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Analysis of Flood Vulnerability Assessment in Urban Area (Case Study: North Semarang District)

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Abstract: The disasters occurred in Semarang, as the capital city of Central Java, must be considered. This is because it can cause various impacts that can affect the wheels of government. One of the problems which continously occur in the Semarang city is flood. Flood can cause a variety of damage and losses both of material and non-material. This flood can be caused by various factors. In this study, analysed the causes of flooding that occurred in the Semarang City. The location in this study specifically was in the North Semarang District. Analysis was done using scoring analysis with approach method based on preview research. The scoring method performed by Haryani et al. (2012) was adopted in this study. This method used five variables. The variables were rainfall, land coverage, slope shape, land system, and elevation. According to analysis, it shows that four of five variables which are land coverage, slope shape, land system, and elevation, which related to topography and land use, have maximum score to influence the occurrence of flooding in North Semarang District. Accordingly, the North Semarang Subdistrict is categorized as prone to flood hazard. Moreover, with a lot of human activities as result of increasing the population growth, it influences the land use of North Semarang District which further increases the vulnerability of North Semarang District to flooding.

Keywords: *flood vulnerability; variable; North Semarang District; scoring*

1. Introduction

Semarang City is a capital city of Central Java located in the north of the Java Island. Semarang City is not only the center of government, but also business and economy activities are conducted in this city. However, Semarang has several disaster problems related to civil engineering aspect. As the examples are landslide and flood. Landslide is movements of soil due to reduced shear strength. Meanwhile, flood is excessive water flow soaking the land. The occurrence of these disasters cannot be separated from the topography of Semarang as one of its factors. Based on its topography, Semarang City can be divided into the upper and lower parts of region. Landslide problems mainly occur in the upper part of Semarang, while flooding problems are common in the lower part of Semarang City.

In Semarang City, flood occurs almost every year. This problem can cause various damages and losses both material and non-material for the community. So that, this problem cannot be avoided. Many factors can cause flood, internal and external factors. The internal factors such as topography of the Semarang City area itself. As it is known that flooding problems generally in

the lower part of Semarang City due to characteristic of things, in this case water, to move by gravity from higher to lower place. Whereas, the external factor such as continuous rainfall in the rainy season can increase discharge of water that must be accommodated.

Generally, there are three types of flood that happen in urban areas, local flood (due to rainfall), shipment flood (due to overflow from the upper area), and tidal flood (due to sea water level and land subsidence). Local flood or inundation is flood occurring in its area. This flood occurs because the rainfall is quite abundant but the capacity of the drainage cannot accommodate the water. Moreover, this can be happened also because wastewater from household and industrial areas around causes the water capacity will increase. In the other hand, shipment flood is a flood caused by the overflow of rainwater from a higher area towards a lower area or inundation area. The shipment flood will result in an increase in the amount of water that must be accommodated by the lower area. This water runoff can pass by existing drainage or river channels.

Furthermore, there is also tidal flood. In Indonesian language, tidal flood is called rob. Tidal flood is caused by patterns of sea level fluctuations. It is influenced by the attraction of celestial bodies, especially by the Moon and the Sun toward to the mass of sea water on Earth [1]. By Semarang's lower altitude below sea level and sea tides, the Semarang coastal area is very prone to tidal flooding. This is compounded by the land subsidence which increase steadily year to year. As the impact, it allows sea water to go into the land easily.

Land subsidence can be influenced by various factors. First, because of the exploitation of ground water. Ground water has benefit to fulfill the requirement of human lives. However, taking ground water without being restricted will cause rise of voids to soil. So that, soil will decrease faster. Besides, the type of soil in Semarang is soft soil. Characteristic of soft soil is low bearing capacity. It means that capacity of soil to retain heavy burden of the structure above it is weak. Semarang as Capital city has many buildings and infrastructures which will affect its soil. So that, these conditions make soil will experience derivation faster.

In the flood management, the prominent component is risk assessment and decreasing the vulnerability (Ahmad and Simonovic (2012) in [2]). Many researchers have examined flood vulnerability in their regions with a variety of different methods. As example Nasiri et al. [3] which had research study in Kuala Lumpur. They obtained that Kuala Lumpur are most vulnerable to flood hazard with regard to the system’s components, that is, social, physical, environmental and economic.

According to these problems, it is necessary to analyze the level of flood vulnerability in the Semarang region against flooding. This study aims to analysis the flood vulnerability in the Semarang by taking a case study in the North Semarang District. Moreover, the main factor which influence the occurrence of flooding based on existing variables can be determined. Finding the level of flood vulnerability can be disaster mitigation for the region. So that the community will become more aware of the floods that can happen at any time. By knowing the causal factors that increase the vulnerability of flood areas, it is hoped that it can provide more in-depth understanding. Furthermore, a mitigation plan can be carried out so that the actions taken will be more targeted.

2. Study Area of Semarang

Semarang is located in the North of Java Island. Based on Semarang City Central Bureau of Statistics [4], it is at 60 50’ - 70 10’ LS and 1090 35’ – 1100 50’ BT. The border of Semarang in the South is Semarang Regency. In the Semarang Regency, there is Ungaran Mountain. Whereas the border in the East is Demak and in the West is Kendal Regency. Moreover, the border of Semarang in the North is Java Sea. Thus, Semarang also has coastal area which directly adjacent to the sea. According to these borders, it can be known that area of Semarang is divided into different zone depends on its topography.

BPS (2018) stated that the height of Semarang City is located between 0.75 to 348.0 meters above the sea level. It is divided into two area, the upper part and the lower part. The upper part of Semarang consists of Gunung Pati Subdistrict and Tembalang Subdistrict, while the lower part of Semarang consists of the city center and coastal areas which directly borders the Java Sea. In the upper part of Semarang which is hill and hilly area, the altitude is about 90 - 350 meters above sea level. Whereas the lower part of Semarang has an altitude of 0.75 - 2.45 above sea level. More details, based on BPS [4], in the downtown area of Semarang is 2.45 meters above sea level, while for the coast area is 0.75 meters above sea level. This condition can cause the possibility of flooding in the lower part of Semarang area due to gravitational force bring water from upper part move to lower part of Semarang.

According to Dawson et al., 2008; Archetti et al., 2011 in [5], coastal cities with extensive impervious areas are very prone to flood which can be caused by one or several causes of flooding. The Java Sea which borders Semarang in the North is 13.6 km long making the northern part of Semarang City very vulnerable to tidal flooding. Therefore, this northern part of Semarang needs special attention, especially since this region is also an industrial area that serves as the economic driving force in Semarang City.

In this study, the location was taken in North Semarang District (Semarang Utara) which can be seen in Fig. 1. The area of North Semarang District is 10.97 km2. As the Capital District of North Semarang District is Panggung Lor and it has 9 Subdistrict others (BPS, 2018). The North Semarang District is very prone to flood due to it is in the lower part of Semarang and it is also border directly with Java Sea.

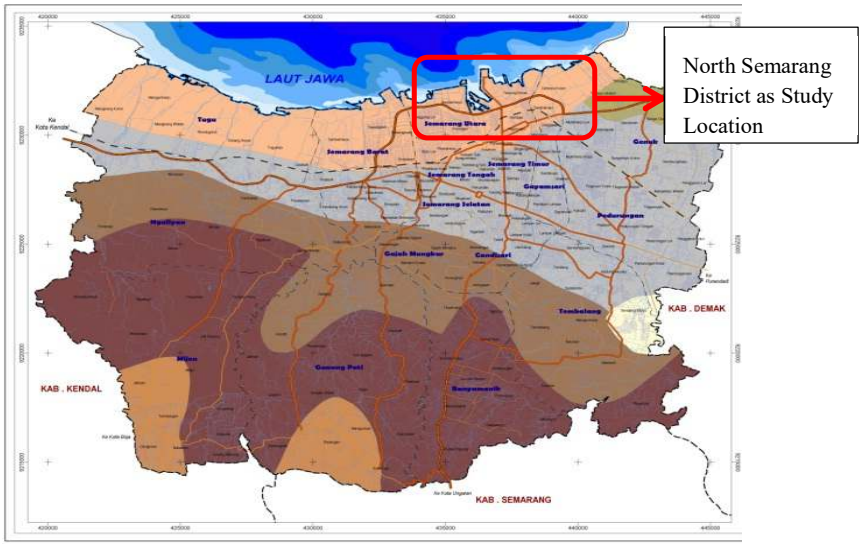

Fig. 1. Research Study Location [6]

Moreover, refers to its topography, North Semarang has alluvial soil types. Alluvial soil is a type of soil with moderate to high fertility. It is usually located on alluvial plains of beaches and rivers. Alluvial soil has a sticky wet consistency which indicates that the cohesion of the soil is possible high enough. From that reason can be assumed that generally in alluvial soil area has low bearing capacity due to the higher cohesion than the friction angle. This means that if there are constructions above alluvial soil area, thus settlement induced land subsidence would be possible to happen. Furthermore, the most extreme area was in the northern part where it was greater than 8 cm/ year [6].

In addition, land subsidence phenomenon can cause land elevation lower than sea level elevation. This causes water from land cannot be disposed of into the sea. The sea water will be easier to flow to the land due to the gravity effect which water flows from a high place to a lower place. Moreover, sea level elevations always increase because of the effects of global warming. Mimura and Harasawa (2000) in Prawira and Pamungkas [7] stated that reports from the IPCC estimated that in the period of 100 years, starting in year of 2000, sea levels would rise as high as 15-90 cm with certainty of a 48 cm height increase. Refers to these reasons, thus the coastal area of the city of Semarang in this case the North Semarang District can have an impact on this.

3. Research Method

Vulnerability is conditions that are determined by physical, social, economic and environmental factors or processes that increase a community's vulnerability to the effects of hazards (ISDR (2004) in MPBI [8]). Thus, between vulnerability and vulnerability cannot be divided. There are conditions that determines whether a hazard (both natural and artificial hazards) that occurs will cause disaster. The flood becomes disaster if it occurs in vulnerable areas. Many factors can be reason so that an area called vulnerable area. As the example the topography, kind of soil, environment, etc. However, many people live in vulnerable area. This is due to restrictiveness of land. As the consequence, it makes them as the first sufferer if disaster happen. Therefore, it is necessary to study the vulnerability of flood disasters.

In this study, vulnerability was calculated by scoring method. Scoring method is method by counting factors as weighting variable. The specified variable used based on the scoring method used. In this study, the scoring calculation was adapted based on the research of Haryani et al. (2012). The reason method used in this study adopted to Haryani et al. (2012), is location study of Haryani's research generally has same condition with North Semarang District. Haryani et al. did research in Sampang District. Sampang District has amount of flow that enters is very large so that the accumulation of flow is very high [9]. Moreover, sedimentation in river is high and poor drainage system in urban area. This condition has resemblance with North Semarang District. Accumulation flow in North Semarang District is not only caused by water in its area but also by water flow from upper part of Semarang. Method in this study is by calculating score refers to variable which has been determined. Based on scoring table from Haryani et al. [9], the variables are climate/ rainfall (CH), land coverage (PL), slope shape (L), land system (SL), and elevation (E). Table 1 shows each variable with its score.

Table 1. Score of Variables based on Haryani et al. [9]

Variable	Criteria	Scoring
Climate/ Rainfall (CH)	Rainfall > 300 mm	5
	Rainfall 200 – 300 mm	4
	Rainfall 100 – 200 mm	3
	Rainfall 50 – 100 mm	2
	Rainfall < 50 mm	1
Land Coverage (PL)	Settlement / Open field / River	5
	rice fields / ponds / mangroves	4
	fields / moor / garden	3
	scrub / sand bush	2
	forest	1
Slope Shape (L)	Flat - slightly (0-8%)	5
	Choppy (8-15%)	4
	rather steep, bumpy, hilly (15-25%)	3
	Steep, very steep (25-45%)	2
	Sheer, very sheer (> 45%)	1
Land System (SL)	Combined Plain of Estuary (KJP), Swamp (MKS)	5
	Bumpy plain (AAR)	4
	small hillside (LAR)	3

Variable	Criteria	Scoring
	rusty core (PSI)	2
	terrace karst (SKN)	1
Elevation (E)	0 – 50 meters	5
	50 – 100 meters	4
	100 – 150 meters	3
	150 – 200 meters	2
	> 200 meters	1

Furthermore, the weighting can be calculated and class interval can be obtained. The weighting calculation by Composite Mapping Analysis (CMA), that can be seen in Equation 1.

$$Scma = 16 \times SCH + 19 \times SPL + 22 \times SL + 27 \times SSL + 16 \times SE \quad (1)$$

Haryani et al. (2012) calculated the weighting by mean spatial analysis. However, in this study as preliminary study the analysis was conducted by calculating the score in each variable. Class interval was multiplication between scoring and weighting. Furthermore, after obtaining a score, it can be classified how vulnerable the North Semarang District was. Areas prone to flooding classified in four classes [9]. More details can be seen in Table 2.

Table 2. Classification of Hazard Class Floods [9]

Flood Danger Class	Class Interval
Not vulnerable	100 - 200
Moderate / quite vulnerable	201 - 300
Prone	301 - 400
Very vulnerable	401 - 500

For complying variable needed, thus the data refers to the Semarang City Government and the Semarang City Central Bureau of Statistics data. Regional characteristics can change either because of climate or global warming can affect the results of the weighting carried out. Therefore, the latest data was used in 2006 – 2017.

4. Results and Discussion

As explained in the method of research, there are several variables used to determine the level of vulnerability of flooding in this study and at the same time limiting problems. Based on scoring table from Haryani et al. (2012) [9], the variables are climate/ rainfall (CH), land coverage (PL), slope shape (L), land system (SL), and elevation (E). The analysis of the variables is explained as follows.

- Rainfall
  The data used based on BMKG data for the Central Java Province, Semarang station, from 2006 - 2015, which can be seen in Table 3. Meanwhile, based on BPS data, the Tanjung Mas region located in North Semarang has a number of rainy days which can be seen in Table 4.

Table 3. Number of Rainfall and Amount of Rainy Days [10]

Year	Number of Rainfall (mm)	Amount of Rainy Days (day)
2006	1142	39.9
2007	1868	156
2008	2690.3	186
2009	2807	169
2010	3228	219
2011	1879	174
2012	2248	164

Year	Number of Rainfall (mm)	Amount of Rainy Days (day)
2013	2628	187
2014	2628	187
2015	1620.7	140
Average	2273.9	162.19

Table 4. Number of Tanjung Mas Rainy Days [4]

Location of Rain Post	Average Number of Rainy Days (days)						
	2010	2011	2012	2013	2014	2015	Average
Tanjung Mas	208	155	150	176	160	160	168.17

Based on Table 1 and Table 2, it can be concluded that North Semarang District has 168.17 days of rainy days and 2273.9 mm of rainfall. Refers to Table 1 adopted by Haryani et al. (2012), rainfall > 300 mm has score 5.

- Land Coverage
  Land coverage related to land use. Based on Semarang City Government data, the Semarang land use map shows that in the North Semarang District, most of them are seaports, settlements and a small part of it is industry [10]. North Semarang Subdistrict does not have rice fields, but has 9 Ha of gardens and 4 Ha of fields. Accordingly, so that the score is 5 (Table 1).
- Slope Shape
  Slope shape related to topography an area. Based on data from the Semarang City Government (2018), North Semarang District has a uniform slope of 0 - 2% [10]. For slope 0-8% has score 5 (Table 1).
- Land System
  North Semarang District is coast system. Thus, for Combined Plain of Estuary (KJP) and Swamp (MKS) has score 5 (Table 1).
- Elevation
  Like the slope shape, the elevation also related to topography characteristic. The height of the North Semarang District area on the coastal area is 0.75 meters above sea level (BPS, 2018). The area above sea level (DPL) for North Semarang District is 1.0 meter, which is the lowest among other Districts in Semarang City along with Tugu District [4]. For elevation 0 – 50 meters has score 5 (Table 1).

The concision of the analysis based on the scoring method of Haryani et al. (2012) can be seen in Table 5.

Table 5. Qualifications and Scoring in North Semarang District based on Haryani et al. (2012)

Variable	Criteria	North Semarang District	Scoring
Climate/ Rainfall (CH)	Rainfall	2357,739 mm	4
Land Coverage (PL)	Settlement / Open field / River	Most regions	5
Slope Shape (L)	Flat - slightly (0-8%)	0 -2 %	5
Land System (SL)	Combined Plain of Estuary (KJP), Swamp (MKS)	Coast	5
Elevation (E)	0 - 50 m	0.75 m	5
Total Scoring			24

Haryani et al. (2012) calculated the weighting by mean spatial analysis. However, in this study as preliminary study the analysis was done by calculating the score in each variable using Equation 1. The result of hazard class can be seen in Table 6.

Table 6. Hazard Class Analysis

Variable	Scoring	Weighting	Total
Climate/ Rainfall (CH)	4	16	64
Land Coverage (PL)	5	19	85
Slope Shape (L)	5	22	110
Land System (SL)	5	27	135
Elevation (E)	5	16	80
	Total		474

Scores in Table 5 based on the analytical method refers to Haryani et al. (2012) is 24. It approaches 25 points or perfect scores. Moreover, the hazard class analysis has 474 score (Table 6). According to Table 2 by number hazard analysis score 401-500 is categorized as very vulnerable classification. This means that flood hazard in the North Semarang District is very vulnerable.

Various factors caused flood have been analyzed. There is rainfall, land coverage, slope shape, land system, and elevation. Land coverage, slope shape, land system, and elevation contribute high values to the level of flood vulnerability in the North Semarang. Moreover, there are related to topography and land use of its area.

Besides, other natural events such as tides and human activities can also be considered. The human activities in the form of coastal area management. Managing coastal areas by humans is the most difficult thing to do. By increasing population growth, the changing conditions of the environment have become increasingly urgent. Population density in North Semarang is 2017 is 10.771 per km2 [4]. The population grow from 118,264 in 2015 become 137,776 in 2017. By the number of populations, the change of environment definitely will change.

This change resulted in reduced land cover. This is also affecting the decrease of vegetation, especially in urban areas. Whereas, the vegetation cover that grows above the earth's surface will cause high runoff. Run off occurs when rainfall has exceeded the rate of soil infiltration. This proves that the vegetation is a regulator of the water system which during the rain the vegetations help the process of infiltration. So that water is stored as underground water and can release during the dry season. Accordingly, human activities influence land use of North Semarang District. It will give impact to the vulnerabilities of its area.

According to analysis which has been done. It is known that land use and topography greatly affect the vulnerability of flooding in North Semarang District. As also stated by Salami et al. at their research in Ibadan Metropolis Nigeria, one of factors that change the level risk in that city is dynamic patterns of land use [11]. Besides, unplanned growth and impacts of climate change can be other factors. So does Maqsood et al. [12] which put land use planning as the key factor contributing to flood risk beside the vulnerable buildings constructed within floodplains.

By knowing this factor, it is expected that flood control in the North Semarang area will be more targeted according to the causes. Moreover, North Semarang District near the coast is a strategic area for economic development because there is the Tanjung Mas Port Area. There is also a primary arterial pathway, which connects Semarang City with the City of Demak. Further, it is also a cultural area, adjacent Old Town and Chinatown areas. Thus, problem solving related to land use in North Semarang has to find out. This is not only in structural or engineering terms (physical) but also non-structural (non-physical) which can be performed by community in its area.

5. Conclusion

Flood mitigation is all actions and efforts to reduce the impact of a flood. By knowing the causes of flooding, it is expected that the mitigation efforts can be more targeted. Based on the analysis that have been carried out, the North Semarang is included in the category of vulnerable to flood hazards. Several variables analyzed show that topography and land use influence flood vulnerability. Effective countermeasures are needed because North Semarang District is a strategic area for economic development because it is the Tanjung Mas Port Area. This problem solving can be done with non-physical (socio-economic to the community) and physical forms through civil engineering are needed.

References

[1] Sunarto. "Geomorfologi Pantai: Dinamika Pantai" (2003) Fakultas Geografi UGM. Yogyakarta.
[2] Nasiri, H., and Kalalagh, S.S. "Flood Vulnerability Index as a Knowledge Base for Flood Risk Assessment in Urban Area" (2013) J Nov. Appl Sci., 2 (8) PP 266-269.
[3] Nasiri, H., Yusof, M.J.M., Ali, T.A.M., Hussein, M.K.B. "District Flood Vulnerability Index: Urban Decision-Making Tool" (2019) International Journal of Environmental Science and Technology 16, PP 2249–2258.
[4] Badan Pusat Statistik (BPS) Kota Semarang. "Kota Semarang dalam Angka 2018" (2018) BPS Kota Semarang.
[5] Lian, J. J., Xu, K. and Ma, C. "Joint Impact of Rainfall and Tidal Level on Food Risk in a Coastal City with a Complex River Network: A Case Study of Fuzhou City, China". Hydrology and Earth System Sciences, 17, 679–689
[6] Semarang City Government (2018).
[7] Prawira, M.P. dan Pamungkas, A. "Mitigasi Kawasan Rawan Bnajir Rob di Kawasan Pantai Utara Surabaya" (2014) Jurnal Teknik Pomits 3 (2), PP C160-C165
[8] Masyarakat Penanggulangan Bencana Indonesia (MPBI) (2007). http://www.mpbi.info/
[9] Haryani, N.S., Zubaidah, A., Dirgahayu, D., Yulianto, H.F., Pasaribu, J. "Model Bahaya Banjir menggunakan Data Penginderaan Jauh di Kabupaten Sampang (Flood Hazard Model using Remote Sensing Data in Sampang District)" (2012) Jurnal Penginderaan Jauh Vol. 9 No. 1, PP 52-66
[10] https://www.bmkg.go.id/
[11] Salami, R.O., Meding, J.K., Giggins, H. "Vulnerability of Human Settlements to Flood Risk in the Core Area of Ibadan Metropolis, Nigeria " (2017) Journal of Disaster Risk Studies, PP 1-14.
[12] Maqsood, T., Wehner, M., Dale, K., Edwards, M. "Development of Flood Mitigation Strategies for Australian Residential Buildings" (2016). AFAC & BNHCRC Conference, pp. 1-10