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Landslide Susceptibility Mapping Using the Geographic Information System (GIS) Approach in Temangan, Machang Kelantan

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Abstract. The purpose of this study is to generate a landslide susceptibility map using Analytical Hierarchy Process (AHP) method using GIS approach at Temangan, Machang District in Kelantan. This research site was encompassed a 25-square-kilometer region. Landslide occurrence was influenced by seven (7) parameters, including lithology, aspect, landuse, slope, distance to road, distance to fault, and distance to stream. The AHP approach was used to determine the weights of parameters and their classes. The landslide susceptibility map classified three (3) susceptibility grades (low, moderate, and high). The higher the class value, the greater the landslide susceptibility, whereas a lower number indicates a reduced landslide susceptibility. Based on the findings of the landslide susceptibility map, it is reasonable to conclude that the studied region has a low susceptibility percentage and a low likelihood of landslide occurrence.

INTRODUCTION

Landslide is a disaster of nature. Globally, landslides every year cause thousands of fatalities and injuries to billions of dollars in damage. Landslide is the mass movement of rock, earth (soil), down a hillside under the power of gravity [1]. The economic impacts of landslides on every living thing on earth have a very serious influence on the country worldwide. In order to accomplish a ground hazard assessment and risk reduction, continuous and reliable data on the incidence of landslides and risk management should be readily available and supplied. In order to be the main information at international and local level for a wide variety of users [2], the private as well as the public, government departments and scientific community should have an accurate susceptibility mapping.

The landslide susceptibility mapping can be established by employing the Weighted Linear Combination (WLC), which includes the Analytical Hierarchy Process (AHP) [3]. By adopting the described approach, the subjective evaluation of experts can be decreased by developing an objective map of the landslide susceptibility. The AHP is the decision-making technique for several criteria which provides for the consideration in decision-making of both subjective and objective aspects [4]. The AHP technique provided a more realistic view of the genuine distribution of

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landslide susceptibility than SMCE and WLC. The aim of this work was to implement an AHP method incorporated in the GIS environment for the production of a landslide susceptibility map in Temangan, Machang District, Kelantan. The landslide susceptibility map was produced using a GIS overlay and raster calculation methods.

METHODS

Study Area

The designated study area is located at Temangan, in Machang district, Kelantan state. This study covers an area of 25 km^2 as shown in Figure 1.

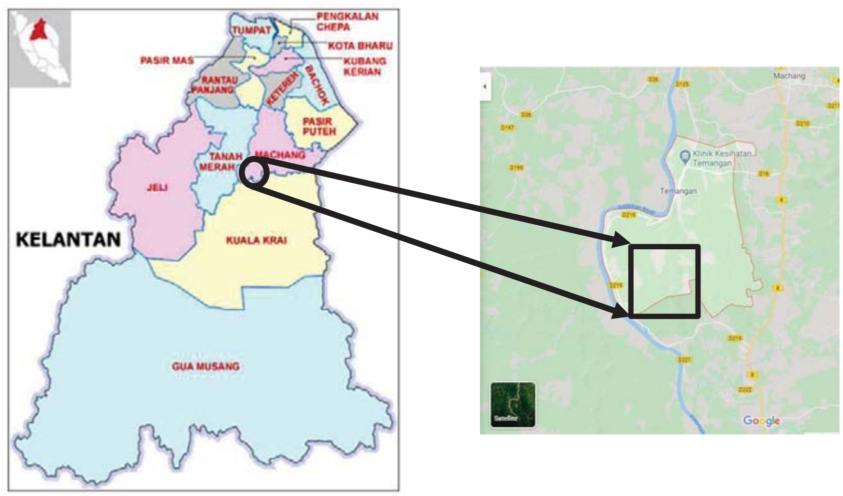

FIGURE 1. Study area (25km^2)

The Temangan region's land usage is comprised of around 47 percent (47%) agriculture, 45 percent (45%) environmental conservation, and eight percent (8%) residential and industrial land use. Agriculture varieties such as rubber plantations, oil palm plantations, and others are discovered in the Temangan region. Temangan forest reserve and mangrove forest have been set aside as part of an environmental preservation programme. The majority of the general population in the study region are plantation workers. However, there are some locals who own micro enterprises such as food stores and small-scale retail shops that supply basic daily essentials to the locals. The rubber plantation dominates the majority of the study area [5].

Landslide Susceptibility Assessment

Assessment of landslide susceptibility has become a requirement for mapping slope instability in the present world. Thus, numerous attempts have been made to classify the slope stability parameters, either directly or indirectly. Typically, geomorphological mapping is accomplished by direct approaches. Furthermore, the indirect approach employs heuristic and statistical methodologies [3,4]. AHP is a multi-criteria decision-making and multi-objective technique that enables decision-makers such as geoscientists or geologists to rationally assign and classify subjective judgments in a hierarchical order and numerical values based on the relative importance of each component or parameter.The weightage assigned to each parameter in the index-based method must reflect its significance in the occurrence of landslides; when combined with the rating values for the separate classes, the level of susceptibility representation is designated. Eventually, the susceptibility map generated in this study was separated into three (3) susceptibility levels (low, moderate, and high).

Landslides can be influenced by a variety of environmental parameters, including lithology, aspect, land use, slope, and a wide number of sets of instability variables, which can be used to assess the risk of landslides in a given location.

In this study, seven (7) parameters were discovered to be utilised to measure the occurrence of landslides (lithology, aspect, landuse, slope, distance to road, distance to fault and distance to stream). Rating and weightage values were assigned to each class of each triggering parameter that had an effect on landslide susceptibility. Finally, the final map was created in ArcGIS 10.3 by superimposing all of the weighted characteristics in raster form by using Spatial Analyst tool.

Preparing Landslide Parameter Layers

In this work, the primary data required for landslide susceptibility and risk assessment were collected (from 2019 to 2020) and stored in a geospatial database. The weightage of landslides in their classes was calculated for each of these thematic maps.

Lithology

It is a well-established fact in geology that lithology has a significant influence on the incidence of landslides. This is because lithological and structural variations frequently result in differences in the strength and permeability of rock and soil. In the studied region, alluvial deposits consist primarily of sand, silt, and clay. While ignimbrite and andesite are classified as igneous rocks, interbedded shale and mudstone are classified as sedimentary rocks. Additionally, this study region contains metamorphic rock and quartz-mica schist (Fig. 2(a)).

Aspect

Certain meteorological conditions, such as the direction of rainfall and the quantity of sunlight exposure, lead to the occurrence of landslides. As a hillside that receives heavy rainfall reaches saturation more rapidly, this has an effect on the infiltration capacity of the slope, which is controlled by a variety of parameters including topographic slope, soil type, permeability, porosity, humidity, organic content, land cover, and climate season. The aspect map was created to illustrate the relationship between the occurrence of various factors and the occurrence of landslides within the study area. Aspect values describe the orientation of physical slopes (Fig. 2(b)).

Land Use

The erosion and landslides of soil are determined by the land cover or usage of the area. A low vulnerability of landslide tends to have a higher possibility in forest and plantation areas as opposed to moderate and high vulnerability risk area. The landuse map of the research area is depicted in Fig. 2(c) where 81 percent (81%) of the study area is covered by rubber plantation.

Slope

The slope angle is frequently utilized in landslide evaluation because landsliding is strongly connected to the slope angle. Generally, the steeper slope is more prone to landslide (Fig. 2(d)).

Distance to Road

Distance to roads is a significant factor influencing the occurrence of landslides [6]. Road construction on hills degrades both the topography and the slope foundation. Alterations in topography and load reduction increased stresses on the slope, which eventually results in slope cracking. Six (6) distinct buffer zones were created in this study, and it was determined that the steep slopes (referring to contour) were located approximately one kilometre away from the main road (Fig. 2(e)).

Distance to Fault

Geological fault zones are often considered to be extremely prone to landslides due to the decrease in rock strength caused by tectonic fractures [7]. When the relationship between landslide and fault lines was examined in this study area, it was discovered that the region has two (2) faults (Fig. 2(f)).

Distance to Stream

Another crucial element in evaluating the possibility of a landslide is the slope's closeness to the drainage network. Drainage networks, such as stream(s), can exacerbate landslide vulnerability by abrading the slope and saturating the underwater portion of the material that constituting the slope (Fig. 2(g)).

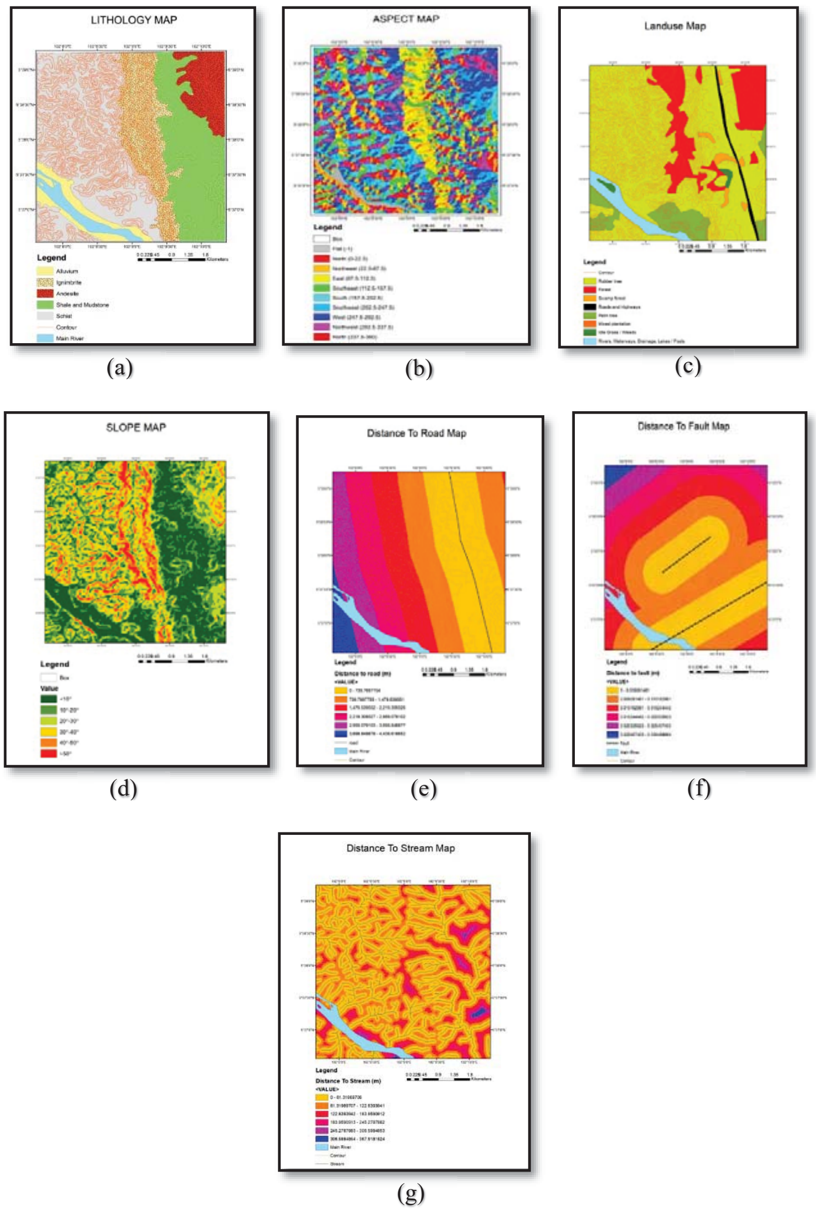

FIGURE 2. Maps of landslide susceptibility parameters: (a) lithology; (b) aspect; (c) landuse; (d) slope; (e) distance to road; (f) distance to fault; and (g) distance to stream

RESULTS AND DISCUSSION

The susceptibility to landslides in the Temangan Machang district of Kelantan was mapped using a GIS-based AHP in this study. The cumulative effect of the susceptible levels of the seven (7) individual parameters determines the area's overall susceptibility to landslides. At a scale of 1:25000, Fig. 3 depicts a map of landslide susceptibility.

Three classes, low, moderate, and high, are also depicted on the map. The greater the index value, the more susceptible the region is to landslide incidents. As can be seen, about half of the research area (53%) is classified as low sensitivity to landslide, while 35% is classified as intermediate vulnerability to landslide. Only 12% of the study region is classified as very prone to landslides. Thus, this study concluded that this area is at a low to moderate risk of experiencing another land slide.

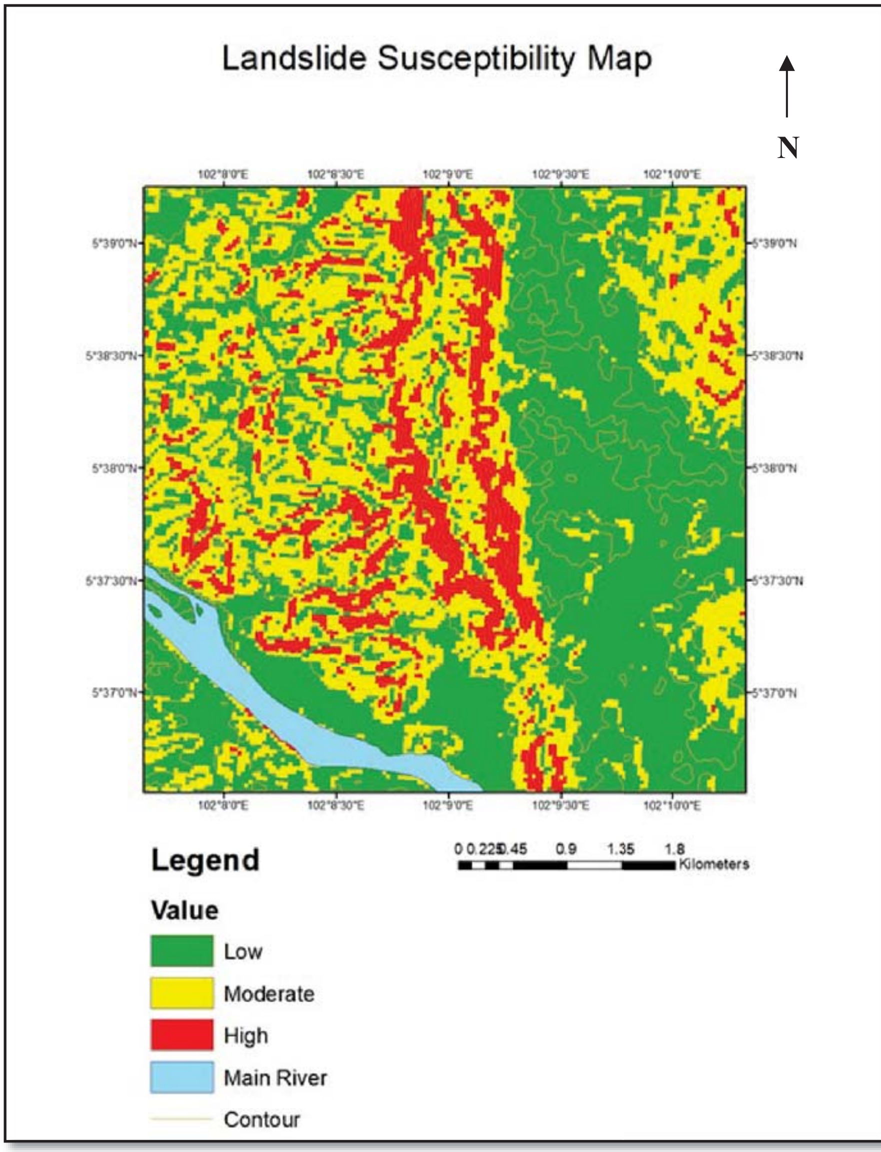

FIGURE 3. Landslide susceptibility map

Table 1 shows the results of the pairwise comparison based on the parameter's relative importance in the landslide susceptibility analysis using the AHP approach. The most critical parameter in determining landslide susceptibility, as indicated by the table, is the slope, which has a final weight of 0.34. Meanwhile, the distance to stream is a less significant parameter, since its absolute weight is only 0.03.

TABLE 1. AHP table for seven parameters

Factor	Slope	Lithology	Distance to fault	Distance to road	Landuse	Aspect	Distance to stream	Final weight
Slope	1	2	3	4	6	7	6	0.34
Lithology	1/2	1	3	5	4	6	5	0.26
Distance to fault	1/3	1/3	1	3	4	5	6	0.17
Distance to road	1/4	1/5	1/3	1	2	3	3	0.08
Landuse	1/6	1/4	1/4	1/2	1	5	4	0.08
Aspect	1/7	1/6	1/5	1/3	1/5	1	2	0.04
Distance to stream	1/6	1/5	1/6	1/3	1/4	1/2	1	0.03

CONCLUSION

As a conclusion, based on the results of the landslide susceptibility map, it can be concluded that the study area is composed of areas with low to moderate susceptibility, covering 17.5 km^2. This research demonstrated that the landslide potential in the study area was minimal.

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