GIS Based Assessment and Analysis of Terrain Variables in Kampung Baru, Jeli, Kelantan

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GIS Based Assessment and Analysis of Terrain Variables in Kampung Baru, Jeli, Kelantan

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Abstract. Kampung Baru is one part of Jeli district that has abundant natural resources and contains several geological features of interest.The landscape of this area is divided into three parts which are mountainous, hilly, and plain areas. This research aims to perform terrain analysis and determine the suitability zone for the construction area. To achieve the objective, the mapping aspect is mainly based on field observations such as geomorphological features, elevation, drainage patterns, etc. Besides, elevation data extracted from Digital Elevation Model (DEM) was employed to characterize the physical features of the landscape for terrain mapping and analysis. All this field-related data was then processed in ArcGIS software to generate thematic maps. The terrain classification was carried out based on five terrain variables: slope gradient, terrain code, activity code, erosion & instability. Then, the suitability of the site for development and construction is created using the terrain attributes. There were five types of classes created in the study area: class I (37.9 %), class II (23.3 %), class III (1.7 %), class IV (29.3 %), and class IV cut slope (7.6 %). The study area was dominated by class I, which means it has few geotechnical constraints and is highly suitable for development. Some cutting and filling of slopes are not expected to be difficult due to their low elevation. From the slope terrain analysis, only 4.89 % of the site is covered by a very steep slope (>60°). The site is mainly high slopes (35º - 60°), equal to 32.20% of the total area, with most of it contributed by the cut slopes. Gently sloping (5° - 15°) to moderate slope rate (15° - 25°) covers about 19.93% and 14.19% of the area respectively. The percentage of flat to gently sloping (0° - 15°) area is shown as 15.34 % of the project site. In conclusion, the parameters including the map prepared using the Weighted Overlay Method (WOM) can be beneficial to engineering geology for the planning of site investigations, preliminary design of foundation systems, and the project layout of the research area.

1. Introduction

Town planners will need basic data such as the geology, topography, and landform of the area, as well as other associated geotechnical facts to determine whether the area is potentially unstable due to the presence of landslides or excessive erosion. With this information, engineers will be able to create layout plans, design the foundation system, and select the best style and manner of construction. A terrain analysis study may offer crucial engineering geology and geomorphological information for lengthy linear engineering projects, aiding in project design options, path selection, and construction design. With the limited knowledge available, these rapid regional assessments are made of the possible geological and geomorphological ground conditions that may be encountered [1].

Techniques for analyzing the topography are thought of as an art without any formal theory and typically rely on the interpreter's implicit terrain-related understanding of the area under study [2]. Such skill comes from years of expensive training and experience. [3]. Because it is practically impossible to construct accurate comparisons between land component maps produced by different analysts, or even by the same analyst at different times, the subjective nature of terrain analysis is a severe drawback [4]. Due to the fractal character of topography, the interpretation and mapping of land components are very time-consuming, labor-intensive, and expensive processes [5] and are challenging to verify in the field [6].

The study of calculating slope gradient using terrain codes such side slope, foot slope, drainage valley, and more is another aspect of terrain analysis. Additionally, stability and erosion can be classified as gully erosion, rill erosion, no evident erosion, and so on. These specifics are essential for engineering to prevent risks like landslides and floods [7].

In recent years, the evaluation of geo-environmental hazards has placed an increasing emphasis on Remote Sensing (RS) and Geographic Information Systems (GIS). In several recent research, flooding was assessed using digital elevation models (DEMs) as the main information source for hazards or disasters [8]. The increasing availability of DEM has promoted the estimation and classification of terrain properties using computer technology. DEM-derived data sets for slope, aspect, hydrographic pattern, and shaded relief are widely used in terrain study. These morphometric properties can be utilized to compare terrain units objectively and quantitatively since they are less subject to human error [9].

When identifying the construction zone boundaries using GIS, basic data like geology, topography, landforms, and possibly unstable zones were needed. Geological terrain mapping studies by [1] have demonstrated that several derivative maps were developed and used in the Cameron Highlands region for the planning and approval of development projects. When identifying the construction zone boundaries using GIS, basic data like geology, topography, landforms, and possibly unstable zones were needed. Geological terrain mapping studies by [1] have demonstrated that several derivative maps were developed and used in the Cameron Highlands region for the planning and approval of development projects.

The investigation of the landscape of Kampung Baru, Jeli, is highlighted in this study. The mapping activities produced several maps, including elevation maps, terrain categorization maps, and construction suitability maps. Understanding environmental processes and modelling the topography of the area are both aided by terrain analysis. The variability of field interpretation is frequently used in biological, hydrological, and geomorphological systems, and it is a crucial component of knowledge for future planning. The field analysis can understand necessary aspects, such a classification attribute, as well as other geotechnical information, like surface stabilization, and can provide helpful data for urban planning, pipeline design, construction, and land use planning.

2. Materials and Methodology

2.1. Study area

The study area is approximately 25km^2 and it’s located within Peninsular Malaysia’s Central belt. This location is ideal for research due to its expansive and mountainous terrain. The longitudes range from 101° 51’45” E to 101° 54’28” E and latitudes ranging from 05° 42’33” N to 05° 39’55” N. The study area composed of three lithological units, which are alluvium, granite, and schist. The oldest rocks in the study area were Schist (Metasedimentary rock) from Bentong Raub Suture formation. The period for this rock unit is Early Triassic and it located east and west at the study area. The second oldest lithology units are granite (igneous rock) also from Bentong Raub Suture formation and it in early Triassic period and found in middle of the study area. The oldest are alluvium and the period time for this lithology are from Triassic and located between granite and schist. Figure 1 represents flowchart of overall research study.

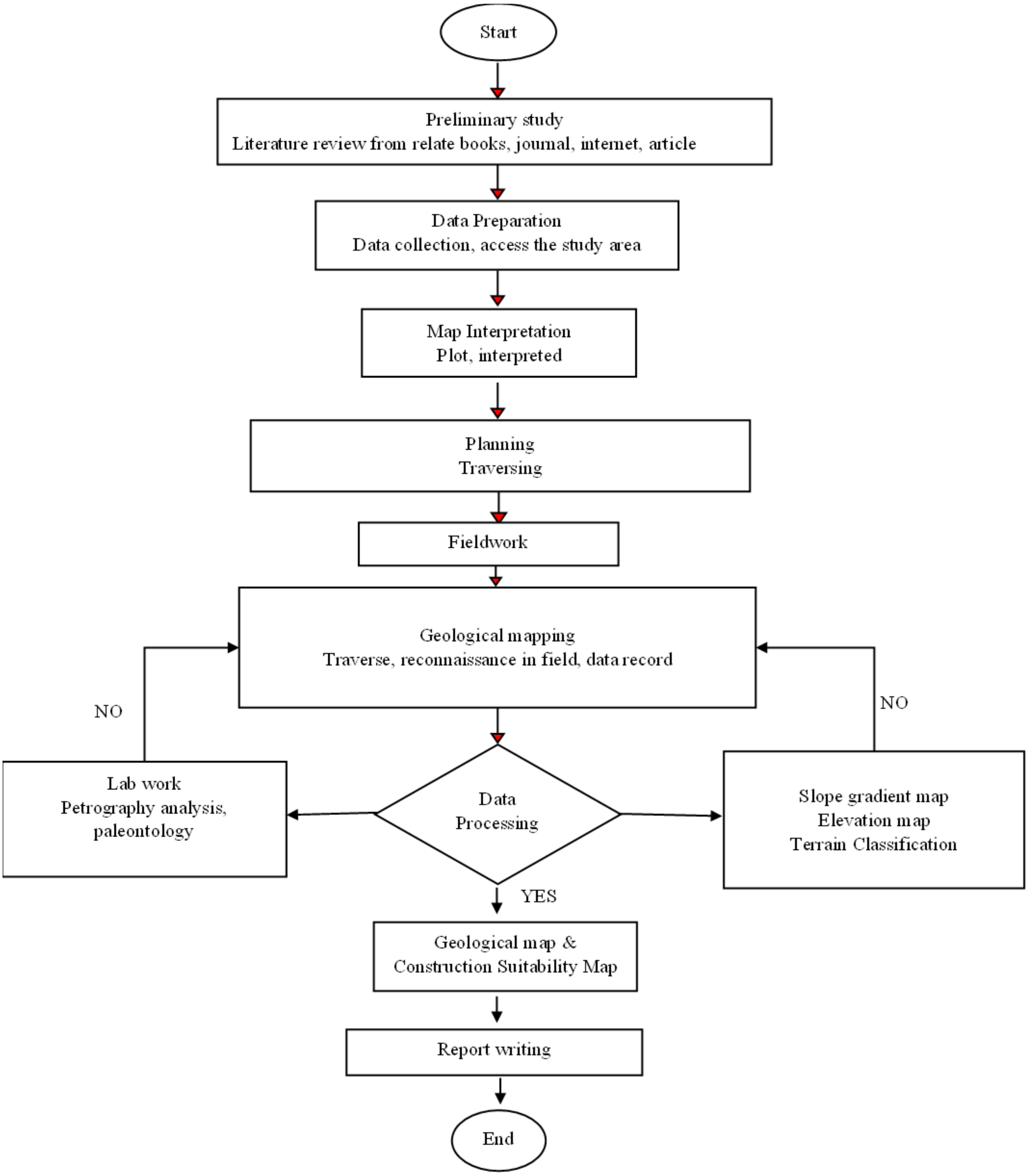

Figure 1. Flow chart of the research methodology

2.2. Data

Data was collected from both primary and secondary sources. The geological mapping aspect of the project was mainly based on fieldwork inputs including collection of samples from fresh outcrops, recording structural trends in rocks, and other field observations such as geomorphological features, drainage pattern etc. All these field related data was then processed in a GIS based platform including the petrographic studies to generate geological and other thematic maps. Secondary data from the United States Geological Survey (USGS) Earth Explorer web service was used, including satellite imageries, topographic map, and DEM. The acquisition date of the DEM is on 23 September 2014 and has its resolution is about 1 arc-second (~30 m).

2.3. Data Processing

ArcMap 10.3 was used to create related maps, such as contour mas, slope gradient map, elevation map, geological map, terrain classification and construction suitability map (CSM). The method of digitizing each layer and creating each layout before integrating them into a single map adheres to the attribute requirements. This method was utilized to create a slope gradient map using GIS technology and raw digital data. Furthermore, the parameters included in the map were created using the weighted overlay approach which can be used for engineering geology, site inquiry planning, preliminary foundation design, and project layout. Topography analysis is frequently used in evaluating the earth features, landforms, and land usage, and it is useful in environmental engineering as well. The details processing stage emphasize on final output map which is classifying terrain and CSM.

2.3.1. Terrain Classification. The 3D Analyst toolbox includes a collection of geoprocessing software for creating field datasets. The latest Terrain wizard was used to create an interactive field dataset. Steps involved in creating a terrain classification map are divided into four stages, which are the construction of terrain, construction of terrain pyramid level including a feature class in terrain, and construction of terrain complete. Following these four steps, a terrain classification was then generated. Additionally, polygons were created in this map to differentiate the type and value of coding based on the terrain classification and land use hazards zonation attributes. The polygons are generated using attributes for terrain classification and land use hazard zonation. The code for the terrain is determined by the type of slopes, such as hillcrest ridge, side slope, foot slope, and drainage valley.

Table 1. Construction Suitability Classification System based on Geoscience and Mineral Department

Class Characteristics	Class I	Class II	Class III	Class IV
Geotechnical Limitations	Low	Moderate	High	Extreme
Suitability for development	High	Moderate	Low	Probably Unsuitable
Engineering Costs for development	Low	Normal	High	Very high
Intensity of Site Investigation Required	Normal	Normal	Intensive	Very Intensive
Examples of Terrain	1. Insitu terrain < 15° minor erosion 2. Cut platform in insitu terrain	1. Insitu terrain 15° – 25°, no instability or severe erosion 2. Insitu terrain <15°, severe erosion 3. Colluvium <15°, no instability or severe erosion	1. Insitu terrain 25° – 35° no instability or severe erosion 2. Insitu terrain 15° – 25°, history of landslips’ 3. Colluvium 15° – 25°, general instability	1. Insitu terrain > 35° 2. Insitu terrain 25° – 35°, instability or severe erosion 3. Colluvium 25° – 35°, moderate erosion

2.3.2. Construction Suitability Map (CSM). The site's suitability for development and construction is determined using topographical characteristics and surface engineering geology, in accordance with the Minerals and Geosciences Department's recommended processes. The type of soil study required based on the construction suitability is split into four types (Table 1). By creating a map of suitability, it is possible to assign a suitable value to each point on the map if the necessary dataset. After preparing various inputs, they must be transformed into a common scale by evaluating a chart describing land-use types using the reclassify method. As it is preferable to construct on alternative land uses regardless of the associated costs, the values must be rated.

To rank the areas on relatively flat land, steep hills must be avoided, and locate level construction areas. The slope tool can create such a map by determining the maximum rate of change in value between each cell and its neighbours. The resulting raster expresses the slope as a series of constantly changing floating-point values. Since preferences vary directly with changes in the slope value, the Rescale by function tool is used to rank this map using the linear function. The final step in the suitability model is to integrate transformed outputs (suitability maps) of land-use forms, hills, distances to recreation areas, and distances. It is important to verify that spatial analysis is corrected once the outcome of any of it is available. The suitability of a site for development and construction is determined using the terrain's attributes and surface engineering geology.

2.3.3. Weight Overlay Method (WOM). WOM is the methodology for assessing the terrain. The overlay of raster layers with all the factors that influence the map of building suitability maps must be used. Each control factor needs to be reclassified by raster layers.

3. Results and Analysis

This section discussed terrain analysis using the Geological Terrain Mapping (GTM) attribute. The analysis is carried out based on the parameters used, which include cut and fill slope, fill slope, terrain analysis, terrain morphology, slope gradient, erosion, instability, and potential geohazard.

3.1. Slope Gradient Map

The slope gradient of the site is shown in Figure 2(a). The site is mainly flat to gently sloping area (>5°) covered 15.34% of the project site. The gentle slope are (5° <15°) covered 19.93%. The moderate slope (15° < 25°) covered 14.19% of the site. The high slope (25° <35°) covered 13.48. The high slope (35°<60°) covered 32.20% and only 4.86% of the site is covered by a higher slope (>60°) with most of it contributed by cut slopes along the main road that runs through the study area.

3.2. Terrain Morphology Map

The main features of the site are the crest, concave side slopes, straight side slopes, convex side slopes, and foot slopes. A drainage valley that is a tributary of a lake in the central west of the study area runs from the center of the study area to the northwest of the project site. Figure 2(b) represents the terrain morphology of the area.

3.3. Erosion and Instability Map

The erosion and instability in the study area were separated into eight types that were no appreciable erosion, minor sheet erosion, moderate sheet erosion, severe sheet erosion, minor rill erosion, moderate rill erosion, severe rill erosion, and minor gully erosion The erosion identified by analyzes elevation map, lithology map, and slope map. The percentage of no appreciable erosion was 22.2 %, the minor sheet erosion was 25.2 %, the moderate sheet erosion was 20.5%, the severe sheet erosion was 15.4%, the minor rill erosion was 10.2%, the moderate rill erosion 5.9%, the severe rill erosion was 1.4% and lastly the minor gully erosion was 0.2%. Figure 2(c) shows the erosion and instability and percentage of erosion map.

3.4. Construction Suitability Map (CSM)

Figure 3 refers to the CSM of the study area. The suitability of the site for development and construction is determined using terrain attributes and surface engineering geology (Table 1). Class I areas have few geological constraints and are ideal for building. The site is covered by 30.54 % of Class I areas. All these areas are flat to gently sloping (15°) with no erosion or instability. Some cutting and filling of slopes is not expected to be difficult because they are generally not steep

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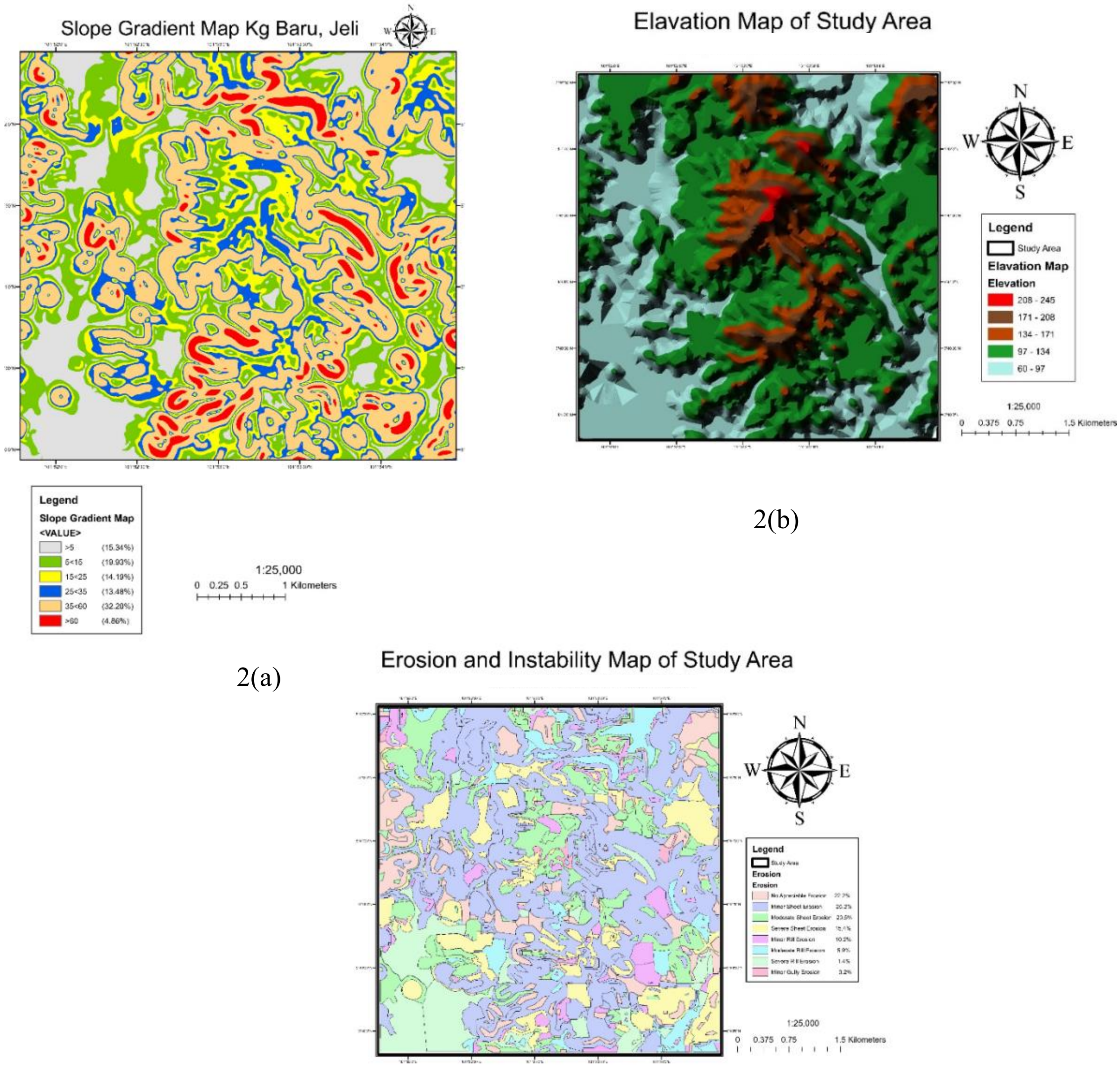

2(b)

2(a)

2(c)

Figure 2 (a) (b) (c). Slope Gradient map, Elevation map, Erosion and Instability map

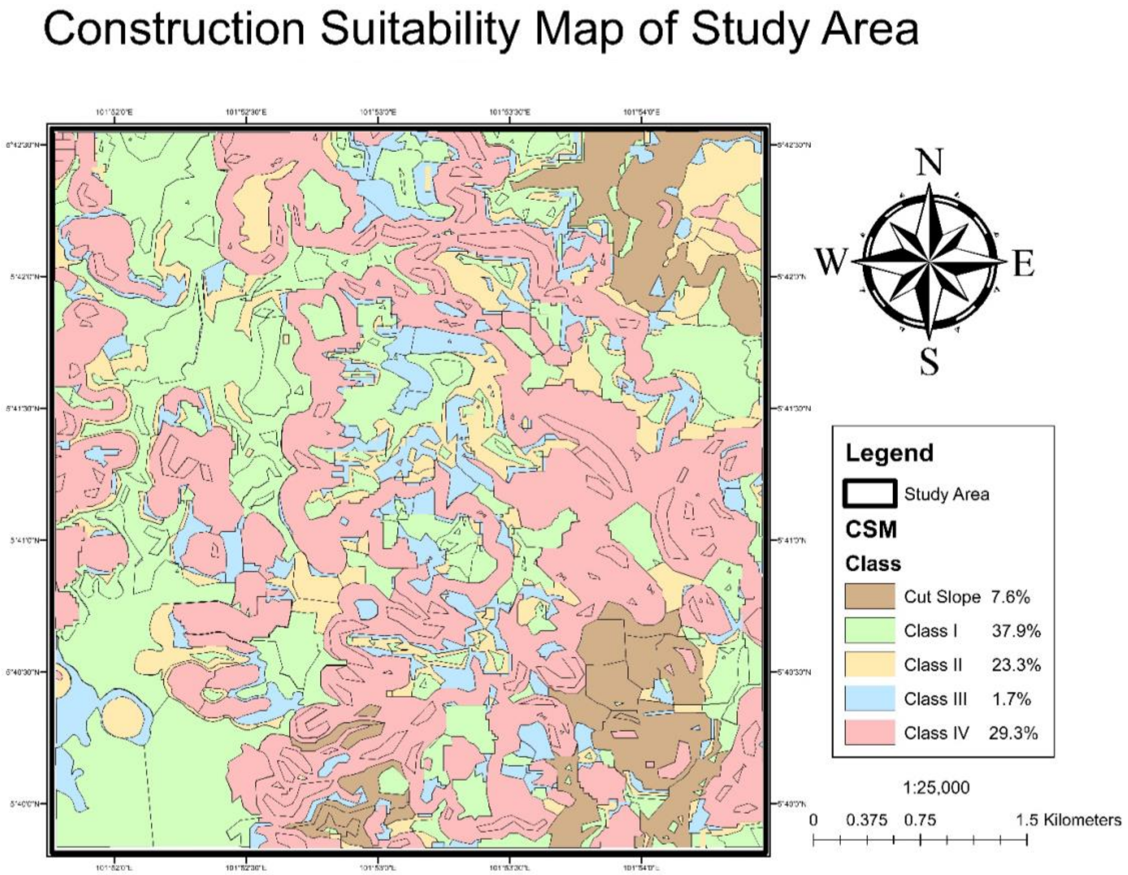

Figure 3. Construction Suitability map of the study area

Class II areas have moderate geotechnical constraints and are moderately suitable for construction. These are moderate slopes (15° - 25°) with some erosion or instability. This class covers approximately 33.9 % of the study area. Construction in Class II areas will necessitate cutting, filling, and erosion on bared slopes where surface runoff is not properly channeled. Construction in these areas is not expected to encounter any major foundation issues. During the excavation process, bedrock might be encountered.

Class III areas have severe geotechnical limitations and are unsuitable for construction. The Class III slope is generally steep (25° - 35°) and covers approximately 27% of the site. There will be a lot of cut and fill in these areas. Severe erosion may occur, and slope stability may be compromised if the slopes are not properly maintained. Excavation in these areas is likely to encounter bedrock. The cost of development in these areas is expected to be high. In Class III areas, a thorough site investigation and geotechnical study are required.

Class IV, which is a very steep hill slope (>35°) represented by cut slopes, has extreme geotechnical limitations and is unsuitable for development, and occurs in less than 8.68 % of the site. The majority of cut slopes are located along earth tracks that run throughout the study area.

3.5. *Potential Geohazard*

There are no major geohazards expected in the study area. The predicted environmental impact is mechanical and chemical evolution, which may result in soil erosion caused by surface run-off water if a proper drainage system is not built. The scale of erosion varies depending on the gradient and type of vegetation covered. The geomorphic process becomes more active at slope gradients greater than 35°, where mass movement occurs for example localized circular failure, and slump. The transportation and deposition process occurred on a gentle slope (gradient 35°), where the top surface material typically contains a lot of clay and silt, which may cause siltation and sedimentation problems.

4. Conclusion

The suitability of the research area for development and construction is successfully determined using terrain attributes. Class I and Class II both areas have few and moderate geological constraints respectively and are ideal for that development purposes. In contrast with class III and IV which has high and extreme geotechnical limitations and are unsuitable for construction. In conclusion, terrain analysis aids in the comprehension of environmental systems as well as the modelling of the area's topography. The variability of field interpretation is commonly employed in geomorphological and hydrological or biological systems and is an essential aspect of future planning information.

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