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Study of Accuracy in Landslide Mapping Assessment Using GIS and AHP, A Case Study of Semarang Regency

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Abstract

Semarang Regency is a region that is very vulnerable to landslides based on the spread of the wider area each year to the occurrence of landslides. The need for a proper assessment of the mapping of landslide hazard so that it can be used as decision making in the mitigation system in Semarang Regency. Geographical Information System (GIS) is the right method of mapping disaster-prone areas for a wide area with a relatively short time. This method is carried out as an effort to analyze risk and hazard mapping through the dissemination of hazard information so that it will accelerate the process of delivering information to the public and can improve preparedness in taking actions to reduce disaster risk. Then, various methods that can be used to obtain weighting and classification, one of which is to make a decision-making method using the Multi Criteria Decision Making (MCDM) method. One of the MCDM methods that can integrate with SIG is the Analytical Hierarchy Process (AHP). this research it can be concluded that the use of the AHP method to the GIS analysis of landslide mapping provides good accuracy with a value of 70.97% of the 31 validation points suitability. The results of this landslide map can be used as a basis for planning landslide disaster mitigation in Semarang Regency.

Keywords: AHP, GIS, landslide, semarang regency, weighting

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1. Introduction

Disasters are events or series of events that threaten and disrupt people's lives and livelihoods caused by both natural and / or non-natural factors as well as human factors. Disasters often result in human casualties, environmental damage, property losses, and psychological impacts. One of the disasters caused by natural factors is landslides. Recorded landslides that occurred in the world resulted in more than 1,000 deaths per year [1], [2] and more than 4 billion USD damage to property as a failure to handle landslides [3]. Based on data on disaster events in 2016 and 2017 by the Regional Disaster Management Agency (BPBD) of Semarang Regency, the incidence of landslides has increased dramatically from 87 events to 158 events. Areas that experienced an increase in landslide disasters were Banyubiru District, Bringin District,

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Getasan District, Sumowono District, Suruh District, Pringapus District, Ungaran Barat District and Ungaran Timur District.

Landslides are natural phenomena that are controlled by geological conditions, rainfall and land use on slopes. Landslides are the transfer of slope-forming material in the form of rocks, rubble, soil or mixed material, moving down or out of the slope. Landslide is one type of mass or rock mass movement, as well as a mixture of both, down or out of the slope due to disruption to the stability of the soil or rocks making up the slope. One of the disaster risk parameters that can be used during a disaster is the making of a landslide threat map. Mitigation efforts can take the form of pre-disaster, disaster, and post-disaster. Disasters take the form of preparedness or efforts to provide understanding to the population to anticipate disasters, through providing information, and increasing preparedness in the event of a disaster so that there are steps to minimize disaster risk [4].

Geographic Information System (GIS) is an appropriate method in mapping disaster-prone areas for a wide area coverage with a relatively short time. This method is carried out as an effort to analyze risk and hazard mapping through the dissemination of hazard information so that it will speed up the process of delivering information to the public and can increase preparedness in taking actions to reduce disaster risk. By integrating GIS technology and appropriate mathematical methods, it can produce spatial analysis with good precision and accuracy. Spatial analysis can be approached by the weighting method and classification of the required criteria. Various methods to get weighting and classification, one of them is to make a decision making using the multi criteria decision making (MCDM) method [5]. One of the MCDM methods that can be integrated with GIS is the Analytical Hierarchy Process (AHP). Analytic Hierarchy Process (AHP) is a decision support method in determining hierarchical priorities with the main input of experts.

Making a landslide map of Semarang Regency is a form of action plan for disaster management. This landslide mapping can also be used as a material to study the ability of the MCDM in completing the processing and analysis of spatial data. Furthermore, the results of mapping using MCDM are compared with the results of disaster threat maps from field surveys and information on disaster events so that the level of accuracy can be measured. The results of the landslide threat mapping can be used as a basis in mitigation efforts aimed at preventing the risk of potentially disasters or reducing the effects of disasters when they occur. This research will produce landslide threat maps using GIS and MCDM methods to analyze the accuracy of the type of the model. Furthermore, from the threat model a landslide assessment will be produced in Semarang Regency.

2. Methods

2.1. Study Area

The area of the case study is Semarang Regency which is located at 110°14'54,7'' up to 110°39'3'' East Longitude and 7°3'57'' up to 7°30'00'' South Latitude. Semarang Regency is located at an altitude of 318 meters above sea level to 1,450 above sea level so that it causes the average air temperature in Semarang Regency to be relatively cool. There are three main rivers that cross the Semarang Regency areas. The three rivers are Garang river that crosses areas in Ungaran Barat, Ungaran Timur, and Bergas Districts, Kali Tuntang which crosses parts of Bringin, Tuntang, Pringapus and Bawen, and Senjoyo River which crosses Tuntang, Pabelan, Bringin, Tengatan and Getasan areas. In addition, in Semarang Regency there is a fairly extensive lake located in the Districts of Banyubiru, Tuntang and Bawen namely Rawa Pening where the lake is the mouth of nine rivers that cross the Semarang Regency.

Figure 1: Study area in Semarang Regency.

2.2. Materials

Some data that used in this study are:

2.3. Development of Landslide Map based on GeoHazard Catalog

In this research, the modeling of landslide hazards refers to the Methodology Catalog of GeoHazard Map Formation with GIS [6]. The parameters used in the formation of a landslide hazard model are rainfall, land cover, rock type (geology) and slope. Furthermore, each parameter is given a score and weight. Scoring and weighting

Table 1: Reseach Data.

Data	Source	Utility
Sentinel 2 Imagery 2017	https://scihub.copernicus.eu/	For development of landcover map
DEM TerraSAR-X 2017	BIG	For development of Slope map
Geology Map 2011	Bappeda Semarang Regency	For development of Geology map
Rainfall data 2017	BMKG Semarang Regency	For development of rainfall map
Events landslide Existing	BPBD Semarang Regency	For validate landslide model

have been given to the catalog as in table 2. From the four parameters, an overlay is performed and the total score and weighting is calculated for each element of the result of the overlay. The final result of a landslide map is a classification of the level of landslide threats from the total score and weight which are then classified according to table 3.

Table 2: Parameters, score, and weight of landslide map [6].

Parameter	Unit	Score	Weight
Rainfall (mm/year)	< 2000	1	
	2000 -- 3000	2	2
	> 3000	3	
Land cover	Water Bodies	0	
	Settlement / Pady Field / Forest	1	
	Moor / Field / Garden	2	2
	Shrubs	3	
Slope	0 -- 8 %	1	
	8 - 25 %	2	
	25 -- 40 %	3	3
	> 40 %	4	
Type of Geology	Andesite, Basalt, diorite, fine grained tefra, coarse grained tefra, rhyolite (class 1)	1	
	Alluvium conglomerate, young marine deposits, young river alluvium (class 2)	2	3
	Mud stone, silt stone, skis, shale,sandstone, limestone, coral stone (class 3)	3	

Table 3: Classification of landslide hazard.

Score * Weight	Class
≤ 10	Very Low
11-20	Low
21-30	Moderate
≥ 30	High

2.4. Development of Weight Parameter using Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process is a decision support model developed by Thomas L. Saaty. This decision support model will describe a complex multi-factor or multi-criteria problem into a hierarchy [7], hierarchy is defined as a representation of a complex problem in a multi-level structure where the first level is the goal, followed by the factor level, criteria, sub criteria, and so on down to the last level of alternatives. The AHP method is based on pairwise comparison matrix assessments of predetermined parameters. The assessment is obtained from experts who have experience in providing values or weights per parameter which are then made in pairs. The AHP method broadly helps planners, policy makers and decision makers to find out the most suitable destination in site selection, suitability analysis, route modeling, regional planning, including in carrying out landslide hazard analysis [8]. To make pairwise comparisons matrix, each factor is assessed against each other factor by determining the dominant value relative to the intensity of important (Table 4). From the results of calculations carried out the calculation of eigen factor with enough iteration to provide the value of the eigen factor is consistent. The result of this eigen factor is the weight value given to the parameters of the landslide model constituent. Not only get the weight value, the eigen factor results can be seen that the most recognized parameters of all parameters forming landslide hazards.

Table 4: Scale for Pairwise Comparison.

Intensity of importance	Description
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance
2, 4, 6, 8	Intermediate values
Recipocals	Values for inverse comparison

In AHP model, an index of consistency, known as the consistency ratio (CR), is used to indicate the probability that the matrix judgments were randomly generated [7].

$$CR = \frac{CI}{RI} \tag{1}$$

where RI is the average of the resulting consistency index depending on the order of the matrix given by [7] and CI is the consistency index and can be expressed as:

$$CI = \frac{(\lambda max - n)}{n - 1} \tag{2}$$

where λmax is the largest or principal eigenvalue of the matrix and can be easily calculated from the matrix and n is the order of the matrix. Consistency ratio (CR) is the ratio between matrix consistency index and random index and its range from 0 to 1. CR values of 0.1 or less indicate a logical level consistency [9] but if the CR value is greater of 0.1 it shows that the assessment of pairwise comparisons is considered inconsistent so it is needed as a revision of the rating of certain parameters.

2.5. Development of Accuracy Assesment of Landslide Mapping

The process of calculating the accuracy in modeling a landslide map is done by comparing the modeling of a landslide map with a validation point. The percentage of validation point suitability in the modeling class is the resulting accuracy value. By assuming if the suitability percentage value is more than 60%, it can be concluded that the landslide map modeling that has been carried out has good accuracy. The validation point was determined in areas where landslides often occur in 2016 and 2017 based on disaster recap data obtained from the Regional Disaster Management Agency (BPBD) Semarang Regency. The number of validation points that have been obtained is 31 points.

3. Result and Discussion

3.1. Result of Landslide Map using Geohazard Catalog

The making of a landslide hazard map in this study was guided by the "Geohazard Map Making Methodology Catalog with GIS" written by Paripurno et al (2008) which was carried out by weighting and overlapping several parameters namely rainfall, land cover, geological rock type and slope. The following details the weight of each parameter used in making a landslide threat map based on the Geohazard Catalog:

3.1.1. Slope Map

The slope map is obtained from the DEM Terra SAR Image. In the processing slope process is carried out to produce slope. In Figure 2a, the following is the result of processing the slope map.

3.1.2. Rainfall Map

Rainfall map is obtained by IDW (Inverse Distance Weight) interpolation method from one year of rainfall data in 2017 which was observed from nine rainfall observation stations. The observation stations are located at Getasan (Kopeng KBB), Susukan (Rejoso), Suru, Banyubiru, Sumowono, Bawen, Bringin (Grenjeng), Ungaran (Tarubudaya) and Salatiga. In Figure 2b, the results of rainfall map processing are displayed.

3.1.3. Land Cover Map

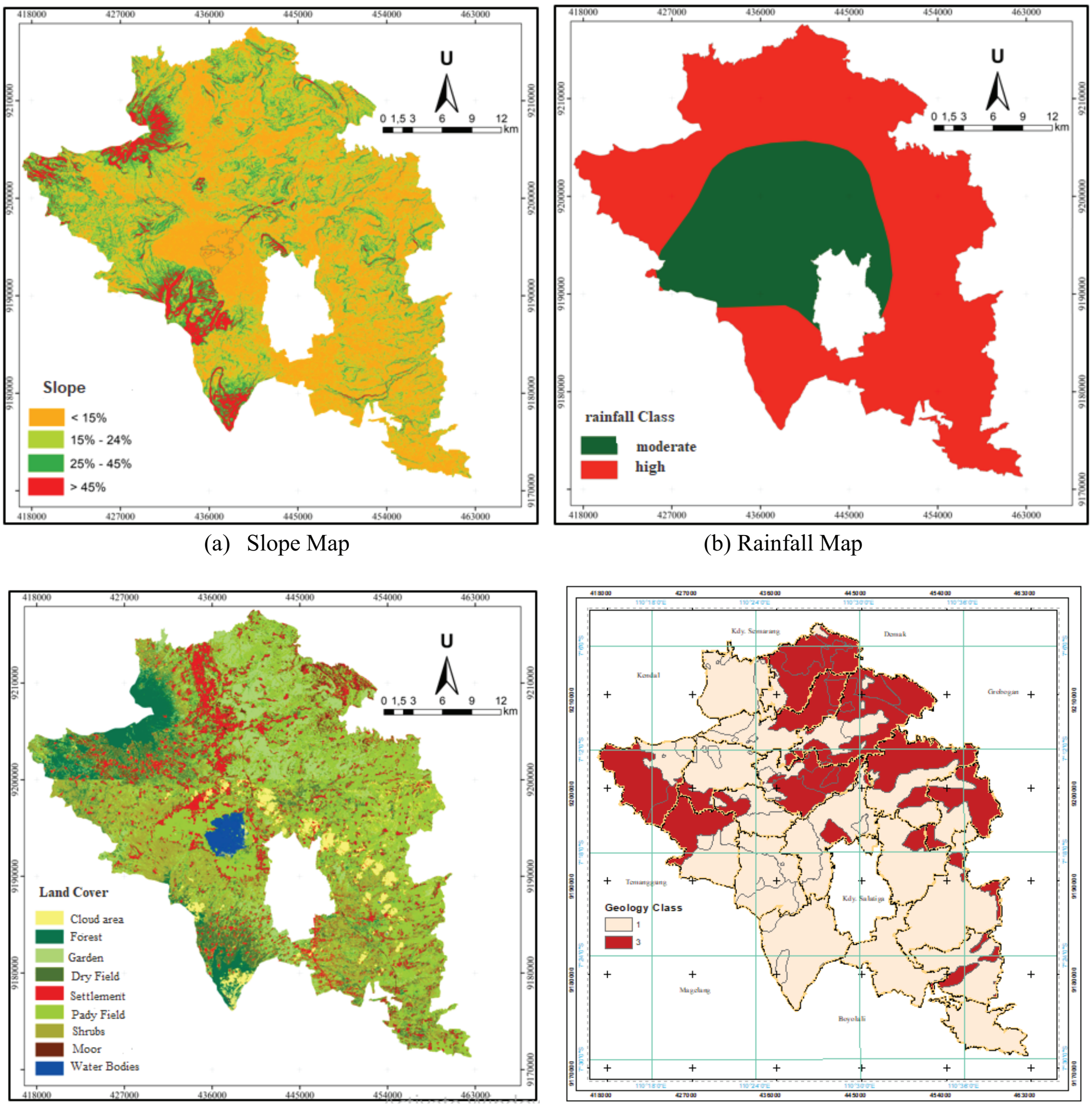
The land cover map was obtained from Citra Sentinel-2 through the supervised classification process in QGIS 2.18.18 Las Palmas. Overall accuracy is calculated using the overall accuracy and kappa coeficient formulas in determining the consistency of classification results. The overall accuracy value obtained is 97.12% and the kappa coeficient value is 96.36%. Based on the overall accuracy and kappa coeficient values, it can be concluded that the results of the supervised classification are at a good level of accuracy. In Figure 2c, the following is the result of processing land cover.

3.1.4. Geology Map

The establishment of the Semarang Regency geological map refers to the Semarang Regency Geological Structure Map from the Regional Development Planning Agency (Bappeda). The results of the classification are divided into several classes based on table 2, with the results of the geological classification map as shown in Figure 2d.

Based on the overlay results of the four map parameters, a landslide map is produced. The landslide map is classified into four classes, namely very low, low, moderate and high classes based on the total score and weighting of each parameter. The results of a landslide map based on the geohazard catalog can be presented as shown in Figure 3.

The results of the process of establishing a landslide hazard map of Semarang Regency showed that areas with a high level of threat to landslides were 491.32 Ha or 0.48% of the Semarang Regency area, then 36,955.008 Ha indicated a moderate level of threat or 36.31% of the Semarang Regency area, then 54,534.393 Ha or 53.58% of the Semarang Regency area showed low threats and 1696.82 Ha showed a very low threat or 1.67% of the Semarang Regency area. For the unexplained area (the area covered by clouds from the results of the map of land cover) is 8,102.6 Ha or 7.96%



(a) Slope Map (b) Rainfall Map

(c) Land Cover Map (d) Geology Map

Figure 2: Map of Parameters Performing Landslide Map.

of Semarang Regency. Then the district with the highest level of threat was found in Sumowono Subdistrict with an area of 164.469 Ha, while the sub-district which had a very low level of threat was found in Tuntang District with an area of 620.201 Ha.

3.2. Results of AHP Process and Landslide Hazard Map using AHP

The first thing to do in the AHP process is to conduct interviews with informants who in this study are the Head of Mitigation Engineering Section of the Regional Disaster Management Agency (BPBD) Semarang Regency. The results of the comparison pair assessment are presented in table 5. Then the results of the comparison pair matrix

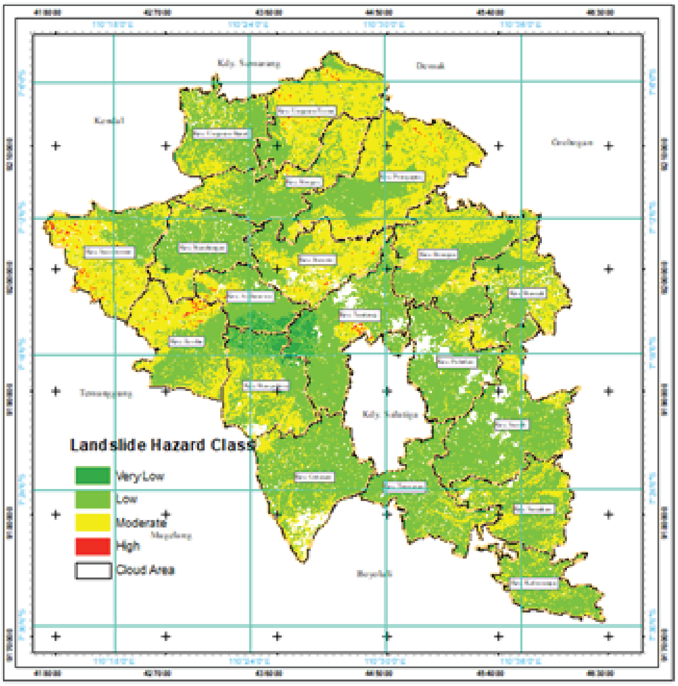


Figure 3: Landslide Map of Semarang Regency.

produce the priority value of the eigen value. This priority value is the new weight value for each landslide map parameter.

To test its consistency, according to equations (1) and (2) a CR value of 0.07 is obtained. The CR results reflect that the weighted value already meets the consistency test.

Table 5: Matrix of Pairwise Comparison.

	Slope	Rainfall	Geology	Land Cover
Slope	1.000	0.333	3.000	3.000
Rainfall	3.000	1.000	3.000	5.000
Geology	0.333	0.333	1.000	3.000
Land Cover	0.333	0.200	0.333	1.000

The weighting that results from the AHP process is then implemented to form a landslide map. The results of changes in weight values are presented in table 6.

The results of the process of establishing a landslide hazard map of Semarang Regency using AHP weight showed that areas with a high level of threat to landslides were 2982.19 Ha or 2.93% of the Semarang Regency area, then 3,6087.90 Ha indicated a moderate level of threat or 35.46% of the Semarang Regency area, then 45,519.8 Ha or 44.72% of the Semarang Regency area showed low threats and 9,087.63 Ha showed a very low threat or 8.93 % of the Semarang Regency area. For the unexplained area (the area covered by clouds from the results of the map of land cover) is 8,102.6 Ha or 7.96% of Semarang Regency.

Table 6: Parameters, score, and weight of landslide map using AHP.

Parameter	Unit	Score	Weight based AHP
Rainfall (mm/year)	< 2000	1	
	2000 -- 3000	2	0.51
	> 3000	3	
Land cover	Water Bodies	0	
	Settlement / Pady Field / Forest	1	
	Moor / Field / Garden	2	0.07
	Shrubs	3	
Slope	0 -- 8 %	1	
	8 - 25 %	2	
	25 -- 40 %	3	0.27
	> 40 %	4	
Type of Geology	Andesite, Basalt, diorite, fine grained tefra, coarse grained tefra, rhyolite (class 1)	1	
	Alluvium conglomerate, young marine deposits, young river alluvium (class 2)	2	0.15
	Mud stone, silt stone, skis, shale,sandstone, limestone, coral stone (class 3)	3	

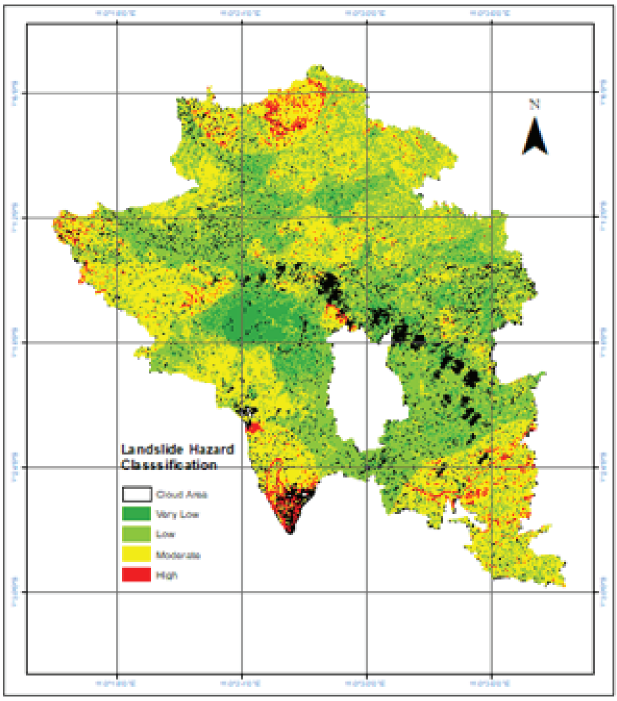


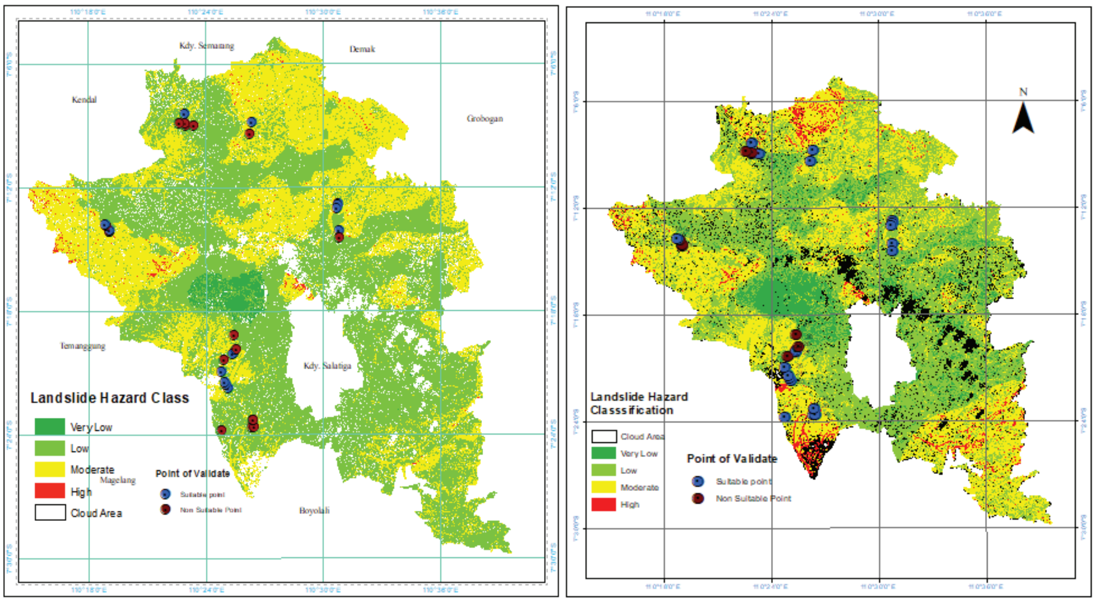
Figure 4: Landslide Map of Semarang Regency using AHP weight.

3.3. Result of Accuracy Assesment of Landslide Mapping

Determination of the accuracy assessment of the two landslide map models can be concluded. By using the validation point, the accuracy of the landslide map model can be generated as shown in table 7. For visualization of the suitability of the validation point with the landslide map model can be seen in Figure 5. The results of the comparison of the two landslide map models can be concluded that the landslide map model using AHP provides better accuracy than the standard from the GeoHazard catalog.

Table 7: Suitability of the landslide map model.

Model Landslide Map	sum of suitable point validate	Suitable percentage (%)
Landslide Map using Catalog Geohazard	13	41.94
Landslide Map using AHP	22	70.97



(a) Landslide Map using Catalog GeoHazard (b) Landslide Map using AHP

Figure 5: Comparison of Landslide Map Model with Point Validate.

4. Conclussion

From the overall work in this research it can be concluded that the use of the AHP method to the GIS analysis of landslide mapping provides good accuracy with a value of 70.97% of the 31 validation points suitability. Furthermore, the landslide mapping of Semarang Regency using the AHP method resulted that areas with a high level of threat to landslides were 2982.19 Ha or 2.93% of the Semarang Regency area, then 3,6087.90

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Ha indicated a moderate level of threat or 35.46% of the Semarang Regency area, then 45,519.8 Ha or 44.72% of the Semarang Regency area showed low threats and 9,087.63 Ha showed a very low threat or 8.93 % of the Semarang Regency area. The results of this landslide map can be used as a basis for planning landslide disaster mitigation in Semarang Regency.

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References

[1] Varnes, D. J., (1981). Slope stability problems of the circum Pacific region as related to mineral and energy resource. In: Halbouty, M.T. (Ed.), *Energy resources of the Pacific region. American Association of Petroleum Geologists Studies in Geology.* No. 12, pp. 489--505. Tulsa, Okla: American Association of Petroleum Geologist,

[2] Lee, S., and Pradhan, B., (2007). Landslide hazard mapping at Selangor Malaysia using frequency ratio and logistic regression models. *Landslides,* vol. 4, no. 1, no. 33-41

[3] Pradhan, B., (2010). Landslide susceptibility mapping of a catchment area using frequency ratio, fuzzy logic and multivariate logistic regression approaches. *J. Ind. Soc. Remote Sens,* vol. 38, no. 2, pp. 301--320. https://doi.org/10.1007/s12524-010-0020-z.

[4] Nugraha L. A., Santosa, Purnama B., Aditya, T. (2015). Dissemination of tidal flood risk map using online map in semarang. *Procedia Environmental Sciences*, vol. 23, no 2015, pp. 64-71

[5] Guzzetti, F. et al., (1999). Landslide hazard evaluation: a review of current techniques and their application in a multi-scale study, Central Italy. Geomorphology 31, 181--216.

[6] Paripurno, E.T., Theml, Sven., Darsoatmodjo, et al. (2008). *Katalog Metodologi Penyusunan Peta Geo-Hazard Dengan GIS.* Badan Rehabilitasi dan Rekonstruksi (BRR) NAD-Nias.Banda Aceh.

[7] Saaty, T.L., (1977). A scaling method for priorities in hierarchical structures. *J. Math. Psychol,* vol. 15, pp. 234--281.

[8] Ayalew, L., Hiromitsu, Y., Norimitsu, U., (2004). Landslide susceptibility mapping using GIS-based weighted linear combination, the case in Tsugawa area of Agano River, Niigata Prefecture, Japan. *Landslides* vol. 1, no. 1, pp. 73--81.

[9] Malczewski, J., (2004). GIS-based land-use suitability analysis: a critical overview. *Progress in Planning*, vol 62, pp. 3--65.