard uses the 2014 high point data and 2016 shoreline data. The results of the mapping are in the form of a tidal flood hazard with a hazard index as a reference for the potential that will occur.

This study produces a map of tidal flood indexes by only considering the altitude point data and shoreline data processed using the map algebra with raster calculation method, so it does not consider other factors that can cause the magnitude of the tidal flood to vary. Besides, the results of this study have also not been validated by the conditions in the field because they are still waiting for several processes that are currently being completed. Based on previous literature studies and research, there are many other factors of tidal floodings such as abrasion, changes in coastline, land subsidence, changes in land use and excessive groundwater extraction and other factors not yet mentioned.

As the study generated tidal flood hazard map and index, it also generated information towards element at risk distribution for the research area. It turns out that the area exposed to tidal flood also exposed to particular number of population, built up area and small portion of productive agriculture land. Indeed, using this analysis, enable decision maker to take a closer look upon any further mitigation strategy towards the area.

5. Conclusion

Based on the results of the analysis that has been done, it can be concluded several things as follows:

1. Tidal flood hazard index maps produce the distribution of tidal floods covering the areas of Terboyo Kulon, Terboyo Wetan, Trimulyo, Banjardowo and Mukthiarjo Lor. Dominance areas affected by tidal floods are the areas of Terboyo Kulon, Terboyo Wetan and Trimulyo. Some parts of Mukthiarjo Lor and Banjardowo are also affected by the tidal flood hazard. The largest extent of the distribution of tidal floods is in Trimulyo Village of 176,820 Ha at the hazard index of 0.2; 185,364 Ha at the hazard index 0.4; 195,931 Ha at the hazard index 0.6; 205,393 Ha at the hazard index 0.8; and 210,361 Ha on the hazard index 1. While the smallest area of the distribution of tidal floods is in Banjardowo and Mukthiarjo Lor Sub-Districts.

2. Within the research area the most exposed element at risk are population and its built-up environment, while active productive agriculture land also prominent to expose from the occurrence.
Acknowledgment
This research was one of the beneficiaries of the grant provided by Universitas Gadjah Mada under the 2019 Final Assignment Recognition (RTA) scheme. Authors would like to thank Universitas Gadjah Mada for supporting this research. The topics discussed in this study are part of a broader topic discussed in the final assignment of the first author.

References
[1] Marfai, A. 2014. Banjir Pesisir : Dinamika Pesisir Semarang. Yogyakarta : UGM Press.
[2] Ramadhany A. S., Anugroho A., et al. 2012. Daerah Rawan Genangan Rob di Wilayah Semarang. Journal of Marine Research Vol. 1 No. 2. UNDIP. Semarang.
[3] BPBD Kota Semarang. 2019. Data Bencana Alam di Kota Semarang Tahun 2017 dan 2018. BPBD. Semarang.
[4] Republik Indonesia. 2007. Undang-Undang Nomor 24 Tahun 2007 tentang Penanggulangan Bencana. Jakarta.
[5] Carter, W.N. 2008. Disaster Management : A Disaster Manager’s Handbook. Asian Development Bank. Philippine.
[6] ISDR, 2004. Living With Risk – A Global Review of Disaster Reduction Initiatives. United Nation (www.unisdr.org).
[7] Schramm, D., dan Dries, R., 1986, Study Guide and Course Text of Natural Hazard. University of Wisconsin Board of Regents. United States of America.
[8] Ramsay, D., Gibberd, B., Dham, J., dan Bell, R., 2012, Defining Coastal Hazard Zones and Setback Line: A Guide to Good Practice. National Institute of Water and Atmospheric Research Ltd. Hamilton. New Zealand.
[9] Republik Indonesia. 2007. Undang-Undang Nomor 27 Tahun 2007 tentang Pengelolaan Wilayah Pesisir dan Pulau-Pulau Kecil. Jakarta.
[10] Wahyudi, S.I., 2007. Tingkat Pengaruh Elevasi Pasang Laut terhadap Banjir dan Rob di Kawasan Kaligawe Semarang. Riptek. 1(1): hal. 27-34.
[11] Marfai, M.A. dan King, L. 2008a. Coastal Flood Management in Semarang, Indonesia. Environmental Geology. 10.1007/s00254-007-1101-3, hal. 1507-1518.
[12] Wibowo, K.M., Kanedi, I. dan Jurnadi, J., 2015. Sistem Informasi Geografis (SIG) Menentukan Lokasi Pertambangan Batu Bara di Provinsi Bengkulu Berbasis Website. Jurnal Media Infotama Vol. 11 No. 1.
[13] Prahasta, Eddy. 2002. Sistem Informasi Geografis : Konsep-Konsep Dasar Informasi Geografis. Bandung: Informatika Bandung.
[14] Jogiyanto. 2005. Analisis dan Desain Sistem Informasi. Yogyakarta : Penerbit Andi.
[15] ESRI. 2019. ArcGIS Desktop Help.
[16] Fariza, A., 2016. Kemampuan GIS Raster. Politeknik Elektronika Negeri Surabaya. Surabaya.
[17] Pemerintah Kecamatan Genuk. 2019. Gambaran Umum Wilayah Kecamatan Genuk. Semarang.
[18] Karunia, Ilma. 2017. Estimasi Kerugian Ekonomi Masyarakat Akibat Banjir Rob di Pemukiman Kecamatan Genuk Kota Semarang. Skripsi. IPB. Bogor.
[19] Wirasatriya, Anindy, Hartoko, Agus, dan Suripin. 2006. Kajian Kenaikan Muka Laut Sebagai Landasan Penanggulangan Rob di Pesisir Kota Semarang. Jurnal Pasir Laut Vol. 1 No. 2.
[20] Wibawa, Efi Aryanta. 2002. Studi Naiknya Muka Air Laut Di Kawasan Pesisir Semarang. Jurnal Mahasiswa Teknik Kelautan, ITS. Surabaya.
[21] BPS Kota Semarang. 2018. Kecamatan Genuk dalam Angka Tahun 2018. BPS. Semarang.
[22] Sunaryo, Ambriyanto, Sugianto, D.N., Helmi, M., Kaimuddin, A.H., dan Indarjo, A., 2017. Risk Analysis of Coastal Disaster of Semarang City, Indonesia. E3S Web of Conferences 31, 12009 (2018) ICENIS 2017. https://doi.org/10.1051/e3sconf/20183112009.
[23] Prayogo, Teguh. 2015. Analisis Pola Perubahan Garis Pantai Pesisir Semarang dan Sekitarnya Berdasarkan Citra Satelit Landsat Multitemporal. *Prosiding. Pertemuan Ilmiah Tahunan XX dan KongresVI, MAPIN*. IPB, Bogor.

[24] Marfai M.A., Almohammad H., Dey S., Susanto B., dan King L., 2008. Coastal Dynamic and Shoreline Mapping: Multi-Sources Spatial Data Analysis in Semarang Indonesia. *Environ Monit Assess (2008) 142:297–308. DOI.10.1007/s10661-007-9929-2.*

[25] Marfai, M.A., dan King, L., 2007a. Monitoring Land Subsidence in Semarang, Indonesia: *Environmental Geology, v. 53 (3), p 651-659. Doi:10.1007/s00254-007-0680-3.*

[26] Nugroho, S.H., 2013. Prediksi Luas Genangan Pasang Surut (Rob) Berdasarkan Analisis Data Spasial di Kota Semarang, Indonesia. *Jurnal Lingkungan dan Bencana Geologi, Vol. 4 No. 1 April 2013: 71-87.*

[27] Marfai, M. A., & King, L. 2007b. Tidal inundation mapping under enhanced land subsidence in Semarang Central Java Indonesia. *Natural Hazards. doi:10.1007/s11069-007-9144-z.*

[28] Marfai, M. A. 2004. Tidal flood hazard assessment: modelling in raster GIS, case in western part of Semarang coastal area. *Indonesian Journal of Geography, 36(1), 25–38.*

[29] Marfai, M. A. 2003. GIS modelling of river and tidal flood hazards in a waterfront city: case study, Semarang City, Central Java, Indonesia. *M.Sc. thesis*, International Institute for Geo-Information and Earth Observation, ITC, Enschede, The Netherlands, 123 pp.