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## Landslide Hazard Analysis On The Built-Up Areas of Banyubiru Sub-District (Semarang Regency) Using Geographic Information System

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### ABSTRACT



Banyubiru Sub-District is the sub-district that experienced the most landslides in Semarang Regency. The condition of steep slopes in several areas in this sub-district is quite dangerous to be used as a residential, industrial, and commercial area because of the high probability of disasters, especially landslides. This research focuses on identifying landslide hazard areas, especially on built-up areas in Banyubiru Sub-District, Semarang Regency. The production of landslide hazard map refers to Peraturan Menteri Pekerjaan Umum Nomor 22/PRT/M/2007. The method used to identify landslide hazard areas is scoring and weighting using several parameters, namely slope, land cover, rock type, rainfall, and soil type. Based on the processing, it can be known that mapping using the average monthly rainfall parameter for three months is more accurate than using annual rainfall. Landslide hazard on built-up areas in Banyubiru Sub-district is divided into three levels with the dominance of medium landslide hazard level covering 69% or approximately 275.70 Ha. The validation results show that out of 55 landslide events in Banyubiru Sub-district, 17 events occurred on built-up areas with medium to high hazard levels. The results of the landslide map on built-up area show that there are several villages whose built-up area have a high level of landslide hazard, one of which is Wirogomo Village. The landslide map of built-up areas is expected to be used by the community and local government to conduct mitigation efforts in areas with medium to high landslide hazard levels to minimize the impact caused by landslides in the future.

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## 1. INTRODUCTION

Semarang Regency is one of the regions in Indonesia that has geographical conditions prone to hydrometeorological disasters. Hydrometeorological disasters that often occur in this region are landslides, floods, and tornadoes. Since 2020, based on disaster data from BPBD Semarang Regency, landslides have been the most frequent disaster compared to other disasters. Landslides are natural disasters in the form of movement of rock or soil material that moves down in the direction of the surface of an inclined plane called a slope (Supriyono, 2014). In 2022, landslides that occurred in Semarang Regency reached more than 100 incidents. In that year, the rainfall at the beginning of the year was high enough to trigger landslides in several areas in Semarang Regency.

Based on disaster data from Badan Penanggulangan Bencana Daerah (2021) Semarang Regency has 12 sub-districts that are prone to landslides and Banyubiru sub-district is the most frequently experiences landslides. In this research, a more detailed mapping will be conducted where the scale of mapping is only focused on the most frequent landslide prone area, namely Banyubiru sub-

district with the smallest scale being the village. This is done in order to minimize the impact of landslides that occur in the region in the future.

The topography of the villages in Banyubiru Sub-district is mostly slope/peak with an average elevation of 611 meters (BPS Kabupaten Semarang, 2022). In the southern part of the sub-district, Banyubiru has a hilly and steep land morphology. In this area, soil fractures and small landslides are often found, especially during the rainy season (Sriyono, 2012). The Regent of Semarang Regency in Kompas.com (2016) said that based on a study by the ESDM Agency of Central Java Province, Dusun Bongkah, Sepakung Village, Banyubiru Sub-district, was previously an area of lava soil from Mount Telomoyo, which is currently in a fragile condition due to poor water and settlement management.

The increasing rate of population growth in Banyubiru Subdistrict will indirectly have an impact on the increasing need for space in the form of housing. In general, residential areas are built in areas that are safe from natural disasters. Areas with a slope of more than 15% are categorized as prone to landslides (Amri, et al., 2016). Banyubiru sub-district has slopes that vary from gentle (>8%) to very steep (45%). Banyubiru Sub-district has steep slopes in some areas. This makes some areas in the sub-district quite dangerous to be used as residential or industrial and trade areas because of the high possibility of disasters, especially landslides (Sriyono, 2012). Identification of landslide hazard areas, especially in built-up areas in Banyubiru Sub-district, is needed to minimize the impact and losses. In identifying landslide hazard areas, Geographic Information System (GIS) technology can be used. Geospatial information related to various factors causing landslides can be loaded using Geographic Information System (GIS) (Rahmad, et al., 2018).

In this research, a landslide hazard map of built-up areas in Banyubiru Sub-district, Semarang Regency was developed as one of the disaster mitigation efforts. The development of landslide hazard map utilized GIS technology and referenced the Minister of Public Works Regulation No. 22/PRT/M/2007 as previously done in (Kinanti, et al., 2022). Parameter processing uses scoring and weighting and overlay methods as conducted by (Umar, et al., 2017). The scoring method is a method of assigning a value or score to each parameter that is used to determine the level of ability possessed in each parameter (Suhardiman, 2012). While the weighting method is used when the parameters used have characters with different roles (Sholahuddin, 2015). The results of mapping the hazard level of landslides which are divided into three hazard levels are expected to help the government in implementing policies for landslide disaster mitigation efforts and spatial planning in Banyubiru Sub-district based on reducing the impact of natural disasters, especially landslides.

## 2. METHOD

### 2.1. Tools and Data

The tools used in this study include a laptop, ArcGIS 10.7.1, SpotLens, Microsoft Office Excel 2019, Microsoft Office Word. Meanwhile the data used in this study include a map of administrative boundaries of Banyubiru Sub-district, rock type map of Banyubiru Sub-district, soil type map of Banyubiru Sub-district, Banyubiru Sub-district rainfall data in 2022, disaster events data in 2018-2023, SPOT 7 satellite image of 2022, and National DEM (DEMNAS).

### 2.2. Research Phases

The implementation of this research is divided into three stages. Preparation stage, data processing stage, and analysis stage. In the preparation stage, a literature study was conducted to review the description of the selected case study location, the tools and data needed, and the methods used. In addition, preliminary surveys and data collection were also conducted. The data processing stage was carried out in the form of parameter data processing and then validating the processing results. Data processing was carried out using scoring and weighting methods. Based on the results of scoring and weighting as well as parameter overlay, the division of landslide hazard level was conducted.

Validation of the results of the landslide hazard map was conducted through interviews and field surveys based on disaster data for 2018-2023 obtained from BPBD Semarang Regency. The next step is to analyze the processing results until map presentation. The outputs of this research are landslide hazard map with annual rainfall and landslide hazard map with average rainfall in

January, February and March. In addition, there are also outputs in the form of built-up area map and landslide hazard map on built-up area.

### 2.3. Research Area

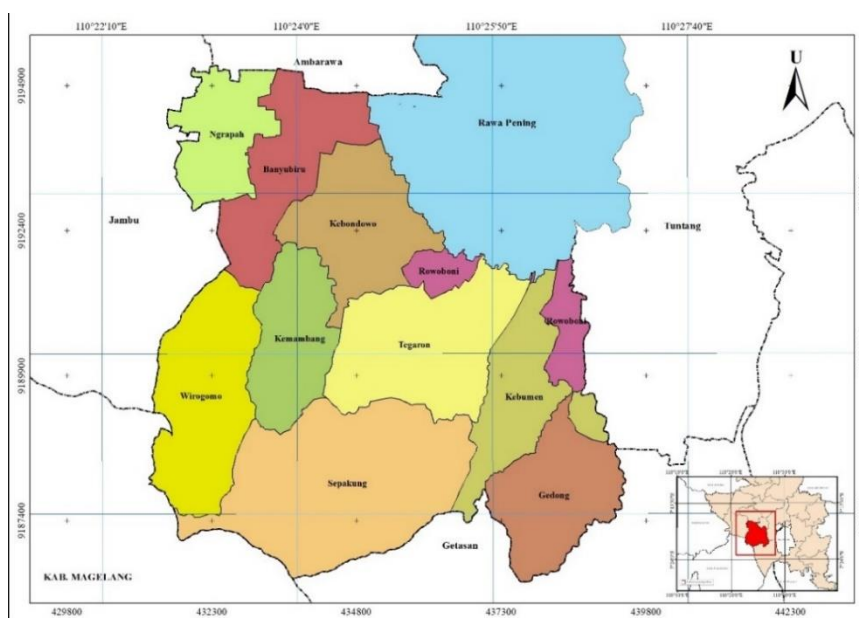
The study location of this research is Banyubiru Sub-district, Semarang Regency. In Figure 1, it can be seen that Banyubiru Sub-District has 10 villages. Most of the area of Banyubiru Sub-district is in the form of slopes or peaks with an average altitude of 611 meters. Based on population data for 2022, Banyubiru Sub-district has a population of 45,205 people, with the largest population in Banyubiru Village with 7,774 people (BPS Kabupaten Semarang, 2022).

Landslides occur quite frequently in Banyubiru Sub-district. Based on BPBD Semarang Regency data, in 2022 there was an increase in landslides compared to the previous year where in 2021 there were only 7 landslides while in 2022 there were 21 landslides. In the previous 4 years the number of disaster events was not as many as in 2022. Where the number of disaster events in 2018 was 8 events, in 2019 there were 13 events, in 2020 there were 11 events and in 2021 there were 7 events.

### 2.4. Parameters

The reference used in determining the parameters and weighting of landslide hazard is Peraturan Menteri Pekerjaan Umum No. 22/PRT/M/2007. Based on the five parameters in Table 1, rainfall parameter is the most dynamic parameter compared to other parameters. In this research, a landslide hazard map is made for the month with the highest rainfall. The rainfall data used is the average rainfall data for three months. The months used are January, February, and March because these three months have high rainfall. In addition, based on archived data from BPBD Semarang Regency, landslides in Banyubiru Sub-district often occur during the rainy season, especially at the beginning of the year.

To determine the landslide hazard level, several parameters are required, one of which is land use parameter. This parameter is one of the parameters that is quite influential to the occurrence of landslides. The less vegetation in an area, the higher the landslide hazard level. After obtaining the results of the landslide hazard map by overlaying the five parameters, the overlay with built-up area is then conducted. In this research, the output to be obtained is focused on analyzing the level of landslide hazard on built-up areas in accordance with the research title. This is done because if landslides occur in built-up areas, the impacts and losses caused will be greater. With the landslide map in built-up areas only, it is expected to facilitate readers to know which residential areas have low to high landslide hazard levels.



**Figure 1.** Map of The Research Area

**Table 1.** Landslide Hazard Parameters with Average Rainfall of Three Months

Parameters	Class	Score	Weight	Description
Slope	<8%	1	30%	<ul style="list-style-type: none"> <li>• Source: DEMNAS</li> <li>• Scale: 1:25.000</li> </ul>
	8% – 15%	2		
	15% – 25%	3		
	25% – 45%	4		
	>45%	5		
Rock Type	Alluvium	1	20%	<ul style="list-style-type: none"> <li>• Source: Rock type map from DPU Semarang Regency</li> <li>• Scale: 1:25.000</li> </ul>
	Sediment	2		
Land Use	Volcanic	3	20%	<ul style="list-style-type: none"> <li>• Source: On screen digitazion from SPOT 7 satellite image</li> <li>• Scale: 1:25.000</li> </ul>
	Forest	1		
	Plantation	2		
	Rice Field	3		
	Built-Up Area	4		
Monthly Rainfall (mm)	Vacant Land, Field	5	15%	<ul style="list-style-type: none"> <li>• Source: IDW processing of 2022 rainfall data from BMKG Semarang</li> <li>• Scale: 1:25000</li> </ul>
	<100 mm	1		
	100 mm–300 mm	2		
	301 mm–500 mm	3		
Soil Type	>500 mm	4	15%	<ul style="list-style-type: none"> <li>• Source: Soil type map from DPU Semarang Regency</li> <li>• Scale: 1:25.000</li> </ul>
	Alluvial	1		
	Andosol	2		
	Latosol	3		
	Lithosol	4		
	Regosol	5		

Sources: Peraturan Menteri Pekerjaan Umum No.22/PRT/M/2007; Ndun, dkk. (2021); Zulaikhah (2020); Kinanti, dkk. (2022); SNI 8196:2015

### 3. RESULTS AND DISCUSSION

#### 3.1. Analysis of Landslide Hazard Map

##### 3.1.1. Slope

The slope parameter is the parameter that has the highest weight compared to other landslide hazard parameters. This means that the slope has a big influence on the occurrence of landslides. The steeper the slope, the higher the influence on landslides (Muthia, R., 2012). Based on the results of the slope parameter processing, Banyubiru Sub-district is dominated by areas with steep slopes (25%-45%) with an area of 1458.78 Ha. Meanwhile, flat areas with a slope of <8% have an area of 965.07 Ha, sloping areas with a slope of 8%-15% have an area of 536.23 Ha, medium steep slope areas (15%-25%) have some areas of 733.02 Ha, and areas with very steep slopes (>45%) have an area of 1020.86 Ha. With the dominant slope in the steep slopes (25%-45%), Banyubiru Sub-district can be said to have a high level of landslide hazard, this is because the steeper the area, the higher the hazard of landslides.

##### 3.1.2. Rock Type

The type of rock owned by an area can affect the stability of the area against landslides. Volcanic rock is a type of rock that has a high influence on landslides (Julacha, et al., 2022). Based on the processing results, Banyubiru Sub-district is dominated by volcanic rock types with an area of 3160.78 Ha or about 62.1% of Banyubiru Sub-district area. Meanwhile, the alluvium rock type is found in an area of 1553.18 Ha. The type of rock owned by an area can affect the stability of the area against landslides. Banyubiru sub-district is dominated by volcanic rock, which is a type of rock that has a high influence on landslides, this is because volcanic rocks generally have fine grains.

### 3.1.3. Land Use

The land use map was obtained from the on-screen digitization process using ArcGIS software. The accuracy test of the on-screen digitization results was carried out using confusion matrix calculation and the Overall Accuracy result was 93.18%. Based on the processing results, the land use of Banyubiru Sub-district is divided into five classes, namely class 1 for forest, class 2 for plantation, class 3 for rice field, class 4 for built-up area in the form of settlements and trade, and class 5 for vacant land and fields. Banyubiru Sub-district is dominated by plantation land use, which covers an area of 2713.05 Ha. Meanwhile, other land use classifications such as forest 496.89 Ha, rice field 1091.06 Ha, built-up area 399.21 Ha, vacant land 0.51 Ha, and field 13.24 Ha. Land use has an influence on the occurrence of landslides, if a land has little vegetation or plants then the level of influence on landslides is greater. Banyubiru Sub-district is dominated by plantation land use, which means that land use in Banyubiru Sub-district is categorized as low enough to be a factor in causing landslides.

### 3.1.4. Rainfall

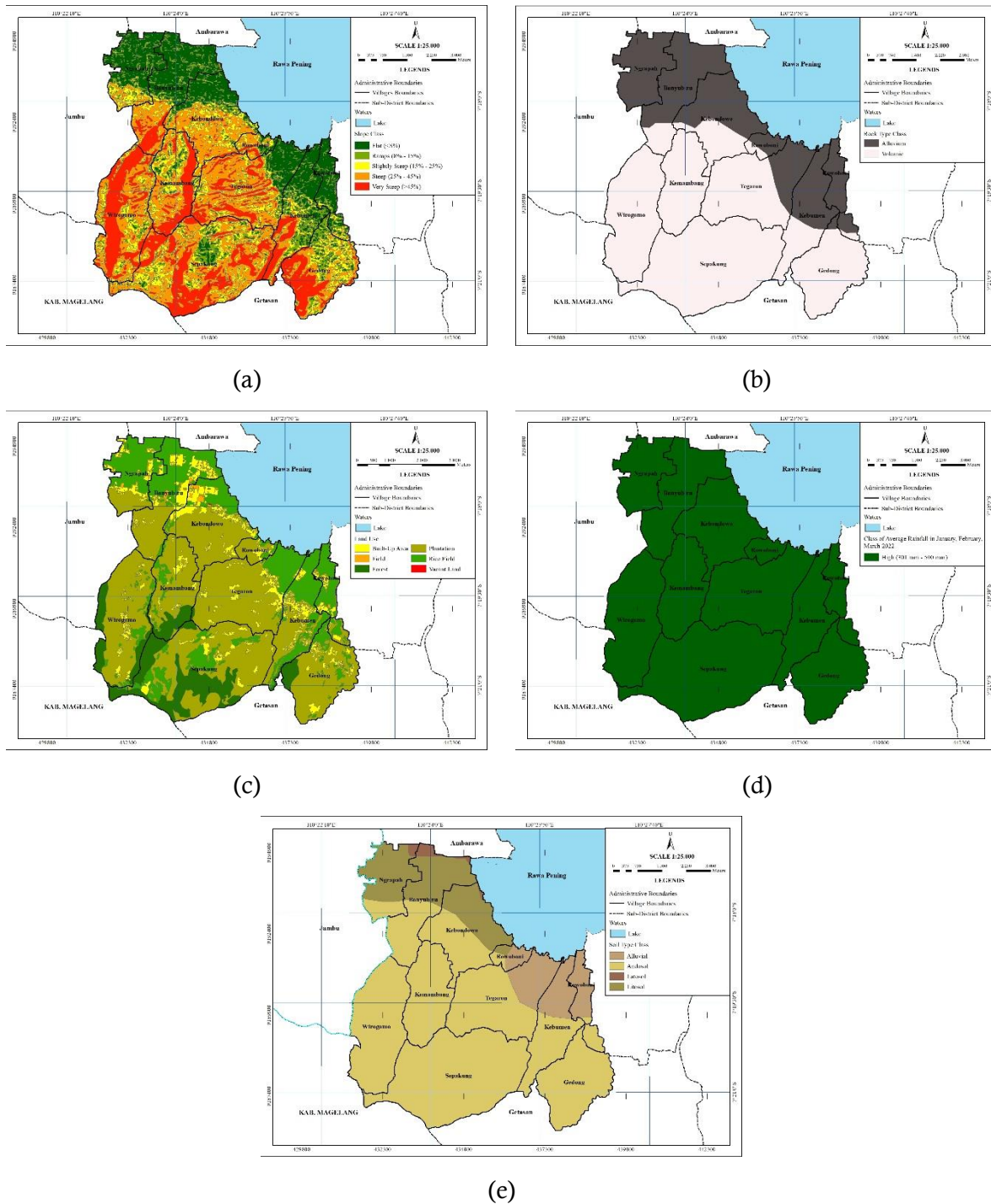
Rainfall mapping was conducted for the month with the highest rainfall, where the data used was the average of three months of rainfall. Based on the rainfall data used, January, February and March are the three months with the highest rainfall throughout 2022. The rainfall data in the three months is calculated as an average, then IDW interpolation is carried out. Based on the processing results, it can be known that in January, February, and March, all areas in Banyubiru Sub-district are in the same class, namely the high class with average rainfall ranging from 301-500 mm/month. Rainfall is one of the factors that is quite influential in the occurrence of landslides. During the period of 2022, rainfall in Banyubiru Sub-district is categorized as high, which means that Banyubiru Sub-district is prone to landslides because it has a trigger factor in the form of high rainfall.

### 3.1.5. Soil Type

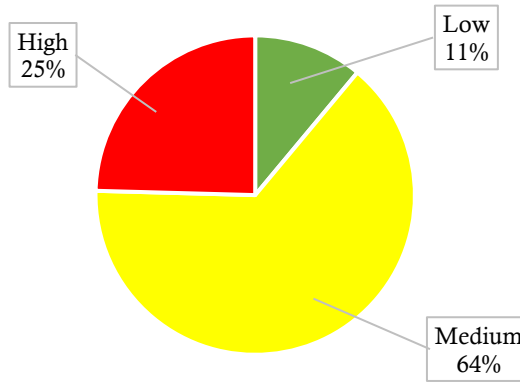
The type of soil in an area can affect the occurrence of landslides. Soil types with loose consistency, such as regosol soil, have a high influence on erosion (Dewi, et al., 2012). Based on the processing results, it can be known that Banyubiru Sub-district has four classes of soil types, namely alluvial, andosol, lithosol, and latosol. The soil type of Banyubiru Sub-district is dominated by andosol with an area of 3548.55 ha or about 69.7% of the area of Banyubiru Sub-district. Meanwhile, the alluvial soil type has an area of 450.52 Ha, the latosol soil type has an area of 41.04 Ha, and the lithosol soil type is located in an area of 673.85 Ha. Soil types with a loose consistency will have a high influence on erosion due to the low ability of the soil to retain water and nutrients. Banyubiru sub-district is dominated by andosol soil types that have a loamy texture, making it less likely to be a factor in causing landslides.

### 3.1.6. Landslide Hazard Map with Average Rainfall of Three Months

Landslide hazard map created using rainfall parameter in the month with the highest rainfall. The rainfall used is the average rainfall of the three months with the highest rainfall throughout 2022, namely January, February and March. Based on the map in Figure 3, it can be seen that the landslide hazard with average rainfall of three months in Banyubiru Sub-district is divided into three levels, namely low, medium and high. Banyubiru Sub-district is dominated by the medium landslide hazard level with 64% of its area. In the center to the south, some areas with steep slopes (25%-45%) to very steep (>45%) are in the high landslide hazard level.



**Figure 2.** (a) Slope Map, (b) Rock Type Map, (c) Land Use Map, (d) Rainfall Map, (e) Soil Type Map

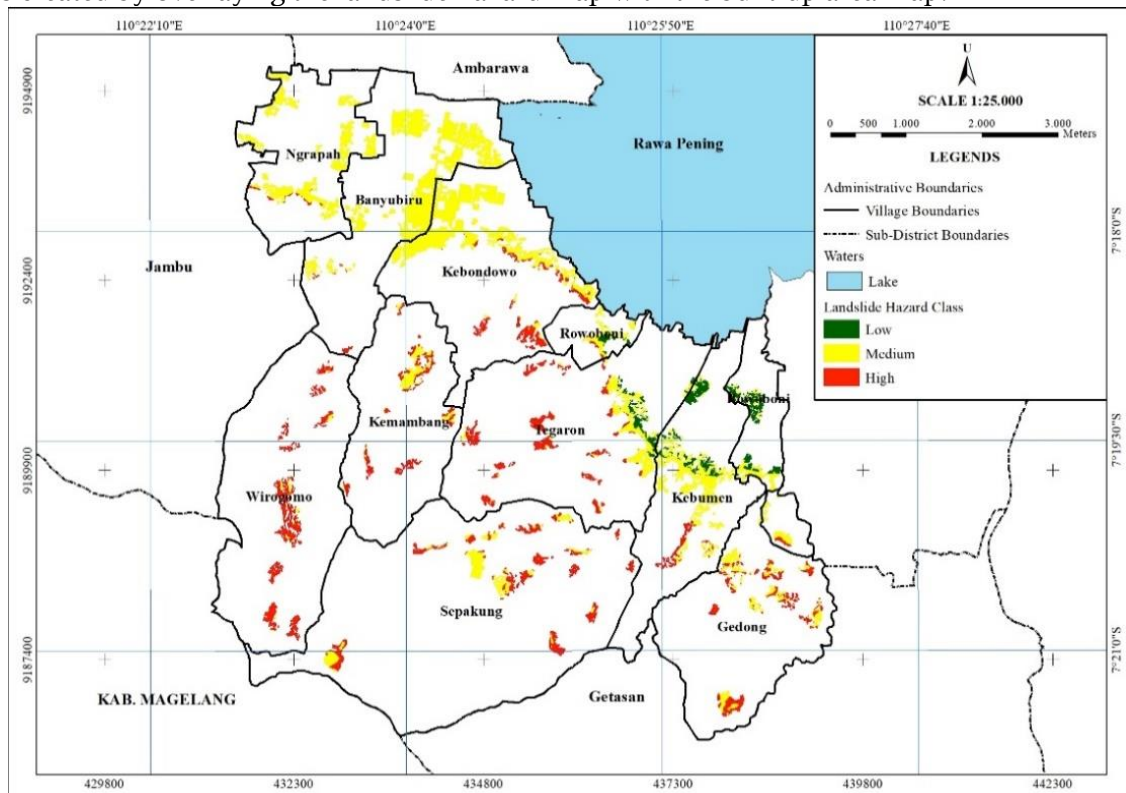


**Figure 3.** Percentage Chart of Landslide Hazard Map with Average Rainfall of Three Months

Based on the percentage chart in Figure 4, it is known that Banyubiru Sub-district is dominated by medium landslide hazard level with an area of 64% or around 3034.37 Ha. Meanwhile, the low hazard level has an area of 11% or around 521.44 Ha and the high hazard level has an area of 25% or around 1158.16 Ha of the total area of Banyubiru Sub-district. The largest area with a low level of landslide hazard is in Kebumen Village. The largest area with a medium and high level of landslide hazard is located in Sepakung Village.

### 3.2. Analysis of Landslide Hazard on Built-Up Areas Map

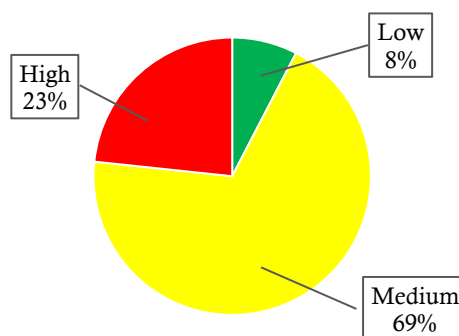
The built-up area map is obtained from the on-screen digitization process on the SPOT 7 satellite image. After digitizing, validation will be carried out to check the accuracy of the digitized results. Based on field validation conducted at 79 points, it was found that 75 validation points or around 94% were in accordance with the results of the digitization. Landslide hazard map in built-up areas was created by overlaying the landslide hazard map with the built-up area map.



**Figure 4.** Landslide Hazard on Built-Up Area Map

**Table 2.** Landslide Hazard on Built-Up Area in Each Village

Village	Low (Ha)	Medium (Ha)	High (Ha)	Area (Ha)	Population
Banyubiru	0	71.49	0.73	72.23	7,774
Gedong	0	14.39	11.97	26.36	2,424
Kebondowo	0	63.16	9.54	72.70	7,101
Kebumen	10.85	29.64	4.15	44.64	5,915
Kemambang	0	9.19	8.41	17.60	1,908
Ngrapah	0	36.04	0.83	36.87	4,206
Rowoboni	12.27	12.06	0.42	24.75	2,660
Sepakung	0	18.19	19.30	37.49	4,501
Tegaron	7.29	19.04	17.54	43.87	5,586
Wirogomo	0	2.50	20.22	22.72	3,130
<b>Total</b>	<b>30.41</b>	<b>275.70</b>	<b>93.10</b>	<b>399.21</b>	<b>45,205</b>

**Figure 5.** Percentage Chart of Landslide Hazard on Built-Up Area

Based on the map in Figure 5, it can be seen that landslide hazard in built-up areas in Banyubiru Sub-district is divided into three levels, namely low, medium and high. Most of the built-up areas are in areas with a medium hazard level. The area with the largest built-up area, namely Banyubiru Village, is dominated by the medium hazard level. Meanwhile, in the southern part of Banyubiru Sub-district, most of the built-up area is in the medium to high hazard level. Most of the built-up area is in the medium to high hazard level because the area is located on steep slopes.

Based on the percentage chart in Figure 6, it is known that the built-up area in Banyubiru Sub-district is dominated by medium landslide hazard level with an area of 69% or around 275.70 Ha. Meanwhile, the low hazard level has an area of 8% or around 30.41 Ha and the high hazard level has an area of 23% or around 93.10 Ha. The largest area with medium landslide hazard level is in Banyubiru Village. Meanwhile, the largest area with a high landslide hazard level is in Wirogomo Village.

### 3.3. Landslide Hazard Map Validation

Validation results of the landslide hazard map was carried out by checking the suitability of the map results with data on landslide events in Banyubiru Sub-district in 2018-2023 obtained from BPBD Semarang Regency. Based on the suitability check, the landslide hazard map showed that out of 55 landslide events in Banyubiru Sub-district, 17 occurred in built-up areas with medium to high landslide hazard levels. Out of 55 events, 25 events occurred in areas with high hazard level, 29 events occurred in areas with medium hazard level and 1 event occurred in areas with low hazard level. Meanwhile, based on the suitability check conducted, on the landslide hazard map in the month with the highest rainfall, it was found that 41 events occurred in areas with high hazard level, 13 events occurred in areas with medium hazard level, and 1 event occurred in areas with low hazard level. Based on the validation results, it was found that out of 55 landslide events in Banyubiru Sub-district, 17 events occurred in built-up areas with moderate to high landslide hazard levels. Of the 17 incidents, 15 occurred in built-up areas with a high hazard level. Meanwhile, 36 incidents occurred in garden areas and 2 incidents occurred in forest areas. Documentation of landslide on built-up area in Banyubiru Sub-district can be seen in Figure 7.





**Figure 6.** Documentation of Landslide on Built-Up Area in Banyubiru Sub-District

#### 4. CONCLUSIONS

Based on the processing results, it can be known that Banyubiru Sub-district is dominated by medium landslide hazard level of 64% or about 3034.37 Ha. Meanwhile, the built-up area of 399.21 Ha is dominated by moderate landslide hazard level of 69% or around 275.70 Ha. The validation result shows that out of 55 landslides in Banyubiru Sub-district, 17 landslides occurred in built-up areas with moderate to high hazard level.

Based on the results of the built-up area landslide map, Wirogomo Village is the village with the largest built-up area that has a high landslide hazard level. This is because Wirogomo Village mostly has steep to very steep slopes. During high rainfall or during the rainy season, Wirogomo Village has a high landslide hazard level. Therefore, with this research and the output in the form of maps and analysis of landslide on built-up areas, it is expected to be used as a reference for mitigation efforts for residents and local government. In some residential areas in Banyubiru Sub-district that have medium to high landslide hazard levels, efforts need to be made to minimize the impact that may be caused if landslides occur in the future.

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