Assessment of soil erosion and landslides susceptibility based on hydrophysic soil properties in Karangkobar catchment, Banjarnegara, Indonesia

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Abstract. Landslides and erosion are highly influenced by soil properties. Soil texture, structure, particle density, bulk density, and porosity are the properties which correspond to infiltration rates. This study aimed to assess soil erosion rate and landslide in upland of Karangkobar catchment and to explore its correlation to hydrophysic soil properties. Material used in this study were topographical maps, land use maps, administrative maps on scale 1:25000, and soil samples. An unit land map was created by overlying topographic, landuse, and administrative maps. This study found 16 unit lands. Soil sampling and infiltration test were conducted in every unit land. Infiltration test adopted double ring infiltrometer test, while Horton's formula was applied to determine the value of infiltration capacity. Soil hydrophysic properties in catchment area Karangkobar: texture loam, granular structure, bulk density 0.62 – 1.09 g cm⁻³, particle density 1.83 – 2.47 g cm⁻³, and infiltration capacity 1.5 cm hour⁻¹ – 67.9 cm hour⁻¹. Erosion rate was 2 mm year⁻¹ with the potential landslides classified as high. Soil hydrophysic properties which have a strong correlation to erosion was bulk density (r = 0.517 *) and potential landslides was infiltration rate (r = 0.641 **).

1. Introduction
Landslides are becoming common in Indonesia. Landslides struck in the Karangkobar, Banjarnegara in 2014. There are so many factors that cause landslides. Slope, soil, rainfall, land use, vibration, and deforestation are generated of landslides [1,2]. Landslides are a type of soil erosion which transports soil at a short time and very large volume. While causes of soil erosion are rainfall, soil, slope, vegetation, and humans. Landslides and erosion are being related to the soil. Texture, structure, particle density, bulk density, and porosity are influence of soil infiltration and hydrophysic soil [3].

Soil Erosion is process destroyed the soil by rainfall. After that, a soil was being transported to another place by surface runoff [4,5]. While the process of landslides when water adsorbs into the soil can increase the weight of the soil. When the water to penetrate to the impermeable soil and reach slip plane, then the soil becomes slippery and move out of the slope [6].

Among all the predictive equations developed to estimate soil erosion, the most accepted, used, convenient and suitable technique, is the Universal Soil Loss Equation (USLE). USLE is a soil erosion model designed to predict long-term soil erosion from sheet or rill erosion [7,8]. Hydrophysic is a branch
of geophysics that studies the natural state of water and physical processes in the hydrosphere on the earth. Hydrophysic soil can mean the process, nature, and condition of water in the soil. The hydrophysic soil properties are the interaction between fluid and soil components [6,7]. Based on the results of the study of [8] that the hydrophysic soil properties depended on infiltration. The purpose of this study is to identify the hydrophysic soil properties, calculate the soil erosion rate and mapping potential landslides, and analyze the correlation of potential soil erosion and landslides based on the hydrophysic soil properties.

2. Methodology
The study conducted at Karangkobar catchment, Banjarnegara from Maret until November 2018. The material used in this study were topographical maps, landuse maps, administrative maps on scale 1:25000, soil sample, and infiltration test. There were some steps: survey, secondary data, and analyze laboratory. An unit land map created by overlying topographic, landuse, and administrative maps. This study found 16-unit lands. Soil sampling and infiltration test were being conducted in every unit land. Infiltration test adopted double-ring infiltrometer test, then analyzed using Horton formula to determine the value of infiltration capacity. The methods to analyzed soil physical properties of bulk density are ring sampler, particle density is pycnometer, texture with pipe method, structure with USB digital microscope, and porosity were being calculated based on the formula of Hanafiah [9].

\[
\text{Porosity} = 1 - \frac{\text{bulk density}}{\text{particle density}} \times 100\% \tag{1}
\]

The predictive of soil erosion used the USLE method with ArcGIS. The soil erosion unit converted ton/ha/year to mm/year.

\[
\text{A} = \text{R} \times \text{K} \times \text{LS} \times \text{C} \times \text{P} \tag{2}
\]

Where:
A = the average annual surface erosion rate (ton/ha/year)
R = the erosive rainfalls (KJ/ha)
K = soil erodibility (ton/KJ)
LS = slope length coefficient and slope degree (%)
CP = cover-management and conservation measures (value)

The classification of landslide areas used an assessment (scoring) of trigger parameters of landslides. The assessment based on expert judgment through consultation with related experts. Thematic maps overlay by considering scores to get a class of distribution of landslide areas. The physical properties of the area used as trigger parameters for landslides are being presented in Table 1.

| Variable     | Description       | Value | Data Source                  | Citation          |
|--------------|-------------------|-------|------------------------------|-------------------|
| Rainfall (D) | < 500             | 1     | Automatic Rainfall Record    | BP-DAS            |
| (mm/year)    | 500 – 999         | 2     | Karangkobar catchment        | Jeneberang-Walanae, 2010 [10] |
|              | 1000 – 1999       | 3     |                               |                   |
|              | 2000 – 2999       | 4     |                               |                   |
|              | > 3000            | 5     |                               |                   |
| Slope (A)    | 0 – 8 %           | 1     | Topographic maps             | SK Menteri       |
|              | 8 – 15 %          | 2     | Pertanian Nomor 837/KPTS/UM/19|                   |
|              | 15 -25 %          | 3     | 80                            |
|              | 25 – 45 %         | 4     |                               |                   |
|              | > 45 %            | 5     |                               |                   |
| Land use     | Forest land       | 1     | Land use maps                |                   |
Calculated using the formula proposed by Dibyosaputro (1999) [13]:

\[
I = \frac{C-B}{A}
\]

Where:

| (B) | Dryland | Built-up | Mixing garden | Cropland |
|-----|---------|----------|---------------|----------|
| Soil (Infiltration rate) | < 0.1 | 0.1 – 0.5 | 0.5 – 2 | 2 – 6.5 | 65 – 12.5 | 12.5 – 25 | > 25 |
| (cm/hour) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

Infiltration test Arsyad (2000) [12]

3. Result and Discussion

Table 2 shows that the texture Karangkobar catchment dominated by loam and silt loam textures. Based on the results of the study of Apriyono [14] that clay is often found in Indonesia comes from volcanic eruptions. Soil structure dominated by granular dominant. Based on the results of the study of Dai et al., [15], that granular soil structure decreases soil erosion rate. But, according to Karnawati [16] that is effective for trigger landslides. The highest bulk density is unit land P-1 and the lowest is unit land P-3. This is by the opinion of Hadi et al., [17] that on land was being subjected to continuous pressure resulting in compaction so that the contents of bulk density will be higher.

Meanwhile, the particle density in all observation points ranged from 1.82 to 2.41 grams/cm³. This is under the opinion of Surya et al. [18] that particle density is not changed in the long term because it is being associated with a stable of the solid composition. Table 2, the highest porosity is unit land P-3 by 68.82% and bulk density by 0.61 gram/cm³. Bulk density has negative and significant correlation with porosity, that is \(r = -0.881^{**}\). This means that the increase in bulk density, porosity is low. This is under the opinion of Kurnia et al., [19] that bulk density affects soil porosity.

Based on Table 2, the highest infiltration rate in unit land K-1 by 43.1 cm/hour. Soil with a low bulk density causes high porosity and will increase the infiltration rate [20]. Porosity has positive and significant correlation with infiltration rate \(r = 0.522\). This means that the increase of porosity, the infiltration rate is high.

**Table 2.** Hydrophysic soil properties at Karangkobar catchment

| No | Unit land | \(\rho_b\) (gram/cm³) | \(\rho_s\) (gram/cm³) | Porosity (%) | Infiltration (cm/jam) | Texture | Structure |
|----|-----------|-----------------|-----------------|--------------|-----------------|---------|-----------|
| 1  | K-1       | 0.80            | 2.04            | 60.77        | 43.1            | loam    | Granular  |
| 2  | K-2-A     | 0.81            | 1.97            | 58.91        | 8.5             | loam    | Granular  |
| 3  | K-2-B     | 1.03            | 2.18            | 52.90        | 12.1            | loam    | Granular  |
| 4  | K-2-C     | 0.78            | 2.02            | 61.27        | 6.2             | silt loam | Granular  |
Karangkobar catchment has a predictive soil erosion rate was 42.8 tons/ha/year or 2 mm/year. The results of soil erosion prediction of Karangkobar catchment shown in Figure 1. The analysis shows that soil erosion in Karangkobar catchment is being dominated by very low 58.6%, soil erosion low 33.8%, soil erosion medium 3.9%, and finally soil erosion high 3.7%. Figure 2 shows a comparison of the rate of predicted soil erosion in Karangkobar catchment in unit land. The highest soil erosion prediction rate occurred in unit land K-2-B with erosion rate of 194.6 tons/ha/year or 8.6 mm/year. The unit land K-2-B, the soil erosion rate is being dominated by the high at 84% and medium at 16%. While the smallest soil erosion prediction rate occurred in unit land K-2-C with erosion rate of 1.1 ton/ha/year or 0.1 mm/year. The unit land K-2-C, the soil erosion rate is being dominated by very low at 100%.

The hydrophysic soil properties cause the rate of high soil erosion in the Karangkobar catchment by low bulk density and high porosity. Bulk density has positive and significant correlation with erosion rate ($r = 0.517^*$). This means that the increase of bulk density, the soil erosion is high. While porosity has a negative and significant correlation with erosion rates of ($r = -0.507^*$), this means that increase porosity, the soil erosion rate is low. This is in accordance with the opinion of Hakim [21] that porosity is the ability of the soil absorb water. The soil is harder to absorb water, the porosity is smaller.

![Figure 1](image1.png)  ![Figure 2](image2.png)

**Figure 1.** The soil erosion area at Karangkobar catchment  **Figure 2.** Soil Erosion rate at unit land of Karangkobar catchment

Figure 3 shows the prediction of landslides in Karangkobar catchment with a high of 67%, medium by 18%, a very high landslide of 11%, and potential low of 4%. Based on PUPR Regulation No. 22 of 2007 [22], the landslide occurred when rainfall rate is high (> 2,500 mm/year), with steep slopes (> 40%), and earthquake-prone areas. This is in accordance with the prediction of landslides which occur in the Karangkobar catchment on steep slopes > 40%. While the slope of less than 15% the potential is low.
Based on Figure 4, unit land that has very high potential landslide at unit land K-I and S-I. The unit land K-I and S-I have fast infiltration rate. This is in accordance with the opinion of Karnawati [16] that soil is easy to absorb water will effective to triggers of landslides on the slope. The infiltration rate has positive and significant correlation with landslides \( (r = 0.641^{**}) \). This is in accordance with the statement of Arrozi et al. [23] that the increase of infiltration from rainfall cause saturated soil layers and increase load on the slope.

![Figure 3. The landslides area at Karangkobar catchment](image)

![Figure 4. Potensial landslide at unit land of Karangkobar catchment](image)

4. Conclusion
Karangkobar catchment is being dominated by clay texture with bulk density values \((0.61 – 1.09 \text{ g cm}^{-3})\), particle density \((1.81 – 2.47 \text{ g cm}^{-3})\), soil porosity \((48 – 68\%)\), and infiltration rate \((1.5 – 43.1 \text{ cm hour}^{-1})\). The erosion rate in Karangkobar catchment is \(42.8 \text{ tons ha}^{-1} \text{ year}^{-1}\) or \(2 \text{ mm year}^{-1}\) with a high potential of landslides of \(67\%\), medium by \(18\%\), very high by \(11\%\), and low by \(4\%\) of the total area Karangkobar catchment. The hydrophysic soil properties have a significant correlation with soil erosion are bulk density \( (r = 0.517^{*}) \). Whereas the hydrophysic soil properties have significant correlation with potential of landslides are infiltration rate \( (r = 0.641^{**}) \).

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