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GIS-Based Landslide Disaster Risk Areas and Ground Movements Mapping to Support Disaster Mitigation Activities (Case Study: Tasikmalaya Regency)

Novi Asniar [1*], Anri Noor Annisa Ramadan[1] dan Aso Sudiarjo[2]

[1]Civil Engineering Study Program, Faculty of Engineering, Universitas Perjuangan Tasikmalaya. Jl. Peta No.177, Kahuripan, Kec. Tawang, Tasikmalaya, Jawa Barat 46115
[2]Informatics Engineering Study Program, Faculty of Engineering, Universitas Perjuangan Tasikmalaya. Jl. Peta No.177, Kahuripan, Kec. Tawang, Tasikmalaya, Jawa Barat 46115

Correspondence: noviasniar@unper.ac.id
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Abstract. Tasikmalaya Regency is an area that is prone to landslides and ground movements. The availability of comprehensive and accurate information in controlling land use for regional development in areas prone to landslides and ground movements is very important for casualty prevention and other losses such as physical, social and economic. This information must be disseminated to the public as an early warning system to support disaster mitigation efforts. Identification of the characteristics of landslide and ground movement prone areas requires the mapping of risk areas to mitigate disasters. This can be done using Geographic Information System (GIS). This mapping activity was carried out using the method of collecting digital data from five vulnerability controlling factors of landslides and ground movements, namely rainfall, rock type, soil type, land cover and slope. The analysis is continued by weighting the factors that influence landslides and ground motion and then overlaying the five controlling factor maps (with their respective weight values) to produce a landslides and ground movement vulnerability level map which is then inputted into WebGIS. This map can then be used by local governments and the public as an information medium to support disaster mitigation activities.

Keywords: Controlling factors, landslide, vulnerability, WebGIS, disaster mitigation

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INTRODUCTION

Landslides and ground movements can cause significant repercussions such as damage and loss. The losses experienced can affect local communities. These losses can be in the form of loss of human life, damage to property and disruption of natural ecosystems (Alhasanah, 2006). Therefore, it is necessary to take action, especially in productive areas, economic routes, settlements and infrastructure (Zakaria, 2010).

The availability of comprehensive and accurate information in controlling land use for regional development in areas prone to landslides and ground movements is very important for casualty prevention and other losses such as physical, social and economic. Such information should be disseminated to the public as an early warning system. In some areas with high population density and pre-existing early warning systems, such information is not distributed evenly, leading to the possibility for differing perceptions. This may cause panic and chaos and in effect, greater loss of both property and life (Noor, 2014).

Efforts that can be done to minimize the impact of landslides and ground movements are through the recognition of the characteristics of vulnerable areas. To identify the characteristics of disaster-prone areas, the mapping of disaster-prone areas is needed (Rahmad et al., 2018). Disaster risk mapping is an activity that presents the consequences of a disaster (Aditya, 2010). The development of Geographic Information System (GIS) can provide accurate geospatial data information and an accurate analysis system. This supports mitigation efforts to prevent risks that have the potential to become disasters or minimize losses from such disasters (Faizana et al., 2015).

Geographic Information System (GIS) is a system or set of objects and ideas that are interconnected (interrelationships) and displayed as geographic information which can be presented as software technology. This technology can then be used as a tool for entry, storage, manipulation, analysis, and display of field conditions with the help of data and spatial attributes. Comprehension of the "real world" will be better if the processes of data manipulation and presentation related to geographic locations are understood. (Munir, 2014).

PROBLEM

The output target of this community service activity is to produce an information system that is directly accessible for the public regarding the mapping of at-risk areas in the Tasikmalaya Regency. This information system is a tool to support disaster mitigation activities in Tasikmalaya Regency. With information that can be accessed directly, the public

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can be more selective of residential choices, be more aware of disaster risks and be better prepared for potential disasters.

METHOD OF IMPLEMENTATION

Mapping of Landslide-prone Areas

The Making of landslide-prone area maps is based on secondary data such as rainfall maps, geological maps, slope maps, soil type maps, land cover maps and data on landslides and ground movement events that have occurred in Tasikmalaya Regency between 2013 - 2020.

Data in the form of rainfall maps, soil type maps, geological maps and contour maps are then inputted into a GIS software. The data entry process is done through a set of computers using ArcGIS 10.1 software. This output data is then used as a reference for mapping analysis of landslide-prone areas in the Tasikmalaya Regency.

Analysis of the landslide susceptibility map is carried out after the thematic parameter maps, namely rainfall maps, soil type maps, geological maps and slope maps of the area are available in the form of digital maps. Each type of map is classified based on scores and given weight, the scores are then grouped together and analyzed. The mapping was done using ArcGIS 10.1 software. In the mapping process, each parameter has a classification score which is multiplied by the weight of each parameter according to the 2004 Puslittanak estimation model. The results of the score and weight multiplication are tallied based on the compatibility of their geographical locations. Based on the 2004 Puslittanak estimation model, the parameters used to determine the level of vulnerability are land cover, soil type, land slope, rainfall and geological formation (Table 1-5).

The model used to analyze landslide susceptibility is an estimation model that refers to the 2004 Research Center for Research and Development with the following formula:

$$\text{TOTAL SCORE} = 0{,}3FCH+0{,}2FBD+0{,}2FKL+0{,}2FPL+0{,}1FJT$$

Description:

FCH	= Rainfall Factor	FPL	= Land Cover Factor
FBD	= Rock Type Factor	FJT	= Soil Type Factor
FKL	= Land Slope Factor	0,3;0,2;0,1	= Score Weight

Table 1. Rainfall Classification (mm/year)

Parameter	Weight	Score
Very wet (>3000)		5
Wet (2501-3000)		4
Moderate (2001-2500)	30%	3
Dry (1501-2000)		2
Very dry (<1500)		1

Source: Puslittanak Bogor (2004)

Table 2. Rock Type Classification

Parameter	Weight	Score
Volcanic rocks		3
Sedimentary rocks	20%	2
Alluvial rocks		1

Source: Puslittanak Bogor (2004)

Table 3. Land Slope Classification

Parameter (%)	Weight	Score
>45		5
30-45		4
15-30	20%	3
8-15		2
<8		1

Source: Puslittanak Bogor (2004)

Table 4. Land Cover Classification

Parameter	Weight	Score
Moor, rice fields		5
Bushes		4
Forest and plantations	20%	3
City/settlements		2
Ponds, reservoirs, bodies of water		1

Source: Puslittanak Bogor (2004)

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Table 5. Soil Type Classification

Parameter	Weight	Score
Regosol		5
Andosol, podsolic		4
Brown latosol	10%	3
Yellowish-brown latosol association		2
Alluvial		1

Source: Puslittanak Bogor (2004)

Classification of the results uses score analysis and is carried out by classifying 4 types of landslide susceptibility, namely: low, medium, high and very high based on final score numbers. The greater the score number, the higher the level of vulnerability, by establishing the following score intervals:

(Highest score – Lowest score) : (Number of class classification)

Creation of a WebGIS that can be accessed by the public for free

After the landslide vulnerability map has been prepared, the next step is to post various geographical information that can be accessed by the public. The developed system must be able to provide functional and non-functional requirements.

RESULTS AND DISCUSSION

Overview of the Tasikmalaya Regency Area

Tasikmalaya Regency is an agrarian area populated by a religious community, located in the eastern region of West Java Province between 07°2'00” - 07°48'00” South Latitude and 107°54'00” - 108°26' 00” East Longitude. The western part of Tasikmalaya Regency is bordered by Garut Regency, in the east by Ciamis Regency, in the north by Tasikmalaya City and Ciamis Regency and in the south by the Southern Indonesian Ocean. Tasikmalaya Regency has an area of 2,708.81 km2 or 270,881 ha and administratively consists of 39 sub-districts (Figure 1).

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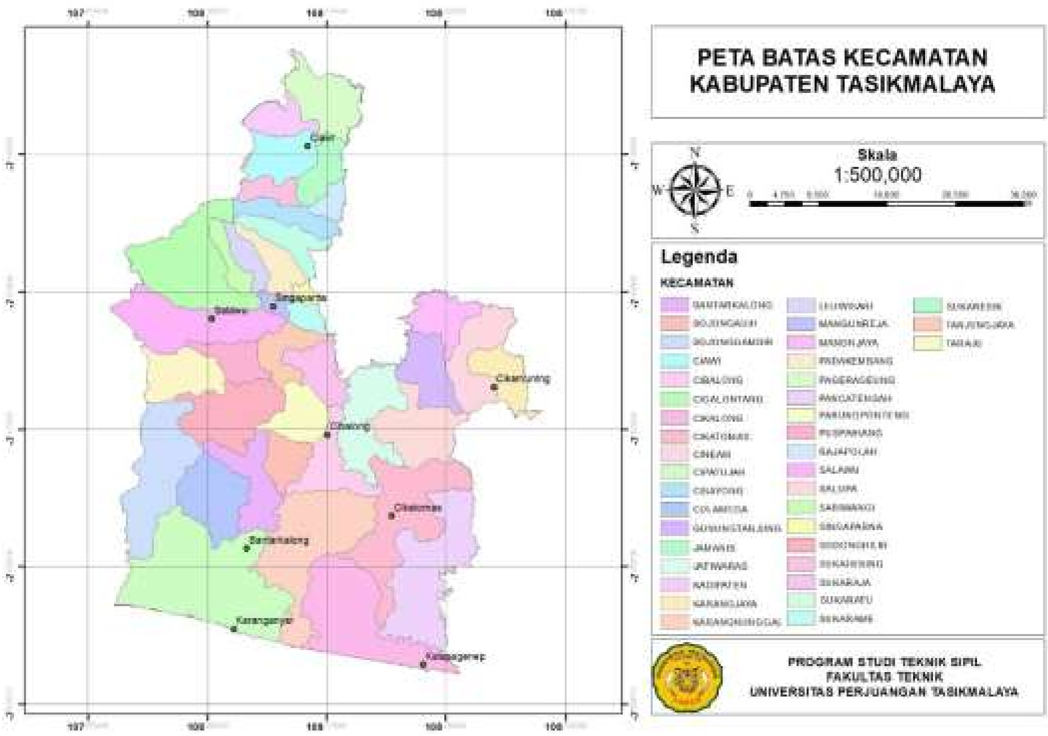

Figure 1. Tasikmalaya district boundary map

Factors Which Influence Landslides in Tasikmalaya

1. Rainfall

As one of the parameters that define landslide-prone areas, rainfall maps are produced based on the amount of rainfall, rainfall intensity and rainfall distribution. The Rainfall Map of Tasikmalaya Regency obtained from Climate Hazards Group Infrared Precipitation with Stations (CHIRPS) 2016 - 2020 is shown in Figure 2. Based on the classification of rainfall from the Bogor Research and Development Center (2004), the Tasikmalaya Regency area has high rainfall intensity.

Based on the classification of rainfall from Puslittanak Bogor (2004) all areas of Tasikmalaya Regency obtained a score of 5 because of its high rainfall wetness (> 3000 mm/year). The higher the value of rainfall intensity, the greater the influence on landslides. Likewise, heavy, and long-lasting rainfalls can increase soil mass which triggers landslides.

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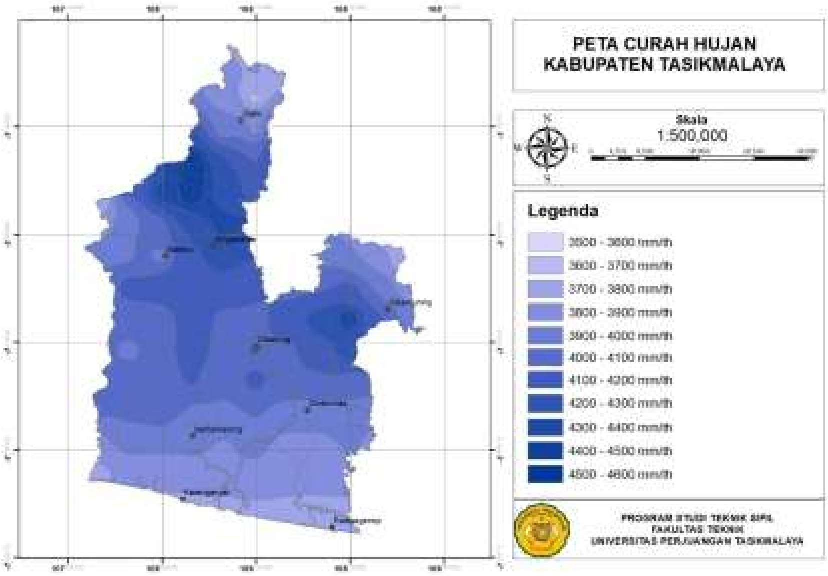

Figure 2. Tasikmalaya regency rainfall map

2. Rock Types

Rock types in Tasikmalaya Regency can be seen in Figure 3. Based on Puslittanak classification, rock formations found in Tasikmalaya Regency consist of 2 types of rock, namely volcanic rocks and alluvial rocks. Volcanic rocks consist of volcanic and limestone formations, while alluvial rocks consist of southern coastal rock formations. The rock type map is weighted based on Table 2, then inputted into ArcGIS which will eventually be overlaid with other mapping parameters.

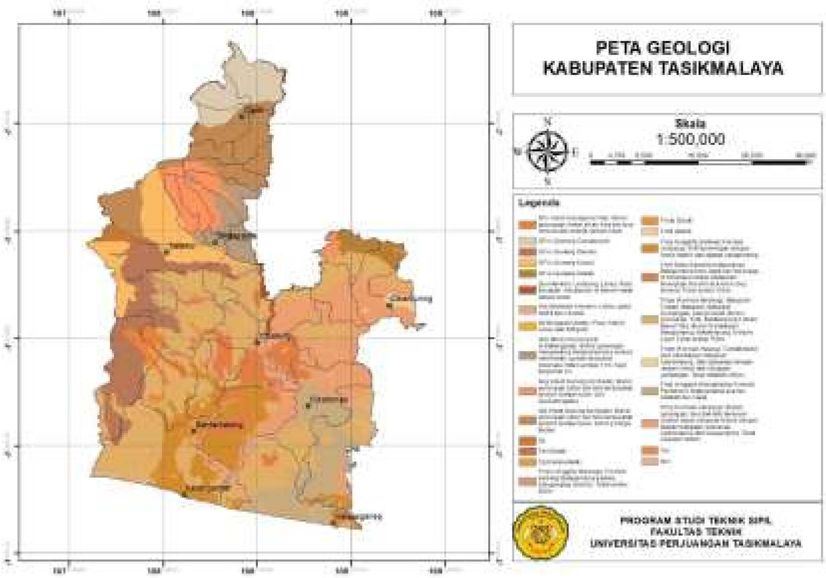

Figure 3. Geological map of Tasikmalaya regency

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3. Soil Type

Soil type maps are generated from SHP data which is downloadable for free from the government's official website. The naming of soil classification to the determining of the sub-group levels are conformed to the Soil Taxonomy (Soil Survey Staff, 1990).

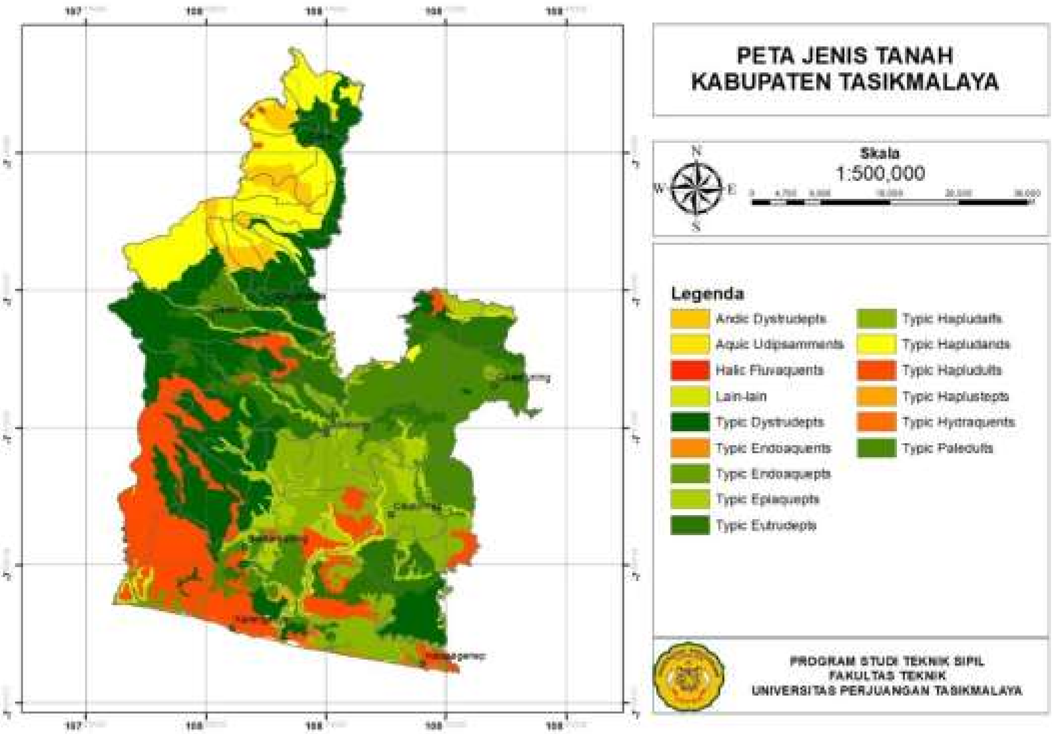

Figure 4. Soil types map of Tasikmalaya regency

To ease the scoring process of the soil types map, the distribution of soil types in Tasikmalaya Regency was classified, in accordance to the National soil classification system, into 6 soil types namely, Alluvial, Brown Forrest, Andosol, Red-yellow Podsolik, Latosol and Regosol. The soil types map scoring is based on Table 5.

4. Land Slope

The land slope conditions in Tasikmalaya Regency are respectively: Very Steep (> 40 %) of 1.39% of Tasikmalaya Regency area, Slightly Steep (25 % - 40 %) of 25.35 %, Steep (15 % - 25 %) of 27.11%, Sloping (8% - 15%) of 13.27 %, and Flat (0% - 8%) of 32.87% of Tasikmalaya Regency area. From the slope data, it is readily apparent that most of the Tasikmalaya Regency's landscape is dominated by flat to slightly steep surfaces. Areas with fairly high slopes can produce landslides. The scoring for the slope map is based on Table 3.

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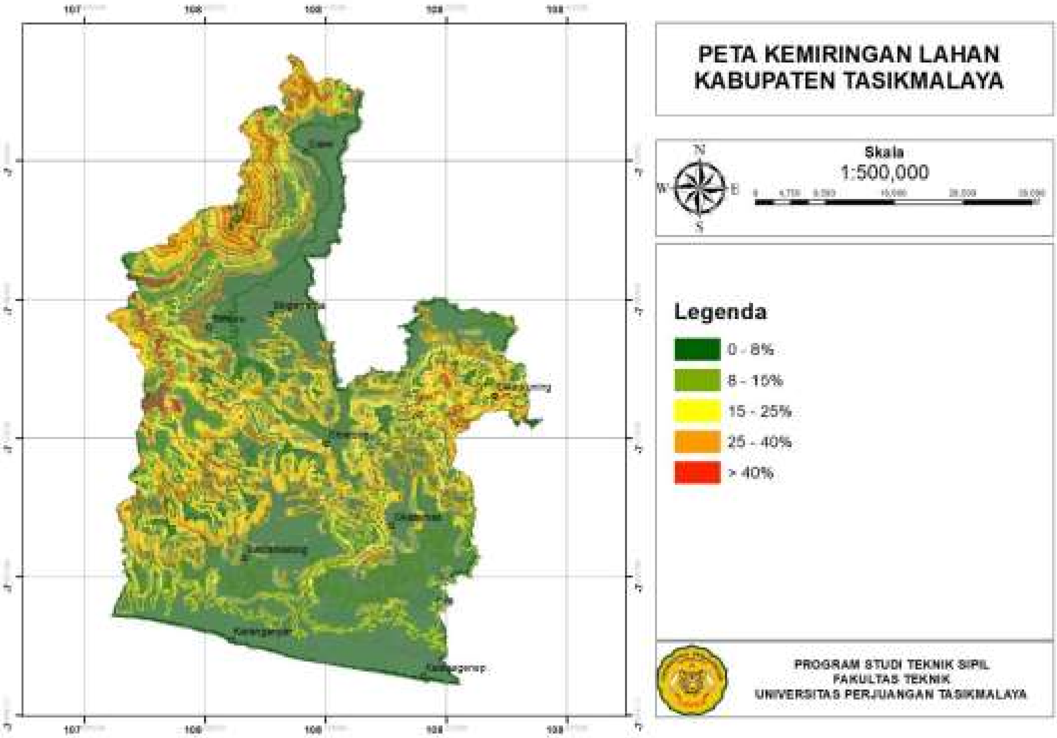

Figure 5. Land slope map of Tasikmalaya regency

5. Land Cover

Land cover within an area is closely related to economic conditions and the area's demographic. Based on the digitized land use map of Tasikmalaya Regency, five types of land cover were obtained, namely: forests, settlements, plantations, rice fields/agricultural areas and embankments (Figure 6). Based on the land cover map, the Tasikmalaya Regency area is dominated by dry mixed agricultural areas and secondary dry land forests. Dry land agriculture is generally in the form of open/empty lands which are usually cultivated during rainy seasons and left empty during dry seasons. Such a condition is very vulnerable to landslides in the event of rainfall on empty areas/areas with no vegetation to absorb water. The weighting/scoring of the land cover types map is based on Table 4.

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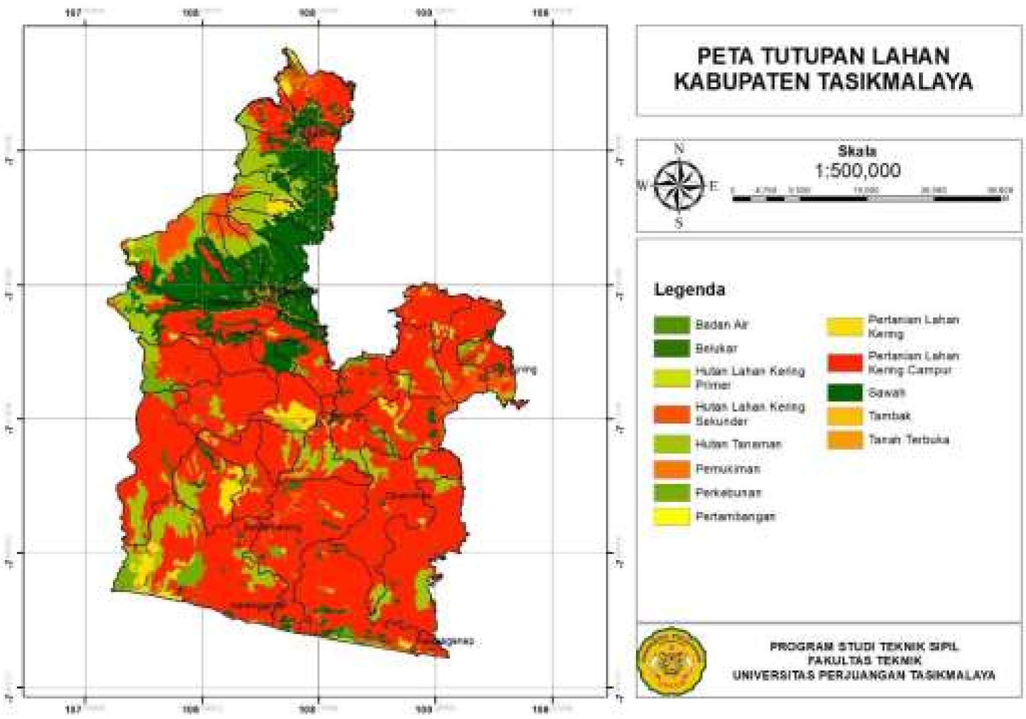

Figure 6. Land Cover Map of Tasikmalaya Regency

WebGIS Design for Landslide Disasters and Ground Movements That are Accessible to the Community

1. Landslide vulnerability and Ground Movement Maps of Tasikmalaya Regency

Estimation of landslide-prone areas was carried out using an estimation model sourced from the Research Center for Research and Development in 2004. Based on this model, the parameters used to estimate landslide-prone areas include Soil Type, Land Cover, Rock Type, Rainfall, and Land Slope. All of these parameters are classified based on their scores and weighted according to their respective contributions and subsequently processed. Based on the analysis of five landslide vulnerability parameters using the Puslittanak Landslide Vulnerability Estimation model in 2004, four landslide susceptibility criteria were obtained, namely Low, Medium, High and Very High. In the 2004 Puslittanak Landslide Hazard Estimation model, the rainfall factor was weighted at 30%, the rock type, land slope and land cover type was at 20%, while the soil type factor was at 10%.

Landslide Hazard Map and ground movement of Tasikmalaya Regency were obtained by combining (overlaying) five parameter maps and then calculating them. The results are then classified based on vulnerability levels. The results of this classification are shown in Figure 7.

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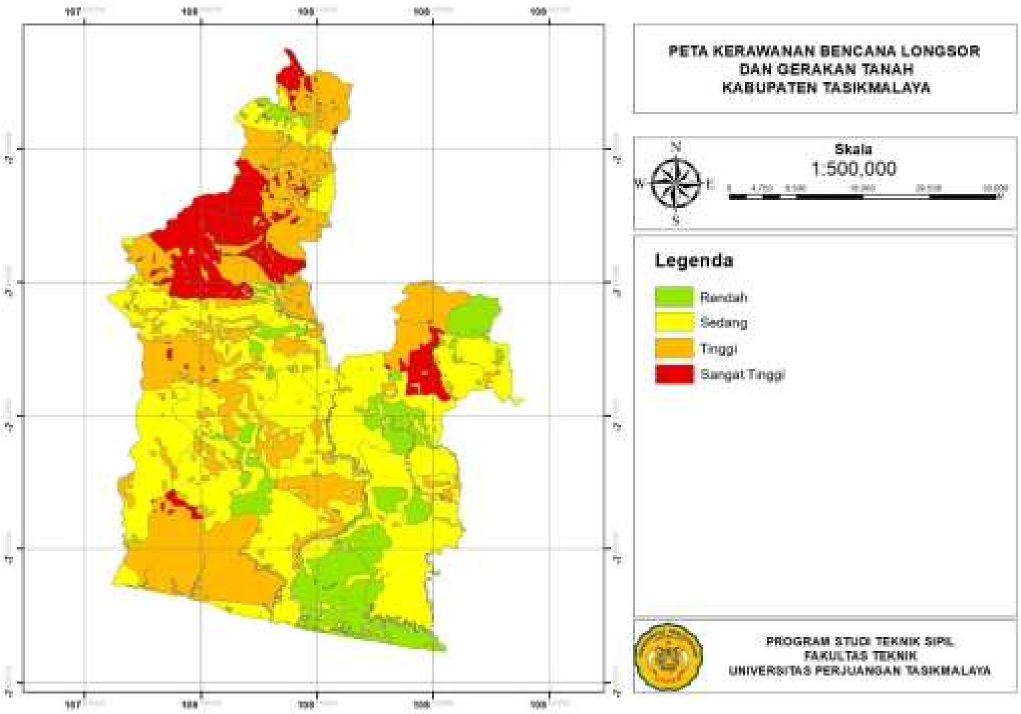

Figure 7. Landslide vulnerability and ground movement map of Tasikmalaya regency.

Based on the map, the Tasikmalaya Regency area generally has moderate to high levels of landslide and ground movement vulnerability. This needs to be watched out for because Tasikmalaya Regency has a high rainfall intensity. Generally, landslides and ground movements occur in areas that have high rainfall intensity, high land slope and land covers in the form of vacant lands, rice fields or grasslands that cannot hold water.

2. WebGIS design accessible to the public

WebGIS contains various information about landslides and ground movements in Tasikmalaya Regency that can be accessed by the public. The front page of this WebGIS can be seen in Figure 8.

Figure 8. Front View of WeGIS Landslide Disaster and ground movement of Tasikmalaya Regency

WebGIS is still in a development stage and open to future improvements. Information obtainable from WebGIS includes:

1. Locations where landslides and ground movements occur every year, which are displayed on Google Maps which was integrated into WebGIS.

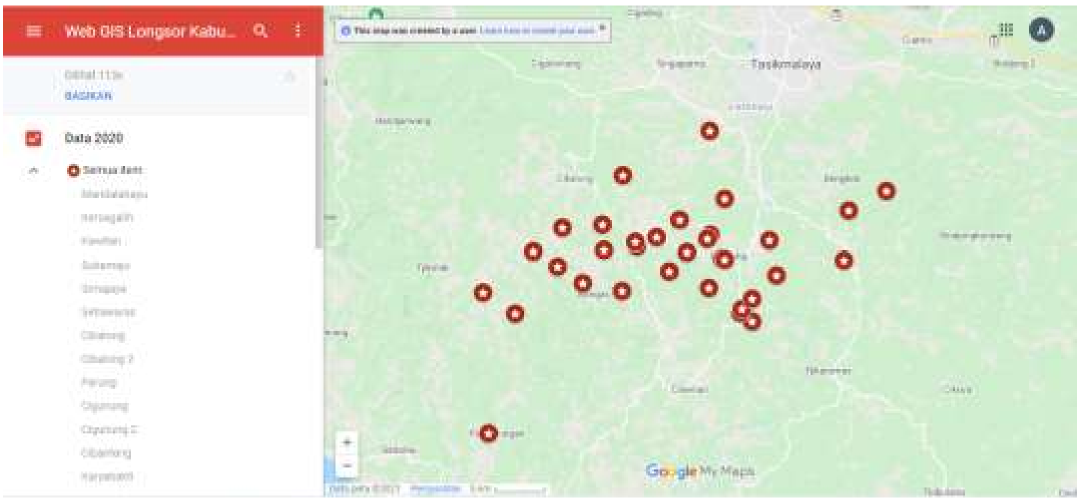

Figure 9. The location of the landslide events and ground movement in Tasikmalaya regency on the year of 2020

2. Locations of Landslide Disasters and Ground Movements in Tasikmalaya Regency throughout 2020.
3. Landslide Vulnerability and Ground Movement map of Tasikmalaya Regency throughout 2020.
4. Landslide Disaster Mitigation Poster.

CONCLUSION

This community service activity aims to create a landslide vulnerability and ground movement map using an estimation model sourced from the Research Center for Research and Development in 2004 based on the scoring of five parameters, namely rainfall map, rock type map, land slope map, land cover map, and soil type map. Based on this weighting, Tasikmalaya Regency was divided into 4 criteria of landslide susceptibility, namely Low, Medium, High and Very High. After the landslide vulnerability map was compiled, the next activity was to create a WebGIS that can display various geographic information of landslides and ground movements that can be accessed by the public. In addition, the WebGIS also contained posters concerning mitigation for landslides and ground movements.

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Original Title:
Pemetaan Daerah Resiko Bencana Longsor dan Gerakan Tanah Berbasis SIG untuk Menunjang Kegiatan Mitigasi Bencana (Studi Kasus : Kabupaten Tasikmalaya)

Abstrak. Kabupaten Tasikmalaya merupakan daerah yang rawan bencana longsor dan gerakan tanah. Tersedianya informasi yang lengkap dan akurat dalam pengendalian pemanfaatan lahan di kawasan rawan bencana longsor dan gerakan tanah dalam pengembangan suatu wilayah menjadi hal yang sangat penting dalam meminimalisir adanya korban jiwa dan kerugian-kerugian baik fisik, sosial maupun ekonomi. Informasi tersebut harus disebarkan kepada masyarakat sebagai sistem peringatan dini dalam upaya mitigasi bencana. Identifikasi karakteristik daerah rawan longsor dan gerakan tanah diperlukan sebuah pemetaan risiko kawasan rawan longsor dan gerakan tanah dalam upaya mitigasi bencana dapat dilakukan menggunakan Sistem Informasi Geografis (SIG). Kegiatan pemetaan ini dilakukan dengan menggunakan metode pengumpulan data-data digital dari lima faktor pengontrol kerawanan bencana longsor dan gerakan tanah, yaitu curah hujan, jenis batuan, jenis tanah, tutupan lahan dan kemiringan lereng. Analisis dilanjutkan dengan melakukan pembobotan faktor-faktor pengontrol longsor dan gerakan tanah selanjutnya menumpangtindihkan (*overlaying*) kelima peta faktor pengontrol (dengan nilai bobot masing-masing) sehingga menghasilkan peta tingkat kerawanan bencana longsor dan gerakan tanah yang diinput ke WebGIS. Peta ini kemudian dapat dimanfaatkan oleh pemerintah daerah dan masyarakat sebagai media informasi dalam menunjang kegiatan mitigasi bencana.

Kata kunci: Faktor pengontrol, longsor, kerawanan, WebGIS, mitigasi bencana