GIS-Based Landslide Hazard Evaluation and Zonation of Kg. Chas, Kuala Betis, Gua Musang, Kelantan

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Abstract. This research entitled GIS-Based Landslide Hazard Zonation and Evaluation of Kg. Chas, Kuala Betis, Gua Musang, Kelantan. The study area is located in Kuala Betis, Gua Musang, Kelantan with the area covered is 25 km². The aim of this research is to evaluate the landslide causative factors and to produce the landslide hazard zonation map with scale of 1:25000. The method used in generating the landslide hazard zonation map is by using the Geographical Information System (GIS) which is using the Weighted Overlay Method (WOM). The parameters that triggered the occurrence of landslide were analyzed and overlaid in order to generate the landslide hazard zonation map. Digital Elevation Model (DEM) data were used to extract the parameters. Normalized Difference Vegetation Index (NDVI) methods were used to identify the changes of the vegetation and to locate the locations of the past landslides in the study area. The results showed that the landslide hazard zonation map were divided into 5 classes. Class 1 is no hazard, class 2 is low hazard, class 3 is medium hazard, class 4 is high hazard and class 5 is the highest hazard. Based on the landslide hazard zonation map, the study area is covered with a low hazard of landslide and the probability of landslide to occur is low.

1. Introduction

Landslide is one of the natural disasters. It can occur naturally but in a very slow rate. Due to human’s activities, activities such as urbanization, deforestation, and many more will trigger landslide to occur. This is because, humans activities or land use change the natural distributions of the land. Landslide can become hazardous toward humans when people live or work at the area where it occurs. In geomorphology, a landslide is the movement of a mass of rock, debris or earth down a slope, under the influence of gravity [1].

Based on Tareq et al. [2], landslides often occur in tropical countries such as Malaysia. It is the main constraints for development projects in the highlands of the country because it occurs mostly in developed area like in the town and highways. Landslides are resulted because of intrinsic and external triggering factors [3].

Works by Hashim et al. [4] on landslide susceptibility in Kelantan, have shown that causative factors for the landslide to occur are slope, aspect, soil, lithology and amounts of precipitations. It also stated that the main factors that trigger the landslide are the amount of precipitations. The rainfall distributions is the main causative factors due to excessive amounts of rainfall during the Kelantan’s flood 2014. Apart from that, the land use or land cover and the development near the slopes also became the second biggest contributions towards landslide. Manmade activities such as illegal logging...
activities in the forest, agricultural activities, and development near the slope also factors that can cause the landslide [5].

Technologies’ nowadays including GIS and remote sensing is a very useful tool that can be used in mapping especially in landslide mapping. According to Cruden and Varnes [1], the GIS based statistical and probability was used. This probability method is used by calculate the weight each of the causative factors. The raster calculator tools are needed in this method.

Several Landslide Hazard Zonation (LHZ) techniques have been developed over the past and these can be broadly helps not only to map and monitor landslides but also to predict future slope failures [6].

The present study area is located in the highlands under Gua Musang town and territory in Kelantan, Malaysia. It is the largest district in Kelantan. The area is frequently experienced the Northeast Monsoon from October to March. During this season in Kelantan, excessive amount of rainfall may lead to natural hazard such as landslide and flood. The consequences are the people have been permanently displaced from their residences.

The lack of study regarding the landslide hazard of that particular area become one of the issue that needs to be highlighted. Due to the improper of strategic planning and mitigation of landslide, the landslide will easily occur and harm the community. Therefore, vulnerability of the lives and property of the people by landslides in the area need immediate implementation.

The main objective of the present study was to prepare a LHZ map of the study area. The general methodology followed includes landslide inventory mapping, followed by preparation of a statistical hazard model based on various causative factors and their interrelation with past landslides. Finally, LHZ map was prepared based on relative influence of various causative factors.

2. Methodology

For the present study WOM method was followed. In this approach the main objective is to determine each causative factor map and its parameter map classes. Later, based on the class distribution and the landslide density, respective weights can be derived. Further, the general quantitative prediction was developed to rate the causative factors that might result in landslides. Thus, with the derived weights, factor maps were combined to get the landslide hazard zonation map.

In order to produce LHZ map, all pertinent data required for landslide hazard evaluation were collected from primary and secondary sources. Pre-field work included secondary data collection related to topographical maps, satellite images, and Digital Elevation Model (DEM) data. According to Chong et al. [7], the present satellite image data can be compared to the historical satellite imagery data to assess landslide conditions over different periods of time and to examine progressive development. Field investigation was mainly undertaken to have all relevant information about the past landslide activities in the area and to verify various causative factor maps prepared during the pre-field works.

2.1 Landslide Inventory

All existing landslides in the study area were thoroughly studied and relevant data necessary for hazard evaluation were collected. Thus, data on location, type of failure, dimension and material involved in past landslides were collected. Majority of the landslides in the study area were identified by the field surveying and the GPS point data along the periphery were collected.

2.2 Evaluation of Causative Factors and Landslide Distribution

During the present study for landslide hazard evaluation five prominent causative factors namely; (i) slope, (ii) elevation (iii) aspect, (iv) vegetation and (v) drainage were considered. These causative factors were considered based on observation of past landslides and their possible contribution in inducing instability to the slopes in the area.
2.2.1 Elevation

Elevation of the study area data were determined from the topographical map that was generated from the topography of the study area. Different elevation represents different types of lithology. This is due to different resistance of the lithology towards weathering process. Based on the 2-D map in the Figure 1, there are four different colours that indicate the different in elevation of each landform area. For the dark green colour, it shows the elevation between 300 m to 400 m. For the elevation >300 m, the landform type is the mountainous area. The lithology is mainly is igneous which is granite. For the elevation from 76 m to 300 m, it represents the hilly type landform. The light green colour, the light brown colour and the dark brown colour represent the same landform type which is hilly landform.

![Figure 1. Elevation map](image1)

![Figure 2. Slope map](image2)

2.2.2 Slope

In general, if the slope is steeper it will be more susceptible to instability as compared to gentle slope. The gravity pull which is the main driving force for instability is directly proportional to the slope gradient [8,9]. The slope for this research study was extracted from the satellite image data. The slope was then categorized by its slope degree. The slopes from the past landslides were compared to the current result. The slope map shows the distributions of the slope based on its angles (Figure 2). The slopes angles were divided into 5 classes. Most of the study area has an angle between 0-5° which is considered as low slope angle.

2.2.3 Aspect

The aspect map also were generated from the satellite image data that been downloaded from the US Geological Survey Earth Resources Observations and Science Center (USGS) website. Aspect map is the map that shows the ground slope direction for a terrain with respect to North. The aspect map also generated from the DEM data. Figure 3 shows the aspect map of the study area. The aspect map is divided into 10 classification of slope direction that due to North. The aspect map is also important as a parameter in landslide hazard zonation map as different direction of slope map resulting in different effect of gravitational force.
2.2.4 Vegetation

For this research study, the vegetation data were derived from the satellite image year 2013 and 2017. The vegetation changes were developed by calculating the Normalized Difference Vegetation Index (NDVI) values. The NDVI values were obtained by using the raster calculator in the ArcGIS software. NDVI is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum and is adopted to analyse remote sensing measurements and assess whether the target being observed contains live green vegetation or not [10]. From NDVI analysis, the spotted landslide locations were proven by comparing its values of different years. The range of NDVI is between -1 to +1, where -0.5 to 0 indicates water body or wetland, less than 0.1 shows barren area of rock, sand or snow, between 0.2-0.3 refers grass and shrub while ≥ 0.5 describes temperate and tropical rainforest or thick vegetation cover. Based on Table 1, there were significant changes of the landslide locations based on NDVI analysis between 2013 with 2017 respectively. It also shows there was a change in the vegetation cover in each of the targeted landslide locations. There is a decreasing trend in NDVI values for L3 until L7. This shows that the existing vegetation covers have been removed due to the occurrence of landslides in these few locations.

| LOCATION | COORDINATE | NDVI 2013 | NDVI 2017 |
|----------|------------|-----------|-----------|
| L1       | 101°48'5.65"E 4°57’41.166"N | 0.12 | 0.17 |
| L2       | 101°46'59.933"E 4°57'6.578"N | 0.30 | 0.29 |
| L3       | 101°48'48.596"E 4°57'3.696"N | 0.10 | 0.16 |
| L4       | 101°49'3.584"E 4°57'55.866"N | 0.15 | 0.16 |
| L5       | 101°49'20.878"E 4°56'49.285"N | 0.12 | 0.15 |
| L6       | 101°49'22.895"E 4°56'5.185"N | 0.15 | 0.16 |
| L7       | 101°47'40.862"E 4°55'27.427"N | 0.05 | 0.13 |
2.2.5 Drainage

The drainage density is important because the relationship between drainage density and mean erosion rate depends on the dominant hill slope transport process through landslide and the presence or absence of a threshold for runoff erosion. The drainage density map was generated from the USGS satellite image from the USGS website. The pattern of the drainage in the study area was also determined. The stream density map is essential in determining the fluvial network in the study area. Figure 4 shows the stream density which also extracted from the DEM data. The blue colour shows the low density of the stream and the yellow colour shows the high density of steam. Stream density is important as it related to erosional rate. The higher the values of density show the higher rate of erosion and have a higher probability of landslides to occur.

![Figure 4. Stream Density Map](image)

2.3 Landslide Hazard Evaluation

For the landslide hazard zonation, the method Weighted Overlay Method (WOM) were used. From the satellite image and data collection that was obtained, all the causative factors were mapped then converted into raster. The raster then were weighted. A rating scheme in which the factors and their classes were assigned as numerical values was made as it is shown in Table 2. The hazard map of the study area was prepared by setting a weight equal to ‘1’ for each of the 5 causative factors (Table 2). Equal weight for all causative factors was assigned with an assumption that each of the causative factors has contributed to landslides in the area and the relative contribution of each parameter cannot be assessed in quantitative terms. Further, landslide hazard zonation map of the study area was prepared by using ‘raster calculator’ tool, available in ArcGIS 9.2. Total influence of raster must be equal to 100%.

Based on field judgment and logical consideration Hazard (x) at any pixel was classified into five classes as; No hazard (NH), Low hazard (LH), Medium hazard (MH), High hazard (HH) and Very high hazard (VHH). In order to get the most suitable hazard zonation in the present study area various distributions of Hazard (x) values were made. For each such attempt overlay analysis with past
landslide data was attempted. The classification of Hazard (x) values presented in Table 3 provided the most reliable validation results with the past landslide data in the present study area.

Table 2. The weightings, hazard index, and hazard class for causative factors

| Causative factors (j) | Class (i)               | Weighting (Wj) | Hazard index (Hji) | Hazard index scaled to 1 (Hji) | Hazard class |
|-----------------------|-------------------------|----------------|-------------------|-------------------------------|--------------|
| Lithology             | Limestone               | 1              | 1.1               | 1                             | 5            |
|                       | Sandstone               | 0.77           | 7                 | 4                             |              |
|                       | Gypsum                  | 0.8            | 0.72              | 4                             |              |
| Soil type             | Alluvial                | 1              | 0.38              | 0.06                          | 2            |
|                       | Colluvium limestone origin | 6           | 1                 | 5                             |              |
| Slope (degree)        | 0-5                     | 3              | 0.06              | 2                             |              |
|                       | 5-14                    | 6.67           | 0.14              | 3                             |              |
|                       | 14-25                   | 47             | 1                 | 5                             |              |
|                       | 25-35                   | 0.41           | 0.01              | 1                             |              |
|                       | 35-45                   | 0.19           | 0.004             | 1                             |              |
|                       | >45                     | 0.13           | 0.002             | 1                             |              |
| Aspect                | Flat                    | 1              | 0                 | 1                             |              |
|                       | N                       | 3.04           | 1                 | 5                             |              |
|                       | NE                      | 1.30           | 0.42              | 4                             |              |
|                       | E                       | 0.55           | 0.18              | 3                             |              |
|                       | SE                      | 0.13           | 0.04              | 1                             |              |
|                       | S                       | 0              | 0                 | 1                             |              |
|                       | SW                      | 0              | 0                 | 1                             |              |
|                       | W                       | 0.85           | 0.28              | 4                             |              |
|                       | NW                      | 1.19           | 0.4               | 4                             |              |
| Land use              | Water body              | 1              | 0                 | 1                             |              |
|                       | Bush land               | 0.84           | 0.4               | 4                             |              |
|                       | Barren land             | 0.3            | 0.14              | 3                             |              |
|                       | Cultivated land         | 2.10           | 1                 | 5                             |              |
|                       | Grazing land            | 0.75           | 0.36              | 4                             |              |
|                       | Open forest             | 7              |                   |                               |              |
|                       | Plantation              | 5              |                   |                               |              |
|                       | Agriculture             | 6              |                   |                               |              |
| Drainage              | None                    | 0.5            |                   |                               |              |
|                       | Blocked                 | 0.4            |                   |                               |              |
|                       | Fair                    | 0.3            |                   |                               |              |
|                       | Good                    | 0.2            |                   |                               |              |

Table 3. Hazard index and their hazard class name

| Hazard class | Hazard index classification (Hji) | Hazard class name |
|--------------|----------------------------------|-------------------|
| 1            | 0.0-0.05                         | No hazard (NH)    |
| 2            | 0.05-0.12                        | Low hazard (LH)   |
| 3            | 0.12-0.18                        | Medium hazard (MH)|
| 4            | 0.18-0.75                        | High hazard (HH)  |
| 5            | 0.75-1                           | Very high hazard (VHH)|
3. Results and Discussion

Figure 5 presents the landslide hazard zonation map of the study area. Perusal of Figure 5 clearly indicates that very high hazard (VHH) zones are mainly concentrated in the southwestern regions of the study area. High hazard (HH) zones are mainly scattered distribution in eastern and northern regions in the study area. The moderate hazard (MH) zones have scattered distribution toward eastern and northern regions of the study area. Low hazard (LH) zones are more concentrated toward the northwestern region and scattered distribution in central and eastern regions of the study area. No hazard (NH) zones are mainly concentrated in the centered region with scattered distribution of the study area.

3.1 Landslide influencing causes in the study area

In general, the major causes of landslide in the study area were found to be hydrological and hydrogeological conditions, associated with gravity movements favored by typical geological and geomorphological conditions prevailing in the area. As per information gathered from the local respondents, the landslides in the area have been triggered solely due to heavy rainfall and big flood that occurred in 2014 [8]. Most of the landslides have occurred after heavy rainfall with high intensity, especially during or just after the rainy season, followed by an extremely dry season. Further, findings suggest that the most susceptible material responsible for landslide occurrence in the present study area is cut slopes which has angles around 30° for plantation purpose.

4. Conclusion

The present study was conducted in parts of Gua Musang District in Kelantan, Malaysia. The main aim of the present study was to prepare a landslide hazard zonation map of the study area. For this a thorough inventory of past landslides was undertaken to understand the relationship of various
causative factors on past landslides and their likely contribution for landslides in the area. The causative factors that were considered in this study are; vegetation, slope, aspect, elevation and stream density. As a part of the methodology followed, spatial relationship between causative factors and landslide occurrence was derived by using the weighted overlay method. In this study, GIS based was used to rate the governing parameters and later customized raster calculation was applied to develop the landslide hazard map. The general findings of the present study revealed that the major causes of the landslide in the present study area are hydrological and hydrogeological conditions associated with gravity movements favored by typical geological and geomorphological conditions that prevailed in the area. The landslides in the area have been triggered solely due to heavy rainfall during the North East Monsoon from November till March. The changes of vegetation were clearly seen after the big flood in 2014. Due to all these factors, some zones are potentially dangerous for any future habitation and development. Thus, there is an immediate need to implement mitigation measures in the very high hazard and high hazard zones, or such zones need to be avoided for habitation or for any future developmental activities.

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