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LANDSLIDE SUSCEPTIBILITY DELINIATION USING ANALITYCAL HIERARCHY PROCESS IN BANJARNEGARA REGENCY, CENTRAL JAVA

*Risky Ramadhan[1], Widiatmaka[2] and Untung Sudadi[3]

[1]Departement of Geography Universitas Negeri Padang, Indonesia;
[2,3] Departement of Soil Science, Institut Pertanian Bogor, Indonesia

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ABSTRACT

Understanding the role of controlling factors and their geographical patterns is very important to predict landslide insecurity in the future. Until now, several qualitative, quantitative and semi-quantitative methods have been used to produce landslide-prone maps such as the Analythical Hierarchy Process (AHP). This study aims to: 1) identify landslide-prone factors in Banjarnegara Regency, 2) delination spatial patterns of landslide-prone areas using the AHP method in Banjarnegara Regency. Factors that cause Banjarnegara Regency to be prone to landslides are slope slope, rainfall, soil type, lithology, land use and land shape. Landslide-prone classification using AHP method produces 5 zones, namely very low prone zones (32.97%), low (19.69%), medium (25.31%), high (17.46%) and very high (4.55%). Landslide prone assessment using AHP method has an accuracy rate of 81%, so the classification of landslide prone zones is categorized as high.

Keywords: Landslide, Susceptibility, AHP, GIS, Banjarnegara

INTRODUCTION

Indonesia isincluded in the top 10 countries that suffered the worst damage from landslides with the intensity of events amounting to 31% of the total occurrence of all disasters (BNPB, 2019). Banjarnegara Regency is a regency that has a high landslide potential in Central Java Province (BNPB 2019). On the record, this disaster has been going on for a long time. On April 16-17, 1955, Mount Pengamun-amun located around Dieng Area hoarded Legetang Hamlet, Batur Subdistrict, claiming the lives of 300 people. Then pthere on January 4, 2006 landslide disaster in Cijeruk Village, Banjarmangu Subdistrict, claimed the lives of 76 people. The landslide in Jemblung Village, Karangkobar District on December 12, 2014 has resulted in 105 deaths,11 missing people and 2,038 people displaced as well as damage to facilities and agricultural land (BNPB 2014). The consequences of landslide problems can actually be reduced through effective space planning and management (Rajakumar et al., 2007). Understanding the role of controlling factors and their geographical patterns can be very useful for predicting future landslide insecurity (Guzetti et al., 2005; Van den Eeckhaut et al., 2006). Landslide-prone zoning allows planners to establish and determine the level of risk by considering the prevention or mitigation of current and future landslides (Althuwaynee, 2012; Ahmed, 2014). To date, several qualitative, quantitative and semi-quantitative methods have been used to produce landslide-prone maps such as Analytical *Hierarchy Process* (AHP) (Daneshvar, 2014), artificial *neural network* (ANN) (Matori et al., 2011) and *weighted linear combination* (WLC) (Ayalew, Yamagishi and Ugawa, 2004). Other research shows that the combination of AHP method and geographic information system (SIG) is reliableenough to decirate landslide-susceptibility areas (Boroushaki and Malczewski,

*Corresponding Author: riskyramadhan@fis.unp.ac.id; 081283439468

2010; Khodadad and Jang, 2015). The objectives of this study are: 1) identify landslide-susceptibility factors in Banjarnegara Regency, 2) deliniation spatial patterns of landslide-susceptibility areas using the AHP method in Banjarnegara Regency.

METHODS

The research area is geographically located at 7°12'–7°31' S and 109°29'– 109°45'50" E. Banjarnegara regency consists of 20 sub-districts and 278 villages with an area of 114,493.67 ha (Figure 1).

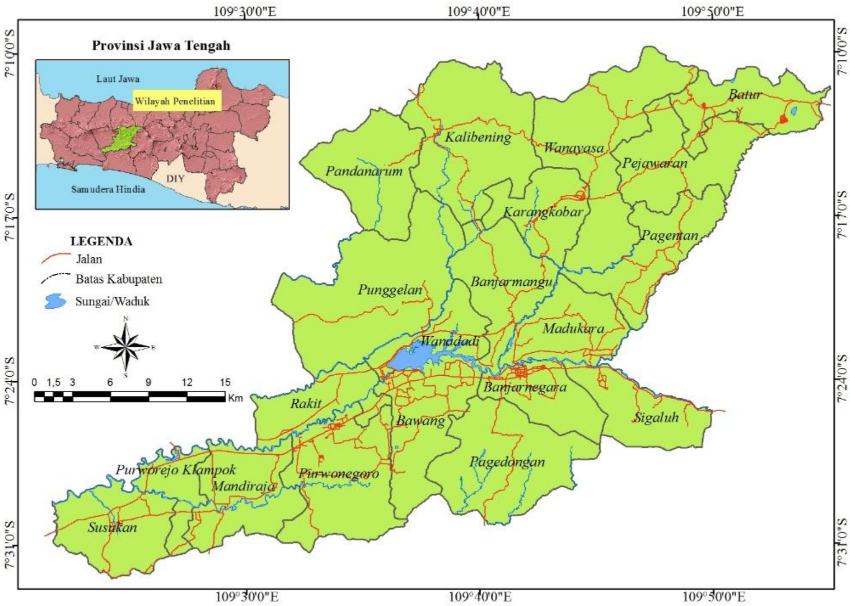

Figure 1 Research Location

Landslide Susceptibility Assessment with AHP Method

The AHP method is used to determine weights based on expertassessment. Scoring is based on the best scale of 1 to 9 compiled by Saaty (1983). The figures imply expert assessment of the factors that caused landslide suscetibility in the research area. Values and definitions of comparison scales presented in Table 1;

Table 1 Comparison Scale Values (Saaty, 1983)

Value	Description
1	Criterion A is as important as criteria B
3	A is slightly more important than B
5	A is definitely more important than B
7	A is clearly more important than B
9	A is absolutely more important than B
2,4,6,8	When in doubt between two adjacent values

The criteria and sub-criteria used in this study were compared in pairs (see Table 2). Paired comparison values are then processed to determine the relative rank of all criteria and sub-criteria (Poudel et al., 2010; Feizizadeh and Blaschke 2013). Each criterion is compared according to the *judgemet* obtained to produce weight.

*Corresponding Author: riskyramadhan@fis.unp.ac.id; 081283439468

Table 2 Matrix Comparison Paired Landslide Susceptibility Criteria

Criteria	Factor - 1	Factor - 2	Factor - 3	Factor - 4	Factor - 5	Factor - 6
Factor -1	**1**	-	-	-	-	-
Factor -2	-	**1**	-	-	-	-
Factor -3	-	-	**1**	-	-	-
Factor -4	-	-	-	**1**	-	-
Factor -5	-	-	-	-	**1**	-
Factor -6	-	-	-	-	-	**1**

Measuring the consistency of expert answers will have an effect on the validity of the assessment results (Eastman 2012). The procedure used is *the calculation of consistency ratio* (CR). CR formula;

$$CR = \frac{CI}{RI}$$

Aftergetting the weighting value on each criterion, then all thematic maps used in this study were integrated using SIG (*overlay*) to determine the levelof insecurity based on the class of insecurity is very low, low, medium, high and very high (PVMBG, 2014). Formulas used as follows.

$$Interval\ Landslide\ Susceptibility (ILS) = \frac{High\ Values - Low\ Values}{All\ Class}$$

Landslide Susceptibility Model Validation Test

Landslide-susceptibility model validation tests are conducted statistically by calculating *overall accuracy* and accuracy of *kappa* values based on error matrix. This technique is very useful in building a model with different classes or different parameter criteria (Utah University 2003).

Table 3 Confussion Matrix Landslide Susceptibility

Landslide Susceptibility Class		Landslide Sample Data 2003-2015 (PVMBG)					
		Very Low	Low	Medium	High	Very High	Total Rows
Class	Very Low	X_{+i}					X_{+ii}
	Low		X_{+i}				X_{+ii}
	Medium			X_{+i}			X_{+ii}
	High				X_{+i}		X_{+ii}
	Very High					X_{+i}	X_{+ii}
Column Totals		X_{+ii}	X_{+ii}	X_{+ii}	X_{+ii}	X_{+ii}	$\sum X_{+ii}$

Correction of the data assessment to the level of accuracy can be interpreted from the resulting *kappa* value. The accuracy level of *kappa* belongs to the high category if it is worth 0.81-1.00 (Landis and Koch 1977). The formula for calculating the accuracy value of kappa is;

$$K_{hat} = \frac{N \sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} (x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r} (x_{i+} \times x_{+i})}$$

Where:
- x_{+i} : Number of pixels resulting from the classification of landslide susceptibility i
- x_{i+} : Number of reference pixels in the i-1 landslide susceptibility
- x_{ii} : Number of reference pixels in the i-landslide susceptibility corresponding to the first landslide-susceptibility classification pixel
- i : Rows or columns
- r : Number of landslide- susceptibility classes
- N : Total number of reference pixels
- K_{hat} : *Kappa* accuracy value

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RESULT AND DISCUSSION

Identification of Landslide Susceptibility Factors

Landslides are caused by the interaction of natural factors that destabilize the slopes and trigger factors that drive landslides to occur faster (Mondal, 2013). Factor-factors causing landslides in Banjarnegara District based on interviews with experts from PVMBG and IPB are presented in the description below.

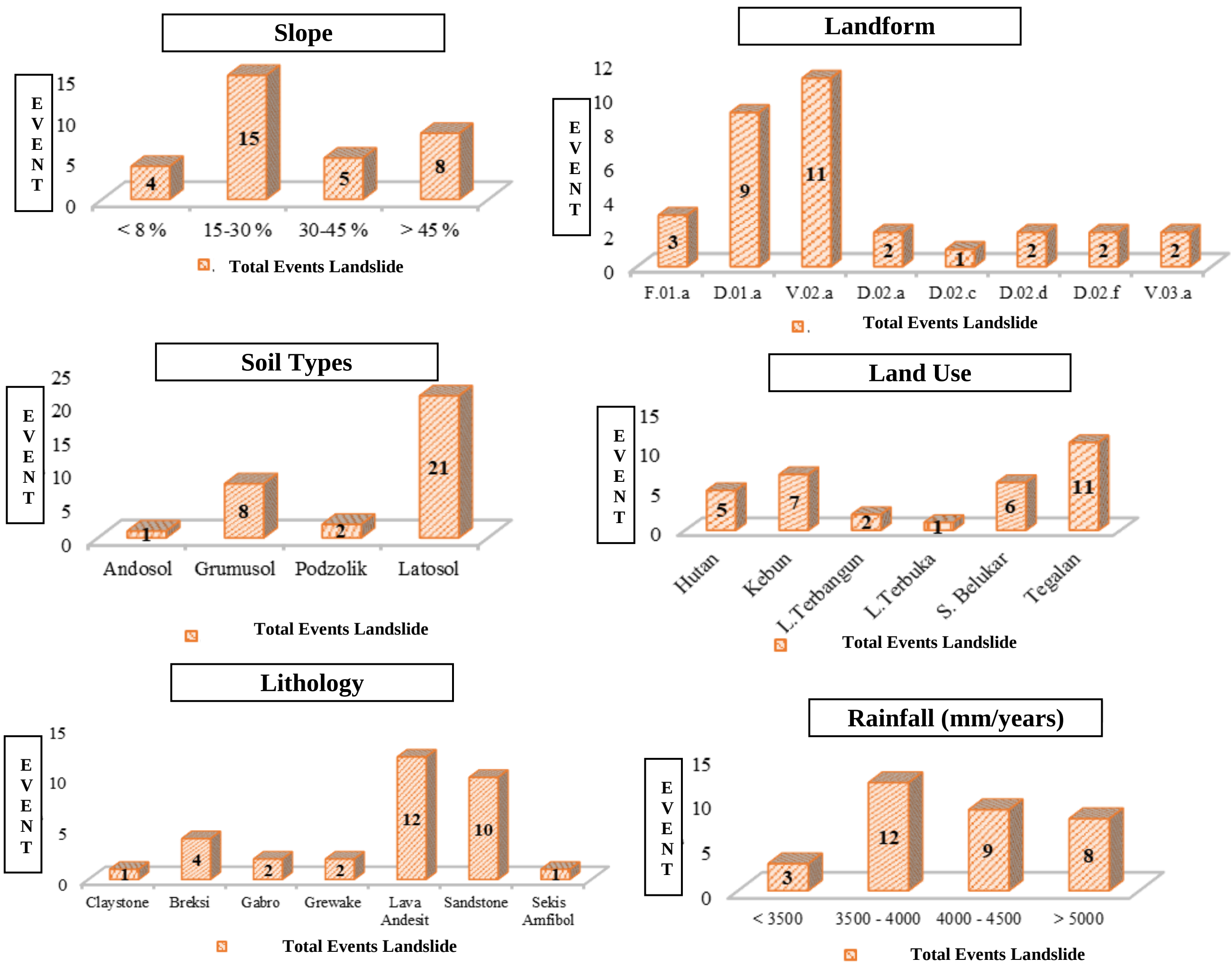

Figure 2 Relationship of landslide events (2003-2018) with landslide control factors: slope, landform, soils, landuse, lithology, and rainfall

The application of the AHP method with a paired comparison matrix is used to assess the relative importance of each factor (Daneshvar, 2014). The paired comparison matrix is calculated using Expert Choice software. According to the empirical classification of AHP, rainfall intensity, slope slope, soil type, lithology are the most important criteria with a weight of 0.269 each; 0,255; 0.145 and 0.144, while land use and landforms have the smallest weights with weight values of 0.121 and 0.095.

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AHP weighting results combined with GIS to produce landslide-prone zoning in Banjarnegara Regency. Maps of landslide-causing factors in the form of vector data models are converted to raster data models with pixel dimensions of 30 x 30 m. To produce a landslide-prone zoning map, calculations are performed with formula:

$$\mathbf{LH} = (0{,}269*\mathbf{CH}) + (0{,}255*\mathbf{KL}) + (0{,}145*\mathbf{JT}) + (0{,}144*\mathbf{LT}) + (0{,}121*\mathbf{LC}) + (0{,}095*\mathbf{BL})$$

Table 4 Landslides Susceptibility Classfied and Persentase Area

Landslides Susceptiility Zone	Interval	Area	
		ha	%
Very Low	4,71 – 9,94	37.898,3	32,97
Low	9,95 – 15,17	22.636,4	19,69
Medium	15,18 – 20,40	29.092,6	25,31
High	20,41 – 25,63	20.079,3	17,46
Very High	25,64 – 30,87	5.236,7	4,55

The value of raster overlay results for landslide susceptibility zones in the research area ranged from 4.71 – 30.87. Intervals are obtained based on *the natural breaks'* method in Arc *gis.* A value close to 0 indicates a contribution to an increasingly low landslide and vice versa. The sum of all values is used to classify landslide-susceptibility. Classification is divided into 5 classes, namely very low (32.97%), low (19.69%), medium (25.31%), high (17.46%) and very high (4.55%). A total of 47.32% of the area in Banjarnegara Regency is in the medium to very high landslide susceptibility zone.

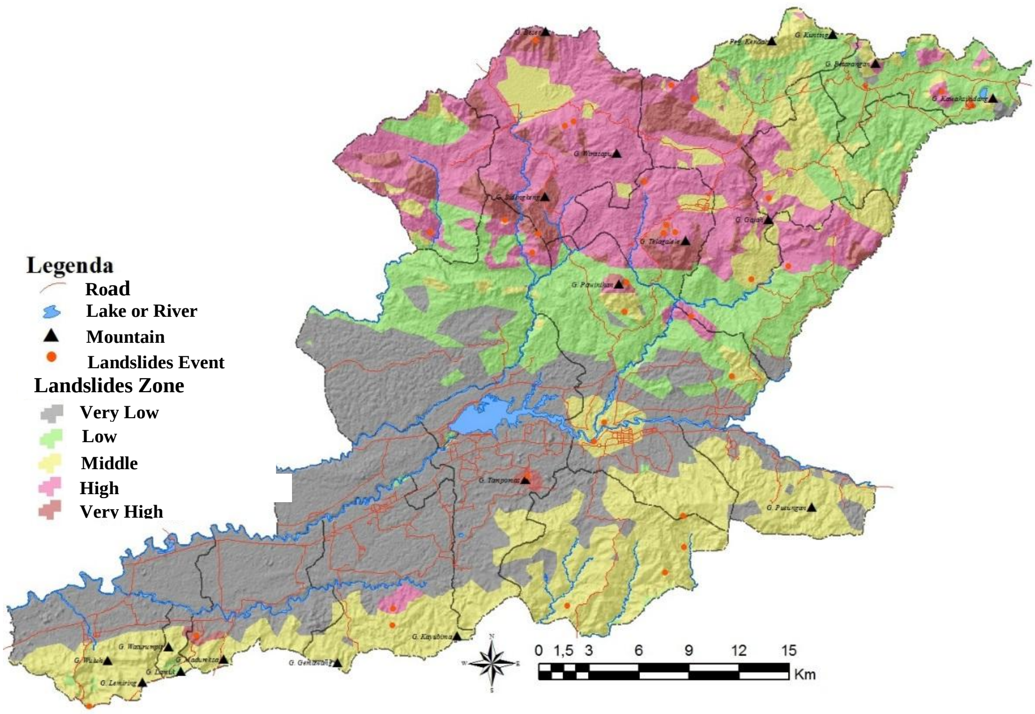

Figure 3 Landslide-Susceptibility Deliniation using AHP

*Corresponding Author: riskyramadhan@fis.unp.ac.id; 081283439468

Validation of landslide prediction accuracy is done by calculating overall *accuracy* and *kappa* index based on cross-*correlation matrixs* (Mather, 2009). Based on Table 5, the amount of overall *accuracy* is calculated from the total number of correct classifications with the total number of reference data as many as 32 samples resulting in overall *accuracy* of 87.5% with a *kappa* index of 0.81. The match between AHP landslide susceptibility map and landslide event has been well estimated with an accuracy rate of 81%.

Table 6 Producers Accuracy, User Accuracy, overall accuracy dan kappa uses cross-correlation matrixs

Calculation	Medium	High	Very High
Producer's Accuracy	90.9	78.6	100
User's Accuracy	83.3	100	77.8
Overall Accuracy	87.5		
Kappa	0.81		

CONCLUSION

The results of the analysis revealed that rainfall intensity, slope slope, soil type, lithology are the most important criteria with a weight of 0.269 each; 0,255; 0.145 and 0.144, while land use and *landforms* have the smallest weights with weight values of 0.121 and 0.095. Classification is divided into 5 classes, namely very low (32.97%), low (19.69%), medium (25.31%), high (17.46%) and very high (4.55%). A total of 47.32% of the area in Banjarnegara Regency is in the medium to very high landslide susceptibility zone. Validation of landslide prediction accuracy resulted **in** *overall accuracy* of 87.5% with **kappa index** of 0.81. This means that the match between the AHP landslide susceptibility map and the landslide event has been well estimated with an accuracy rate of 81%.

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