Expert judgement criteria for mapping landslide susceptibility in Tangse Sub-District, Pidie District, Aceh Province, Indonesia

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Abstract. Referring to The Center for Research on the Epidemiology of Disaster (CRED) data shows that landslides are responsible for at least 17% of all fatalities from natural hazards worldwide. One of the disasters that commonly occur in Indonesia is landslides, especially in Tangse Sub-District, Pidie District, Aceh Province. The main objective of this research was to determine the parameters and the weight of each parameter that causes landslide susceptibility by using expert judgement criteria. The expert decision can be accepted if the Consistency Ratio (CR) <0.1. The results showed the value of CR from 0.04 to 0.3. Expert judgement decisions with a value of CR = 0.04 (<0.1) were the most reasonable criteria of parameters for mapping landslide susceptibility. Those parameters were slope (42%), rainfall (36%), soil type (12%), and land use (10%). By using these criteria, there were four classes of land susceptibility in this area, namely very high, high, moderate, and low covering an area of 805.40 Ha (1.03%), 46,526.72 Ha (59.27%), 30,600.38 Ha (38.98%), and 573.61 Ha (0.73%), respectively. Disaster mitigation could be carried out by socializing the vulnerability of landslides, soil protection through slope stabilization, and vegetative conservation.

1. Introduction
Many lives could have been saved if we had been known early the knowledge about forecasting and mitigation. Planning and monitoring are considered necessary and needed. The amount of research related to landslide disaster prevention helps us to reduce the risk of loss of life and material. Generally, a landslide is caused by natural factors. The following natural factors were bedrocks, slope, depth of soil, soil structure, soil permeability, soil porosity, land use/land cover (LULC), and hydrology [1]. Besides, another study stated that parameters that affect the occurrence of landslides were lithology, slope angle, slope length, elevation, and the location of waterways [2].

This study applied expert judgement to determine the main causative parameter of a landslide. Expert judgement is used to get the solution from qualitative data to become quantitative. Besides, expert judgement is needed to understanding the dimension of the problems, developing the alternative, collecting all of the data, choosing the best model to analyze and solve the problem [3]. Analytical Hierarchy Process is one of the methods that implementing expert judgement to solve complex problems [4], and ArcGIS is used to mapping landslide susceptibility.

One of the disasters that commonly occur in Indonesia is landslides, especially in Tangse Sub-District, Pidie District, Aceh Province. Landslides can result in loss of property and damage to public
facilities in the area. This year, several landslides in Tangse Sub-District occurred, for example, on May 20, 2020, landslides made the national road from Sub-District of Tangse to Mane impassable, and landslides on June 5, 2020, caused transportation from the sub-District of Beuruenun to Tangse to be blocked. Meanwhile, the research on the parameters that cause landslide susceptibility using expert judgement criteria in this area has never been carried out. The main objective of this research was to determine the parameters and the weight of each parameter that causes landslide susceptibility by using expert judgement criteria.

2. Research method
The study site which covers approximately ±78 km² located in Tangse Sub-District, Pidie District, Aceh Province, Indonesia. Processing data was carried out in the remote sensing and cartography laboratory, Soil Science Departement, Agriculture Faculty, Syiah Kuala University. The study area is presented in Figure 1.

![Figure 1. Location map of the study area.](image)

The Analytical Hierarchy Process (AHP) was used in this study to determine and analyze landslide susceptibility’s causative parameters based on expert judgement. The weighting of causative parameters could be done by making an open questionnaire in a pair-wise comparison matrix. Then, it calculated using Expert Choice, with the condition if the value of consistency ratio (CR) is greater than 0.1, the comparison matrix is inconsistent and should be revised [5]. The making of the pair-wise comparison matrix was done by considering the scale of preference shown in Table 1. The flow chart of the research is presented in Figure 2.

3. Results and discussion
3.1. Landslides parameter based on Expert Judgement
The results of expert judgement on the landslides parameters, namely slope, rainfall, type of soil, and land use can be seen in Figure 3. The assessment of each expert indicated that there was a difference in the percentage of weight given to each parameter of landslides. For the slope parameter, for example,
Expert 1, Expert 2, Expert 3, Expert 4, and Expert 5 give weight percentages of 42, 11, 67, 9, and 21, respectively. For the rainfall parameter, Expert 1, Expert 2, Expert 3, Expert 4, and Expert 5 give weight percentages of 36, 45, 8, 4, and 12, respectively. Likewise, for the type of soil and land use parameters, there is a difference in the percentage of weight given by each expert based on their experience and knowledge regarding landslides.

**Table 1. Scale of preference.**

| Preference factor | Degree of preference | Explanation |
|-------------------|----------------------|-------------|
| 1                 | Equally              | Two factors contribute equally to the objective |
| 3                 | Moderately           | Experience and judgement slightly to moderately favor one factor over another |
| 5                 | Strongly             | Experience and judgement strongly or essentially favor one factor over another |
| 7                 | Very Strongly        | A factor is strongly favored over another and its dominance is shown in practice |
| 9                 | Extremely            | The evidence of favoring one factor over another is of the highest degree possible of an affirmation |

**Figure 2. Flow chart of research.**
To determine which expert's judgement is the most reasonable as previously described, the CR value must be less than 0.1. Based on an open questionnaire in a pair-wise comparison matrix, there are three of the CR values that have a value greater than 0.1, namely 0.2, 0.27, and 0.3. Conversely, there are two of the CR values that are smaller than 0.1, namely 0.08, and 0.04. However, the value of CR > 0.1 can not be used to find out the reasonable criteria of parameters for landslide susceptibility [6]. Thus, the most reasonable weights of each landslide parameters based on the smallest value of CR (0.04) are slope (42%), rainfall (36%), type of soil (12%), and land use (10%) as shown in Table 2. Furthermore, all the weights of the landslide parameters are taken into consideration in mapping the landslide susceptibility [7].

![Diagram showing the weights of each parameter of landslides.]

**Figure 3.** The weights of each parameter of landslides.

**Table 2.** The weights of each landslide parameters.

| No | Parameters   | Weights (%) |
|----|--------------|-------------|
| 1  | Slope        | 42          |
| 2  | Rainfall     | 36          |
| 3  | Type of Soil | 12          |
| 4  | Land Use     | 10          |

CR = 0.04

3.1.1. **Slope.** The steep slope is one of the conditions for landslides. The slope is the main causative parameter of a landslide than others [8]. Landslide may not occur if it is not on a steep slope [9]. The greater the slope, the greater the risk of landslide [10]. The movement water on a gentle slope is slower than the steep slope [11].
3.1.2. Rainfall. The risk of landslide would be greater in line with the high rainfall intensity in a short time and occurs on impermeable soil [12]. The impermeable layer would be caused by a runoff if no land cover can store water when it rains [13]. The risk of landslide will increase in line with the high rainfall intensity. The high intensity of rainfall associated with steep slope can trigger the landslide happens [14]. Then, the water of rain not only enter through the soil fracture and quickly expand, but also accumulated causing a lateral water movement [15].

3.1.3. Type of soil. Lithology, soil depth, distribution of soil type can be considered as a causative landslide [16]. The differences in soil development, mineral content, soil structure, and the fertility of the land itself [17] in each type of soil affect their sensitivity to landslides.

3.1.4. Land use. The increasing of landslide susceptibility is in line with the presence of infrastructure and humans [18]. Human activities contribute to landslides, especially activities that do not comply with soil and water conservation provisions.

3.2. Landslide susceptibility distribution
Analysis of the distribution of landslide susceptibility shows Tangse Sub-District has four landslide susceptibility classes, namely low, moderate, high, and very high. The high covered the largest area of 46,526.72 Ha (59.27%), followed by the moderate covered an area of 38,600.38 Ha (38.98%). The class of very high and low covered only a small part of the region. Figure 4 and Table 3 show landslide susceptibility distribution of the Tangse Sub-District.

![Landslide susceptibility distribution](image_url)

Figure 4. Landslide susceptibility distribution of tangse sub-district.

Landslide susceptibility class of high and very high in settlements can cause damage to facilities and infrastructure. The landslide location is on a cliff road that can endanger land transportation users crossing the area [19]. Furthermore, landslides not only damage the public facilities in the field, but also damage agricultural land and endanger settlements around riverbanks [20-22].
Table 3. Landslide susceptibility classes.

| No | Classes    | Ha   | %   |
|----|------------|------|-----|
| 1  | Low        | 573.61 | 0.73 |
| 2  | Moderate   | 30,600.38 | 38.98 |
| 3  | High       | 46,526.72 | 59.27 |
| 4  | Very high  | 805.40 | 1.03 |
|    | Total      | 78,506.11 | 100  |

Based on the results of spatial analysis, the forest is the largest land use type in Tangse Sub-District. Generally, landslide susceptibility classes ranging from moderate to high found in forest areas compared to other uses. Therefore, cooperation between the government and the community needs to be done to prevent casualties and material loss as a result of landslides, especially forest areas that are traversed by roads. Disaster mitigation can be done by socialization about landslide susceptibility and protect the soils through slope stabilization as well as to conduct vegetative conservation.

4. Conclusion

Expert judgement criteria to determine the parameters and the weight of each parameter that causes landslide susceptibility showed the value of CR from 0.04 to 0.3. Expert judgement decision with a value of CR = 0.04 (<0.1) were the most reasonable criteria of parameters for mapping landslide susceptibility. Those parameters were slope (42%), rainfall (36%), soil type (12%), and land use (10%). By using these criteria, there were four classes of land susceptibility in this area, namely very high, high, moderate, and low covering an area of 805.40 Ha (1.03%), 46,526.72 Ha (59.27%), 30,600.38 Ha (38.98%), and 573.61 Ha (0.73%), respectively. Disaster mitigation can be carried out by socializing the susceptibility of landslides, soil protection through slope stabilization, and vegetative conservation.

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