Residential relocation for landslide prone residences in the upper Ciujung watershed

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Abstract. Lebak Regency, which is in Banten Province, is an area in Indonesia that has many years affected by the landslide disaster. Banten Province itself is a disaster-prone area. In Indonesia, Banten Province is a province with a fairly high hazard rating according to BNPB in the Indonesian Disaster-Prone Index book. Landslide disasters often occur in regions of Indonesia that have diverse topographies. Landslides can cause various kinds of losses like physically, socially, and economically. In early 2020, Lebak Regency experienced flash floods which leads to many residential areas especially areas on the upper ciujung watershed to be affected by landslide. From this disaster that happened on 1st January 2020 alone, 20 bridges were damaged in the 6 affected sub-districts. The analysis in this study used the Spatial Multi-Criteria Evaluation (SMCE) method and an overlay. This study aims to produce locations which have the potential to be relocation areas for landslide prone residences in the Upper Ciujung Watershed which includes 5 district, Cipanas District, Lebakgedong District, Sajira District, Muncang District, and Sobang District. From this research, it was found that areas that have the potential to be the location of residential relocation are only in 4 of the sub-districts within the research areas with a total area of 88.12 Ha which is in the eastern part of Cipanas District, southeast of Lebakgedong District, and also in the western part of Muncang District.

Keywords: Landslide, relocation, disaster, SMCE

1. Introduction
Indonesia has geological, hydrological, demographic, and geographic conditions that are prone to disasters with a high frequency. This makes Indonesia need systematic, coordinated, and integrated disaster management [1]. Lebak Regency, located in Banten Province, was also affected by landslides. Banten Province is a province with a fairly high vulnerability rating according to BNPB in the book "Indonesia's Disaster-Prone Index" [2]. According to BNPB, Lebak Regency itself has a high level of disaster vulnerability with a disaster-prone index score of 85 and is ranked 66 nationally [2]. Based on the Map of Landslide Prone Areas in Lebak Regency, there are 4 districts including landslide-prone areas in Lebak Regency, including Cipanas District, Muncang District, Cibeber District, and Bayah District (BPBD Banten Province 2018). The earliest water catchment areas that act as water storage for the survival of living things are in the upstream part of the river [3]. Relocation is part of a government policy that includes spatial planning which is carried out to increase economic and social welfare [4].

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SMCE is a qualitative and quantitative analysis approach and to identify disaster risk zones and can facilitate processes in sustainable disaster risk mitigation and help make decisions to make evaluations or policies based on predetermined criteria for identification such as priority areas [5] SMCE needs to enter criteria value information that will be combined with geographic data as part of the criteria evaluation process series. The results of the SMCE analysis not only affect the results of the distribution of attributes/criteria but need to include elements of value justification into the decision-making process [6].

Natural disasters in the form of landslides often occur in watershed areas (DAS), especially in the upstream part of the watershed. What is often the main cause of landslides in a watershed area is that there are many topographies with steep slopes [7]. In early 2020, on January 1, 2020, some of the Lebak areas experienced a flash flood disaster which also resulted in landslides at several points, one of the causes of which was the high rainfall in this district. The Lebak Regency Government, Banten Province itself implemented its area as a disaster-prone emergency area from January 1, 2020, to January 14, 2020. The disaster at the beginning of that year according to the National Disaster Management Agency (BNPB) occurred in 6 sub-districts in Lebak Regency. These sub-districts include Sajira District, Maja District, Cipanas District, Curug Bitung District, Cimarga District, and Lebakgedong District. According to BNPB (2020), this disaster was caused by high rainfall and the presence of several illegal mining points along the Ciberang river. This disaster resulted in severe losses for the 6 affected districts in the form of losses both socially and economically. According to the disaster loss data recapitulation of the Banten Province BPBD in infrastructure, at least 20 bridges were damaged in the 6 affected sub-districts. This disaster also resulted in the loss of the lives of 5 residents and damage to at least 2167 housing units submerged and resulted in damage to 580 houses scattered in 6 sub-districts. With several bridges that were cut, the evacuation process was difficult and resulted in some areas being isolated. This incident at the beginning of 2020, then raised fears of an upcoming disaster, which then the local government made plans to relocate its residents from a similar disaster that would come (BPBD Lebak Regency, 2020). This study aims to produce locations which have the potential to be relocation areas for landslide prone residences in the Upper Ciujung Watershed which includes 5 districts, Cipanas District, Lebakgedong District, Sajira District, Muncang District, and Sobang District.

Hidayat [2], conducted a study entitled Landslide Vulnerability Mapping for Landslide Victim Relocation. This study aims to create a landslide hazard map so that land suitability for the residence can be achieved for settlement development by referring to the level of landslide hazard. This study made a slope stability model using Transient Rainfall Infiltration and Grid-Based Regional Slope-Stability (TRIGRS) with the required variables such as Digital Elevation Model (DEM) data, Soil data index, soil engineering properties, and rainfall. The results of the modeling carried out in this study then produce that the value of the landslide safety factor ranges from 0.8 to 10. A value below 1.2 is the area with the highest level of vulnerability and to be used as a relocation area an area must have a value above 1.2. This research has its resemblance with the research on this paper which both research aim is to create a suitable area for relocation but differs in methods used, research area, and determination for landslide-prone areas. The research done by Hidayat et al analyzed using TRIGRS but the research in this paper is analyzed using ArcMAP application with SMCE method and scoring.

2. Methodology
This research was conducted by utilizing the Geographical Information System (GIS) to determine the relocation areas in the Upper Ciujung River Basin area. Variables in the form of physical aspects in this study including land cover, slope, road network buffer, and also landslide vulnerability of the upper Ciujung Watershed. In determining the relocation location in this study, 4 variables are needed from the physical aspect as well as the spatial distribution data of landslide hazard levels. The variables from the physical aspects used to determine the relocation location will have a weight that has been determined based on the following 4 parameters:
1. Located in an area with moderate and low landslide-prone levels.
2. The slope of the relocation location is less than 15%.
3. Located 100 meters from the right and left of the main road.
4. The relocation location has land cover in the form of moor or fields.

The analysis in this study was conducted to answer research questions that arise from the background and problem formulation of this study and also so that the objectives of this study can be achieved. In this study, the analysis carried out was a spatial, overlay, and descriptive analysis accompanied by table or map data used to help make the research easier to understand. To produce a spatial distribution of landslide vulnerability levels in the study area, a spatial, overlay, and descriptive analysis was carried out. This analysis was carried out by applying the spatial overlay method using the SMCE analysis method. Descriptive spatial analysis was carried out on the results of the data processing map to achieve the first research objective, namely mapping the spatial distribution of landslide vulnerability levels in the Ciujung Hulu watershed area. To determine the location of residential relocation in the study area, spatial analysis, overlay, and descriptive analysis were carried out. This analysis was carried out by assessing the 4 predetermined parameters and then overlaying and conducting a descriptive spatial analysis to achieve the second research objective, namely determining a suitable location to be used as a relocation location for settlements in the Ciujung Hulu watershed area.

3. Results and discussion
The level of landslide vulnerability in this study resulted from the application of the descriptive spatial analysis method by relying on the overlay method in the ArcGIS 10.6.1 application. The analysis in this study was carried out by overlaying the variables of the slope, rainfall, soil type, rock type, groundwater presence, seismicity, vegetation, road network, and land cover. The weighting value used in this analysis is based on a book published by the Directorate General of Spatial Planning in 2007 entitled Guidelines for Spatial Planning which is based on the Regulation of the Minister of Public Works No. 22/PRT/M/2007 [8]. From data processing carried out using the ArcGIS application with a tool in the Arc Toolbox called Weighted Overlay, this study produces a spatial distribution of landslide hazard levels which are divided into three classifications, namely low landslide hazard, moderate landslide hazard, and high landslide hazard. Based on the three classifications of landslide hazard levels used, the area of each classification is obtained as follows:

Based on the table that shows the results of the data processing carried out by the researcher which can be seen in table 1, the Ciujung Hulu watershed area has a classification of landslide hazard levels which are dominated by moderate landslide hazard levels with a total area of 35,651 Ha spread across the five sub-districts which are the research areas. The total area of moderate vulnerability covers 77.0% of the total area of the study area (46,275 Ha). This moderate level of vulnerability is spread from the north to the south of the study area, most of which have a relatively gentle to steep slope, namely 21–40%. Areas with moderate landslide prone areas can become one of the priorities.

| Classification          | Area (Ha) | Percentage (%) |
|-------------------------|-----------|----------------|
| 1 Low Landslide Hazard  | 1.79      | 0.004          |
| 2 Moderate Landslide Hazard | 35,651.41 | 77.0           |
| 3 High Landslide Hazard | 10,622.70 | 22.9           |
for relocation of residents’ settlements located in high disaster-prone areas or those that have been hit by previous landslides. The classification that has the next largest area is an area with a high landslide hazard level with a total area of 10,622 Ha covering 22.9 % of the total area of the study area. Spatially, the areas that have a high landslide hazard classification are scattered in the southern part of the study area as can be seen on figure 1.

The third classification is the classification of low landslide hazards with a total area of 1.79 Ha, which means that it only covers approximately 0.004 % of the total area of the study area. It can be seen from the results of data processing that areas with high landslide hazard level classifications are located on a steep to a relatively convex slope, ranging from 31 % to > 40 %. The areas classified as low landslide susceptibility levels are located on a flat slope of 0–8 % and are the most suitable areas to be used as residential relocation locations. Annual rainfall in the whole study area tends to be high with a value of > 2500 mm/year in the entire study area.
From the distribution of the resulting landslide hazard levels, a settlement distribution map can be made, which can then be seen the level of vulnerability to landslides. In figure 2, you can see the distribution of settlements in the Ciujung Hulu watershed area and their location at the level of landslide vulnerability. The Ciujung Hulu watershed has a total of 1,075 Ha of residential area. Most of the settlements are in areas with a moderate landslide hazard level with a total area of 706 Ha of settlements that are at a moderate landslide hazard level which is marked as green settlements. Then there are 369 Ha of settlements located in areas with a high level of landslide hazard which is marked as cyan settlements, where these settlements need to be relocated due to their vulnerability to landslides (table 2).

The location of settlement relocation in this study was chosen based on the variables and parameters that have been determined. In table 3, it can be seen that the resulting relocation location area. From the total area of the study area, it was found that 88 Ha of land suitable for use as a location for relocation of settlements were spread over 4 sub-districts of the 5 sub-districts that were determined as research areas. From the analysis carried out from the 4 sub-districts of Lebak Gedong sub-district, it has an area that can be used as the largest relocation location with an area of 66.18 Ha which is in the northern part of this sub-district. The second sub-district is the Muncang sub-district which has 18.83 Ha of land which can be used as a relocation location, followed by Cipanas District and then Sobang District. For Sajira Subdistrict itself, it does not have land that can be used as a location for residential relocation because it can be seen from its topography which has a mostly steep slope and also inappropriate land use. The spatial distribution of areas that can be used as relocation locations can be seen on the map of the distribution of relocation locations in the Upper Ciujung River Basin in figure 3.

Figure 2. Vulnerability of settlements to landslides in the Upper Ciujung Hulu watershed map
(Source: Data Processing, 2020)
Table 2. Area of the level of settlement hazard to landslides in the Upper Ciujung River Basin

| Landslide hazard level | Settlement area (Ha) |
|------------------------|----------------------|
| 1 High landslide-prone settlement | 369.06 |
| 2 Moderate Landslide Prone settlement | 706.04 |
| 3 Low landslide-prone settlement | 0 |

Table 3. Area of potential relocation area of each district

| District          | Area (Ha) |
|-------------------|-----------|
| 1 Cipanas Sub-District | 2.88     |
| 2 Lebakgedong Sub-District | 66.18   |
| 3 Muncang Sub-District  | 18.83   |
| 4 Sajira Sub-District | 0       |
| 5 Sobang Sub-District  | 0.23    |
| 3 TOTAL             | 88.12    |

Figure 3. Relocation location suggestion map
(Source: Data Processing, 2020)
As a result, this research manages to determine a total of 88.12 Ha that has the suitability for residential development. The research area has a total of 369 Ha residential area that locates in an area with high landslide hazard that needs to be relocated so there's less than 50% of the total area that could be relocated in this research area based on the analysis that the author report in this paper.

4. Conclusion
From the results of the analysis carried out in this study, it can be concluded that of the total residential area in the Ciujung Hulu watershed area with a total area of 1,075 Ha, there is 706 Ha of settlements located in areas with a moderate level of disaster-prone, 369 Ha of settlements at a high level of vulnerability, and there are no settlements located in areas with low landslide-prone levels. Of the 369 Ha of settlements located in high landslide-prone areas and need to be relocated, only 88 Ha of land have the potential to become a relocation location which is located in the eastern part of Cipanas District, southeast of Lebakgedong District, and also in the western part of Muncang District.

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