Landslide susceptibility analysis in Kampung Renok Baru, Gua Musang, Kelantan

Cite as: AIP Conference Proceedings **2454**, 050039 (2022); https://doi.org/10.1063/5.0078822

Wani Sofia Udin and Nur Syarienna Razmi

AIP Conference Proceedings **2454**, 050039 (2022); https://doi.org/10.1063/5.0078822

Landslide Susceptibility Analysis In Kampung Renok Baru, Gua Musang, Kelantan

Wani Sofia Udin[a] and Nur Syarienna Razmi[b]

Faculty of Earth Science, Locked Bag No 100, Universiti Malaysia Kelantan (Jeli Campus), 17600 Jeli, Kelantan, Malaysia

[a]Corresponding author: wanisofia@umk.edu.my
[b]syarienna.e17a0049@siswa.umk.edu.my

Abstract. This study was conducted in the Kampung Renok Baru region of Gua Musang, Kelantan. The purpose of this research is to identify landslide causative factors and develop 1:25,000 scale landslide susceptibility maps. Primary and secondary sources were used to acquire all of the information needed to estimate landslide vulnerability. The pre-field work included secondary data collecting related to topography features, satellite imageries, and the Digital Elevation Model (DEM). The likelihood of a landslide is influenced by slope, aspect, lithology, land use, drainage density, and distance from the road. In this research, the Weighted Overlay Method (WOM) was applied. The densities of landslide incidents were computed within each causative factor map and associated parameter map classes. A generic quantitative prediction was also developed to rate the causal components that could produce landslides in similar scenarios. The landslide susceptibility map was created by combining the causative factor maps with the resulting weights. The landslide risk map for the study area was separated into three categories. Class 1 is low hazard, class 2 is medium hazard, and class 3 is high hazard. Finally, decision-makers can use the generated map for land use planning and landslide mitigation.

INTRODUCTION

Landslides are one of the most common natural disasters in the world, particularly in mountainous places. Landslides are caused by high-intensity rainfalls caused by human activities such as deforestation, road and building development, forestry, urbanisation, and others [1]. Despite the fact that Malaysia is not a mountainous country (mountains and hills make up less than 25% of the terrain), landslides are a common occurrence. Kelantan is located in Peninsular Malaysia's northeast part. The northeast monsoon will hit this state around the end of the year, from October to March. The significant rainfall monsoon had an impact on landslide events of varying sizes in the Kelantan river basin as well as in Gua Musang [2].

Slope, aspect, drainage density, land cover and precipitation, among other factors, can all contribute to landslide hazard [3]. A key aspect of the hazard assessment is extracting important geographical characteristics about the risk of landslides. The use of Remote Sensing (RS) data in conjunction with a Geographical Information System (GIS) is an useful tool for generating and analysing spatial data.

Landslide susceptibility is defined as the likelihood of a landslide occurring in the area based on local terrain and hydrological circumstances [4]. Landslide susceptibility classification refers to the division of land into homogeneous regions or domains based on the degree of actual or anticipated risk. The most often used mathematical method for constructing a susceptibility model for predicting possible landslides using landslide inventories and causative factors is landslide susceptibility analysis. The results of the landslide susceptibility analysis are then utilised to produce landslide susceptibility maps and differentiate susceptibility levels for the research area. Landslide susceptibility maps can also be utilised in urban land-use planning, construction site selection, and risk control decision-making [1].

International Conference on Bioengineering and Technology (IConBET2021)
AIP Conf. Proc. 2454, 050039-1–050039-7; https://doi.org/10.1063/5.0078822
Published by AIP Publishing. 978-0-7354-4193-4/$30.00

Works by [5] have shown that poor strategic planning and landslide mitigation can put the community in peril. One issue that has to be addressed is the lack of research into the landslide risk in that particular area. According to a large-scale study [2], careful planning was made to avoid the landslide phenomena, which has a significant risk of occurring due to the slow rainfall that affects the landslide hazard. The goal of this study is to discover landslide causative factors and produce landslide susceptibility map in the study region, which was divided into three categories: high, moderate, and low.

METHODS

Study Area

As indicated in Figure 1, Kampung Renok Baru is located in Gua Musang, with latitudes of 4°55'15.0" N, 4°57'55.0" N, and longitudes of 102° 1'45.15" E, 102° 4'25.30" E. The environment of Kampung Renok Baru is flat and mildly hilly, with heights ranging from 100 to 300 metres. This study location is accessible by road or the Gua Musang – Kota Bharu Highway. Agriculture, towns, and settlements are all covered by the site. The study region also has different sorts of agriculture activity, including rubber and pam oil plantations.

In order to produce map of landslide susceptibility, the secondary data such as topographic map, rainfall map and satellite imagery were used. All of the data were collected from USGS, Google Earth Pro, and Department of Drainage & Irrigation (JPS) in the digital form. Secondary data such as topography maps, rainfall maps, and satellite photos were utilised to create landslide susceptibility. All of the data was gathered from the USGS, Google Earth Pro, and the Department of Drainage and Irrigation (JPS) in the digital form.

The Weighted Overlay Method (WOM) was employed in this study. The weighted overlay method is a simple bivariate method for assessing possible landslide area that is both simple and effective. This method may select weights based on the link between landslide causative components and landslide frequency in the study area [6]. WOM method is an innovative method in making multi criteria decision systems.

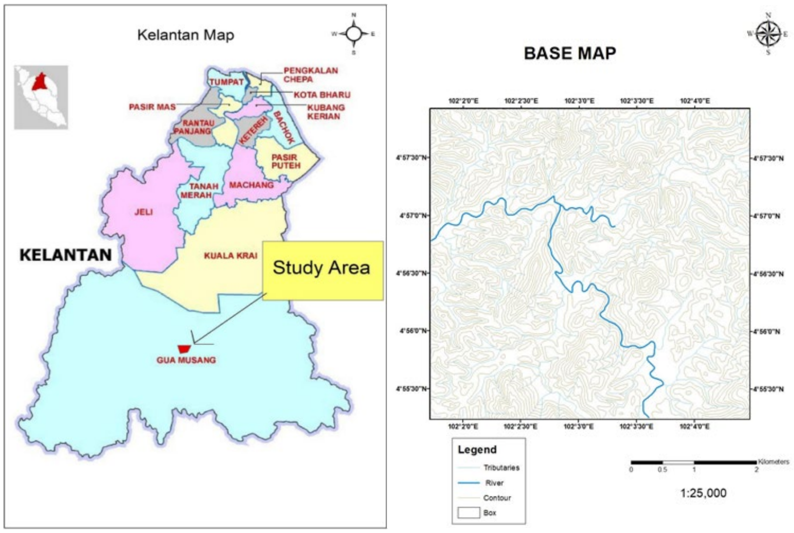

FIGURE 1. Kelantan map and Base map of Kampung Renok Baru, Gua Musang

Data

Secondary data of topographical data, Digital Elevation Model (DEM), and satellite imageries is required to create the landslide susceptibility map. The land cover variations for Kampung Renok Baru, Gua Musang, were determined using Landsat data dated 12.2008 (path 127, row 057) and Landsat photos dated 12.2016 (path 127, row 057). Table 1 shows the characteristics of satellite imageries for determining land cover changes.

TABLE 1. Landsat data for a land cover change

Technical properties	Data type (Landsat satellite imageries)	
	Year 2008	Year 2016
Source	Google Earth	Google Earth
Spatial resolution	30 meter	30 meter
Path / Row	127/ 056	127 / 056
Projection	UTM	UTM
Datum	WGS84	WGS84

The slope, aspect, and drainage density maps were created using DEM data from year 2014 and 2019. Both DEMs have a spatial resolution of 30 metres. This information was obtained from the US Geological Survey Earth Resource and Science Center (USGS), therefore it has to be constructed from raw data such as contour data and elevation, rather than a pre-existing map. This DEM data was used to create a landform map and identify the occurrences of landslide sites.

Data Processing

In general, the nature of the study area and the availability of data should be taken into account while selecting landslide causative factors. Using aberrant topography procedures, such as diverging contours, isolated topographic benches, crenulated contours, and altered drainage patterns as major markers of possible landslide-related features, the landslide detection process was assisted. Distance from the road, slope, aspect, land use, lithology, and drainage density are six causative factors that have been employed to create landslide susceptibility maps in this study. The data was processed using special tools in the Arc Toolbox of ArcGIS 10.3 to build thematic maps once all of the secondary parameter data was available.

Image classification was used to convert raw image data (remote sensing data) to thematic information in order to produce thematic maps of each parameter. The rasterization process is the initial phase. Using ArcGIS 10.3, all of the parameters were transformed from vector to raster. Reclassification was applied to the determined natural factors of thematic map, constructed using the Spatial Analyst module of ArcGIS 10.3 programme, as well as their subunit and factor weights, after the values corresponding to the units were determined.

The next step in creating a landslide susceptibility map was to perform a weighted overlay of reclassified maps using the Weighted Overlay Method (WOM) module of ArcGIS 10.3 programme. The weighted overlay, according to [7], is a strategy for assessing inputs that have distinct values, or different units, in order to do an integrated analysis. The solution of spatial problems requires the analysis of many different factors.

Data Analysis and Interpretation

The topography of an area, climatic conditions, geology, land use/land cover, and anthropogenic variables all influence the spatial distribution and density of landslides [8]. As a result, assessing the impact of these causative elements on the spatial distribution of landslides is critical for understanding their failure mechanism and developing a landslide susceptibility map. The creation of landslide susceptibility maps in this study was based on six causative factorss. From a Digital Elevation Model (DEM) with a cell size of 30 m by 30 m, topographic parameters such as slope, aspect, and distance from road maps were calculated. Fieldwork and Google Earth image interpretations were used to create lithology, drainage density, and land use maps. The landslide susceptibility area was produced based on landslide susceptibility level (Table 2).

TABLE 2. Landslide Susceptibility Index Classification & Class Name [9]

Landslide susceptibility class	Landslide susceptibility index classification	Landslide susceptibility class name
1	2-3	Low
2	3.01- 4	Moderate
3	4.01- 5	High

RESULTS AND DISCUSSION

Because each class of materials has varied shear strength and permeability characteristics, lithology is one of the most important governing criteria in slope stability [10]. Different rock types have different compositions and structures, which, in a favourable or negative way, contribute to the slope material's strength. In comparison to the softer/weaker rock units, the stronger rock units provide higher resistance to the driving forces. The research area's lithological map was created using an existing regional geological map (Figure 2). Merapoh Limestone and Telong Formation were the two formations that made up the research area. Metasedimentary rock covered 80% of the study region, tuff covered 15%, limestone and alluvium made up 3% and 2% of the study area, respectively.

Slope

The slope is one of the most major causative factors that influence landslide occurrence in the study area. Due to a lack of soil and rock strength, erosion or a landslide happened down a slope. Figure 3 depicts the study area's slope map. It was classified into six categories: $0–5^{o}$, $5^{o}–10^{o}$, $10^{o}–20^{o}$, $20^{o}–30^{o}$, $30^{o}–35^{o}$, and $35^{o}–52^{o}$. The majority of the research area has a slope of 10° to 20°, which is considered moderate. The least covered area is on a very steep slope with an inclination greater than 35°.

Aspect

Aspect, as defined by [11], relates to the slope orientation, which is commonly stated in degrees ranging from 0 to 360 degrees. It controls the slope's exposure to sunshine, wind direction, rainfall (degree of saturation), and discontinuity conditions, making it an indirect factor determining the slope's vulnerability. The DEM data was used to create a slope aspect map (Figure 4) that was separated into nine classes: flat (-1), north (0 – 22.5, 337.5 – 360), northeast, east, southeast, south, southwest, west, and northwest.

Landuse

Land use change is widely acknowledged as one of the most important factors impacting the prevalence of rainfall-triggered landslides around the world. Slope instability can be triggered by changes in land use/cover caused by man-made activities such as deforestation, overgrazing, intensive farming, and agriculture on steep slopes [12]. Vegetation has an important role in preventing slope displacement. The shearing resistance of the slope material is increased by vegetation with a well-spread network of root systems. This is due to the slope materials' natural anchoring. In addition, it lowers erosion and improves the slope's stability. In another sense, bare or sparsely vegetated slopes are more likely to be subjected to erosion, which increases slope instability. The land use map in the research area is shown in Figure 5. The research area was mostly covered by forestry and plantation, but at Kampung Renok Baru, there were also nucleated and linear patterns of settlement area populated by a population of villagers.

Drainage Density

With the help of satellite imagery, a drainage density map was also created using DEM data. The proximity of the slopes to stream networks, in particular, appears to be another important factor affecting the slopes' stability. Streams contribute to the slope's strength by entering the soil until the water level rises, causing a rise in soil pore pressure, and they can also alter the slope's stability due to toe erosion. Furthermore, the higher the drainage density, the lower the water penetration into the soil and the faster the movement surface flow [3]. The drainage density in the study area was divided into three equal intervals, as illustrated in Figure 6. The closest location to the streams and the alluvium deposition site had the highest steam density.

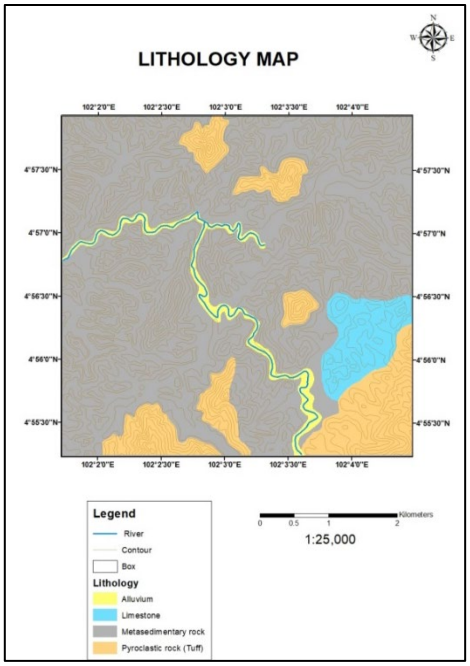

FIGURE 2. Lithology map

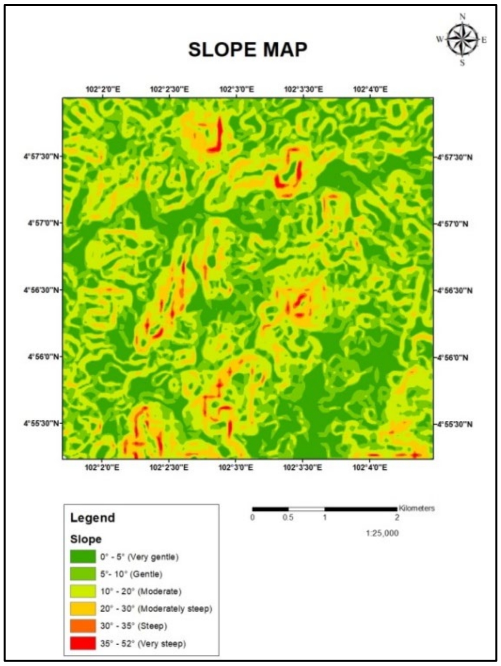

FIGURE 3. Slope map

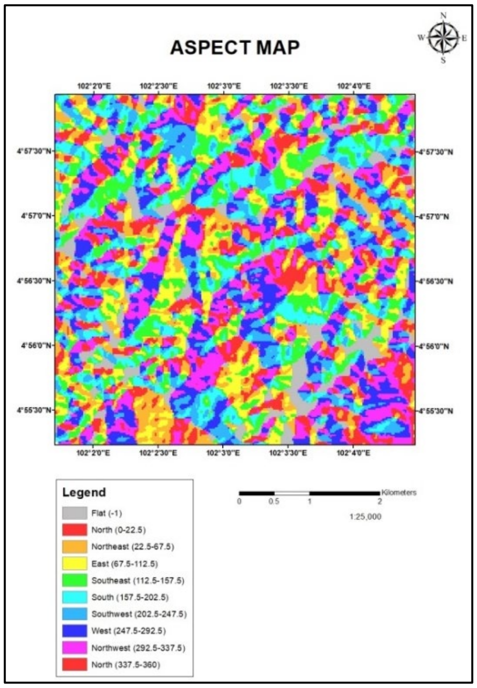

FIGURE 4 Aspect map

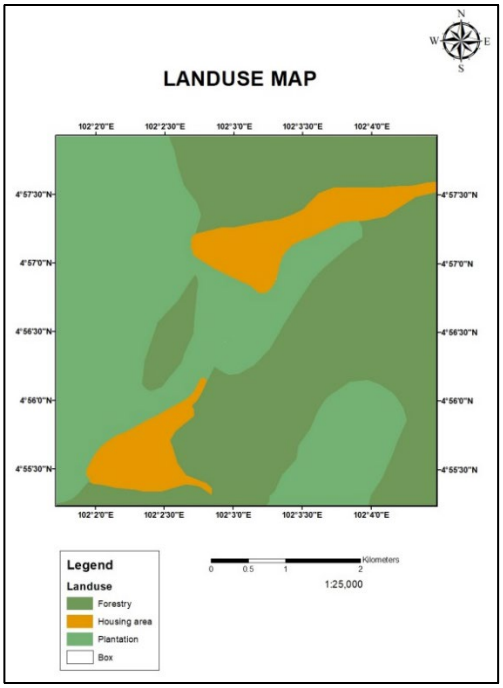

FIGURE 5 Landuse map

Distance to Road

There were numerous landslide hazards near the route. The route's cutting had an impact on the slope's stability along the roadway. As illustrated in Figure 7, the distance from the road map was generated and separated into five classes. The closest distance to the road indicates a higher risk of landslide than the furthest distance, but it also depends on other factors that can cause a landslide.

Landslide Susceptibility Map

The landslide susceptibility map of Kampung Renok Baru is shown in Figure 8. The study area was divided into three classes based on the map. Low susceptibility is classified as class 1, moderate susceptibility as class 2, and high susceptibility as class 3. According to the developed landslide susceptibility map, low susceptibility towards landslide occurrence dominated the study region with a total percentage of 53%, moderate susceptibility with 34%, and high susceptibility with 13%. The association between six causative factors and the occurrence of landslides was investigated in this study. Slope, lithology, and drainage density all play a part in landslide susceptibility studies and are becoming increasingly relevant characteristics. Landslides are more likely to occur on slopes with a steeper pace. Because the rock and soil that formed in the area have variable porosity and voids, the lithology has an impact on the landslide. Because most landslides occur along rivers and streams, the intensity of drainage density indicates that the hydrological element can trigger landslides. In the research area, the kind of land use also influences the occurrence of landslides. The land use types of forestry, dwelling, and plantation had the greatest weights or ratings, indicating a high likelihood of landslide occurrence. When it comes to the relationship between landslide occurrence and distance from the road, the occurrence of landslides normally reduces as the distance from the road increases. The landslide phenomena is moderately influenced by the aspect map. However, it is also crucial in landslide analysis in the study region in terms of other metrics and factors caused. Table 3 depicts the landslide susceptibility classes in the study area. According to the landslide susceptibility map in Figure 8, landslides are more likely to occur in mountainous areas and along roads because of steep slopes. Hence, this concludes the reason of study area dominant with low susceptibility to landslide..

TABLE 3. Analysis of Landslide Susceptibility

Susceptibility class	Risk	Area (%)	Area (km2)
Low	0 – 50%	53	13.25
Moderate	50 – 75%	34	8.50
High	>75%	13	3.25

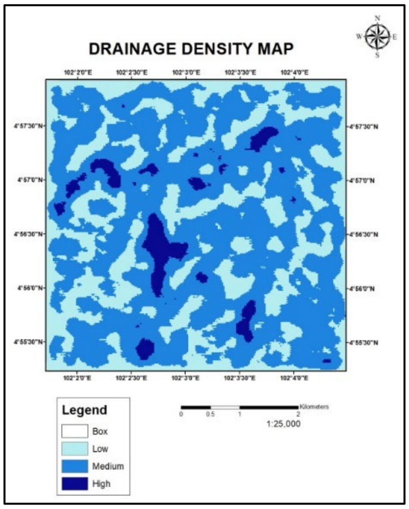

FIGURE 6. Slope map

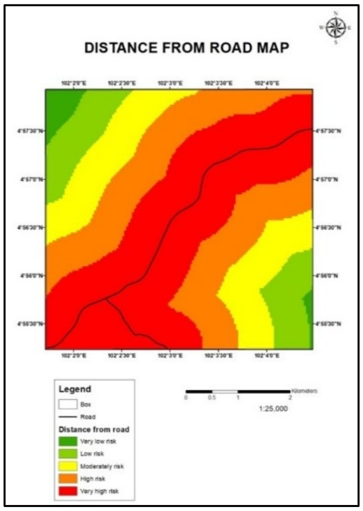

FIGURE 7. Distance from road map

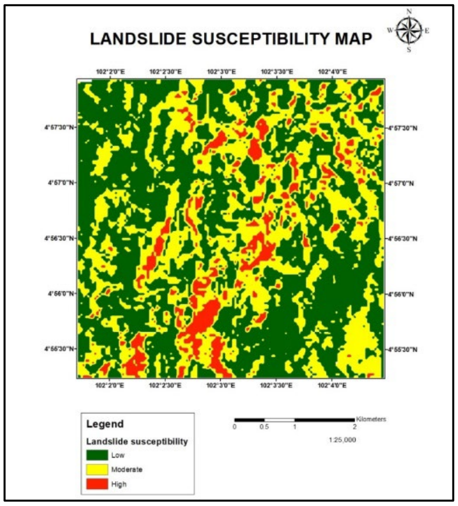

FIGURE 8. Landslide susceptibility map

CONCLUSION

Finally, using the WOM approach in ArcGIS software, a map of landslide susceptibility of the research area with a scale of 1:25000 was successfully constructed. To study, assess, and establish the spatial relationship of these parameters with landslides, six landslide causative factors were considered: slope, aspect, lithology, land use, drainage density, and distance to road. It demonstrated the need of incorporating multiple elements that cause landslides in the research area. The landslide map was classified into three classes: class 1 represents minimal risk, class 2 represents moderate risk, and class 3 represents a high risk of landslide. As a result, the research region was susceptible to landslides in 34% moderate, 13% in severe cases, and 53% in low cases. Local residents living in mountainous areas and valleys have been impacted by landslides in the study region. In order to limit the impact of future landslide hazards in the area, it is critical to advise the appropriate preventative measures in the high and very high susceptibility classes.

ACKNOWLEDGMENTS

The authors would like to acknowledge Ministry of Higher Education for funding Fundamental Research Grant Scheme (FRGS 2020/1) (R/FRGS/A0800/00433A/002/2020/00886). A special thanks to Universiti Malaysia Kelantan for providing facilities and equipment for this research, making this vital research viable and effective.

REFERENCES

1. T. Thongwan, A. Kangrang, R. Techarungreungsakul, and R. Ngamsert, Adv Civ Eng **2020**, (2020).
2. M. Hashim, A. B. Pour, and S. Misbari, in *J Phys Conf Ser* (IOP Publishing, 2017), p. 12023.
3. S. I. M. Shariffuddin and W. S. Udin, in *IOP Conf Ser Earth Environ Sci* (IOP Publishing, 2020), p. 12055.
4. C. T. Cheng, C. M. Huang, L. W. Wei, C. F. Lee, and C. T. Lee, Int Consort Landslides Landslide Teach Tools Chapter Part **1**, 50 (2013).
5. N. S. Syafril, W. S. Udin, and A. M. A. Bahar, in *IOP Conf Ser Earth Environ Sci* (IOP Publishing, 2020), p. 12013.
6. P. K. Shit, G. S. Bhunia, and R. Maiti, Model Earth Syst Environ **2**, 21 (2016).
7. J. Malczewski, Prog Plann **62**, 3 (2004).
8. H. Khan, M. Shafique, M. A. Khan, M. A. Bacha, S. U. Shah, and C. Calligaris, Egypt J Remote Sens Sp Sci **22**, 11 (2019).
9. B. Koley, A. Nath, S. Bhattacharya, S. Saraswati, and B. C. Ray, (2020).
10. A. Yalcin and F. Bulut, Nat Hazards **41**, 201 (2007).
11. T. Mersha and M. Meten, Geoenvironmental Disasters **7**, 1 (2020).
12. T. Glade, Catena **51**, 297 (2003).
13. E. Cevik and T. Topal, Environ Geol **44**, 949 (2003).