Geology and Landslide Susceptibility Using GIS at Kampung Belahat, Jeli, Kelantan

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Abstract. The geological study of Kampung Belahat in Jeli, Kelantan, Malaysia, which is located close to the Thai border in northeastern Peninsular Malaysia, is the main subject of this research. The Jeli district, which spans an area of roughly 2,552 square kilometers, has three different geomorphological types: low, hills, and mountainous. Kampung Belahat is surrounded by a mix of flat, hilly, and mountainous terrain due to the area's height range of 80m to 900m. The goal of the study is to update Kampung Belahat's geological map, with a particular emphasis on geomorphology, lithology, and structural geology and to determine the landslide susceptibility of study area. Comprehensive geological data was gathered by laboratory work, sampling, and traversing during the geological mapping process. The area's lithology consists of high-grade metamorphic rock types and intrusive igneous rock, with granite and gneiss being the main rock types. The granite rock shows signs of metamorphic processes, including 33% biotite, 46% quartz, 11% alkali feldspar, and 10% plagioclase. Gneiss rock, on the other hand, has flattened minerals as a result of metamorphism; it contains 13% alkali feldspar, 35% quartz, and 52% biotite. Granite was the primary geological structure observed, combined with visible quartz veins and joint and fault structures. The study took into account five factors: aspect, drainage density, lithology, slope, and land use. The Weightage Overlay Method (WOM) was used to process the data. The study area is categorized into three risk levels on the resulting landslide susceptibility map: low (5%), moderate (30%), and high (65%). This knowledge is essential for putting safety precautions in place, reducing potential harm during future development in the area, and reducing the likelihood of landslides.

1 Introduction

Landslides are one of the recurrent natural problems that are widespread throughout the world, especially in mountainous areas which caused a significant injury and loss of human life, damage in properties and infrastructures [1, 2, 3, 4, 5, 6]. Landslides are caused by different triggering factors such as heavy or prolonged precipitation, earthquakes, rapid snow

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melting and a variety of anthropogenic activities [7]. Landslides are one of Earth's most destructive geological hazards, resulting in severe damage to land infrastructure and life threats to humans in regions where the landslide process is high [8].

One of the geohazards covered by the category of natural disasters was a landslide. The word "landslide" refers broadly to any earthly phenomenon that involves sliding motion [9]. It happened when the shear strengths of the materials were outweighed by shear stresses and gravity, resulting in a slope. It may have evolved gradually yet naturally. Variations in land usage and human activity may have changed the way land is distributed. There may have occasionally been more than one type of movement inside a single landslide. In recent years, many landslide susceptibility maps were produced using GIS-based statistical approaches like Frequency Ratio (FR) and Weights of Evidence (WoE) models [7]. Tools for handling and analysing geospatial data like GIS may facilitate the application of quantitative techniques in landslide hazard assessment and mapping [10]. A susceptibility to landslides refers to the likelihood of a location experiencing a landslide based on the local topographic characteristics. This study proposes to investigate and evaluate the landslide susceptibility classes in Kampung Belahat, Jeli, Kelantan.

2 Geological setting

Jeli is situated in western part of Kelantan, strategically located near Kelantan-Perak state border and Malaysia-Thailand international border [11]. This study was carried out in Kampung Belahat, Jeli neighborhood. It situated in Peninsular Malaysia's northeast, which had a shared northern border with Thailand (Figure 1). The study area is divided by two types of rock from the same rock formation, which is the Stong Migmatic Complex formation comprising granite and gneiss formations. Aged Late Permian, the coarse-grained granite, an intrusive igneous rock, consisted of quartz, hornblende, and biotite. Meanwhile, the Early Triassic gneiss, a metamorphic counterpart, showcased foliation and shared a mineral composition with granite. Their coexistence within the same formation demonstrated how turbulent the history of the Earth was. The combination of Early Triassic metamorphism and Late Permian igneous activity woven a story of Earth's long-lasting change. This Stong Migmatic Complex geological patchwork served as a witness to the complex processes that have shaped our planet over a very long period of time. In the region that stretches from northern Kelantan to northern Pahang, the Gua Musang Formation was superimposed on top of the Gunung Rabong Formation. The uppermost part of the Gua Musang Formation was in contact with the Semantan Formation, Telong Formation, and Gunung Rabong Formation [12].

https://doi.org/10.1051/bioconf/202413104009

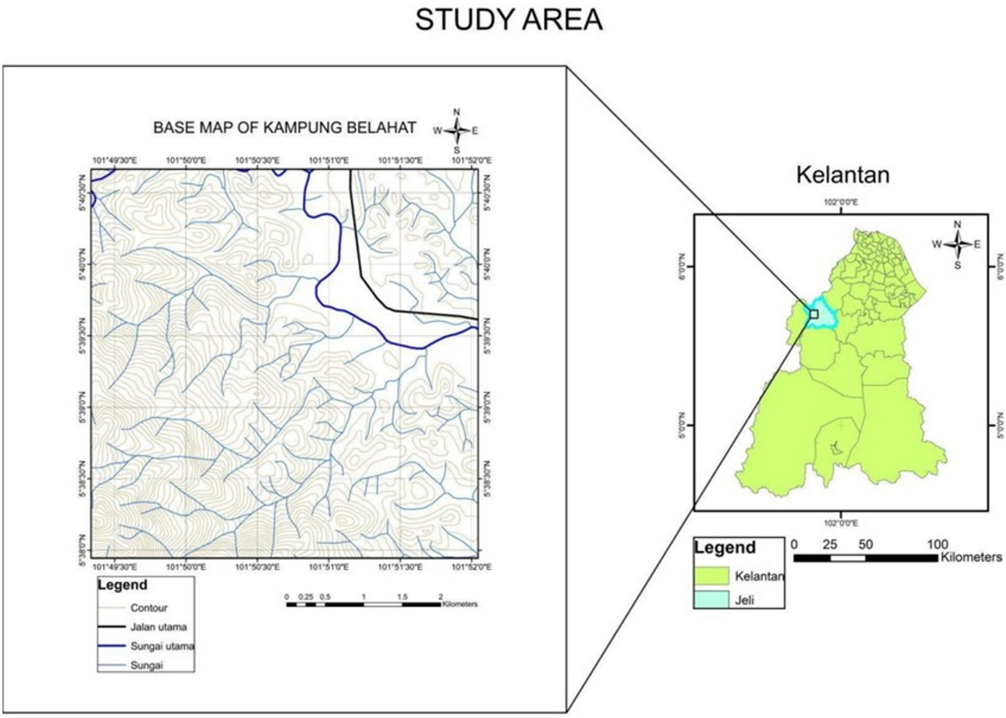

Figure 1. The basemap of study area located at Kampung Belahat, Jeli, Kelantan**.**

3 Methodology

Landslide susceptibility mapping is a geographical analytic technique used to evaluate and forecast the probability of landslides happening in a certain region. The following crucial steps, which involved gathering data, were typically included in the process. Important information was gathered, including specifics about the plants, land use, drainage density, slope, and lithology. To obtain exact geographic information, satellite imagery, aerial photography, and data from remote sensing were often used. In contrast, the landslide susceptibility map was produced by combining image processing with field data. Using the satellite image and geological mapping, maps of drainage density, vegetation, slope, lithology, and land use might be created for the landslide susceptibility map. This will be achieved by applying the weighted parameter and causative factor to determine the possible landslide area inside the research region. The distribution of the landslide susceptibility area was determined by utilizing the Weightage Overlay Method (WOM) and processing the drainage density, vegetation, slope, lithology, and land use. A map that showing the geology and landslide danger of the research area has been created.

The direction of the slope has an impact on landslides, hence aspect was employed as a criterion. The risk of landslides decreased when the slope tilted east or west because this enhanced plant dispersion and decreased moisture content. The second factor is drainage density since more drainage in a particular location raises the risk of landslides. In addition, the lithology of the Kampung Belahat region included gneiss and granite. Landslides were highly resistant to both kinds of rock. The slope grade then had a major impact on the likelihood of landslides. A landslide was more likely to occur on a slope with a higher slope angle. Finally, the study area's land usage was considered. The risk of landslides was lower in places covered with vegetation than in developed areas. Landslide rates were also higher in alluvial areas.

4 Results and Discussion

4.1 Aspect

Aspect, in the context of geographical information systems (GIS) and terrain analysis, is a crucial topographic feature that characterised the slope's orientation with respect to the four fundamental directions (north, east, south, west). Aspect was quantified in degrees, where 0° represented the north direction, 90° represented the east direction, 180° represented the south direction, and 270° represented the west direction. The inclination of a slope was a pivotal factor in several environmental and geological phenomena, such as the vulnerability to landslides. The direction of slopes had a significant role in the occurrence of landslides since it impacted elements including sunshine exposure, moisture buildup, and plant distribution. Figure 2 shows the aspect map of Kampung Belahat.

A slope's aspect affected how much sunshine it got. Different places received different amounts of sunlight at different times of the day and in different seasons. The temperature, plant cover, and soil moisture content were all factors that might be affected by sunshine and hence increased the risk of landslides. A slope's aspect determined how much precipitation it got. In the northern hemisphere, north-facing slopes frequently received less solar exposure, which led to longer moisture retention. This may lead to increased soil saturation and increased landslide vulnerability. The aspect of a hill affected the distribution of plants. Because it can prevent soil erosion and promote root cohesiveness, vegetation helped stabilize slopes. Changes in aspect may lead to variations in plant cover, which may impact the stability of slopes.

4.2 Drainage Density

A drainage density map was a graphical representation that showcased the spatial arrangement of the stream or river network within a certain region. It was commonly obtained from digital elevation models (DEMs) and could be quantified as the overall length of streams or rivers per unit area. Drainage density was commonly determined by dividing the aggregate length of the drainage network by the overall area of the watershed. Landslide susceptibility referred to the chance of a certain region encountering landslides. Figure 3 shows the result of the drainage density map of Kampung Belahat. There discovered a significant correlation between a region's topography and drainage density. Greater slopes and rough topography were frequently accompanied with larger drainage densities, which may have enhanced the likelihood of landslides. Elevated drainage density indicated the presence of a well-designed drainage system that carried water effectively. This event may have resulted in increased erosion and silt movement, undermining slopes and increasing the risk of landslides. Water distribution on the ground was influenced by drainage density. The hydrological system's interconnection and drainage density were inextricably linked. Areas with high drainage density may have had interconnected drainage channels, affecting water flow and contributing to groundwater building, making them more prone to landslides. Geospatial analysis might have been utilized to determine landslide susceptibility through the combination of drainage density maps with additional significant factors such as slope, geology, land cover, and land use.

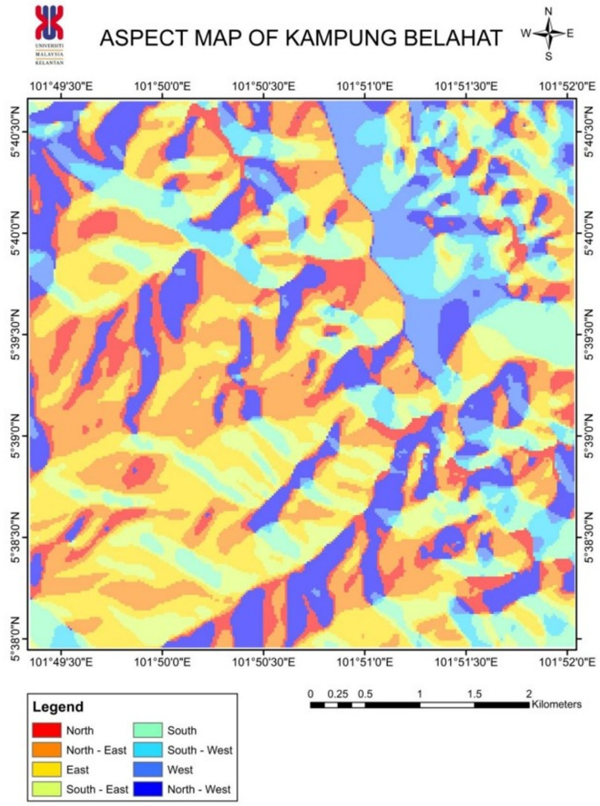

Figure 2. Aspect Map of Kampung Belahat.

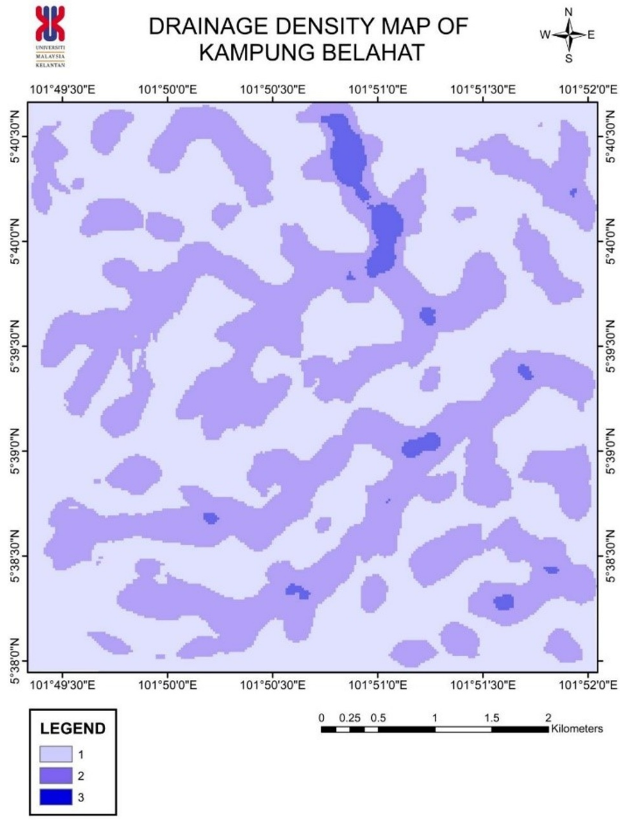

Figure 3. Drainage Density Map of Kampung Belahat.

4.3 Lithology

A lithology map was an essential aid in the fields of geology since they offered significant data on the geological composition of a particular area. Figure 4 shows the lithology map of Kampung Belahat. The mechanical properties of rocks and soils played a crucial role in determining the likelihood of landslides. A higher shear strength made some lithologies more resistant to landslides, whereas a lower shear strength made other lithologies more prone to collapse. The moisture content of rocks and soils impacted their stability, however water retention was more common in some kinds of rock formations, perhaps resulting in higher pore pressure and poorer stability. Weathering processes differ between lithologies and can weaken rocks and soils, increasing the risk of landslides. Faults and fractures in lithological layers may influence the likelihood of landslides. Large fissures can cause places to become less cohesive and porous, making them prone to landslides. The shape of rocks might impact the stability of a slope. For example, the presence of specific rock formations may make slopes steeper or more vulnerable to collapse.

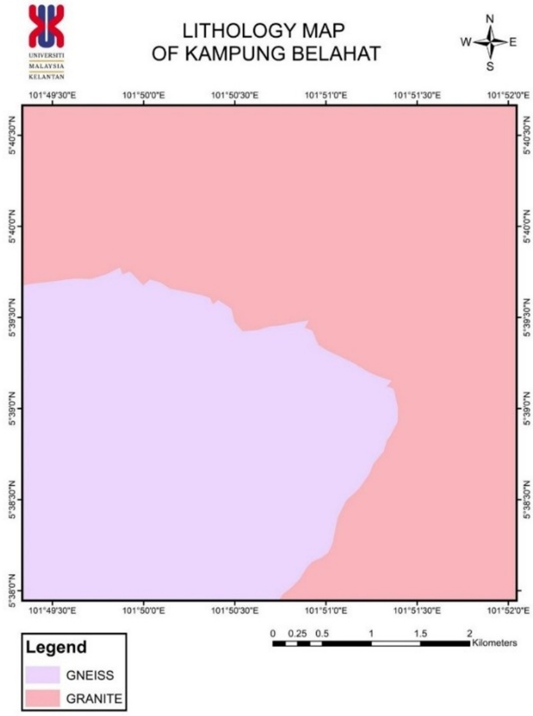

Figure 4. Lithology Map of Kampung Belahat.

4.4 Slope

A slope map was a graphical indication of the degree of incline or gradient of the topography in a certain area. It is frequently produced from topographic data or digital elevation models (DEMs) and used to exhibit and examine the slope characteristics of the landscape. Slopes were typically explained as ratios or degrees. The slope map was crucial for assessing the possibility of landslides and their likely occurrence.

The slope angle had a direct influence on ground stability. Greater inclines were often more prone to landslides due to their increased susceptibility to gravitational forces. As the slope became steeper, the likelihood of downslope movement for the materials on it increased. Landslides frequently happened when the slope approached a critical or threshold point, at which the likelihood of collapse significantly increased. Through the process of mapping slope characteristics, namely by identifying places with slopes beyond specific thresholds, geologists were able to pinpoint zones that were more susceptible to landslides. Slope maps could be categorized into many classifications, such as low, medium, and high, to classify the terrain according to its slope angle. Slope maps were commonly combined with other terrain-related variables, such as aspect, curvature, and elevation, to develop a comprehensive model for predicting the likelihood of landslides. Concave slopes were more prone to landslides compared to convex slopes. Figure 5 shows the slope map of Kampung Belahat.

4.5 Land Use

A land use map is a visual representation that illustrated the allocation and utilization of land in a particular region for various uses, including residential, commercial, agricultural, industrial, and recreational regions. Land use maps provided important information on how people arranged their activities in space and how land was used in a particular location. Given that human activity had a significant effect on ground stability, there was a significant correlation between land use maps and the risk of landslips. Figure 6 below displays the land use map of Kampung Belahat.

Urbanization and infrastructure development procedures sometimes resulted in modifications to natural environments. This might alter the natural drainage patterns, increase surface runoff, and upset the slope balance, making people more vulnerable to landslides. The vegetation cleared by logging or agricultural deforestation substantially contributed in slope stabilization. Loss of vegetation, particularly in hilly or mountainous locations, reduced the soil's capacity to withstand erosion and raised the risk of landslides. The mining and quarrying extractive sectors possess the capacity to compromise the stability of the earth's surface, consequently elevating the likelihood of landslides. This map helped identify locations where a region is more susceptible to landslides due to a combination of land use practices and other variables. Comprehending the connection between land utilization and the likelihood of landslides was essential for effectively managing land, developing urban areas, and reducing the risk of disasters in locations that were susceptible to such events.

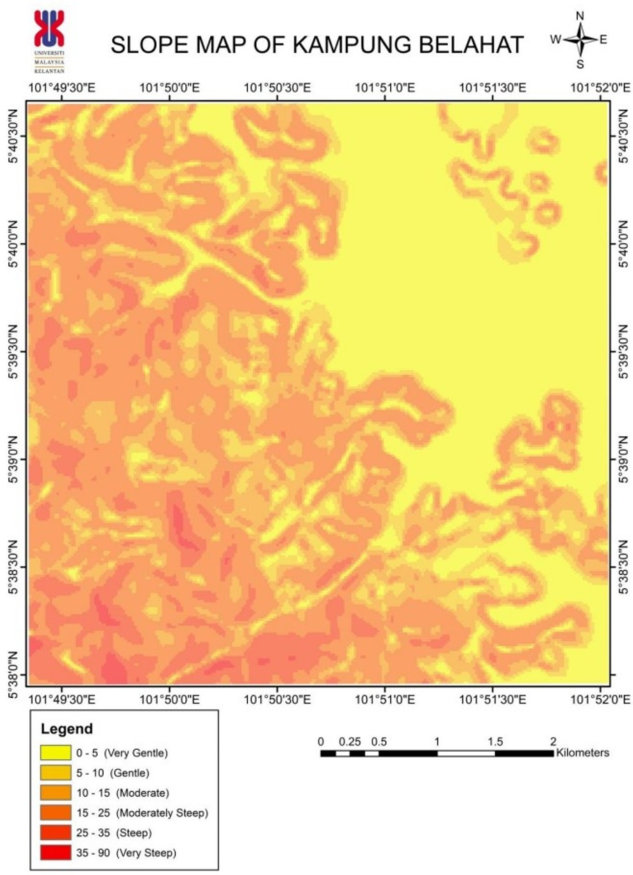

Figure 5. Slope Map of Kampung Belahat.

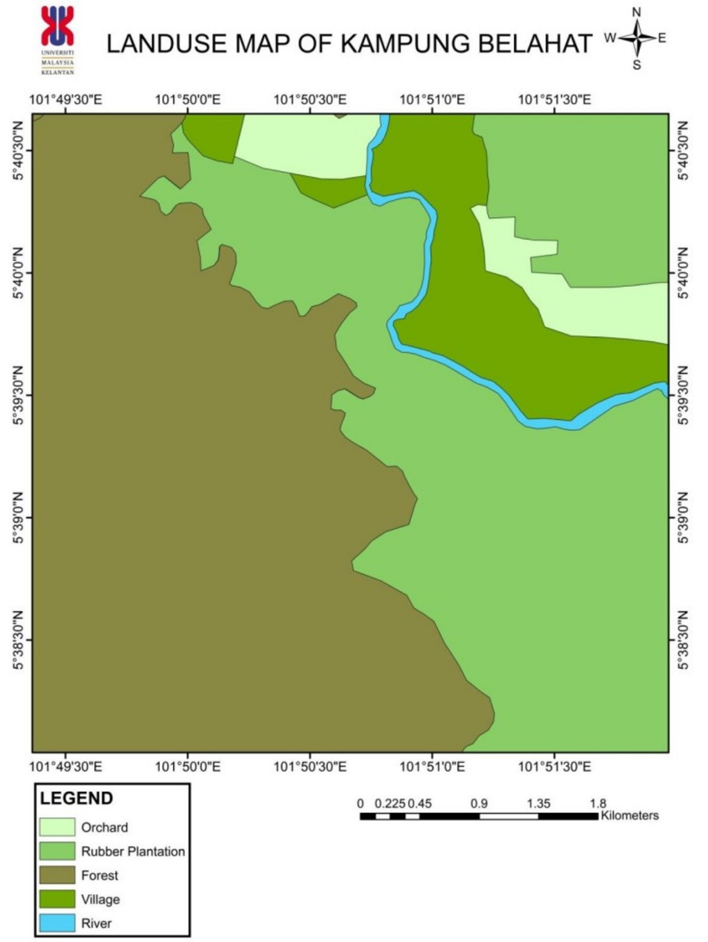

Figure 6. Land Use Map of Kampung Belahat.

4.6 Landslide Susceptibility Map

Landslide susceptibility map is shown in Figure 7. The planning land use, evaluating risks, and managing disasters are required in this map [13]. An aspect, drainage density, lithology, slope, and land use, must be taken in order to create a comprehensive GIS (Geographic Information System) map of landslide susceptibility. Each component was assigned a weight based on how important it was in relation to landslides by using the Weightage Overlay Method (WOM). The weights were multiplied by the matching factor values and totalled to produce an all-inclusive susceptibility estimate for every region. This data was obtained using satellite pictures, topographic maps, geological surveys, and land-use databases. The result is identified locations that were more prone to landslides, providing critical information for land use management and risk mitigation in the landslide susceptibility map. Within the research region, 30%, 65%, and 5% of the areas were classified as low, moderate, or high risk of landslides. This indicated that the risk of landslides remained low throughout the study zone, making it safe to develop and live in.

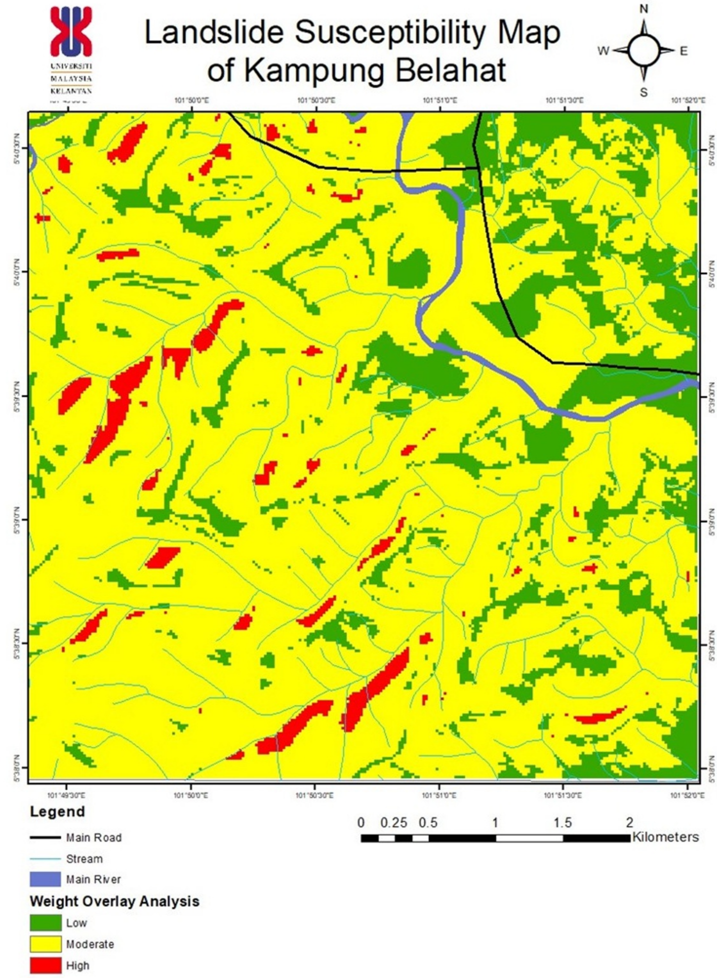

Figure 7. Landslide Susceptibility Map of Kampung Belahat.

5 Conclusion

The five variables identified as landslide triggers were effectively employed to construct the landslide susceptibility map. The map showed three landslide susceptibility levels. The three levels of landslide threat that exist in the research region are classed as low, moderate, and high. The results of this landslide susceptibility map allowed the area to expand by lowering the risk of unforeseen events such as injuries and property loss. A susceptibility map was created, identifying different sites depending on their landslide risk. The map's vulnerability falls into four categories: low (5%), moderate (30%), high (65%), and extremely high (90%). Mapping landslide sensitivity to disasters was a critical technique for deploying early warning systems, planning land use, and reducing disaster risk. Local communities and governing organizations can take proactive actions to mitigate the potential impact of landslides by identifying high-risk regions.

The authors would like to thank Faculty of Earth Science for their technical support. All research participants should be sincerely thanked for their fantastic efforts and participation.

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