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Flood Exposure of Settlement Areas in Bekasi City

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Abstract. Flooding is one of the hydrometeorological disasters that often-hit Bekasi during rainy seasons. Flood in Bekasi is caused by its topographical characteristics and poor drainage condition. As Jakarta's buffer zone, the mobilization inhibition of Bekasi people will impact economic activities in Jakarta. Therefore, a mitigation measure is needed to reduce losses. This research aims to map the flood exposure of Bekasi's settlement areas as a reference for mitigation action. The level of exposure in this research is analyzed by assessing rainfall, land use, slope, altitude, drainage conditions, and distance from rivers. This exposure mapping uses remote sensing data based on Geographic Information Systems (GIS). The results show that Bekasi's settlement areas prone to flooding are in sloping areas, areas near the river, and areas with poor drainage conditions. These areas include the South Bekasi Subdistrict, East Bekasi, North Bekasi, West Bekasi and Rawalumbu.

Keywords: Exposure, Settlement, GIS, Flooding.

1. Introduction

Hydrometeorological disaster is the most frequent disaster occurred in Indonesia. Recorded from 2005 to 2015 for about 78% of disasters that occurred in Indonesia were hydrometeorological disasters, one of them was flood disaster. Flooding is a puddle on land that is usually dry, such as on agricultural land, settlements, and downtown. Flooding is caused by high rainfall on the plains that have relatively flat reliefs in the lowlands. Flooding can also occur because the discharge or volume of water flowing in a river or drainage channel exceeds or over its drainage capacity [1]

Bekasi City is one of the cities that is vulnerable to exposure by floods [2]. This is because the topography of Bekasi City is relatively flat, with a slope of around 0–2 percent. Bekasi City is located at an elevation of 11 to 81 meters above sea level, and is surrounded by rivers [3]. In addition to the topographic conditions of flooding problems in Bekasi City is also caused by overflow of drainage channels due to the flow of water over the discharge that can be accommodated by drainage [4]. This condition can trigger high rates of exposure in Bekasi City, one of them in the settlement area.

Settlement is an important asset that must be maintained. Settlements in Bekasi City have an important role as a buffer for Jakarta residents. This is marked by the high level of Bekasi commuter activity towards the capital city [5]. Settlements exposed to flooding will inhibit citizens to work, so that it can disrupt the economic activities of the capital.



For this reason, it is necessary to map the exposure zone of settlements to floods to cover the population who are living in the settlement. The mapping of the exposure of settlements to these floods can be used as a reference in disaster mitigation and minimize losses due to flood disasters on element at risk (settlements). These efforts can be done by focusing mitigation on settlements that are highly exposed to flooding. Element at risk is a population, property, economic activity, including public services, or other definite values that are exposed to hazards in an area [6]. This mapping aims to estimate the level of exposure of settlements to flood disasters. Exposure shows the degree, duration and or opportunity of a system for contact or shock or disturbance [7][8].

2. Method

The research area in this study is Bekasi City. Geographically, Bekasi City is in the position of 106°48'28" to 107°27'29" East Longitude (EL) and 06°10'06" - 06°30'06" South Latitude (SL). Administratively, Bekasi City is divided into 12 sub-districts, which are: Pondok Gede Subdistrict, Jati Sampurna, Pondok Melati, Jatiasih, Bantar Gebang, Mustika Jaya, East Bekasi, Rawalumbu, South Bekasi, West Bekasi, Medan Satria, and North Bekasi Sub-district [3].

The parameters used for determining flood exposure with the GIS approach include: Distance from river, annual precipitation, slope percentage, elevation, and drainage conditions [9]. This parameter is then overlaid with elements affected by the disaster and *element at risk*. Element at risk in this study is settlement.

The data Which have collected in this study are: slope percentage and elevation obtained by processing Digital Elevation Model (DEM) data which are obtained from ASTER GDEM data; distance data from rivers is obtained by buffering river data obtained from BIG (Badan Informasi Geospasial); and annual precipitation data obtained by processing BPS (Badan Pusat Statistik) data with *isohyet* method to delineate the same rainfall points so as to form an area of rainfall distribution; Data on drainage conditions obtained by field observations, the sample was taken based on the distribution of Bekasi City flood points from the BPBD (Badan Penanggulangan Bencana Daerah) Bekasi City which was overlaid with the flood exposure map which then selected 3 samples from the flood points in the exposure zone class.

The technique used in this study is overlay technique using *ArcMap 10.1 software* as one of the GIS-based approaches. In the overlay process is also carried out scoring and weighting on each parameter to obtain a map of flood disaster exposure in Bekasi City. Scoring and weighting is carried out to determine the value of danger. Mathematically, the scoring and weighting are carried out using the following formula:

$$\text{Exposure} = \text{Annual Precipitation Score (30\%)} + \text{Distance from River Score (30\%)} + \text{Elevation Score (20\%)} + \text{Slope Percentage Score (20\%)} \dots\dots\dots (\text{Karisma, 2015 with modifications})$$

The data on the exposure of settlements to floods that have been processed are then analysed by descriptive spatial analysis. This analysis will illustrate the distribution of the level of exposure to flooding in the study area spatially. The results of the analysis are expected to clearly describe the flood exposure zone in Bekasi City settlements based on its classification, so that it can be used as a reference in the selection of flood mitigation priorities in Bekasi City.

3. Result

The elevation area consists of five classes. The areas that have the highest potential for flooding include class "below 12.5 meters above sea level". This is because the elevation land area which is very low causes the region to be a dangerous region to flooding, because floods will flow to areas of lower elevation. Based on the data of the elevation area, Bekasi City is dominated by heights at 12.5 - 25 meters (78.88 km²) which

means that the elevation of Bekasi City is still low. This means that based on elevation, Bekasi City is dominated by high levels of danger to floods.

Slope has a relationship that is inversely related to flood exposure. The steeper the slope, the lower the flood exposure. Based on slope percentage data, Bekasi City is dominated by slope areas between 0 - 2% (198.21 km²), which means the slope in Bekasi City is relatively flat. Flood exposure will be high because water flow will easily be trapped on flat terrain. This means that based on slope percentage, Bekasi City is dominated by high levels of danger to floods.

The distance from the river is divided into four classes. Classes that are at a high level of danger to floods are found in areas that are "25 m away from the river". This is because when there is a water volume increase in river, areas that are too close to the river will be easily exposed to flooding. Based on the distance data from the river, Bekasi City is mostly in the class "more than 250m" (107.88 km²). This shows that the parameters of the distance from the Bekasi City River are low exposure.

Annual precipitation has a relationship that is directly proportional to the level of flood exposure, because the higher the annual precipitation of an area, the higher the exposure. In this study rainfall is divided into three classes. Classes that are at a high level of danger to floods are found in areas that have rainfall of more than 1650mm per year. Based on rainfall data taken from The Teluk Pucung station, Kranji, and Bendungan Bekasi in 2016 the results showed that Bekasi rainfall was dominated in the class "1500 - 1650 mm" which is 193.79 km². Based on rainfall data, Bekasi City is not classified as high or low in exposure.

4. Discussion

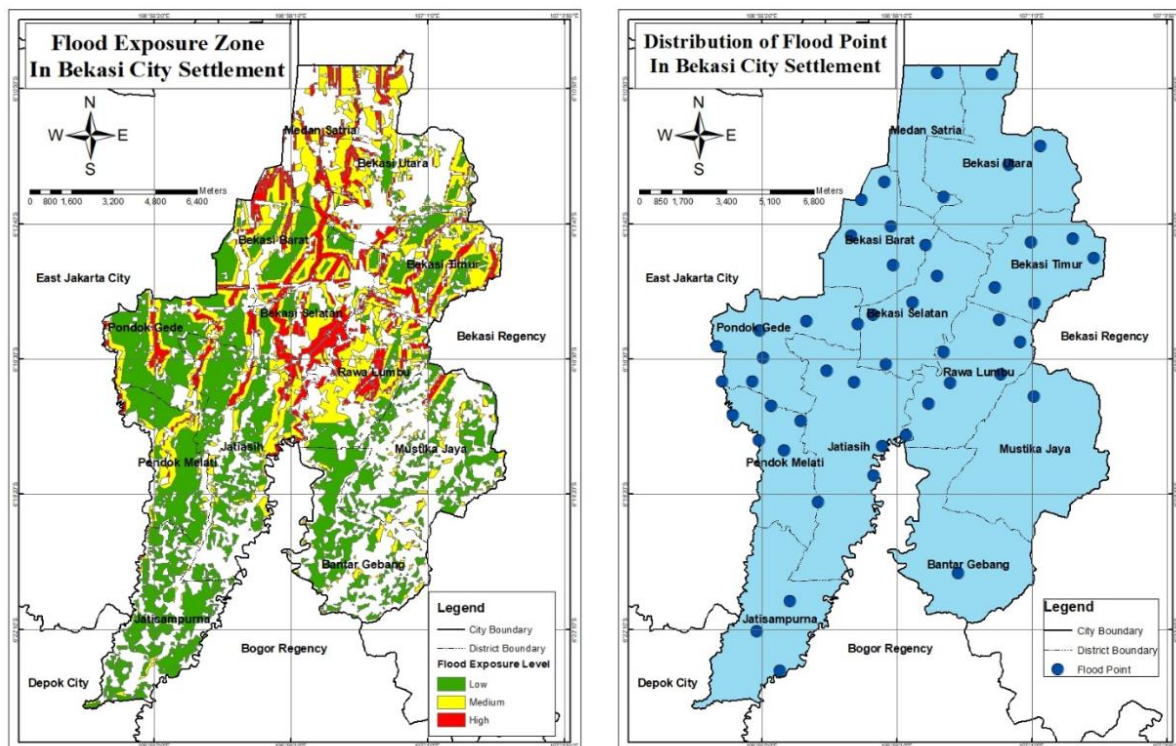


Figure 1. (a) Flood Exposure Zone in Bekasi City (b) Distribution of Flood Point in Bekasi City

Based on **Fig. 1(a)** most of the settlements in Bekasi City are in areas with low to medium exposure levels. Settlements in high exposure to flooding are dominated by areas in the centre to the north of Bekasi City with low elevation areas, flat reliefs, has high rainfall and close to the river. Likewise, conversely, the residential areas in the moderate to low exposure to floods are dominated by areas in the east, west and south of Bekasi City with higher elevation areas, and far from rivers.

Figure 1 (b) shows the distribution of locations of flood subscriptions in Bekasi city settlements since 2007 according to BPBD data. If we compare the two images above with the crossing process, it will be seen how much match the results of the exposure zone mapping with the facts of flood events in Bekasi City. Based on the results of the observation, it was found that from 49 flood points in Bekasi City, 19 flood points were in the high exposure area, 21 points were in moderate exposure, and 9 points were low exposure points based on the Bekasi City flood exposure map. This shows that based on the elevation, slope, rainfall, and distance from the river parameters, there is a high match between the exposure mapping and the incidents in the area.

Table 1. Floods exposure level of settlements in Bekasi City

Flood Exposure Level	Area	
	Km ²	Percentage (%)
Low	62,71	50,77
Medium	41,51	33,60
High	19,31	15,63

Based on **Table 1** settlements in Bekasi City are dominated by areas with low exposure levels, which are 62.71 km² or 50.77% of the total residential area of Bekasi City. In addition, the moderate exposure area is 41.51 km² and the high exposure area is 19.31km².

Table 2. Floods exposure level of settlements in Bekasi City by subdistrict

Flood Exposure Level	Area (Km ²)					
	Medan Satria	Bekasi Utara	Bekasi Barat	Bekasi Timur	Bekasi Selatan	Pondok Gede
Low	0,28	1,7	3,91	3,45	2,15	8,63
Medium	3,45	6,45	4,55	5,27	3,92	3,16
High	1,74	2,91	2,82	2,01	4,36	1,48

Flood Exposure Level	Area (Km ²)					
	Rawa Lumbu	Jati Asih	Pondok Melati	Mustika Jaya	Bantar Gebang	Jati Sampurna
Low	2,68	9,82	6,57	7,05	7,2	9,22
Medium	5,61	3,89	2,15	1,72	0,86	0,46
High	2,09	1,28	0,24	0,28	0,05	0,02

Based on **Table 2**, the sub-districts which have the widest low exposure level are the Jatiasih sub-district, which is 9.82 km². The widest sub-district which have area of settlements in the middle exposure level is the North Bekasi sub-district, which is 6.45 km². Sub-districts that have the widest high exposure level is South Bekasi District, which is 4.36 km².

Data on drainage conditions were taken by conducting field observations on the distribution of flood points in each classification of flood exposure as many as 3 samples. Assessment of drainage conditions seen from the presence or absence of technical or system problems, technical problems related to the depth and existence of drainage, while system problems are seen from the presence or absence of drainage

channels to the estuary or river [10]. The results of the assessment of drainage conditions in each class of exposure zones found that areas with high exposure did not have problems both technically and systemically, while in medium and low exposure found drainage problems both systemically and technically. This shows that even though the area has low exposure, if the drainage system is poor it will cause the increased of flood exposure.

The drainage channel determines how fast the water flow discharge increases and decreases [11]. If the drainage conditions are bad, the water will quickly rise and fall due to clogging and the channel will not be able to accommodate the water discharge as happened in the Pulo Permatasari residential area. The drainage channel in the area was closed due to the construction of the apartment, so that because the water dropped smoothly the flood had receded after two days of flooding [12]. The longer flooding floods, the longer the community cannot work.

5. Conclusion

Based on the Flood Exposure Map in Bekasi City in general the settlement of Bekasi City is in the "low" to "medium" exposure. This is influenced by the distance from the river, elevation, slope, and rainfall, and strengthened by drainage conditions. The most influential factors are distance from the river and rainfall. Settlements in Bekasi City are dominated by "low" exposure, which is an area of 62.71 km², where the Jatiasih Subdistrict is the widest sub-district (9.82 km²). Settlements with the widest "medium" exposure in North Bekasi District (6.45 km²), and settlements that the widest in having the highest exposure to flooding, is the South Bekasi sub-district, which is 4.36 km².

Floods in settlements that are in low and medium exposure zones are happening due to poor drainage systems. As the suggestion from the author is to overcome flooding in Bekasi City it is needed to do the revitalisation of drainage systems in micro and macro. Micro revitalization can be in the form of deepening and cleaning of drainage in the settlements so that it can accommodate a larger flow discharge, and for macro revitalization can be done by the government by monitoring and improving the closed city drainage system due to the development and land conversion function.

6. References

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