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Determination of Flood Susceptibility Index Using Overlay-Scoring Data Method based on Geographic Information System (GIS) in Semarang City, Central Java, Indonesia

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Abstract

Semarang City is the capital of the Central Java Province, located in the lowlands and directly adjacent to the north side of the Java Sea. This geographical condition makes this city very vulnerable to being affected by floods. This study aims to determine the distribution of flood-prone locations and classify the level of flood susceptibility that occurs in the Semarang City. Quantitative descriptive is the type of research with an overlay method based on scoring parameters related to environmental conditions. These parameters include slope, soil type, rainfall, altitude, land use and river flow buffers. The scored parameters are then entered into the overlay stage with other parameters in the geographic information system (GIS) application to form a map of the flood susceptibility level. The data analysis technique used the descriptive method. The level of flood susceptibility map resulting from this study is in one area of the Pemali-Juana Sub-watershed. The results also show that the scattered highly vulnerable areas in the northern part of Semarang City are areas with low elevations and flat slopes, then dominated by settlement land use that lacks infiltration areas, small river buffer sizes. These are what make the area classified as an area that is very prone to flooding.

Keywords: mapping; natural disaster; rainfall; sub-watershed

INTRODUCTION

A flood is an event that occurs when there is an overflow or puddle of water originating from either a river or other body of water (Pandey et al., 2021). The event which is categorized as one of the natural disasters, is caused by excessive rainfall and the supply of tidal waves which then inundated low-lying areas (Santika, 2018; Musliyadi, 2019; Putri, 2020). Lowlands that often occur in floods can be categorized as flood plains (Sedyowati et al., 2021). Semarang City is one of the areas in Indonesia that has been categorized as a flood plain (Aliefyanto and Suwartono, 2020).

Floods that occur in Indonesia are generally caused by logging actions without reforestation, garbage dumped carelessly in water bodies (rivers, lakes, reservoirs), house construction on the riverbanks, the low topography of an area as well as problems with drainage in the area (Harsoyo, 2013; Marhendi et al., 2017; Reinhardt-Imjela et al., 2018; Thapa et al., 2020; Ijaz et al., 2021). Another important factor in causing flooding in an area is the lack of land surface that can become a water catchment area (Kefi et al., 2020). This is because the soil surface has a lot of closed pores and lacks plant roots to absorb water (Wihaji et al., 2018). As a result, rainwater that falls to the earth's surface cannot infiltrate properly, so it pools on the surface (Basri et al., 2021). The volume of rainwater that is too large, indicates a greater chance of flooding in the area (Kundzewicz et al., 2019; Marengo et al.,

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2020). These factors will have an impact on decreasing the function of the watershed and causing severe flooding. The various mechanisms of flood problems mentioned previously generally occur in big cities (Abedin and Stephen, 2019). One of the big cities that often experiences floods is Semarang City.

Semarang City is located in the Pemali-Juana Sub-watershed area, is often hit by floods (Sadewo et al., 2022). Various types of floods occur in this city. One is the tidal flood caused by natural factors (Gultom et al., 2018). Natural damage caused by human activities also causes those, referred to as regular water floods (Sari et al., 2021). Data obtained from Regional Agency for Disaster Management (BPBD) in the last 10 years stated that there were 1,090 flood events spread across 16 sub-districts in Semarang City (BPBD, 2021). The river that is often the main source of flooding in the Semarang City is the East Flood Canal, which belongs to the East Semarang drainage system (Suripin and Kurniani, 2016). Several factors cause increased flooding in Semarang City, including land degradation, land conversion and the impact of climate change (Suripin and Hilmi, 2015).

Several efforts to reduce the potential for flooding in the Semarang area have been carried out (Suripin and Kurniani, 2016). The development of drainage systems and flood control, in general, has also been carried out by the city government (Rani, 2015). Several educations related to waste management as well as socialization to the public regarding the reuse of used goods into reusable goods, have been carried out by community components who care about the Semarang environment (Anik et al., 2012; Sudarmanto, 2016; Anwar et al., 2019). There is no graphical information from the data that explains the flooding in the Semarang City. The government said that one of the important efforts that can be made in disaster mitigation is the availability of data through maps containing information on disaster-prone areas (Regulations of the Ministry of Home Affairs, 2006). The map is expected to be the basis for the community and local government in making several decisions regarding the development of conservation land and critical watershed areas, then as a basic material for creating and placing areas, or categories of embankment locations, determining factories and others (Dwijayanti, 2021).

Geographic information systems (GIS) can be used to classify flood-prone areas (Darwiyanto et al., 2017; Putri, 2017). GIS can provide a comprehensive picture of the phenomenon of spatial data, in terms of location, linkages with other spatial phenomena, and changes in time for a spatial phenomenon (Kaundinya et al., 2013; Fischer et al., 2019). The data used to support the making of the map are in the form of slope data, elevation, soil type, land use and rainfall (Das et al., 2022; Edalat et al., 2022). Utilization of existing flood parameters in the field, as well as processing on a GIS basis, is expected to be able to map the level of flood vulnerability in Semarang City. This study's objectives are to determine the distribution of flood-prone locations and classify the level of flood susceptibility in the Semarang City. Developing a strategy to deal with the level of flood vulnerability is necessary because flood disasters affect food production and impact human health (Parvin et al., 2015; Garcia et al., 2020; Raimi et al., 2021).

MATERIAL AND METHODS

This research is a quantitative descriptive study that describes the characteristics of the level of flood susceptibility in the Semarang City. The research was conducted by utilizing GIS as an application that plays a role in analyzing data. The flood disaster that has occurred in the Semarang City is the main object of this study. While the map obtained from the overlay results with data obtained from the government is the subject of this research.

Secondary data is the main study in this study. The secondary data is obtained through data analysis studies, archives of reports as well as scientific books, and other forms of publications owned by the relevant agencies. Government and private agencies that cover various kinds of data that record flood disasters and the impact of their losses are an information source for this research. Rainfall data in this study were obtained from the Pemali-Juana river basin organization (RBO) for the last 10 years from 2012 to 2021. Other secondary data studied in this study include elevation and slope (Java digital elevation model), soil type (Semarang National Coordinating Agency for Survey and Mapping), river buffer and land use (indogeospatial). Secondary data are the basis for making several parameters

that are the main material in this study, namely rainfall, soil type, altitude, slope, land use and river buffer.

Each parameter will be classed according to the parameter criteria, to get the index value in each parameter. The index value of each parameter is adjusted to the assessment obtained from the data results. This index value is a description of the actual conditions in the environment and it will refer to the determination of the flood susceptibility level in the Semarang City. The value of the criteria for each parameter as a component to determine the index is presented in Table 1.

Table 1. Rainfall index classification

Rainfall (mm)	Classification	Description	Index
3000 <	Very wet	Highest	5
2501 - 3000	Wet	Higher	4
2001 - 2500	Medium	Medium	3
1501 - 2000	Dry	Lower	2
< 1500	Very dry	Lowest	1

Source: Putri (2017)

From Table 1, it can be seen that the greater rainfall value of an area, the greater index score obtained. Otherwise, the lower rainfall value of an area, the lower index score obtained. Each value that counts as a representative result in an environment is then adjusted to each index value in each criterion and accumulated to determine the level of flood susceptibility.

Table 2. Soil types index classification

Soil types	Infiltration rate	Description	Index
Aluvial, Planosol, Ultisol, Oxisol	Slow	Highest	5
Latosol	Rather slow	Higher	4
Mediteran	Medium	Medium	3
Andosol, Laterik, Grumusol, Podzol	Rather fast	Lower	2
Regosol, Litosol, Organosol, Rendzina	Fast	Lowest	1

Source: Asdak (1995); Darmawan et al. (2017)

Table 2 shows that various soil types also affect the flood susceptibility valuation. It can be seen in Table 2 that soil type with a fast infiltration rate will be given the lowest score. Otherwise, the soil types with a slow infiltration rate will be given the highest score. It means that the soil types with the bad condition in infiltration (slow) classify as an area prone to flooding.

Table 3. Altitude index classification

Altitude (m asl)	Classification	Description	Index
< 20	Very low	Highest	5
20 - 75	Low	Higher	4
76 - 130	Medium	Medium	3
131 - 155	High	Lower	2
156 <	Very high	Lowest	1

Source: Darmawan and Theml (2008)

From Table 3, it can be seen that various types of altitude are very influential on the occurrence of floods. The lower altitude of a place, the highest score will be given. The higher altitude of a place, the lowest score will be given. Based on these statements, it is known that areas with low elevations are highly prone to flooding. Otherwise, areas with high elevations are significantly less prone to flooding.

Table 4. Slope index classification

Slope (%)	Classification	Description	Index
0 - 8	Flat	Highest	5
8 - 15	Sloping	Higher	4
15 - 25	Rather steep	Medium	3
25 - 45	Steep	Lower	2
> 45	Very steep	Lowest	1

Source: SCS (1986); Matondang et al. (2013)

Based on the information presented in Table 4, it is known that a flat slope will be given the highest score. The very steep slope will be given the lowest score. The previous statements show that the flatter the slope of an area will be prone to flooding. The steeper the slope of an area, the less prone it is to flooding.

The information in Table 5 shows that population density is very influential on the incidence of flooding. On the type of settlement classification, the highest score will be given. The denser the vegetation of an area, the lowest score will be given. It means that the presence of vegetation can reduce the possibility of flooding. The less vegetation, the more likely it is to flood.

Table 5. Land use index classification

Types of land use	Classification	Description	Index
Settlement	Very vulnerable	Highest	5
Ricefield, Pond	Vulnerable	Higher	4
Field, Moor	Vulnerable enough	Medium	3
Shrubs	Less vulnerable	Lower	2
Forest	Not vulnerable	Lowest	1

Source: Darmawan and Themil (2008)

Table 6. River buffer index classification

Buffer distance (m)	Classification	Description	Index
0 - 200	Vulnerable	High	5
201 - 500	Vulnerable enough	Medium	3
> 500	Not vulnerable	Low	1

Source: Latif et al. (2020)

Table 6 consists of information about the river buffer and its distance. Close buffer distance will be given a high score. Far buffer distance will be given a low score. It means that the close the buffer distance, the more prone that area is to flooding. Some of the parameters indicate that the level of flood susceptibility can be measured through these indicators. These indicators are then compiled into one aspect. Those aspects are arranged as a series of accumulated values to determine the level of flood susceptibility is in some areas. Thus, a technique is applied in making a flood susceptibility map consisting of some stages, namely:

Overlay data

An overlay is one of the important steps during susceptibility map composition. It's an important procedure in GIS analysis. Overlays are the ability to place some graphics of a map over another map and display the result on a computer screen or a plot (Darmawan et al., 2017). Briefly, overlay a digital map on the other digital map with devices and their attributes to produce a combined map of the two with attribute information of the two maps. An overlay is a process of pooling data from different layers to layers. In simple terms, overlay is a visual operation requiring more than one layer to physically combine (Guntara, 2013).

GIS utilization

A basic computer application used to compile and map the appearance of the earth and analyze the existence of some location that happens on the earth's surface is the definition and a general function of GIS. This system integrated the general database operation such as query

and statistical analysis with some unique visualization. This system also gives some advantages to geographical analysis through a map. Based on the previous statements, it is known that GIS has unique and specific characteristics that make GIS different from other information systems. The method used in data processing in this research uses the overlay method with an assessment of the existing parameters. All parameters will later be scored with the weights and values according to their respective classifications, which are then overlaid using ArcMap software 10.8.

River buffer map preparation

A river buffer is prepared to classify the side distance between the right and left sides of the river by utilizing the GIS application. The calculations used to determine the distance between the right and left sides of the river can be seen in Table 6. Making river buffer through the vector taskbar, then selecting tools buffer also determines the width of the right and left sides of the river.

Data analysis

Parameters classification

Classification of each parameter is carried out at the beginning of the research stage after displaying all the data obtained. The classification is divided into two stages: the provision of index scores and weighting. The scoring for each parameter is adjusted according to the classification table (Table 7). More vulnerable the parameter class to the chance of flooding, the higher the index score given. The weighting of each parameter is based on the effect of the parameters on the flood probability. The greater impact of the parameter on the probability of flooding, the greater the weight that will be given. The smaller the influence of a parameter on the probability of flooding, the smaller the weight will be. The classification of parameter weights is presented in Table 7.

Overlay

The analysis was carried out by overlaying several maps containing score and weight descriptions. The overlay process is carried out in stages, in pairs. The slope map was overlaid with an altitude map, soil type map with a rainfall map, and river buffer map with a land use map. Merging the two maps will produce a new map with more complex information than combining the two pieces of information. Each overlay map that has been combined with the previous map will create the latest map to classify flood susceptibility levels in Semarang city.

Table 7. Flood parameter weighting classification

Parameter	Weighting index
Rainfall	10
Soil types	15
Altitude	15
Slope	25
Land use	20
River buffer	10

Source: Hasan (2015)

Flood susceptibility level analysis

Flood susceptibility values can be classified through mathematical equations by combining the index and the weighting of each parameter (Equation 1). The accumulated result of each parameter will present the number of flood susceptibility levels.

$$x = \sum_{i=1}^{n} (Wi \times Xi) \qquad (1)$$

Where; x = flood susceptibility level, Wi = weight for i parameters, Xi = score for i parameters, n = amount of data (Utami et al., 2018).

The results of these equations are used to determine the standard value for scoring on the new map. The maps consist of integrated information to espouse the flood susceptibility level classification. The flood susceptibility level can be determined based on Table 8.

Table 8. Score index of flood susceptibility classification

Classification	Score index
Not vulnerable	100-199
Vulnerable enough	200-299
Vulnerable	300-399
Very vulnerable	400-499

Source: Sholahuddin (2015)

RESULT AND DISCUSSION

Rainfall classification

Rainfall is the height of rainwater that falls on a flat place with the assumption that it does not evaporate, does not seep and does not flow (Biasutti, 2019). A rainfall value of about 1 mm represents 1 mm of rain that falls and is accommodated on a flat area of 1 m2 assuming that nothing evaporates, flows and seeps (Mulyono, 2014). Semarang City represents a research location spread into three rainfall classifications.

Based on the Figure 1, it is known that Semarang's rainfall consists of three types. They are very dry (< 2,000 mm), medium (2,000-2,500 mm) and wet (> 2,500 mm). Based on the map, rainfall dominance in Semarang City is medium with rainfall value of about 2,000 to 2,500 mm. As much as 94.89% of the area of Semarang City is classified as a medium rainfall class. From the data in Table 9, Semarang City has an average probability of rain. For this parameter, three points will be given for fulfilling the rainfall classification as data obtained to determine flood susceptibility level in Semarang. Rainfall classification in this research is in line with Mahesti et al. (2020) who classify Semarang as a medium until wet rainfall class. As mentioned by Utama and Naumar (2015), the medium and wet rainfall classes are having the same probability of flood, and it totally depends on the land characteristic itself and also drainage management of some area to control and suppress water runoff during rain (Ramadhanis et al., 2017; Lund et al., 2018; Chen et al., 2021).

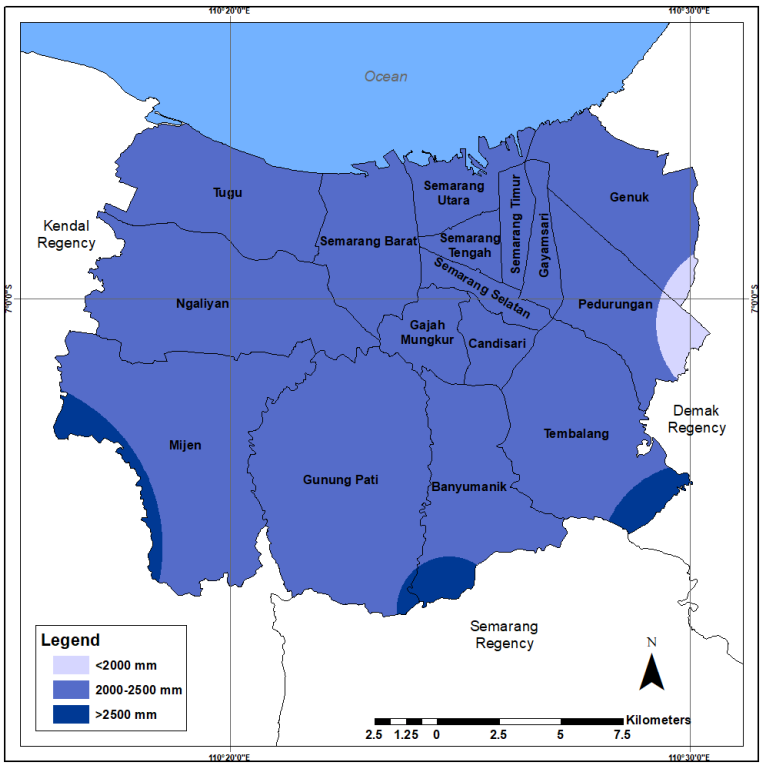

Figure 1. Semarang City rainfall classification map scale 1:120,000

Table 9. Score index of Semarang rainfall classification

Rainfall (mm)	Area (ha)	Percentage (%)	Index	Weighting	Score
2,500 <	1,445	3.72	5		50
2,000 - 2,500	36,817	94.89	3	10	30
< 2,000	538	1.39	1		10

Source: Secondary data

Soil types classification

Soil is very dynamic, it is constantly changing, which is influenced by climate (rainfall and temperature), the shape of the area (relief or the shape of the soil surface), parent material, time and organisms (Kabała et al., 2019). Several soil characteristics must have their role in the soil types classification, such as physic, chemistry and biology specifically (Stanturf and Schoenholtz, 2019; Delgado-Baquerizo, 2020). Concerning the discussion of flood susceptibility level, soil's physical characteristic has a common impact (texture, permeability, porosity, etc.) (Beven, 2020). The higher the level of soil porosity, the lower the water retention ability (Peng et al., 2019). Soil texture affects water infiltration process (Rahmati et al., 2018). The point is poor soil characteristics can affect the rate of water infiltration so it will cause runoff when it rains and result in flooding (Roy et al., 2021).

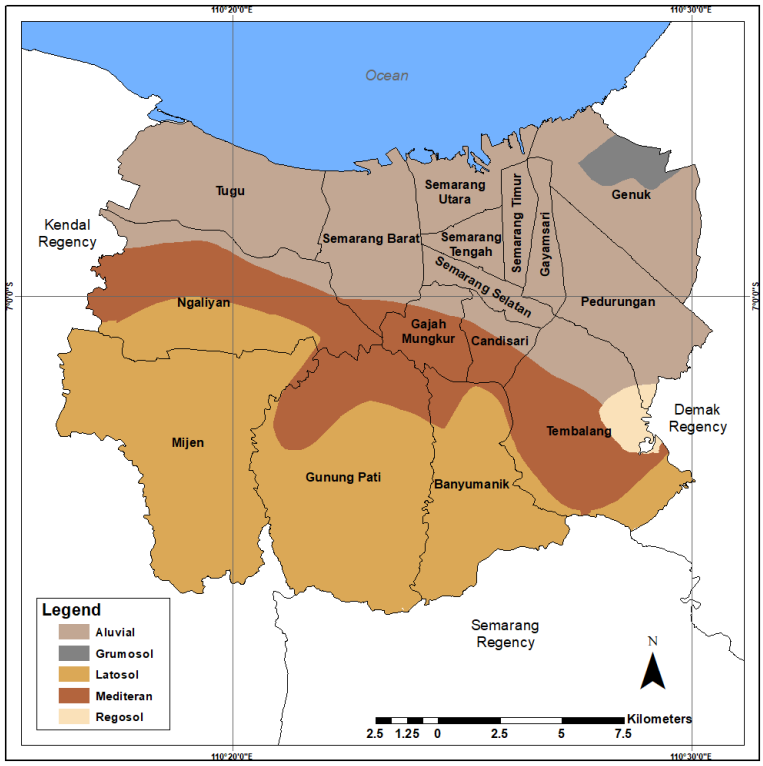

Figure 2. Semarang City soil types classification map scale 1:120,000

Table 10. Score index of Semarang soil type classification

Soil types	Area (ha)	Percentage (%)	Index	Weighting	Score
Latosol	15,292	39.39	5		75
Alluvial	15,002	38.64	4		60
Mediteran	7,568	19.49	3	15	45
Grumusol	524	1.35	2		30
Regosol	414	1.13	1		15

Source: Secondary data

Figure 2 presents a soil type classification of Semarang City, which is latosols and alluvial dominant. The distribution of the latosol soil is about 39.39% and the distribution of alluvial soil is about 38.64% (Table 10). Latosol soil is a type of soil with a clay texture. Clay particles dominate this soil, so the infiltration ability tends to be rather fast to slow (Yang et al., 2019). This clay texture also indicates the soil ability to hold water (Libohova et al., 2018). If there is a lot of vegetation above the soil surface and no obstructions around the ground, then rainwater infiltration can move quickly and percolate smoothly (Katkov et al., 2020). On the other hand, if there is no vegetation around the ground and many obstructions (impermeable) on the soil

surface, then it can cause rainwater infiltration's not easy (Zhang et al., 2020; Galle et al., 2021). This mechanism explains how possible for runoff to occur then. Runoff which is then inundated will result in flooding.

Semarang is one of the metropolitan areas in the Central Java Province, which is dominated by the presence of buildings. The existence of the building will reduce the water catchment area (Bashar et al., 2018). Several previous studies also examined the orderliness of building construction in the Semarang City to flood incidents (Naim, 2018). The solution is not to build buildings around water catchment areas and watercourses (Grill et al., 2019). Sempadan border is one of the main studies in this city as an effort to increase water catchment areas and the movement of water runoff when it rains (Dewi et al., 2021), hopefully that these efforts can reduce the incidence of flooding in Semarang.

Altitude classification

The altitude of a place is the height level of some location measured from the lowest point namely sea level (Katuuk et al., 2019). The altitude of the place is one of the factors or parameters to measure flood susceptibility. Measurement and distribution of altitude classification of Semarang City are shown in Figure 3 and Table 11.

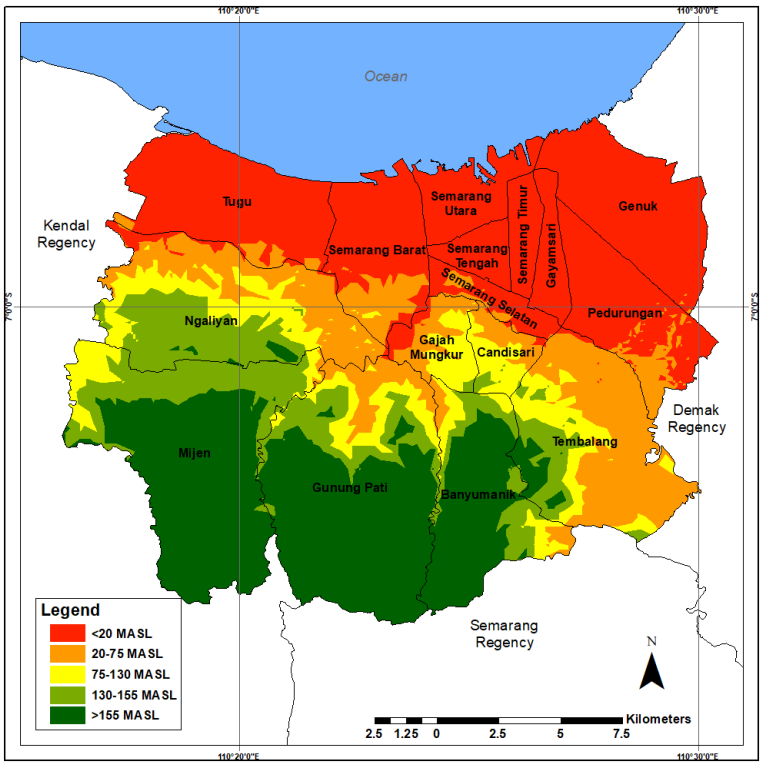

Figure 3. Semarang City altitude classification map scale 1:120,000

Table 11. Score index of Semarang altitude classification

Altitude (m asl)	Area (ha)	Percentage (%)	Index	Weighting	Score
< 20	12,900	33.25	5		75
20 - 75	6,487	16.72	3		45
76 - 130	4,029	10.38	1	15	15
131 - 155	5,067	13.06	2		30
156 <	10,317	26.59	4		60

Source: Secondary data

Figure 3 showed that Semarang City is classified as a low land. About 33.25% of the Semarang area is under 20 m asl. But it doesn't mean that it can't find a high land topography. From the data in Table 11, for about 26.59% of the Semarang area is more than 156 m asl.

From the map in Figure 3, show that the low lands of Semarang City are distributed along the north side of this city and directly adjacent to the sea. Otherwise, the high lands of Semarang City are distributed along the south side of this city and directly adjacent to the Ungaran Mountain. Darwiyanto et al. (2017) explained that altitudes are a common issue in the flood incident. The higher the altitude, the lower the chance of flooding. This statement is in line with BPBD Semarang (2021) that during 2021, flood incidents were happen arround north side of Semarang (Tugu, Semarang Barat, Pedurungan, Genuk, Gajah Mungkur Sub-districts) that classified as low land. It means that flood incidents in Semarang City in 2021 were on low land. As the party in charge of this flood disaster, the government has to find a solution, either through natural improvements (greening to increase water catchment areas) or mechanical improvements (town planning). Those efforts as a way to overcome flooding and avoid its losses.

Slope classification

The slope is defined as the angle formed by differences in land surface height (relief) between the flat land and horizontal plane and is generally calculated in percent (Syafri, 2015). The slope is also defined as an angle formed between the vertical and horizontal distance of the land, with units of percentage or degrees (DiBiase, 2018). The slope is one of the most important factors in determining the level of flood susceptibility (Vojtek and Vojteková, 2019). The slope of Semarang City is classified and shown in Figure 4 and Table 12.

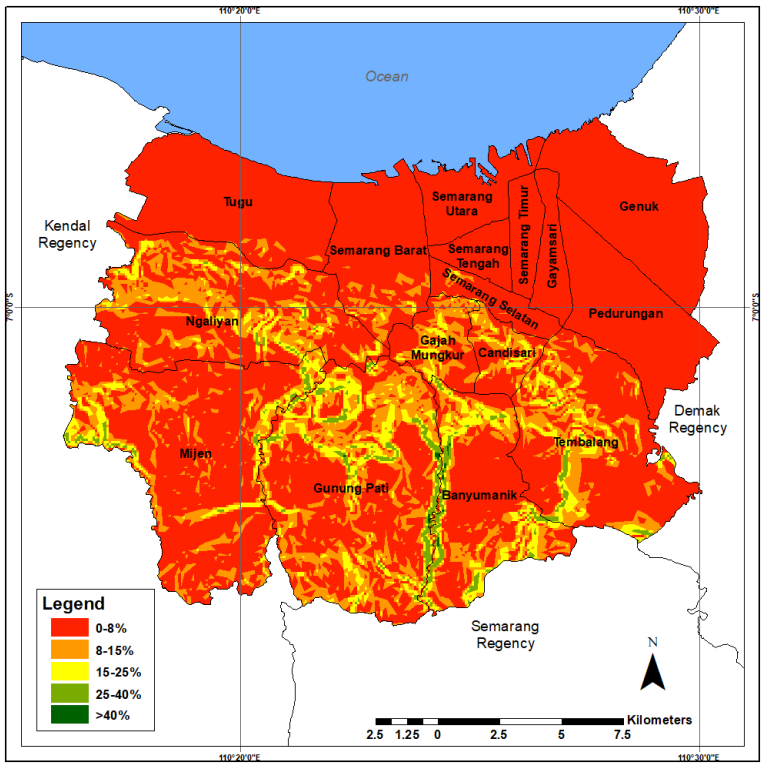

Figure 4. Semarang City slope classification map scale 1:120,000

Table 12. Score index of Semarang slope classification

Slope (%)	Area (ha)	Percentage (%)	Index	Weighting	Score
0 - 8	28,360	73.09	5		125
8 - 15	7,231	18.64	4		100
15 - 25	2,582	6.65	3	25	75
25 - 45	606	1.56	2		50
45 <	21	0.06	1		25

Source: Secondary data

Based on the map and Table 12, it is known about 73.09% area of Semarang City is classified as flat land (0 to 8%). The slope map in Figure 4 illustrates that the flat slope has the widest distribution around the north to east. Those areas based on BPBD (2021) are classified as an area that often frequent floods. Previous research in the same study showed that some areas with flat slopes potentially flood incidents (Hutauruk et al., 2020). When the rain comes and raindrops hit the land surface, the water will flow and look for lower areas. In short, those areas will be a target area for flooding. Generally, areas with a flat slope will be the destination for an inundation of water from runoff that comes from the more sloping areas (Haque et al., 2021).

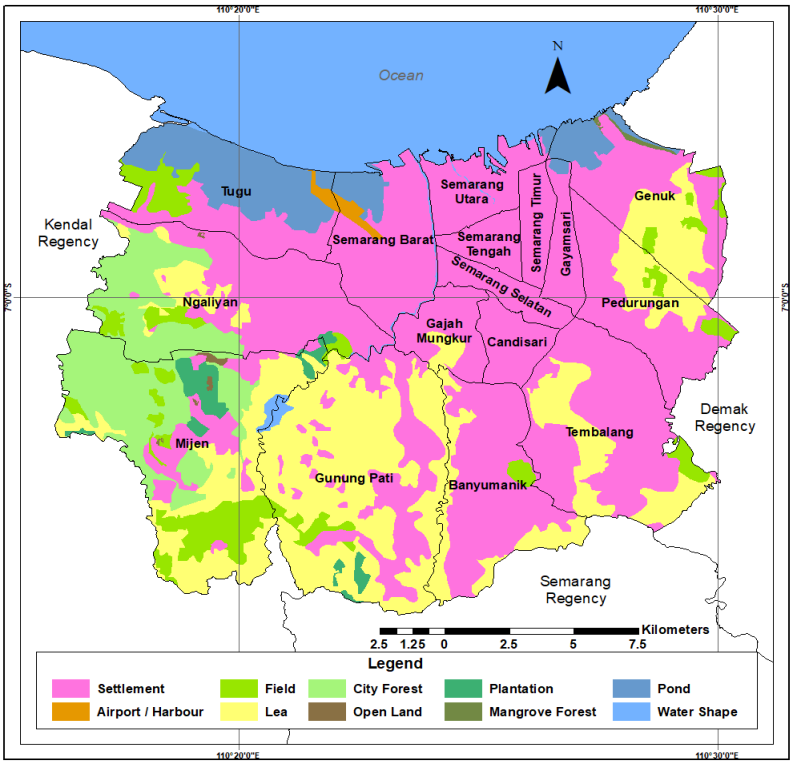

Figure 5. Semarang City land use classification map scale 1:120,000

Table 13. Score index of Semarang land use classification

Types of land use	Description	Area (ha)	Percentage (%)	Index	Weighting	Score
Settlement	Settlement	20,393	53	5		100
	Airport /harbor	162				
Rice field, Pond	Pond	2,371	6	1		20
	Water shape	211				
Field, Moor	Field	2,198	8	2	20	40
	Open land	48				
	Plantation	485				
Shrubs	Lea	9,498	24	4		80
Forest	City forest	3,385	9	3		60
	Mangrove forest	49				

Source: Secondary data

Land use classification

Land use is a manifestation of human culture to take advantage of nature, the ecosystem and the surrounding environment to meet their needs so that humans can support their lives and achieve success (Sitorus, 2018). Various forms of growth and development in today's era encourage changes in the mindset of humans which ultimately affect their culture in meeting their needs, including land use (Wamsler et al.,

2020). This drives land use changes over time (Surya et al., 2020). Land use changes will affect the land's characteristics (Sharma et al., 2018). Figure 5 is a map of the land use of Semarang City, also score index of Semarang land use classification (Table 13), as one of the bases for determining the level of flood susceptibility in the Semarang City.

Land use in the Semarang City is very complex because this city is a metropolitan city in Central Java. Based on the data in Table 13, Semarang has 10 kinds of land use specifically. From the map of Semarang land use classification in Figure 5, show that the widest land use is settlements (for the settlement itself and airport/harbor). This land use (settlement) is very vulnerable to flood susceptibility. Nur (2017) explained that settlement is very vulnerable to flood incident, due to their position which covers all of the soil surfaces and block the way of precipitation water from leaking, then causing runoff and flood just happened. A common problem in urban areas, especially in settlement areas, is the poor waterways management in the surrounding environment (Hobbie and Grimm, 2020). The only solution that must be done soon to face this flood problem is fixing the drains way (Xu et al., 2021). The government as responsible part for environmental conditions, must be able to create good drainage channels, so it will bring an impact on reducing flood risk (Raikes et al., 2019). The other interesting type of land use in Semarang is lea and it's about 24% covered in this city. This land use is spread in the southern part, which is classified as a low-risk area to flood (BPBD, 2021). Lea or also mentioned as grasslands are kind of open areas with grassy vegetation types whose roots can hold water very well (Bond, 2019). That mechanism explains the low incidence of flooding in the South Semarang area.

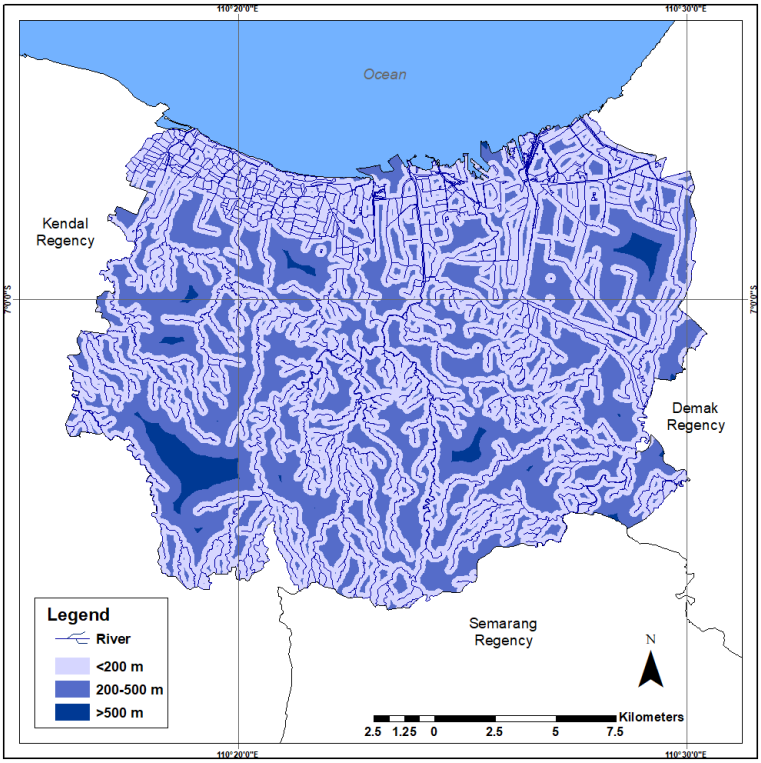

Figure 6. Semarang City river buffer classification map scale 1:120,000

Table 14. Score index of Semarang river buffer classification

Buffer distance (m)	Area (ha)	Percentage (%)	Index	Weighting	Score
0 - 200	25,768	66.41	5		50
201 - 500	10,610	27.34	3	10	30
> 500	2,422	6.25	1		10

Source: Secondary data

River buffer classification

The river buffer zone or the same epithet as the river borderline is located on the right and left along the river and it is reserved for vegetation for eco-hydrological function protection (Lind et al., 2019). River buffer affects the occurrence of flooding (Njoku et al., 2018). When the river's capacity cannot accommodate the water discharge, the water will stagnate in the area around the river (Widén et al., 2022). Then, it would cause a flood incident. This river buffer parameter is used in this research to count a flood susceptibility level. Propagation of the river channel in the Semarang City can be identified through the map (Figure 6) and table of river buffer classification (Table 14).

From the map of the Semarang City river buffer classification (Figure 6), show that Semarang has a small buffer distance from the river. About 66.41% of the river buffer area in Semarang is classified as a small buffer distance that is vulnerable (0 to 200 m). The results of previous research show that a small river buffer is very vulnerable to the possibility of flooding. Poor river management will also impact an area's high flood susceptibility so Semarang has to manage this river very well to reduce the flood incidents and flood susceptibility level (Mahmoud and Gan, 2018).

Flood susceptibility index

Maps that have gone through the scoring and weighting stage will be overlaid gradually. The mapping results will produce a classification of each area in Semarang on the level of flood susceptibility. The results of the flood susceptibility map are presented in the Figure 7.

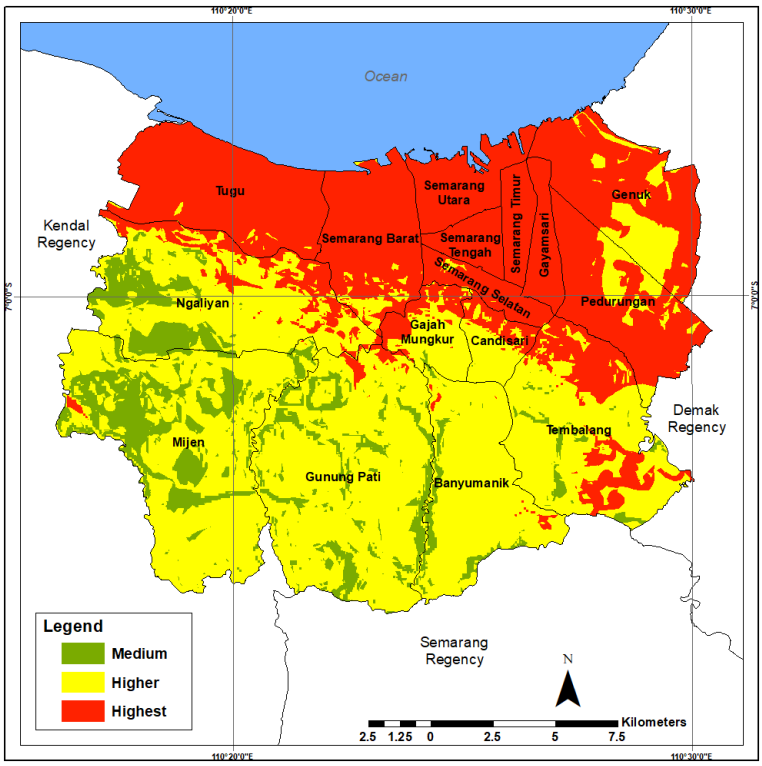

Figure 7. Semarang City flood susceptibility classification map scale 1:120,000

Table 15. Semarang flood susceptibility classification

Flood susceptibility	Area (ha)	Percentage (%)
Medium (vulnerable enough)	3,945	10.16
Higher (vulnerable)	19,728	50.81
Highest (very vulnerable)	15,127	39.03

Source: Secondary data

Semarang City flood susceptibility classification map shows that this city is classified into three flood susceptibility levels. Those classes are medium (vulnerable enough), higher (vulnerable) and highest (very vulnerable). In each class, the susceptibility level is related to 6 variables that are used to create a flood susceptibility map. Classification of flood susceptibility levels can be seen in Table 15 which shows the total score for each polygon after the overlay process is carried out. Figure 7 show that the distribution of very vulnerable areas to flood is located on the north. As shown together and as mentioned before in the previous explanation in each parameter that the north side of Semarang is classified as a vulnerable area due to its condition that classified as an area with low altitude, flat slope, then dominated by settlement land use that lacks infiltration areas and small river buffer size.

As explained in the previous discussion, Semarang is an area that often occurs in flood disasters. And the level of flood susceptibility analysis results classifies Semarang as an area that is vulnerable to flood. A total of 19,728 ha of Semarang area and it's about 50.81% classified as a vulnerable flood area. Guidelines for the use of flooded area space (Directorate General of Spatial Planning, 2003), the factor of natural conditions with the shape of a plain or basin is one of the characteristics of areas prone to flooding or inundation. The slope affects the number and speed of runoff, surface drainage, land use and erosion (Fadhilah et al., 2018). It is assumed that with more slope, then the runoff flow will be slow and the possibility of inundation or flooding becomes greater while getting steeper the slope will cause surface runoff to be fast and not inundate the area, so the risk of flooding is small. Furthermore, the factors that also cause this area to be included in the vulnerable category are the slow infiltration process. The type of soil that composes this area is alluvial with clay soil type. Clay soil is a type of soil that quickly saturates in wet conditions and have tight pores (Stanturf and Schoenholtz, 2019). If it rains hard enough will result in the infiltration process running slowly so that it will cause puddles of water on the surface (Mamonto et al., 2020).

This type of flood in this area is caused by overflowing rivers found in the Pemali-Juana Sub-watershed and tidal flooding due to high rainfall and seawater overflow (Pratikso and Sudarno, 2019). This is one of the characteristics of flooding in the vulnerable zone area. In addition to these factors, poor city drainage is also a factor cause of flooding in this area (Manawi et al., 2020). One of the suggested efforts by the government to reduce the impact of flooding in this area is to add a water catchment area (Pour et al., 2020). Sub-district areas that are vulnerable zones are Tugu, Semarang Barat, Semarang Utara, Semarang Tengah, Semarang Timur, Gayamasan, Genuk and some part of Pedurungan and Gajah Mungkur.

CONCLUSION

Semarang City flood susceptibility classification map shows that this city is classified into three flood susceptibility levels. Those classes are medium (vulnerable enough), higher (vulnerable) and highest (very vulnerable). Sub-district areas that classified as vulnerable zones to flood are Tugu, Semarang Barat, Semarang Utara, Semarang Tengah, Semarang Timur, Gayamasan, Genuk and some part of Pedurungan and Gajah Mungkur. The recommended way to mitigate flood disasters in the Semarang City is to restore the function of the land according to its designation. Forests are returned as recharge areas, rice fields are used as discharge areas, city drains are interconnected and avoid development by covering yards with cement.

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