Landslide hazard assessment based on human activity in the upstream area

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Abstract. Hazard is an event that can cause damage, loss of human life, or environmental damage. One of the hazards that often occurs in the upstream area is landslides. Karangkobar is one of the regions in the upstream area that had experienced a major landslide at 2014 which resulted 105 houses buried in land and 95 people were dead. The landslide disaster that has occurred in the Karangkobar catchment area is caused by the topography of the hills, high slopes, thick soil solum, soil texture, cropping pattern and treated land that inconsistent with conservation rules. This research aimed to analyse the hazard of landslide disaster based on physics and human activity aspects in the Karangkobar catchment area. Assessment of hazard analysis made by overlay between physics and human activity aspects then given scores and weights. Overlay created with Arc GIS 10.4.1 and scoring is given to assign values to each parameter disaster. The weighting was analysed by Analytical Hierarchy Process (AHP) with pairwise method and using Expert Choice V.11 software. The result showed that the percentage of landslide hazard in the Karangkobar catchment area based on physics are 42.06% low, 38.03 % medium, and 19.38 % high, while based on physics that combine with human activities are 34.64% low, 46.05 % medium, and 19.3 % high. This shows that total area for medium hazard was increase in the Karangkobar catchment area. It caused not only by natural conditions, but also human activities give effect on it.

1. Introduction
Hazard is an event that can cause damage, loss of human life, or environmental damage. One of the hazards that often occurs in the upstream area is landslide. Landslide is one of the hydrometeorological disasters that cause a lot of casualties since 2014 to 2017. Karangkobar catchment area had 1,046.58 Ha which is part of Serayu Watershed. It was located in Banjarnegara district that are prone to landslide around 68% of the total area is used for agriculture land. As an upstream area, Karangkobar catchment is hilly, where the event of landslide usually occurred on rolling, hilly, and mountainous areas [1]. Other characteristics as upstream area are high slope, deep soil depth, high rainfall, and clay soil texture, cropping pattern and treated land that inconsistent with conservation rules. The highest average rainfall was 3,000 mm / year or 100 mm / day. The high intensity of rainfall can increase the load on the slopes that can lead to increased water content in the soil and reduce the shear strength of the soil causing the occurrence of landslides [2]. Not only that, excavation and cutting slope will affect the magnitude of the slope angle and increase the magnitude of the threat of landslides. The causes of landslides in Karangkobar catchment area, especially in the
Jemblung hamlet, are heavy rain for 3 days on Wednesday to Friday with daily rainfall > 100 mm. The morphology of the source of the formation has steep slopes. The depth of the soil is very thick (more than 5 meters) which has very high water absorbing so it is easily saturated and makes slope instability.

The community used the land for paddy fields at the foot of the hill to the middle, while in upland, they used for agriculture and agroforestry farming patterns. In addition, the building of soil and water conservation that they make on the land is an improper building. This shows that landslide in the Karangkobar catchment area not only caused by physical but also human aspect. Physical aspect related to topographic, landform, slope [3] and human activities [4] such as land conversion, agricultural land use, and settlements. To reduce the hazard of landslide need integrated approach of geological, geotechnical and social investigations were carried out, especially to provide landslide hazard map with respect to the improvement of community resilience [5]. This research aimed to analyse the hazard of landslide disaster based on physical and human activity aspect. It should be highlighted that the results of this study are expected to be able to know the characteristics of human activity as a trigger for landslides and expected awareness and action to reduce the trigger.

2. Method
2.1. Location
Karangkobar catchment area had 1,046.58 Ha which is part of Serayu Watershed. It was located in Banjarnegara district that all areas are vulnerable to landslide. Karangkobar catchment area is hilly with high slope, deep soil depth, high rainfall, and clay soil texture.

2.2. Data
This research used several data such as spatial data, statistical data, and supporting data which is related to hazard assessment in Karangkobar catchment area. There were two aspect for analyze the hazard, physical aspect and human activity aspect that the assessment based on land unit. The score is given to each class in each hazard parameter. The score will be high, if the parameter effect is greater for hazard landslides. The observations were also made at the points of the previous landslide occurrence and human activities on land.

a. Physical Aspect
Hazard landslide analyses based on physical aspects are rainfall, slope, soil conditions (soil permeability, soil texture and soil depth), geology, and land use. The cumulative rainfall scores in 3 days include geology, soil depth and land use, start from low until high [8] with modification. Slope score between 1-5 [9], soil texture and soil permeability category using range from 1 until 6. The score will be high, if the parameter effect is greater for hazard landslides.

b. Human Activity Aspect
Hazard landslide analysis based on human activities aspect are excavation and slope cutting, cropping patterns, building water pond by community, drainage, frequency of soil cultivate, construction and mitigation efforts that has been done by the community. Human activity scores start on 1 for low effect until 3 for high effect to hazard.

2.3. Analyse the data
Assessment of hazard landslide is obtained by overlay between all aspect then given scores and weights. The overlay based on land unit that created with Arc Gis 10.4.1, scoring is given to assign values to each parameter disaster. Weighting was analysed by Analytical Hierarchy Process (AHP) with pairwise method and Expert Choice V.11 software, Weighting determined based on AHP scale. The AHP approach was applied to calculate the weighing and scoring of all parameters controlling the landslide susceptibility and hazard [4].
Table 1. Weighting of physical aspect for hazard landslide.

| No. | Physical Aspect for Hazard | Weight |
|-----|----------------------------|--------|
| 1   | Rainfall                   | 0.352  |
| 2   | Slope                      | 0.259  |
| 3   | Land use                   | 0.138  |
| 4   | Geology                    | 0.095  |
| 5   | Soil texture               | 0.059  |
| 6   | Soil depth                 | 0.053  |
| 7   | Soil permeability          | 0.044  |

Table 2. Weighting of human activity aspect for hazard landslide.

| No. | Human Activity Aspect for Hazard | Weight |
|-----|----------------------------------|--------|
| 1   | Excavation and slope cutting     | 0.448  |
| 2   | Cropping pattern                | 0.177  |
| 3   | Frequency of soil cultivate      | 0.152  |
| 4   | Mitigation efforts by the community | 0.095 |
| 5   | Building of water pond by community | 0.054 |
| 6   | Drainage                        | 0.042  |
| 7   | Construction                    | 0.033  |

Table 3. Weighting for hazard landslide.

| No. | Hazard Landslide    | Weight |
|-----|---------------------|--------|
| 1   | Physical Aspect     | 0.525  |
| 2   | Human Activity Aspect | 0.475 |

Based on the results of the assessment of the weight of each parameter then the hazard assessment is:

\[
\text{Hazard} = (0.525 \times \text{physical aspect}) + (0.475 \times \text{human activity aspect})
\]  

After all process finished, spatially landslide hazard maps were made and divided into three zones: high, medium, and low zones.

3. Results and Discussion

3.1. Physical aspect

3.1.1. Rainfall

Rainfall affects the landslides because water that seeps into the soil can cause a waterproof coating and it causing slides on the slope. Based on rainfall data from Jemblung and Tamansari rain stations, the Karangkobar catchment area has the highest daily rainfall of 122.4 mm / day and the highest 3-day cumulative rainfall of 183.4 mm / 3 days. High intensity rainfall (more than 100 mm) that occurs in areas with steep and unstable slopes can cause the landslides. According the community information, landslide events usually occur during the rainy season, especially in November to February which is the peak of the rainy season in the study area. This result showed that high intensity rainfall in the Karangkobar catchment area as an upstream area can be a trigger for landslide event and can be increase the level of landslide hazard.

3.1.2. Slope

The research area is the upstream of the Serayu watershed which is dominated by a very steep slope class (> 40%) with an area of 73.17%. If the slope gets steeper, the stability will be smaller and make
it easy to landslide. The magnitude of the angle slope is able to increase the driving force so that the potential for landslides will also be higher.

3.1.3. Land use
Land use in the Karangkobar catchment area consists of four land uses. They are paddy fields, farm lands, mix planting and settlements. Land use is dominated by farm land which is 51.08%. In the study area there was no forest. Many people use the land until the steep slope for the farm land. In terms of soil conservation aspects, land with very steep slopes is not suitable for crop cultivation and must be conservation / protected area.

3.1.4. Geology
Based on the results analysis showed that the majority of the Karangkobar water catchment originated from Jembangan Volcano which compiled a unit of volcanic land form (70.43%). The Jembangan volcanic rock unit is in the form of lava, breccia and pyroclastic, lava, and alluvium. Breccia rock has a water-resistant which causes the field to slip when the soil in its top layer is unstable.

3.1.5. Soil texture
The results of soil texture analysis showed that 72.69 % was loam which was included in the category of medium textured soil and the other was fine soil texture. If the soil texture class gets smoother, the soil condition becomes more unstable and easy to move because the soil is prone to wrinkles.

3.1.6. Soil depth
The depth of soil in the Karangkobar Catchment Area is in the category of deep soil (> 3 meters) which is 68.67%. Soils that have deep soil (> 90 cm) and have a loose structure will make it easier for rainwater to be infiltrated into the soil. If the amount of infiltrated water increases, it will impact the saturation of the soil so that the soil pores are easily destroyed. Consequently, the soil aggregation becomes very weak causing the soil shear resistance to decrease.

3.1.7. Soil permeability
Permeability of land in the Karangkobar catchment area is in the medium to slow category. These conditions indicate that the water in the soil will be difficult to flow out. Water held in the soil can cause the soil to become saturated, so that the stability of the soil aggregate will be weak and the weight of the soil mass increases. If the weight of the soil increases, the load on the slope will increase and the slope becomes prone to landslides.

3.2. Human activity aspect
3.2.1. Excavation and cutting slope
Human influence on slope changes is indicated by excavation and slope cutting. The pressure of population that occupied sloping lands causes an increase in landslides. The field observations showed that 97.45% of the community cut the slopes for road construction, settlements and land clearing for planting areas. The impact of these activities is increase the angle of slope and increase the load on the slope.

3.2.2. Cropping pattern
Observations in the field showed that almost all areas were planted with improper cropping patterns (99.46%). Inaccurate cropping patterns carried out by the community are the slopes are planted with a few plants with taproot roots and the bottom is used for vegetable crops, annual crops and tubers. In fact, there is a community land that is planted entirely with agricultural roots with fiber roots but does not plant hardwood trees. The selection of plant species for slope stability is very important in relation to root systems and tree loads.
3.2.3. Frequency of soil cultivate

Intensive cultivation activities can have a negative impact on the land used. The results show that 56.05% of the people cultivate the land 2-3 times a year because the cropping pattern applied is mixed. The community will dig up the soil and make the soil become loose so that the aggregate stability will decrease and is very prone to landslides. Land use that is increasingly intensive causes the possibility of landslides getting higher.

3.2.4. Mitigation effort by the community

Mitigation efforts by the community are making terraces, drainage channels and retaining structures. Terrace making by the community aims to reduce the magnitude of the slope angle on the land, although there are also people who do not make a terrace so that the vegetation is planted on sloping land. Drainage canals on dry fields appear to be maintained because every 3 or 4 months land processing and channel maintenance are carried out. But at the mix planting land, there is no sewerage or is there but is not maintained due to lack of land processing. The cropping lines made by the community are mostly cutting contours. This is a common phenomenon found in the upstream area but the technique does not follow the principles of soil conservation. The community explained that the plants that did not want the high humidity so they used contour cropping techniques. Farming techniques like this have a high level of risk of erosion and landslides during the rainy season.

3.2.5. Building of water pond by the community

The construction of ponds in the Karangkobar catchment area is mostly not done by pavement (75.02%) so that it affects the hydrological conditions of the slopes. This case directly increases the hydrostatic pressure of the water due to seepage and raises the water content in the soil, so that the shear strength of the soil will decrease and lead to soil movement.

3.2.6. Drainage

Field observations show that most of the land does not have drainage (48.89%) or there is drainage but not treated (41.36%). Drainage or untreated channels can cause water to be infiltrated so as to increase the slope load by water. The manufacture and maintenance of drainage channels is needed in landslide-prone areas to control the flow of the surface, so that water will quickly flow to the waterways below the slopes.

3.2.7. Construction

The results show that the construction building is dominated by semi-permanent buildings that are considered to have moderate loads. Construction of construction on sloping slopes can increase the load on the slope, while construction and settlement construction at the bottom of the vulnerable slope can increase the risk of landslide hazard.

3.3. Hazard

Hazard is an event that has the potential to cause damage, loss of human life, or environmental damage. Hazards usually come from nature which is supported by uncontrolled human activities. Utilization of land resources and mismanagement of cultivation by humans can increase the magnitude of the threat of landslides. The results of the landslide hazard analysis without human activity are dominated by low hazard level of 42.06%. But, the level of hazard increases when human activities are involved becomes 46.05 % on medium level. This result showed that utilisation of land resources and mismanagement of cultivation by humans can increase the magnitude of the hazard of landslides in Karangkobar catchment area.
Table 4. Classification of hazard level.

| No | Level | Without Human Activity | With Human Activity |
|----|-------|------------------------|---------------------|
|    |       | Area (Ha) | Area (%) | Area (Ha) | Area (%) |
| 1  | Low   | 445.8281   | 42.60    | 362.5498  | 34.64    |
| 2  | Medium| 397.9813   | 38.03    | 482.0012  | 46.05    |
| 3  | High  | 202.7767   | 19.38    | 202.0350  | 19.30    |
|    | Total | 1046.5860  | 100      | 1046.5860 | 100      |

The Karangkobar catchment area has a high threat level of 19.30%. Factors causing high levels of threat are rainfall, slope, excavation of slope cutting, toposequen and land use. The highest rainfall was recorded at 122.4 mm / day which almost occurred throughout the Karangkobar catchment area. Previous research explained that the intensity of rainfall above 50 mm per hour cause shallow landslides and the intensity of rainfall above 100 mm could trigger landslides. High intensity rainfall that occurs in areas with steep slopes and labile slopes can trigger the landslides. The existing slopes are dominated by steep slopes of more than 40% with the majority of land uses being moorings on the lower slopes and middle slopes. The magnitude of the slope in the area is due to the fact that many people do excavation and cutting slopes, thus increasing the angle of the slope. Whereas slopes of 25-40% are located on the top and upper slopes of which land use is nominated by mixed gardens. At slopes of 25-40% there is little excavation and slope cutting because in principle humans will find it difficult to reach the peak and upper slopes, so that the slopes will be left without special measures to reduce the threat of landslides. This is in accordance with previous research that humans will experience a high level of difficulty in processing on very steep slope (> 45%) [10]. In addition, many people use land on the middle and lower slopes because of the ease of accessibility and energy spent in processing less land than the upper or peak slopes. Greater threats of landslides can be occurred when there is more intensive processing of land.

The widest threat level is dominated by the middle class which is equal to 46.05%, which is almost the entire land use is moor. Upland is one of the land uses whose frequency of land processing is intensive because people plant vegetables and other food crops combined with hardwood plants such as *Paraserianthes falcataria*. The high frequency of land processing carried out by the community indicates the maintenance of land and water conservation buildings such as maintenance of water drainage structures. Nearly all regions in this criterion have drainage, both maintained and not maintained. The presence of drainage channels and drainage causes water to quickly descend the slope, so it does not make saturation and does not add to the load on the slope. Other factors that influence the level of hazard are excavation and cutting slopes which cause the angle of the slope to be greater. People use the land on the middle and bottom slopes because it is easy in accessibility and the energy spent by the community in processing the land less than the upper slope or peak. The more intensive land processing causes the increasing on hazard landslide. Another influencing factor is changes in cropping patterns carried out by the community. They plant a lot of agricultural crops such as vegetables, annual crops and tubers. Shallow rooted plants can increase the level of hazard because the roots are unable to grip the soil properly.

The low threat level has an area of 34.64% which is dominated by the plains area. The amount of angle in this criterion is 15-25% to 25-40%. Plains are widely used for garden land use and settlements. The types of plants cultivated such as *Paraserianthes falcataria, Swietenia* sp., coffee, salacca. In areas prone to landslides that have high rainfall, vegetation at the foot of the slope has an important role to reduce the water content in the soil through the evapotranspiration process.

Figure1 showed that the change in distribution low level of hazard is caused by a large landslide event in the area so that the mitigation efforts carried out by the community are increasing. They have the ability to anticipate, overcome, reject and restore the impact of disaster events. In addition, disaster
evacuation and education facilities in areas that have experienced disasters will be different from areas that have not yet experienced a disaster due to community experience and government intervention at the time of previous disaster management. But in other areas that have never experienced landslides there has been an increase in levels from low to medium. Economic factor had influence the utilization of farm land and mix planting. The growth of population and national food needs is able to increase the utilization of land resources, especially agricultural land so it has an impact on agriculture on a large slope angle.

![Figure 1](image1.png)

**Figure 1.** Hazard map without human activity (a) and with human activity (b).

The actual landslide that occurred in the Karangkobar catchment was taken by direct observation in the field. The results (Figure 2) showed that there were 47 landslide events and most landslides were at the high hazard levels. The high levels of landslides are caused by the influence of human activities on land and the utilization that not follow conservation rules. Most of the actual landslides are on dry land. The type of vegetation that exists is that it has shallow roots and fibers that are in the form of corn, zalacca, cabbage, grass, shrubs, cassava, papaya, long beans, bananas, tubers, chili and bamboo. Although there are also some fields that plant agricultural crops with hardwood crops such as *Paraserianthes falcatoria*, jackfruit, red shoots, and coffee. Shallow-rooted plants cause labile soil because there are no strong roots to grip the soil. In addition, there are landslide events at moderate and low hazard levels. Landslides that occur at low levels are on the slopes along the road due to excavation and slope cutting. There are no cliffs retaining buildings that cause the soil become unstable and cause landslides.
4. Conclusion
The level of hazard landslide in the Karangkobar catchment area without human activity was 42.60% low, 38.03% medium and 19.38% high. While, the hazard landslide with human activity was 34.64% low, 46.05% medium, and 19.30% high, respectively. These findings showed that that total area for medium hazard was increased by 8.02%, which also indicated that the hazard in Karangkobar catchment area were caused by both natural conditions and human activities.

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