

Landslide susceptibility mapping using Spatial Multi-Criteria Evaluation (SMCE) method in Camba Sub-district, Maros Regency, South Sulawesi

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Abstract. This research presents the results of a landslide susceptibility mapping using Geographic Information Systems (GIS) based statistical namely Spatial Multi-Criteria Evaluation (SMCE) in Camba Sub-district, Maros Regency, South Sulawesi. Ten physical factors encompassed soil type, slope, slope aspect, rock type, altitude, land cover, distance from the river, rainfall, distance from faults, and distance from the road that collected from several sources and used to determined landslide susceptible areas. SMCE was applied to classify the degree of landslide susceptibility from low to very high classes. Validation using 30 points of landslide events obtained from field survey. The result showed an area with high and very high classes has an area 2079 ha (18,3 %) and 52,5 ha (0,46 %) distributed in the southern region. The results of validation using the R-index for very high and high classes is 55% and ROC shows that of 96.4%, for the P show method of 98%. This landslide mapping can be used for disaster mitigation and disaster preparedness planning purposes.

1. Introduction

Landslides are the slope-forming materials displacement in the form of rubble, soil, rock, or mixed materials, moving down or out from the slope [1]. Instability slope due to several geological factors such as seismic activity and volcanic eruptions, hydrology such as high rainfall intensity, geomorphology and slope destabilization by human activities [2]. Therefore, landslide risk assessment is very important to reduce disaster risk, but assessments of landslide susceptibility are still lacking in Indonesia. Assessment of landslide hazard can be achieved by provide information about landslide events which is accurate to risk managers [3]. Good landslide susceptibility maps are important because that can provide knowledge and information for various groups from the private sector, society, government as well as academia [4].

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Landslide susceptibility is a series of hazard conditions that exist in nature or man-made that can trigger landslides and can cause landslides disaster. Landslide susceptibility is usually represented by cartography by mapping landslide susceptibility mapping. Landslide susceptibility map contains information about areas that are susceptible to landslides by trying to overlay several physical factors that have triggered to landslides in the past [6, 7]. Mapping landslide susceptibility in an area is very important to assess potential risks of landslide that is useful for disaster preparedness planning or mitigation, as a reference for planning land use, and can be used for planning infrastructure such as choosing the most suitable location for building and road construction [8].

Physical factors that have triggered landslides from the information of the past were analysed using statistical analysis, while statistic-based predictions are made for areas that have the same physical conditions but have not experienced landslides [9]. Some of the studies used as reference for this research include the use of the Landslide Susceptibility Index (LSI) method [8] which applies the LSI method to compile landslide susceptibility maps on the Peloponnese Peninsula, Greece.

This research uses the SMCE method because this method has the highest accuracy based on research [16]. Map credibility then validated using the ROC methods and R-Index, resulted the SMCE accuracy of 96%, which is better predictions than the AHP (91%) and WLC (89%). The SMCE also allow users to do multi-criteria assessments spatially, because the SMCE method is an applied science-based method that can be used for spatial analysis using GIS and evaluating various factors with multi-criteria attributes. This is allowed conversion process from spatial and non-input spatial to spatial output and further can be utilized for decision makers [9].

The Camba Sub-district has a geographic condition consists of a plateau formation [10]. According to the Regional Disaster Management Agency of Maros Regency, there are several villages in Camba Sub-district that are susceptible to landslides, one of them is Sawaru Village, which is triggered by heavy rain, geological conditions (included the morphology of the area) and lithological conditions or rocks that make up the area [11]. Therefore, this research aimed to mapping landslide susceptibility and find out mitigation technique in Camba Sub-district, Maros Regency.

2. Data and Methods

2.1 Research area

Camba Sub-district located in Maros Regency, South Sulawesi, with the average annual rainfall of 347 mm/month. According to Oldement, the mixed type in Maros Regency is C2, with wet month rainfall rate is 200 mm/month, lasting for 2-3 sequence months [12]. The geography of Camba Sub-district is in the highlands with altitude of 310 to 750 masl. The slope of Camba Sub-district is dominated by slope >40% [10].

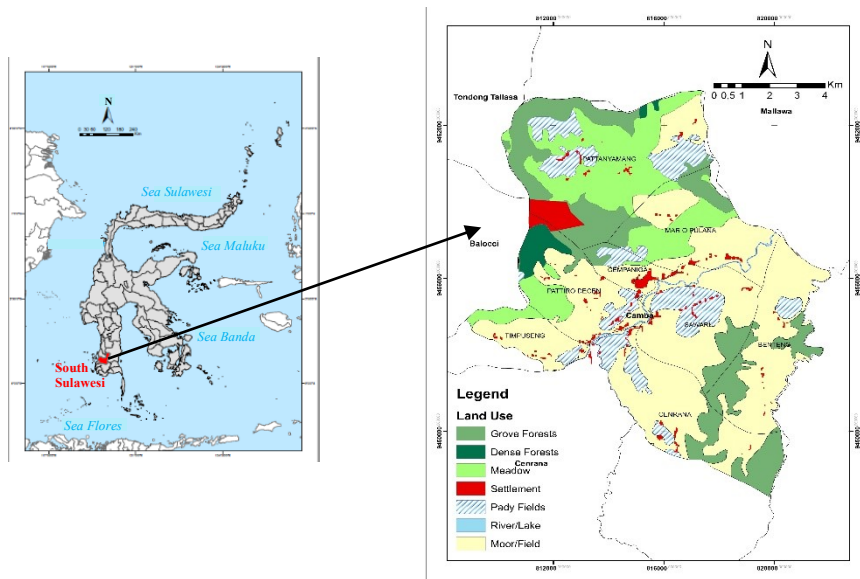


Fig. 1. Research area

2.2 Data

To study the susceptibility of landslides, researchers are looking for information causative factors that might cause soil unstable in the study area. This information is important, because it can help in determining accurate parameters after a landslide susceptibility mapping was made [15]. The first step for making a landslides susceptibility map is collection data that obtained from the results of an evaluation of past landslide events [9].

The data used from this research was obtained from several sources. The first is roads and rivers shapefile the calculated distance from Geospatial Information Agency of Indonesia. Lithology, soil types and distance from the fault were obtained from geological map from the ministry of energy and mineral resources with scale 100.000. Land use data were obtained from National Land Agency of Indonesia 2018 with scale 10.000. Historical rainfall data using data from 28 years (1982-2010) and the station rainfall data interpolated using IDW with Arc GIS 10.1. The last is digital elevation model (DEM) data with 30 meter pixel size which is obtained from USGS. The slope and slope aspect parameters extracted from DEM and reclassified using Arc GIS 10.1.

2.3 Methods

Assessment of landslides is the main tool that can be used to understand the characteristics of slopes that are susceptible to landslides, especially in extreme rainfall. Determining areas which are susceptible to landslides is important to save human lives and prevent negative impacts from landslides, especially in the national and regional economies [13].

In this study we used the SMCE method to produce landslide susceptibility maps. SMCE has been used to process 10 physical factors includes Roads (RO), Rivers (RI), Rainfall (R), Slope (S), Aspect (A), Land Use (LU), Altitude (AL), Fault (F), Soil Type (ST), Lithology (L). The SMCE methods also used to carry out multi-criteria assessments in a spatial approach [14]. The output produced is one or more maps showing areas that have criteria for being susceptible or not to landslides, and thus the map can support decision making [9].

2.3.1 Evaluation Physical Factors and Accuracy Methods.

In this research, ten physical factors that have been determined and converted using Arc GIS 10.1. Data analysis using the SMCE method was carried out with ILWIS (Integrated Land and Water Information System) software. The process carried out in ILWIS is to assign values to each parameter in the range 0 – 1, a value of 0 for factors in each parameter that have no effect for landslides event and a value of 1 for factors in each parameter that greatly affect the occurrence of landslides. Then all parameters that have been input into the SMCE program will be converted into a composite map that produces several areas of susceptibility.

SMCE data processed according to following categories: High Region (0/1, 1/2, 0.75/3, 0.25/4), Very high Region (0/1, 0.25/2, 0.5/3, 0.75/4), Very low Region is (0/1, 0.25/2, 0.75/3, 1/4), Low Region (0/1, 0.5/2, 0.75/3, 1/4) and Moderate Region (0/1, 0.5/2, 1/3, 0.5/4) [9].

Table 1. Pairwise comparison matrices, factor weights and data layer ratio consistency

Parameter	S	A	ST	L	AL	LU	R	RO	RI	F	Weight
S	1										0,123
A	1	1									0,102
ST	5	4	1								0,121
L	2	½	1/5	1							0,097
AL	5	5	2	3	1						0,073
LU	3	5	½	4	1/2	1					0,086
R	2	3	1/5	3	1/2	1/3	1				0,141
RO	5	6	2	5	3	3	5	1			0,084
RI	4	4	1/3	3	1/4	1/3	3	1/5	1		0,081
F	3	3	1/5	2	1/5	1/4	2	1/5	1/2	1	0,062

Consistency Ratio: 0,069 < 0,1 (Accepted)

Table 2. Weight values for each group and parameter weight values use pairwise comparisons for the SMCE model

Parameter Group	Group weight value	Parameter	Parameter Weight Value
Geomorfology	0,132	Slope (S)	0,128
		Aspect (A)	0,112
		Altitude (AL)	0,087
Geology	0,871	Distance from faults (F)	0,073
		Rock types (L)	0,097
Environment	0,124	Soil types (ST)	0,123
		Land use (LU)	0,084
		Distance from road (RO)	0,083
Hidrology	0,146	Distance from river (RI)	0,081
		Rainfall (R)	0,143

2.3.2 Validation of landslide susceptibility prediction map

Accuracy of landslide susceptibility map created using the receiver operating characteristic (ROC) and Relative density index (R-index) by comparing pixels of landslide susceptibility on the map with the point of occurrence of the landslide. Validation formula determined by the following equation:

$$R = \frac{nx}{Nx} \sum \left(\frac{nx}{Nx} \right) \times 100\% \tag{1}$$

Where this is the number of landslides in category x and Nx the number of pixels in category x [5, 7]. AUC is an area under the ROC curve and has a value 0.5 - 1, this value is used to determine the accuracy of the map made. AUC was obtained using SPSS statistical analysis software [16, 17].

To determine the accuracy of predetermined parameters used the results of maps that have been made as predictions (P). The accuracy of the predicted results is made using the equation below:

$$P = \frac{Ks}{S} \tag{2}$$

Ks is an area of landslide in susceptibility above low class and S is an area of landslides in the region [9].

3. Result

3.1 Landslide Susceptibility Mapping

The landslide susceptibility map was reclassified into 5 susceptible regions: very low region, low region, moderate region, high region, and very high region (Figure 2) based on natural break classification method.

The map below shows the result of SMCE processing of 10 parameters that affect the susceptibility of landslides. Each class on the map has different level of susceptibility that will affect overall landslide susceptibility map created. Landslide susceptibility map that has been made from the SMCE approach obtained 1,4% (158 ha) of the total area categorized as very low, 35,50% (4.012 ha) low susceptibility region (which distributed in northern area), 44,23% (4.999 ha) of the moderate susceptibility region (mainly distributed in southern area), 18,39% (2079 ha) were high susceptibility region and 0,46% (52,5 ha) very high susceptibility region.

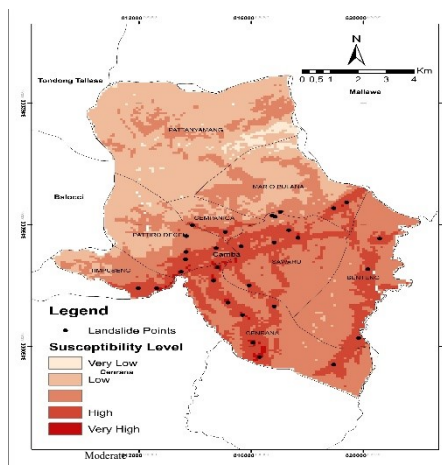


Fig 2. Landslide susceptibility map in Camba Sub-district

3.2 Accuracy of Landslide Susceptibility Map

This research resulted from the statistical method used the accuracy of the method (P) is 98%. The results of validation using the R-Index in the verification class are very high resulting in an accuracy of 55%. The results of the landslide conversation map that were made also compared the landslide events in the real location and showed quite accurate results.



Fig. 3. Landslide inventory data (Source: BNPB, Maros Regency)

In the practice, ROC method is a strong validation method that can be used to predict accuracy of landslide susceptibility map. If value of AUC close to 1 is perfect match, but if close to 0.5 is inaccurate model [8]. Based on the points of validation of landslide occurrence out of 30 occurrence points, 25 of them fell in the very high susceptible region and the remaining altitude fell outside the class. The success rate of verification for the SMCE method shows AUC value is 0.964 and accuracy of prediction is 96.4%.

3.3 Mitigation Technique in Camba Sub-district

The efforts to mitigate landslides in the Camba Sub-district based on interviews with staffs in BPBD office of Maros Regency are still lacking, this is due to cost constraints in carrying out activities for the dissemination of disasters and warnings of disasters especially landslides. Mitigation efforts that have been made include installing signs for landslide susceptible areas (warning of having landslide susceptible areas), making disaster risk studies such as risk maps, susceptibilities, and landslide hazards, socializing in disaster susceptible areas only when disasters occur, holding training in an integrated, planned and continuous manner in order to increase public awareness, alertness and preparedness for disasters on National Disaster Preparedness Day which is held once a year, on April 26th.

4. Conclusions

Landslide susceptibility map resulted areas with moderate susceptibility dominates with an area of 4998,98 ha (44.23%). The results of validation by the ROC show that AUC is 0.964 (96.4%) and the accuracy of the method (P) is equal to 98%.

Some of the landslide disaster mitigation conducted in Camba Sub-district, Maros Regency. Landslide susceptibility mapping in Camba Sub-district, Maros Regency beneficial for disaster preparedness planning, and function as a tool for land use and infrastructure planning.

Acknowledgement

The author would said thank you for the Universitas Indonesia who supported and funded this international conference by using Grants of International Publication Indexed 9 (PIT 9) Number: NKB-0025/UN2.R3.1/HKP.05.00/2019, and also thanks to Regional Disaster Management Agency Maros Regency which helps in providing information and data on landslides disaster.

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