# GEOLOGICAL HAZARD POTENTIAL USING SCORING AND WEIGHTING METHOD IN CITEUREUP SUB-WATERSHED, CITEUREUP DISTRICT AND SURROUNDING AREA, BOGOR REGENCY

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***ABSTRACT***

*Geological hazards are hazard caused by geological processes. Citeureup Sub-watershed, located in Bogor Regency, is a densely populated area threaten by geological hazards. The purpose of this study is to determine the distribution of geological hazards using scoring and weighting method. Factors that analyzed to determine hazards potential including: slope, rocks physical property, lineament density, and rainfall. Hazard potential in study area divided into five different levels, ranging from very low to very high, with geological hazards in the form of mass movement and earthquake. Main factor of mass movement hazard potential is slope, meanwhile earthquake potential hazard main factor is lineament density, which indicates geological structure. Rocks physical property and rainfall are supporting factors that can increase geological hazards potential.*

**Keyword**: mass movement, earthquake, slope, rock physical property, lineament density, rainfall

## INTRODUCTION

Subduction of tectonic plates in the south of Java Island causes the development of geological structures such as folds and faults (Hilmi & Haryanto, 2008). The tectonic activities have the potential to cause earthquakes, tsunamis, mass movements, and trigger volcanic activity. Hazards caused by geological processes are known as geological hazards.

Geological hazards can turn into disasters if they cause losses (Awotona, 1997; BAKORNAS PB, 2007). The more populated an area is, the greater the damage.

Citeureup Sub-watershed, located in western part of Java, is exposed to geological hazards. As a densely populated area, a geological hazard event will result in huge losses. The study of geological hazard potential in Citeureup sub-watershed aimed to determine the distribution of hazard potential, to increase awareness, and as a reference for urban development planning in that area.

Citeureup sub-watershed was chosen as study area because it has a dense population (Badan Pusat Statistik Kabupaten Bogor, 2023). Citeureup sub-watershed is located in Bogor Regency covering Citeureup District, Klapanunggal District, Babakan Madang District, Sukamakmur District, Gunung Putri District and Cileungsi District with the boundaries that can be seen in Figure 1.

## RESEARCH METHOD

The method used in this study is scoring and weighting method (Howard & Remson, 1978). Key aspects of scoring and weighting are listed below.

1. **Factor identification**: identifying factors that will then be given their respective assessments. The factors are geological aspects that have hazard potential;
2. **Scoring**: each factor that has been identified is then given a score according to its influence on hazard potential. The more hazardous a factor is, the greater the score given;
3. **Weighting**: each factor is given a weight value according to its importance to the potential hazard. Factors that are more important or have a greater influence on potential hazards will have a greater score than other factors.
4. **Calculation**: the score obtained from each factor is then multiplied by the weight of the factor. The total score is used to determine the level of hazard potential;
5. After the score of each factor has been calculated, potential hazard divided to different level based on criteria as can be seen in Table 1.



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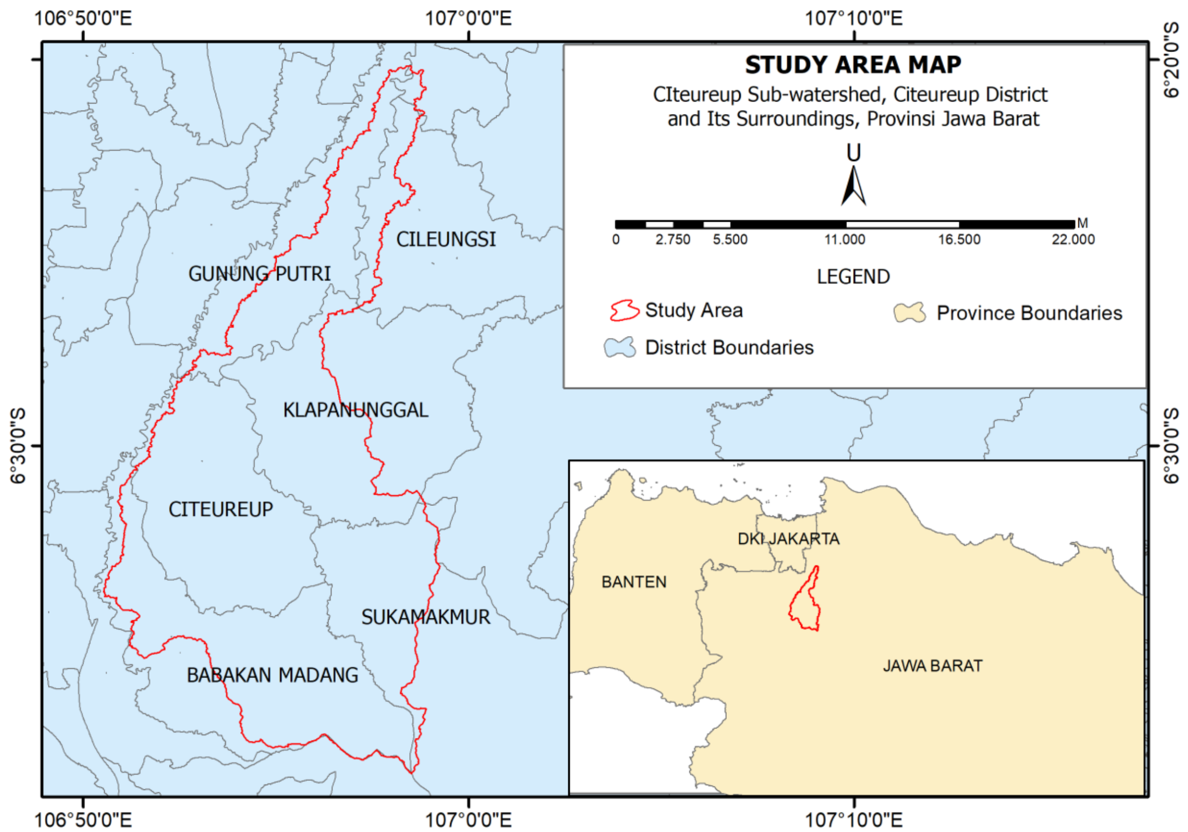


Figure 1 Study area located in Bogor Regency

Table 1 Hazard potential classes and criteria

| Hazard Potential Level | Criteria |
|---|---|
| Very High | $> \bar{x} + 1\frac{1}{2}\delta x$ |
| High | $\left(\bar{x} + \frac{1}{2}\delta x\right) - \left(\bar{x} + 1\frac{1}{2}\delta x\right)$ |
| Intermediate | $\left(\bar{x} - \frac{1}{2}\delta x\right) - \left(\bar{x} + \frac{1}{2}\delta x\right)$ |
| Low | $\left(\bar{x} - 1\frac{1}{2}\delta x\right) - \left(\bar{x} - \frac{1}{2}\delta x\right)$ |
| Very Low | $< \bar{x} - 1\frac{1}{2}\delta x$ |

## RESULT AND DISCUSSION

The factors used for scoring and weighting potential hazards include: slope, rocks physical property, lineament density and rainfall. The results of each factor calculation are displayed in map form to show the distribution of scores in the study area.

### Slope

Slope shows the angular value of a slope against a flat plane. This parameter is related to the potential hazard of mass movements. The steeper the slope, the higher the potential hazard and vice versa. The classification of slope is as follows.

Table 1 Slope classification (Van Zuidam, 1985; Bermana, 2006)

| Angle | Classification |
|---|---|
| 0 – 2 % | Flat |
| 3 – 7 % | Slightly sloped |
| 8 – 15 % | Gently sloped |
| 16 – 30 % | Slightly steep |
| 31 – 70 % | Steep |
| 71 – 140 % | Very steep |
| >140% | Extreme steep |

The slope factor is given a weight of 5, because its significant influence on the occurrence of hazards without being influenced by other factors. This parameter is divided into five classes. Data used for this parameter are obtained from satellite imagery (Digital Elevation Model/DEM) that is processed into a slope map.

The study area has a slope of 3%-103%, which classified into slightly slopes to very



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steep slopes. The slope classification of the study area and its score can be seen in the table below.

Table 2. Slope classification and scoring

| Classification | Weight | Value | Score |
|---|---|---|---|
| Slightly sloped | | 1 | 5 |
| Gently sloped | | 2 | 10 |
| Slightly steep | 5 | 3 | 15 |
| Steep | | 4 | 20 |
| Very steep | | 5 | 25 |

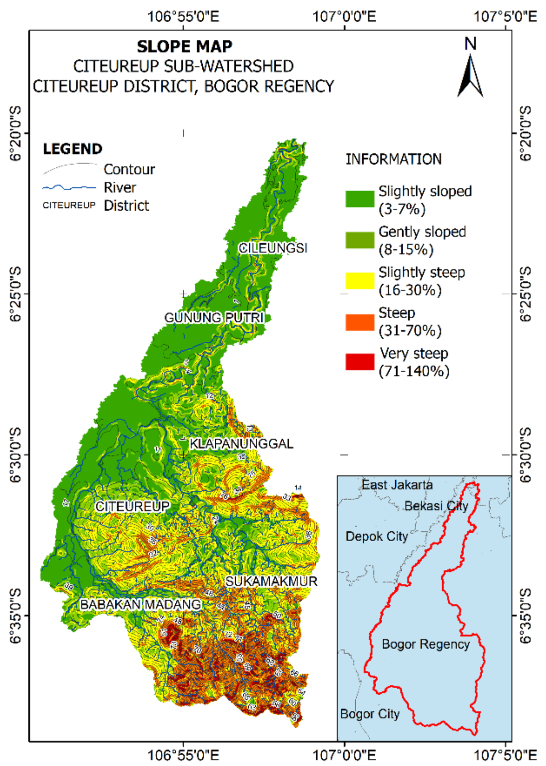


Figure 2 Slope map of study area

### Rocks Physical Property

Rocks physical property referred to the strength of the rock, which affects bearing capacity of the area. Rock with lower strength has higher hazard potential.

Bearing capacity of an area is related to mass movements potential. Weak rocks are more likely to disintegrate when exposed to earthquake-generated vibrations or weaken when exposed to heavy rainfall. This factor is given a weight of 4 because rocks physical properties only able to generate hazards when combined with other factors.

Based on field data, rocks in the study area divided into five units. From highest to lowest strength: igneous rocks; sandstones and conglomerates; tuff and alluvium; limestone; claystone and shale. The score of each rock is presented in the table below.

Table 3 Score of each rocks based on physical property

| Classification | Weight | Value | Score |
|---|---|---|---|
| Igneous rock | | 1 | 4 |
| Sandstone and conglomerates | | 2 | 8 |
| Tuff and alluvium | 4 | 3 | 12 |
| Limestone | | 4 | 16 |
| Claystone and shale | | 5 | 20 |

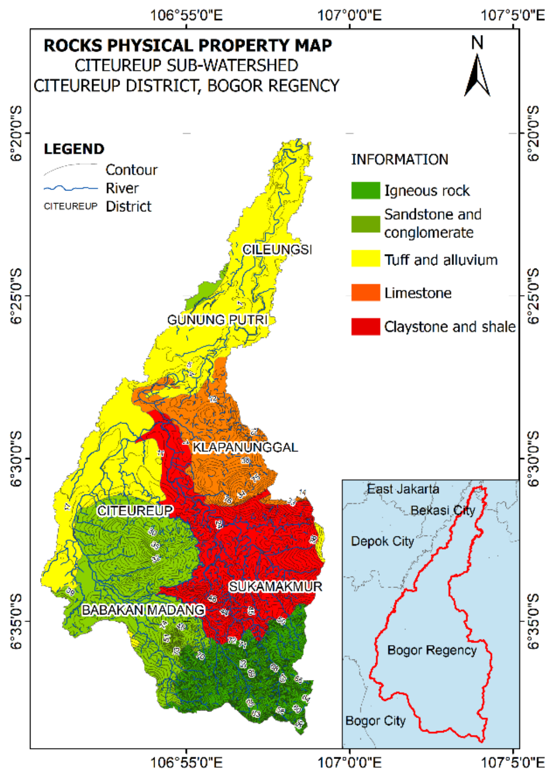


Figure 3 Rocks physical property map of study area

### Lineament Density

Lineament density indicates the development of geological structures in the study area. It indicates tectonic activity and the presence of geological structures such as faults, folds and joints in the area. Tectonic activity is related to hazard potential, specifically earthquake potential.

Lineament density data are obtained from satellite imagery (Digital Elevation Model



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/DEM) and processed with GIS software to show the density of the lineament.

Lineament density factor cannot determine exactly the type of geological structure that developed and is only an indicator of the presence of the structure, so it is given a weight of 3. The division of scores is based on the intersection of lineament and distance to the center of the lineament.

Table 4 Lineament density scoring

| Classification | Weight | Value | Score |
|---|---|---|---|
| Very low | 3 | 1 | 3 |
| Low | | 2 | 6 |
| Intermediate | | 3 | 9 |
| High | | 4 | 12 |
| Very high | | 5 | 15 |

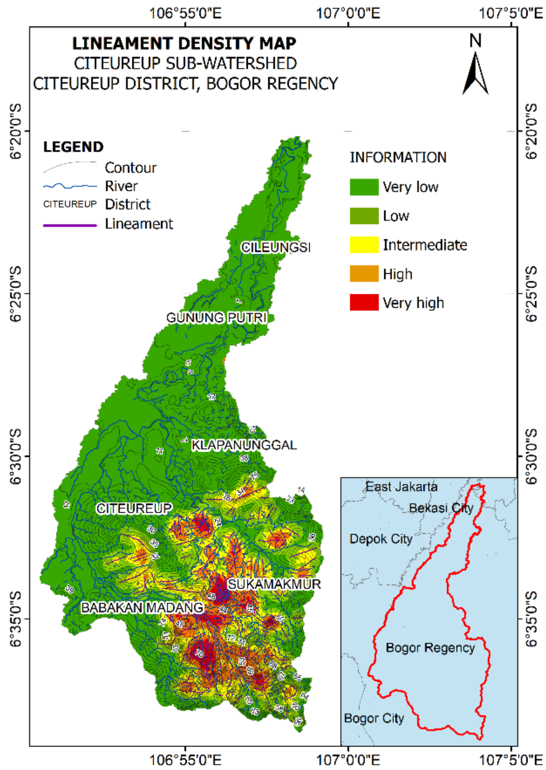


Figure 4 Lineament density map of study area

## Rainfall

Rainfall factor contributes to the occurrence of mass movements. Rainfall is a supporting factor and only able generate hazards if the other factor has a high level of hazard potential, for that reason, the given weight of this factor is 2.

The amount of rain that fall in the study area is calculated based on annual rainfall data from 2019 to 2023. Rainfall in the study area ranges from 2,230 - 3,730 mm/year. The rainfall classification used is based on BBSDLP, 2009 (Azizi, 2020).

Table 1. 5 Rainfall Scoring

| Classification | Weight | Value | Score |
|---|---|---|---|
| <1000 mm | 2 | 1 | 2 |
| 1000 - 2000 mm | | 2 | 4 |
| 2000 - 3000 mm | | 3 | 6 |
| 3000 - 4000 mm | | 4 | 8 |
| >4000 mm | | 5 | 10 |

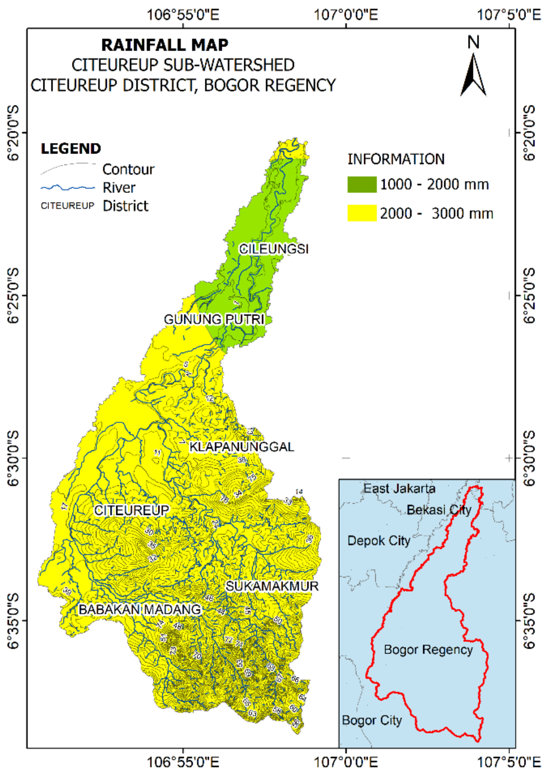


Figure 5 Rainfall map of study area

## Hazard Potential

Hazard potential divided into 5 levels according to their scores. Higher score means a higher level of hazard potential. The calculation of the score is as follows.

A. Total

$\Sigma x = 18287$

B. Mean

$$\bar{x} = \frac{\sum x}{n} = \frac{18287}{435} = 42.43$$



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C. Standard deviation

$$\delta x = \sqrt{\frac{(\bar{x} - x)^2}{n-1}} = 9.15$$

D. Potential Hazard Level

Table 6 Potential Hazard Level Score Range

| Potential Hazard Level | Score |
|---|---|
| Very high | >56,83 |
| High | 47,10 – 56,83 |
| Intermediate | 37,37 – 47,10 |
| Low | 27,63 – 37,37 |
| Very low | <27,63 |

Based on the calculation results and the hazard potential map, it can be seen that the study area is divided into five levels of hazard potential from very low to very high.

1. Very low
   The very low hazard potential level occupies the northern and western parts of the study area. The main factor causing the very low hazard potential in the area is the very gentle slope, so it has almost no potential for mass movements. There is also no lineament found in the area, so it is suspected that no geological structure has developed in the area. In addition, the rocks in the area have relatively strong physical property, namely sandstone, conglomerate and tuff. The rainfall factor in the area also falls into the medium classification.
2. Low
   The low hazard potential is spread across the western, eastern and southern parts of the study area. Each part of the study area with a low level of hazard potential results from a different combination of values for each factor. In the western part the low level results from relatively gentle slopes and tuff that has physical characteristics of rock with a score of 3 or medium. However, the score increases because the area is quite close to a lineament and has high rainfall. In the eastern part or Kecamatan Klapanunggal, the slope and rainfall factors are the same as in the western part, but there is a difference in the physical characteristics of the rocks which tend to be weaker, namely limestone which scores 4. The potential hazard level remains low because the area is far from any lineament. In the southern part or Babakan Madang Sub-district, despite having high rainfall, close proximity to the alignment, and a rather steep slope, the potential hazard remains at a low level due to the very strong physical characteristics of the rocks, namely igneous rocks.
3. Intermediate
   The moderate level of hazard potential is mostly in Sukamakmur and Babakan Madang districts. In Sukamakmur district or the east of the study area, the intermediate level is caused by the physical characteristics of very weak rocks, namely claystone and shale. The slope is relatively steep, close to lineament, and rainfall is high. The area has the potential to experience mass movement, especially if there is an increase in rainfall. Meanwhile in the southern part of Babakan Madang sub-district, the slope factor is slightly steep to steep, close to lineament and high rainfall. The area is not included in the high potential hazard level because it has rocks with strong characteristics, namely igneous rocks. Mass movement may occur if the rocks is weathered, making it weak.
   Meanwhile, in Citeureup and Klapanunggal districts, the medium level is generated from slightly steep to steep slopes and high rainfall. Citeureup district has rocks with stronger characteristics, but closer to the lineament. This is inversely proportional to Klapanunggal Sub-district, which has weak rocks but is not too close to the alignment.
4. High
   The high potential hazard levels all occupy areas with high rainfall. The slopes of the high potential hazard areas are relatively steep. The distance to the alignment is very close and even in the center of the lineament. In the south, the high hazard potential is in the center of the lineament. However, the rocks in the area have very strong physical property so the level is not considered very high. While in other parts, the high hazard potential is generated from relatively weak rocks that are very close to lineament. Areas with a high level of hazard potential can potentially experience mass movements and earthquakes.
5. Very high
   The potential for very high levels of hazard is centered between Babakan Madang and Sukamakmur sub-districts. The area has very steep slopes, very weak rocks, namely mudstone and shale, tight alignment, and high rainfall. These areas have the potential to be the epicenter of earthquakes and experience mass motion events. A small portion of this hazard level is located in Klapanunggal and Citeureup districts. The potential mass movement hazard is higher than the potential earthquake hazard.



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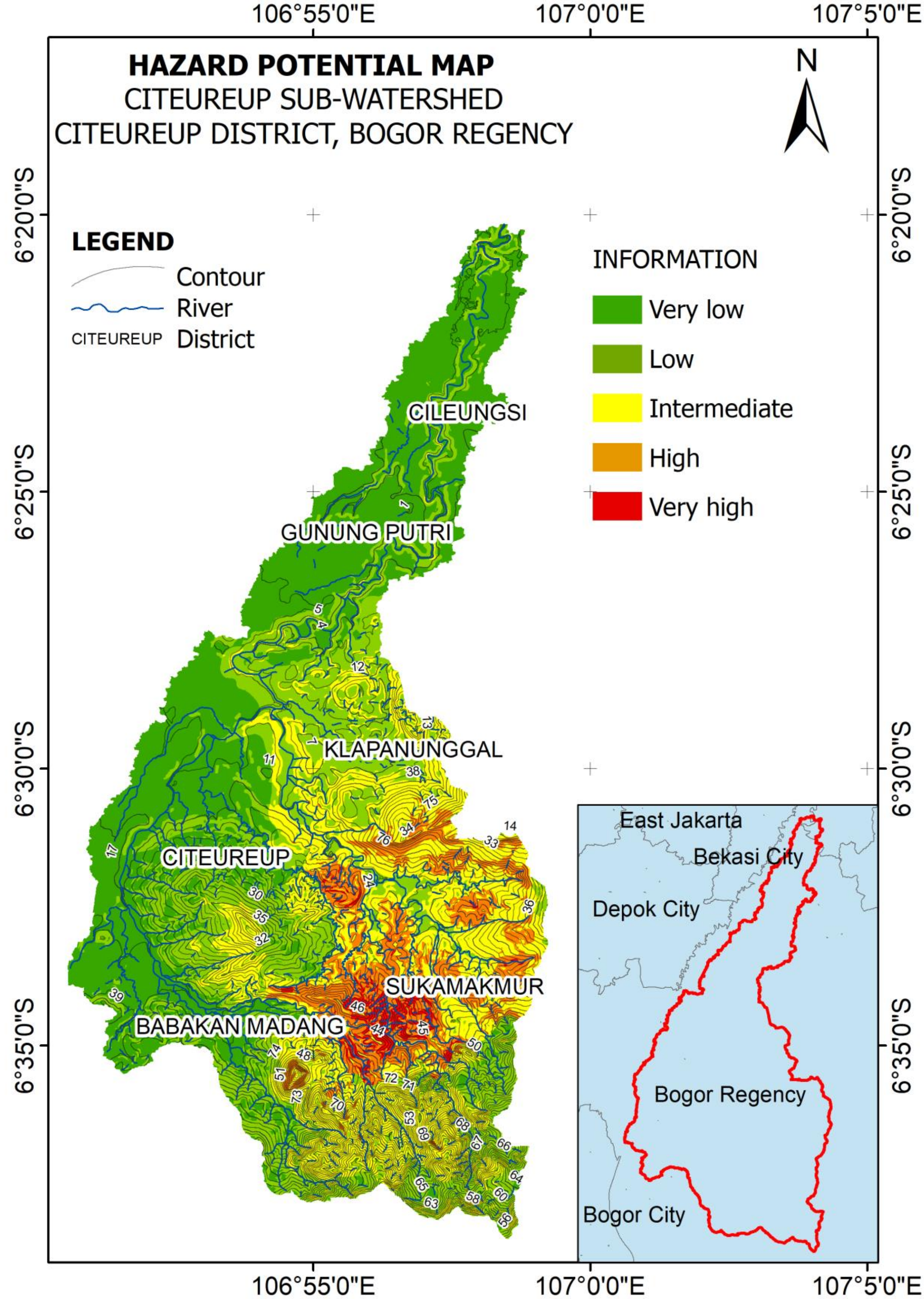


Figure 6 Hazard potential map of study area



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## CONCLUSION

The Citeureup Sub-watershed has very low to very high hazard potential. Very low and low levels of hazard potential occupy the northern and western areas. The level of hazard potential increases in the eastern and southern parts of the study area. While the central part of the study area has a very high level of hazard potential. The high level of hazard potential is caused by relatively steep to very steep slopes, tight lineament and very weak physical characteristics of the rocks. These factors are supported by high rainfall. The existence of potential geological hazards in the Citeureup Sub-watershed, especially in areas with medium to very high levels, needs attention in order to minimize the emergence of losses in the event of geological hazards in these areas.

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