Landslide Susceptibility Zonation of Rongga District and Surrounding Areas Using Weight of Evidence (WoE) Method

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Abstract. Rongga District is located on West Bandung Regency, West Java, which is prone to landslide disaster. Morphological conditions in the form of steep hills become the one of landslide controlling factors. There are many landslide occurrences happen in this area, such as Nyomplong, Cibitung Village on March 23, 2020. The incident was triggered by heavy rain and strong winds. This area was chosen to assess the landslide susceptibility using the Weight of Evidence (WoE) Method. WoE is probabilistic bivariate method which connecting parameters causes landslide against distribution of landslide in research area. Landslide data which generated from direct observation in the field and satellite imagery morphology are 572 landslide events. The data is divided into two groups, the analysis data set (70%) and the validation data set (30%). The parameters used in the analysis are land use, slope, slope direction, curvature, elevation, rainfall, lithology, NDWI, NDVI, distance from road, distance from the river, distance to lineament, flow direction, lineament density, stream density and river density. The parameters validated by determining the value of the area under curve (AUC). AUC value> 0.6 will be used in the landslide susceptibility zonation next analysis. Validation of landslide susceptibility zonation was carried out using 172 landslide events. The result of the WoE validation shows the AUC success rate of 0.70 and AUC prediction rate of 0.76. The value of AUC shows that the modelling is good and acceptable.

Keywords: landslide, Rongga, area under curve, weight of evidence, bivariate.

1. Introduction
Landslide susceptibility identification is the most effective and economical way to provide basic data in spatial planning, land use, adaptation, and disaster mitigation [1]. Although the time and location of landslide events are difficult to predict, landslide susceptibility potential evaluation of an area should be carried out. Landslide susceptibility analysis already developed using various remote sensing-based methods and Geographical Information Systems (GIS) [2,3,4,5,6,7].

One of the methods commonly used is the Weight of Evidence (WoE) method. The Weight of Evidence (WoE) method is one of the popular methods used in the Bayesian Theory approach to determine the conditions of the spatial probability between parameters or in the form of layers. This landslide susceptibility analysis requires many landslide events which associated with factors or parameters [8].
2. Location
The research location is located at Rongga District, West Bandung Regency (Figure 1). The research location is bordered by Cianjur Regency in the west and south, Bandung City in the east and Purwakarta Regency in the north. The research location is approximately 61 km from Bandung City or approximately 1.5 hours by motorcycle via the Cililin route.

Figure 1. The research location is located at Rongga District, West Bandung Regency.

3. Methods
The WoE method is basically a bivariate method based on the Bayesian probability which is analysed using certain software/GIS [9]. The WoE method is a quantitative technique based on data, using many parameters, and a combination of data to produce a map of weighted data, both continuously and categorically validated using the initial (prior) and after (posterior) probabilities [10]. The WoE weighting system is divided into positive and negative. The positive weight of a particular geofactor class describes the weight of landslide probability in a geofactor class. The negative weight describes the weight of improper landslide in a geofactor class.

4. Data
The data used in this study are primary and secondary data. Primary data were obtained directly from the field and observations of landslides using google earth images (Figure 2), while secondary data were obtained from previous research or related references via internet. The data obtained were used to determine the value of each parameter required in landslide susceptibility zoning map using WoE method. The landslide location divided into two data, namely: train data (ls_train) with a percentage of 70% and test data (ls_test) with a percentage of 30%.
Figure 2. An example of landslide collecting using Google Earth time lapse.

Each parameter will be tested using the train data set (ls_train) to determine the AUC value (area under curve). Parameters with AUC> 0.6 are declared to have passed the validation which will be included in landslide susceptibility zoning map analysis using WoE Method (Table 1).

Table 1. Classification of AUC value [11].

| AUC Value | Class     |
|-----------|-----------|
| > 0.9     | Excellent |
| 0.8 – 0.9 | Very good |
| 0.7 – 0.8 | Good      |
| 0.6 – 0.7 | Average   |
| < 0.6     | Poor      |

5. Result and Discussion
Landslide observation data in Rongga area and its surroundings which taken through direct observation in the field (Figure 3) are 66 locations and based on observations through google earth satellite imagery (Figure 4) are 506 locations. A total of 572 landslide events were made into 2 sets of data, they are 70% train data (ls_train; 400 landslide events) for each parameter AUC test and 30% validation data (ls_test; 172 landslide events) for prediction rate validation of landslide susceptibility map (Figure 5).

Figure 3. Example of landslide location which taken direct observation.

Figure 4. Example of landslide location taken through google earth imagery.
The landslide parameters were analysed using commonly used parameters. After reclassification, the parameters are multiplied by the test data (ls_train) using raster calculator on the ArcGIS toolbox to get the table attribute and AUC value. The results of weighting using the WoE method of each parameter that are thought to influence the occurrence of landslide at research location are presented in Table 2.

| No | Parameter           | AUC Value |
|----|---------------------|-----------|
| 1  | Land Use            | 0.60      |
| 2  | Slope               | 0.68      |
| 3  | Slope Aspect        | 0.58      |
| 4  | Curvature           | 0.61      |
| 5  | Elevation           | 0.63      |
| 6  | Rainfall Intensity  | 0.62      |
| 7  | Lithology           | 0.65      |
| 8  | NDWI                | 0.54      |
| 9  | NDVI                | 0.56      |
| 10 | Distance from Road  | 0.58      |
| 11 | Flow Direction      | 0.57      |
| 12 | Lineament Density   | 0.52      |
| 13 | River Density       | 0.60      |
| 14 | Distance from Lineament | 0.56 |
| 15 | Distance from River | 0.60      |

The parameters that pass the AUC value (AUC > 0.6) are: land use, slope, curvature, elevation, rainfall, lithology, river density and distance from the river then totalled using raster calculator on GIS. After obtaining the zoning of landslide susceptibility using the WoE method from the sum of the parameters, it will be validated and reclassified based on SNI 8291-2016.
Table 3. Distribution of landslide susceptibility zoning according to SNI 8291-2016.

| Susceptibility | % LS | % LS Acc | Class WoE | % Area | % Area Acc | WoE Value LS |
|----------------|------|----------|-----------|--------|------------|---------------|
| High           | 60   | 60       | 0-93      | 47     | 47         | 123           |
|                |      |          |           |        |            | -926 -153     |
|                |      |          |           |        |            | 103            |
| Moderate       | 20   | 80       | 94-130    | 13     | 79         | -2,478 -897   |
|                |      |          |           |        |            | 34             |
| Low            | 15   | 95       | 131-184   | 25     | 87         | -10,709       |
|                |      |          |           |        |            | -10,125 -26   |
| Very Low       | 5    | 100      | 185-255   | 15     | 100        | -10,125       |
|                |      |          |           |        |            | 9              |

Furthermore, the landslide susceptibility zone is classified into four classes, namely: very low, low, medium, and high landslide susceptibility. The existing colours are adjusted to the colours that have been regulated in SNI 8291 of 2016, namely: very low is blue (RGB: 0 255 255), low is green (RGB: 0 255 0), medium is yellow (RGB: 255 255 0), and high is magenta (RGB: 255 0 255) (Figure 6). The zoning map is strongly influenced by slope and lithological distribution.

Validation of zoning map is to determine the AUC value (area under curve) so that the map can be seen according to existing standards or not. The AUC value calculated is the AUC success rate and AUC prediction rate. The success rate is obtained by combining the sum of WoE data with landslide train data (ls_train). While the prediction rate is obtained by combining the total WoE data with landslide validation data (ls_test). The AUC value of landslide susceptibility zone success rate by WoE Method was 0.69 (Figure 7). The AUC value of landslide susceptibility zone prediction rate by WoE method was 0.66 (Figure 8). This value indicates that landslide susceptibility model (parameter selection and sufficiency of landslide event data) is quite good and acceptable because the AUC value obtained exceeds the recommended limit of 0.6.
6. Conclusion

There are 8 parameters that pass the AUC value which are used for the analysis of landslide susceptibility zoning map using Weight of Evidence (WoE) method. After summing, the landslide susceptibility zoning map reclassified into 4 zones, they are: very low susceptibility zone with 15% covering area, low susceptibility zone with 25% covering area, medium susceptibility zone with 13% covering area, and high susceptibility zone with 47% covering area. The obtained AUC success rate is 0.69 and the AUC prediction rate is 0.66, both is reflecting that the resulting map is average and acceptable.

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