Landslide risk assessment: human activities influence on an agriculture catchment

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Abstract. A disaster is an event that can cause damage, loss of human life, or environmental damage. One of the disasters 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 is resulted in 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 is clay, cropping pattern and treated land that is inconsistent with conservation rules. This shows that landslide in the Karangkobar catchment area not only caused by natural conditions, but also human activities have an influence on the land. This research aimed to analyze the risk of landslide disaster based on hazard, vulnerability and capacity aspects in the Karangkobar catchment area. Assessment of risk analysis made by overlay between Hazard, Vulnerability, and Capacity is then given scores and weights. Overlay created with Arc Gis 10.4.1, scoring is given to assigning values to each parameter disaster. Weighting was analyzed by Analytical Hierarchy Process (AHP) with pairwise method and Expert Choice V.11 software. Weighting determined based on AHP scale. The result showed that the percentage of landslide risk based on human activity in the Karangkobar catchment are 41.16 % high risk, 38.04 % medium risk, and 14.47% low risk.

1. Introduction
A disaster is an event that can cause damage, loss of human life, or environmental damage. One of the disasters that often occurs in the upstream area is a landslide. Landslide is one of the hydrometeorological disasters that cause a lot of casualties from 2014 to 2017. Karangkobar catchment area had 1,046.58 ha which is part of Serayu Watershed. It was located in Banjarnegara district that is vulnerable to landslide and about 68% of the total area Banjarnegara district is used for agriculture land. As an upstream area, Karangkobar catchment has hilly with high slope, deep soil depth, high rainfall, and clay soil texture, cropping pattern and treated land that inconsistent with conservation rules. Not only that, but the area also has high rainfall, with the highest average rainfall 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 [1]. 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 is dominated by clay, cropping pattern and treated land are inconsistent with conservation rules. This shows that landslide in the Karangkobar catchment area not only caused by natural conditions but also...
uncontrolled human activities in land use. This research aimed to analyze the risk of landslide disaster based on hazard, vulnerability and capacity aspects based on human activity.

2. Methodology
The research was located in Karangkobar catchment area with 1,046.58 Ha. Assessment of risk analysis made by overlay between Hazard, Vulnerability, and Capacity then given scores and weights. The first, all parameter was done by overlay and created with Arc Gis 10.4.1. After that, each parameter of the disaster was given scoring to assign values. Weighting was analysed by Analytical Hierarchy Process (AHP) with pairwise method and Expert Choice V.11 software. Weighting determined based on AHP scale. Determination of the area population is calculated for vulnerability and capacity analysis because not all village areas are included in the Karangkobar catchment area as a whole. So, in this research, there were 6 villages (Karangkobar, Leksana, Sampang, Ambal, Binangun and Pesantren) that have more than 20% included in the catchment area that will analyze.

![Figure 1. Location of Karangkobar catchment area](image)

| Table 1. Area Population of Karangkobar Catchment Area |
|----------------|----------------|----------------|
| No. | Village  | Percent (%)  | No. | Village  | Percent (%)  |
|-----|----------|---------------|-----|----------|---------------|
| 1   | Karangkobar | 89.67         | 7   | Wanayasa | 8.25          |
| 2   | Leksana   | 78.79         | 8   | Slatri   | 3.11          |
| 3   | Sampang   | 67.23         | 9   | Susukan  | 0.97          |
| 4   | Ambal     | 64.39         | 10  | Kubang   | 0.52          |
| 5   | Binangun  | 27.16         | 11  | Purwodadi| 0.44          |
| 6   | Pesantren | 24.63         | 12  | Gumelan  | 0.12          |
2.1. Hazard

Hazard landslide analysis is based on physical aspects and human activities. Physical aspects include rainfall, slope, geology, soil (permeability, texture, and soil depth), land use, whereas human activities include planting patterns, excavation and slope cutting, building water pond by the community, drainage, the community's intensity in cultivating the land, construction and mitigation of man-made efforts. The observations were made at the points of the previous landslide occurrence and human activities on land.

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

(1)

2.2. Vulnerability

Vulnerability analysis based on social, economic, physical and environmental aspects. Vulnerability is a condition of a community or society that leads or causes an inability to cope with disaster threats.

\[ V = (0.311 \times \text{environment}) + (0.297 \times \text{social}) + (0.282 \times \text{economic}) + (0.110 \times \text{physical}) \]  

(2)

2.3. Capacity

Capacity analysis is based on the rules and institutions of disaster management, early warning systems, disaster education and preparedness development on all lines. Capacity is defined as the characteristic of a person or group of people in their ability to anticipate, cope, reject, and recover the impact of a disaster event.

\[ Capacity = (0.25 \times \text{rule and institutional disaster management}) + (0.25 \times \text{early warning system}) + (0.25 \times \text{disaster education}) + (0.25 \times \text{development of preparedness on all lines}) \]  

(3)

2.4. Risk

Landslide risk analysis is conducted by:

\[ Risk = Hazard \times \left( \frac{Vulnerability}{Capacity} \right) \]  

(4)

if the value of threats and vulnerabilities are higher, then the risk value will be higher, but the risk can be reduced with high capacity. The results of the risk analysis consist of three classes: low, medium and high risk level.

3. Result

3.1. Hazard

Based on the results of the overlay between physical aspects and human aspects, it showed that the percentage of hazard in the Karangkobar catchment area is 34.64 % low, 46.05 % medium, and 19.30 % high hazard. Percent and hazard maps are shown in Figure 1. The high hazard level is influenced by a large slope angle of more than 40% due to the biogeophysical upstream area characterized by a large slope. Large slope angles can increase the driving force so that the potential for landslides is also higher. The highest daily rainfall in the area is 122.4 mm / day and the highest 3-day cumulative rainfall is 183.4 mm / 3 days whereas rainfall intensity above 100 mm can trigger the landslides. From the land use factor, it is shown that most of the land use is farmland (51.08%) and plantation (38.62%). The percentage of land use and plantations is influenced by economic factors. The growth of population and national food needs is able to increase the utilization of land resources, especially agricultural land. The results of soil texture analysis showed that 72.69% of the soil texture in Karangkobar catchment was loam which was included in the category of medium textured soil and
26.76% was silt which loam entered into fine soil texture. If the soil texture class becomes smoother, the soil becomes more unstable and easy to move because the soil is prone to wrinkles. The depth of the soil is mostly more than 3 meters. Soil that has deep solum and has a loose structure will allow water to be infiltrated into the soil. If the amount of infiltrated water increases and the soil becomes more saturated. It caused soil pores easy to break and soil aggregation becomes very weak so the soil resistance decreases.

![Hazard map and the percentage of hazard](image)

**Figure 2.** Hazard map and the percentage of hazard

### 3.2. Vulnerability

Almost all villages have a high level of vulnerability based on 4 aspects (social, economic, physical and environmental aspects). Almost all villages have a high level of vulnerability based on 4 aspects (social, economic, physical and environmental aspects) because regional income depends on land.

![Vulnerability map and the percentage of vulnerability](image)

**Figure 3.** Vulnerability map and the percentage of vulnerability
Almost all Karangkobar catchments are productive land and people depend on agricultural products such as vegetables to fill the local and national food needs. The high demand for food can lead to the high utilization of land resources. If landslides occur, the impact is a high material loss, loss of community livelihoods and disruption of food available both locally and nationally. From the environmental aspect, the Karangkobar catchment area is an upstream area. In a watershed, between the middle and the downstream have biogeophysical linkages where all activities and damage that occur in the upstream area will impact the middle and downstream.

3.3. Capacity
Capacity is the ability of individuals, communities, governments to handle hazards in their regions. Capacity analysis is based on the rules and institutions of disaster management, early warning systems, disaster education and preparedness development on all lines. High capacity is owned by villages that have experienced landslides in the past. So that there are already hazard warning boards, evacuation sites and training on handling hazards. But for areas that have not experienced landslides, there is no prevention effort either through socialization or training and no special organization that handles landslide or disaster. Public awareness of landslide hazards is also lacking as evidenced by the lack of mitigation efforts already underway.

3.4. Risk
The level of landslide hazard risk in the Karangkobar catchment area is mostly medium (38.04%) and high risk (41.16%). In addition to the Physical aspects of hazards such as high rainfall, the dominant soil texture is loam, deep depth of soil, the slope is mostly steep category (> 40%) and most of the land use is agricultural crops (51.08%), human activity on land also affects the risk of landslides. Human activities in the area include excavation and slope cutting caused a greater angle of slope. The community cultivates on the land 2-3 times a year. It caused the cropping pattern applied by the community is a mixture of hardwood plants and vegetable crops. The community will process the soil and make the soil become loose so that the aggregate stability will decrease and very easy to a
landslide. Mitigation efforts carried out by the community include technical and vegetative civilians. The vegetative action taken is agroforestry systems. The types of vegetation planted in large numbers are fast-growing species such as *Paraserianthes falcataria* (sengon). Whereas the technical civil action is the terrace, drainage, and wall on the land. In some land use, drainage cannot be found or the drainage is not treated. Inadequate civil engineering buildings caused the water cannot flow so that it increases the load on the slope. The water pool that made by the community is mostly from the ground, that it increases the hydrostatic pressure of the water because there is seepage and raises the water content in the soil so that the shear strength of the soil will decrease and lead to soil movement.

![Figure 5. Risk map with human activity and the percentage of area](image)

Strategies to reduce landslide risk can be grouped into two, the role of vegetation and non-structural mitigation. The role of vegetation in landslide control is among others as evapotranspiration, infiltration, percolation, humidity moisture below and above the surface. Vegetation that has high evapotranspiration with light canopy plays a role in reducing soil saturation so that there is no accumulation of water in the impermeable layer which will become the field of the slip in the landslide. In the case of soil mass stability, the roots of vegetation will strengthen the slope and the water absorbed by going through the transpiration process will reduce soil moisture so as to make the slope strong. Non-structural mitigation consists of arranging regulations, spatial management, training [2] and implement a comprehensive system especially for maintain the slope safety [3].
4. Conclusion
The level of landslide risk in the Karangkobar catchment area are 41.16% high risk, 38.04% medium risk and 14.47% low risk. Human activities that effect the level of landslide are excavation and slope cutting, the community cultivates, cropping pattern and the mitigation that applied by the community. Strategies to reduce the landslide risk can be grouped into two, role of vegetation and non-structural mitigation.

References

[1] Paripurno 2004 Public Participation in Landslide Management in Landslide Problems, Policy and Landslide Disaster Mitigation in Indonesia Jakarta : P3_TPSLK BPPT and HSF.

[2] Soenarmo S H, Sadisun I A and Sapohartono E 2008. Preliminary study of the effect of rainfall intensity on estimation of landslide potential spatial based in Bandung, West Java, Geoaplika Journal, Volume 3 No. 3, page 133-141

[3] UNISDR 2017 Landslide Hazard and Risk Assessment