GIS Based Determination of Landslide Location

by

Sheryl Lin Kuok Tyng

Dissertation submitted in partial fulfillment of

the requirements for the

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(Civil Engineering)

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Civil Engineering

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CERTIFICATION APPROVAL

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Approved by,

____

(Associate Professor Dr. Indra Sati Hamonangan Harahap)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

September 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

SHERYL LIN KUOK TYNG

ABSTRACT

This paper discusses about the Landslide Hazard Assessment (LHA) conducted on Cameron Highlands for October 2013. This site is identified as one of the very susceptible to landslides. In tropical countries such as Malaysia, rainfall is considered as the triggering factor of a landslide. Therefore, the information was obtained from rainfall station gauges to be used in Geographical Information System (GIS) by Kriging interpolation method. The variables including slope, slope aspect, curvature, land use land cover (LULC), elevation, distance from road, distance from river/lake and distance from lineament were used in the GIS system. The system managed to identify few areas that are highly susceptible to landslide using rainfall data on 23rd October 2013. However, it did not manage to identify the area that had mudflow reported on that day with the Landslide Hazard Zonation (LHZ) map produced. This paper provides recommendations to be done in future work in order to obtain more accurate results.

Keywords: Landslide Hazard Assessment; GIS; rainfall interpolation; Cameron Highlands; weighted overlay

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LIST OF ABBREVIATIONS

LHA	Landslide Hazard Assessment
GIS	Geographical Information System
DID	Department of Irrigation and Drainage
MMD	Malaysia Meteorological Department
JUPEM	Jabatan Ukur dan Pemetaan Malaysia
CRS	Coordinate Reference System
LHZ	Landslide Hazard Zonation

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Landslides are known as one of the natural disasters that destroy properties and claim lives. Landslide is described as a "movement of rock, debris, or earth down a slope" which may happen in five distinct mechanisms which are falling, toppling, spreading, flowing and sliding [1]. In Malaysia, Cameron Highlands is one of the areas that are known to be prone to landslides. Thus, it is important to identify the potential landslide sites to minimize the damages caused by landslides. Landslide hazard assessment serves as an early warning system by developing a landslide susceptibility map that could help planners or authorized personnel to plan out suitable mitigation methods in areas that are prone to landslides. In the hazard assessment, there are various parameters that could be the triggering factor to a landslide depending on the study area such as slope aspect, soil stratigraphy, types of soil, distance to road and etc. In this study, the triggering factor that will be studied is the rainfall data. Statistics have shown that rainfall has a direct relationship with landslide. This study will encompass the data from rainfall gauges to correlate the relationship between the amount of rain and its effect on landslide.

There are various ways of conducting landslide hazard assessment but little work or studies are done by applying GIS. GIS can be applied in this hazard analysis to create a dynamic database to control and manage the hazards should there be any changes to the geological or topography data to assess the landslide hazard. It is an easier method to model changes and reduces repetitive manual work.

1.2 PROBLEM STATEMENT

The main triggering factor of a landslide is usually rainfall. In Malaysia, the average precipitation in depth (mm per year) was 2875 mm measured in 2009 and landslide is ranked second after floods as the most frequent natural disaster. There is minimal work done on the early warning system to predict the landslide before it actually happens. It could warn the community about the hazard. In order to learn more about landslide in Cameron Highlands, which is one of the identified areas in Malaysia [2]that is prone to landslides due to its location at the main range known as Banjaran Titiwangsa, this qualitative research aims to study the correlation between landslide and rainfall characteristics using GIS. This study aims to improve the understanding of correlation between rainfall and landslides particularly in Cameron Highlands. The impacts of landslides can be seen through past incidents which will be further elaborated in literature review.

1.3 OBJECTIVES OF STUDY

The objectives of this study are

(i) To develop a qualitative landslide hazard map based on GIS and rainfall characteristics

(ii) To evaluate the accuracy of the developed landslide hazard map

1.4 SCOPE OF STUDY

The scope of study in this research focuses on developing a qualitative landslide hazard map in Cameron Highlands. Rainfall gauge station data that is provided by DID will be processed to interpolate the amount of rainfall on the covered area which will be further elaborated on the methodology. The rain data will be weighted accordingly which will be used to overlay with other spatial data such as slope, slope aspect and curvature. With the weighting system, GIS will be able to map out the areas that are prone to landslides, which is the hazard zonation map. As the figure below depicts the whole Peninsular Malaysia, this is the study area concentrated in the state of Pahang, particularly in Cameron Highlands, where the border is highlighted in pink.

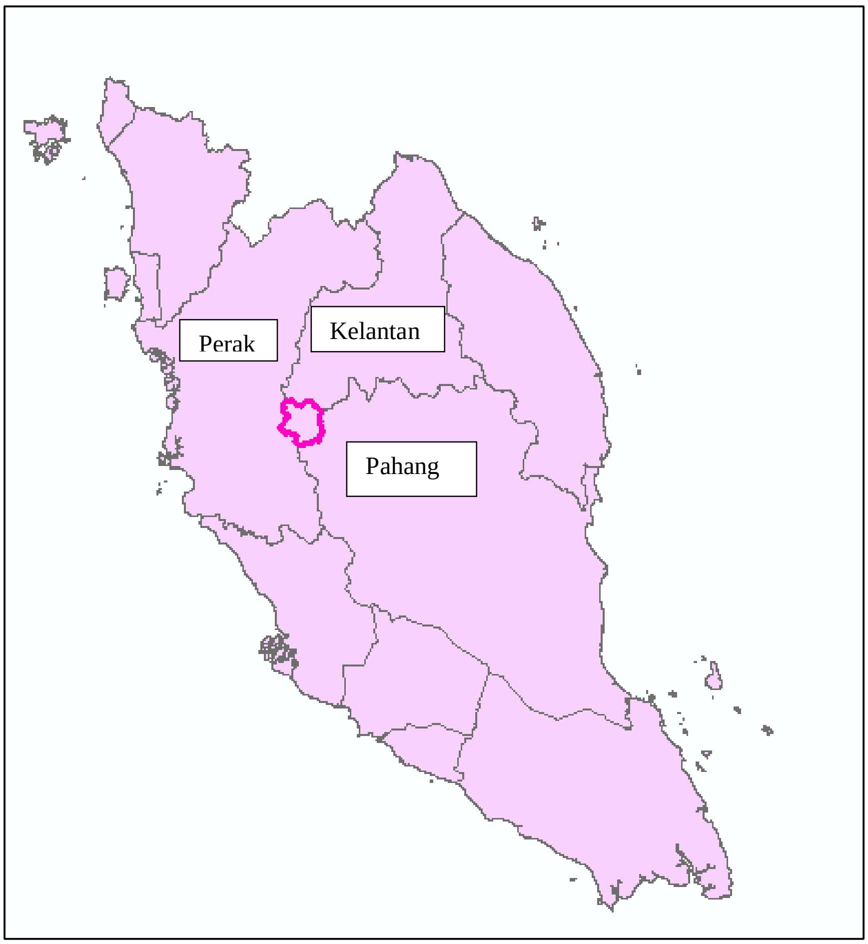


Figure 1: Study Area

1.5 RELEVANCY AND FEASIBILITY OF THE PROJECT

Rainfall is an important triggering factor to landslide, especially for tropical countries such as Malaysia where rainfall happens all year round. Moreover, this study covers the area of Cameron Highlands, where this area is prone to landslides due to its geographical location at the main range. It is thus, essential to study rainfall as an early warning system that could help to minimize damages and avoid loss of lives.

Geotechnical engineers could use this qualitative method to consult and advise town planners to avoid extreme urbanization at areas that are prone to landslides. This could also help government bodies to suggest suitable mitigations and to allow more funds into preventing than curing the effects of a landslide.

The project is feasible within the scope, time frame and budget given. The scope and main objectives had been clearly defined and narrowed, so that the author managed to complete the study within the time frame. A hazard zonation map could be produced within the time frame with the defined boundaries and scope.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents the literature review on GIS and its application in landslide prediction. Besides that, this chapter also presents the literature review on the factors affecting a landslide susceptibility with regards to Cameron Highlands. The last part explains the types of spatial interpolation available in ArcGIS and the method the author has chosen to use.

2.2 GIS APPLICATION IN LANDSLIDE PREDICTION

Environmental System Research Institute (ESRI) defined “GIS integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information”. GIS is a very useful tool for the input, management, analysis and output of spatial data such as topography, geology, soil and land cover [3]. Landslide hazard in Malaysia has taken so many lives away, for example the landslide that occurred in 1996 that cost 44 lives not mentioning about the post landslide effects. To prevent landslide from taking away so many lives and damaging properties, it is important to keep up with the pace of technology to implement GIS to predict landslides as an early warning system. Landslides will not stop happening unless close monitoring and prevention methods are implemented. GIS can be a very useful tool in realizing this effort.

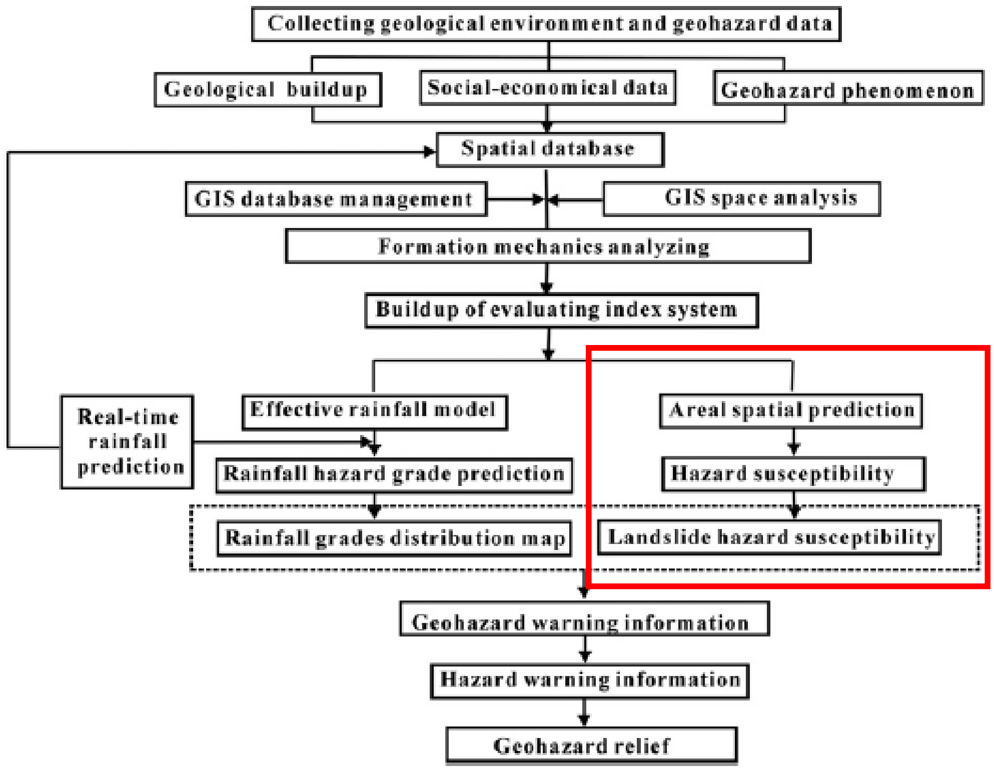


Figure 2: Flowchart of landslide hazard prediction [4]

The flowchart above shows the steps to a landslide hazard prediction, which was branched into the quantitative and qualitative methods. The method used in this study is the highlighted box, the qualitative method, which uses aerial spatial prediction which will then be used to generate the hazard susceptibility and lastly to develop a hazard map combined with all the other causative factors.

The qualitative methods are of two approaches [5], which is 1) use of index or parameter maps and 2) field morphology analysis. Since it is a qualitative method, high resolution of satellite images are essential to complement the required spatial data. In most landslide hazard assessment that uses the qualitative method, landslide distribution or landslide inventory is used as a base map to compare the relationship between landslide and causative factors. This study adopts the use of index or parameter maps which is used to overlay with the rainfall data to obtain the areas that are susceptible to landslides.

The layering system is depicted in Figure 3 on how each weighted layers are overlaid on each other in order to develop a landslide hazard zonation map which shows the areas that are susceptible to landslides.

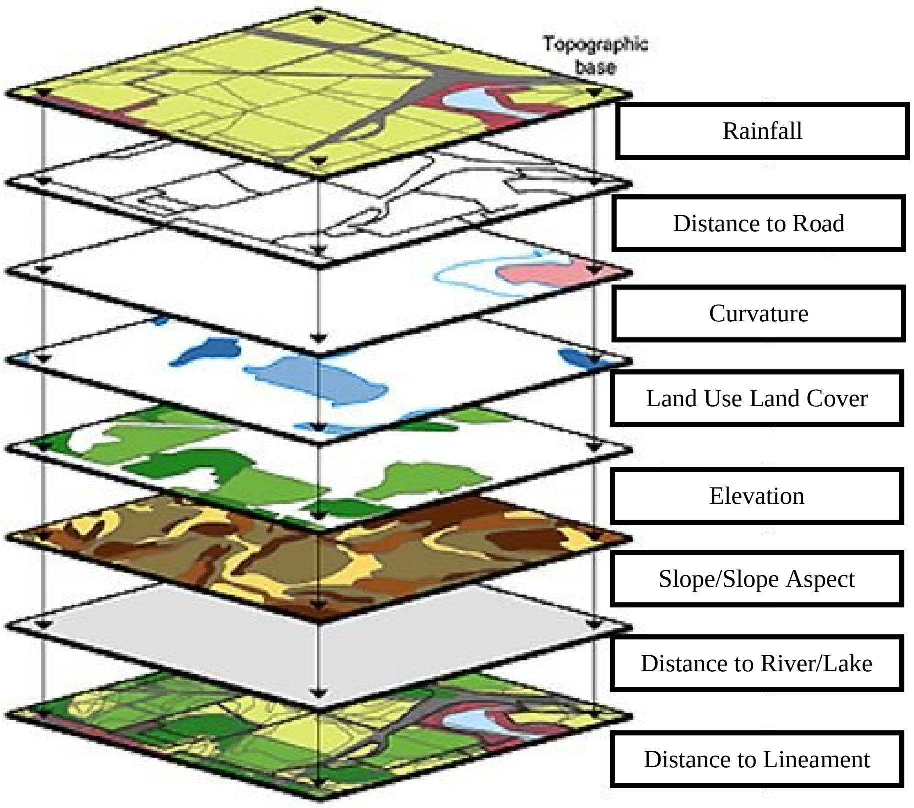


Figure 3: GIS Layers

2.3 TRIGGERING AND CAUSATIVE FACTORS

There is a thin line that differentiates a triggering factor and a causative factor [5]. A triggering factor is a single stimulus that initiates a landslide, while causative factors are the contributors of why a landslide happened. A report stated that most of landslide occurrences in Malaysia were triggered by rainfall; usually after prolonged rainfall. Malaysia is one country that experiences frequent storm and heavy rainfall especially when nearing end of the year. Causative factors are factors that affect the susceptibility of a slope to failure. Landslides could happen due to a single or a combination of multiple causative factors. There are too many causative factors that could be used in the study; however, there are only a few factors that are seen as important and significant [5]. Different researchers will combine different causative factors. But for this study, the causative factors that are included are land use, elevation, slope, slope aspect, curvature, distance to road, distance to lineament, and distance to river/ lake.

2.3.1 TRIGGERING FACTOR: RAINFALL STATION DATA

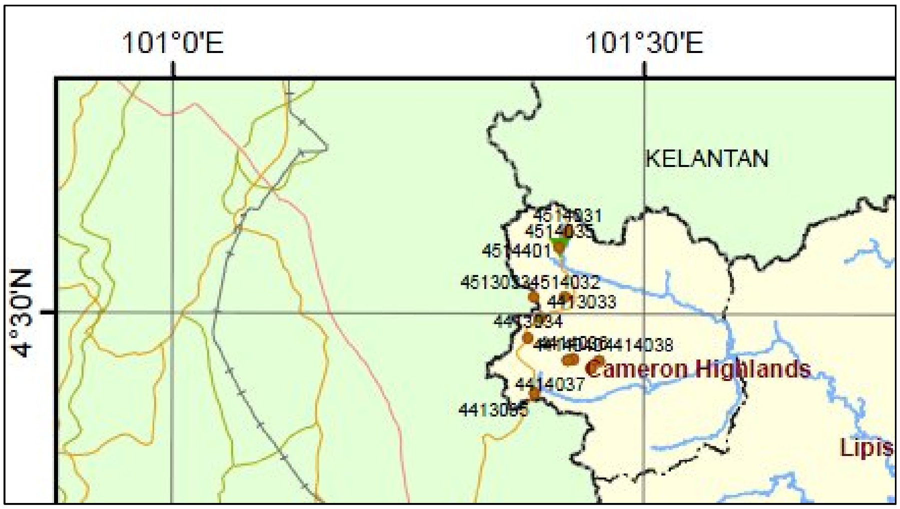


Figure 4: Rain Gauge stations available in Cameron Highlands, Pahang

In their study mentioned that massive landslides in Malaysia are mainly attributed to frequent and prolonged rainfalls, in many cases associated with monsoon rainfalls[6]. With the topography of Cameron Highlands, it is crucial to study the rainfall characteristics with landslide.

In this study, the rain data are obtained from the Tipping Bucket Rain Gauge stations installed in Cameron Highlands area as in the Figure 3. These rainfall gauges are installed by the DID to monitor daily rainfall readings (mm). The readings of these measuring tools are taken at fixed time at 8.00 am every morning from a 203 mm (8”) diameter rain gauge. The picture below shows the rain gauge used to measure the daily rainfall. This gauge has a receiving funnel leading to two small metal buckets. When a bucket accumulates 0.2 mm of rain water, the weight of the water causes it to tip and empty itself. Every time a bucket tips, an electrical contact is made, which enables recording or rainfall amount and intensity with respect to time. The maximum detectable rainfall rate is 200 mm/hr [7].

As seen from Figure 1, the study area is surrounded by the states of Perak, Pahang and Kelantan. Thus, in order to interpolate the intended coverage area of Cameron Highlands, there is a need to gather rainfall data from the three states as much as possible to gain accurate interpolated data.

Figure 5: Rain gauge (Tipping Bucket)[7]

2.3.2 CAUSATIVE FACTORS

As mentioned before, the causative factors that are included in this paper are land use land cover (LULC), elevation, slope, slope aspect, curvature, distance to road, distance to lineament, and distance to river/ lake. The causative factors could also be the triggering factor depending on each location's susceptibility to the factors. Each of the causative factors carries different weightage of the static factors according to the influence of each factor to the susceptibility of the slope failure. But in this study, the causative factors will be maintained as constant variables. The weighting system derived mentioned that each subcategory of causative factors was assigned a weighting value based on landslide frequency at the particular subcategory, which ranges between 1 to 5, representing low to high risk areas [8]. In cases where most frequent landslide events occurred, maximum weightage values were assigned to the subcategories. The weightage table (Table 1) is shown in the following page.

LULC are two separate terms that are often confused and interchangeable when in fact there is a clear difference between the terms. Nation Oceanic and Atmospheric Administration (NOAA) [9] defined land use as “physical land type” whereas the land cover is how people is using the land. LULC is included in this study as land cover can change rapidly over time due to urbanisation. As the human population increases, there is a need for space to be developed. Thus, human activities play a major role in determining LULC and in return the integrity of slopes. Deforestation reduces soil cohesion which allows rainfall with shorter return periods to trigger shallow landslides but on the other hand forested slopes remain stable[10].

Comprehensive topographic factors can be divided 13 factors, but only four factors which are included in this study itself are slope, slope aspect, curvature and elevation as they are deemed as significant factors in LHA studies [11, 12].

Slope gradient is the measure of steepness of a slope which is usually classified in degrees or percentage[5]. High steepness of a slope does not mean it is more prone to landslide. The correlation between slope gradient and landslide is also affected by the surrounding environment and geological settings. Slope gradient is one of the many factors to be studied. Multiple case studies have shown different slope gradients that cause landslides [13, 14]. It is therefore important to include slope gradient in LHA studies in order to find more correlation between slope gradient and landslides.

Slope aspect is the direction of a slope[15]. It is crucial to study this topographic feature because the direction of the slope plays an important role determining the moisture content of the soil due to the exposure to the sunlight. It could be deduced that soil that are exposed to more sunlight will have lower moisture content and higher soil temperature therefore leading to higher rate of soil erosion[16]. Vegetation growth in mountainous terrain is significantly affected by slope aspect where growth is best at shady side of mountain[17].

Curvature is the shape of a hill; either concave or convex, will determine the acceleration or decelerations of colluviums and loose bodies of sediment [5].

Concave slopes tend to act like a channel which contains and retains water from precipitation compared to convex slopes.

Elevation is another factor that is governing the vegetation growth in mountainous terrain. As the elevation goes higher the vegetation growth also increases. Vegetation growth becomes more sensitive in higher multitude areas. It goes further mentioning that the vegetation growth is at its best at elevation of 3400 m. For areas such as Cameron Highlands where vegetation is an active industry, it is relevant to include this factor in this study[17].

Distance from river/lake, distance from lineament and distance from road are also factors that are included in this study. Roads are human activities that cuts slope for urbanization, landslide that happened at the distance of 80 to 100 m from road edge was significantly more than other distances [18]. The nearer a site from the road network, the higher the susceptibility to a landslide. This study buffered the road networks at a distance of every 500 m. Same goes for the distance from river/lake factor, where rate of soil erosion is higher near the banks of the water bodies. The assumption of the nearer it is to the river/lake, the more unstable the slope is. The river/lake networks are buffer at a distance of every 1000 m.

Distance from lineament is another factor that takes geological settings into account, where it measures the distance from faults. Faults are also said to be the triggering factor of a landslide in some cases such as Denali Fault, Alaska back in 2002. The earthquake with a magnitude of 7.9 could have triggered landslides over a broad region of 350 km away[19]. This clearly shows the faults could also act as a triggering factor of a landslide.

2.4 SPATIAL INTERPOLATION

Due to the high rainfall intensity and duration in Malaysia, it is essential to study the rainfall characteristics in order to predict the susceptibility of landslide. Different types of rainfall acts differently on slopes. For example in Zhejiang Province, China, shorter rainfall duration has more obvious effects than long term rainfall [4]. Thus, it is important to analyse the rainfall patterns or characteristics to predict slope failure.

There are various ways and methods to obtain the rainfall distribution. For example, by using image processing which predicts the rainfall and secondly by spatial interpolation method. In this study, the technique used is spatial interpolation to assess the rainfall data distribution. There are a various techniques which are branched into two main groups namely deterministic and geostatistical interpolation methods.

Deterministic interpolation methods includes Inverse Distance Weighting (IDW) and Thiessen polygon which are most frequently used. These methods are using the location of the measured stations and observed values to forecast the regionalized value where the weighted average is accounted for [20]. IDW is described as a simple and intuitive deterministic interpolation method based on the principle that observed values closer to the prediction location have more influence on predicted location compared to observed values that are further apart[21]. There is a major disadvantage to this method which is the bull's eye effect which means there are higher values near observed location.

On the other hand, kriging is a geostatistical interpolation method which uses semivariogram that is based on spatial autocorrelation as the basic tool. ESRI assumes that Ordinary Kriging (OK)'s constant mean is unknown which is the same as the case in this study. Whereas Universal Kriging (UK) assumes that there is an overriding trend in the data[22].

In this study, kriging interpolation method is chosen due to its prediction tends to be less bias and usually accompanied by prediction standard errors[21]. There are various kriging method available in the software. In this study, ordinary kriging has been performed on the rainfall data due to the plane surface where both ordinary and universal kriging do not significantly differ in performance [23]. The mathematical model chosen in this study is exponential with the search radius is set to variable.

2.5 SUMMARY

This chapter has presented literature review on GIS and landslide relationship, mostly on how GIS can be incorporated in assessing landslide susceptibility to causative or triggering factors. This chapter also presented literature review on kriging process of rainfall data in ArcGIS. In the next chapter, the author will present on the methodology used in this study, mainly on research methodology, project activities, key milestone, Gantt chart and tools required.

Table 1: Rating weight of sub-categories of static landslide factors[8]

Landslide factors 1	Classes 2	Number of landslide 3	Weightage 4
Land use	Crop land	182	5
	Forest	93	4
	Built up	39	2
	Cut slope	43	3
	River/lake bank	1	1
Geology	Granite	231	5
	Others/undifferentiated	82	4
	Alluvium	1	2
	Schist	44	3
Elevation	<805 m	4	1
	805–1,070 m	16	2
	1,070–1,335 m	181	5
	1,335–1,600 m	131	4
	>1,600 m	26	3
Slope	<10.2	90	4
	10.2–20.4	82	3
	20.4–30.6	111	5
	30.6–40.8	57	2
	>40.8	18	1
Slope aspect	Flat (−1)	0	1
	North (0–22.5)	17	2
	Northeast (22.5–67.5)	56	5
	East (67.5–112.5)	39	3
	Southeast (112.5–157.5)	44	3
	South (157.5–202.5)	43	3
	Southwest (202.5–247.5)	51	4
	West (247.5–292.5)	37	3
	Northwest (292.5–337.5)	53	5
	North (337.5–360)	18	2
Curvature	<−8.4	19	2
	−8.4–−2.1	76	4
	−2.1–4.2	208	5
	4.2–10.5	46	3
	>10.5	9	1
Distance to road	<500	278	5
	500–1,000	44	4
	1,000–1,500	22	3
	1,500–2,000	11	2
	>2,000	3	1
Distance to lineament	<1,000	143	5
	1,000–2,000	111	4
	2,000–3,000	69	3
	3,000–4,000	28	2
	>4,000	7	1
Distance to river lake	<1,000	123	5
	1,000–2,000	55	4
	2,000–3,000	48	3
	3,000–4,000	60	2
	>4,000	72	1

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The main objective of this chapter is to describe the methodology used for this study. In Chapter One of this report, the main problem and objectives were outlined and will be elaborated further in this chapter. This chapter starts with research methodology used and project activities involved. Furthermore, this chapter also presents key milestone, Gantt chart and tools required. The last part of this chapter elaborates the detailed breakdown of GIS layers used in this study. The project activities involved are clearly presented in Figure 4. This figure shows steps of the author in achieving the objectives of this research.

3.1.2 RESEARCH PROBLEM

Landslides has been a constant hazard to its surrounding people. It is particularly active during rainy days and monsoon seasons when the soil is saturated and carries high water content in the particle. This study aims to study the rainfall characteristics and landslides in a qualitative method. The final result of this study will be a landslide hazard zonation (LHZ) map which indicates the areas which are more susceptible to landslides when there is a heavy rain.

3.2 RESEARCH METHODOLOGY

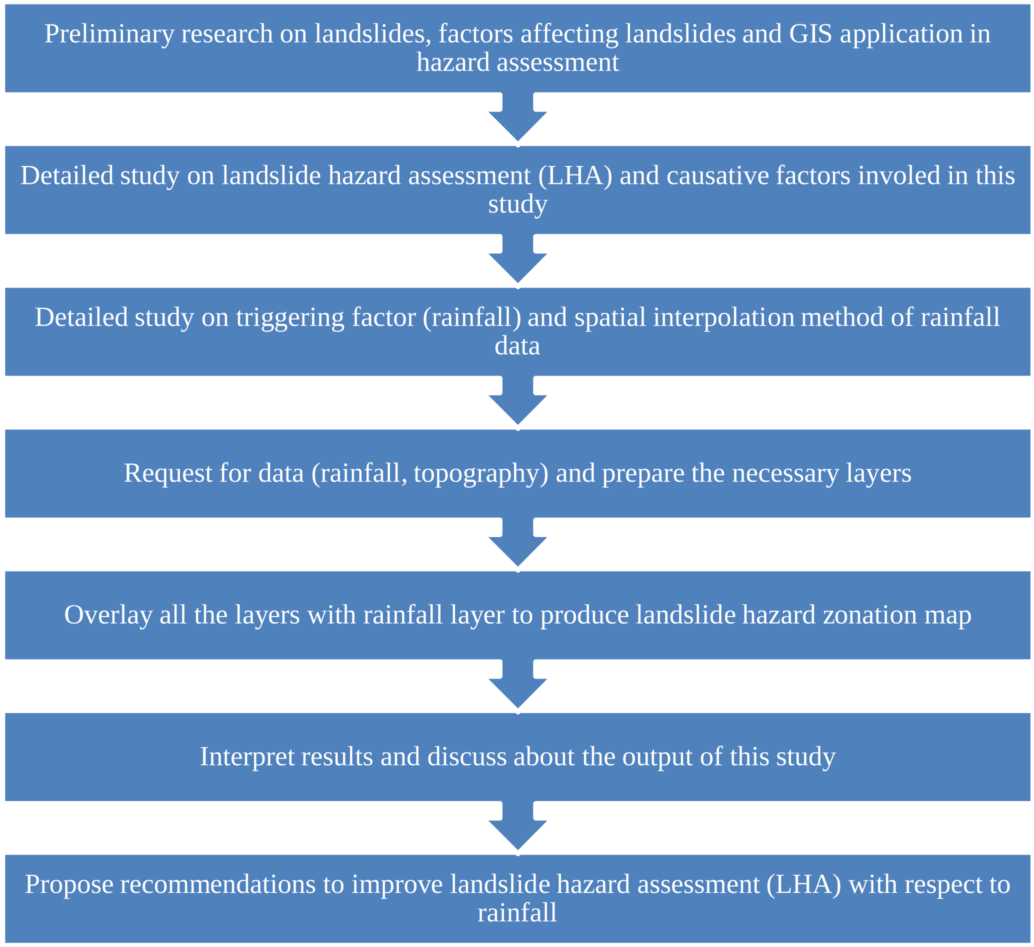


Figure 6: Research methodology

3.3 RESEARCH ACTIVITIES

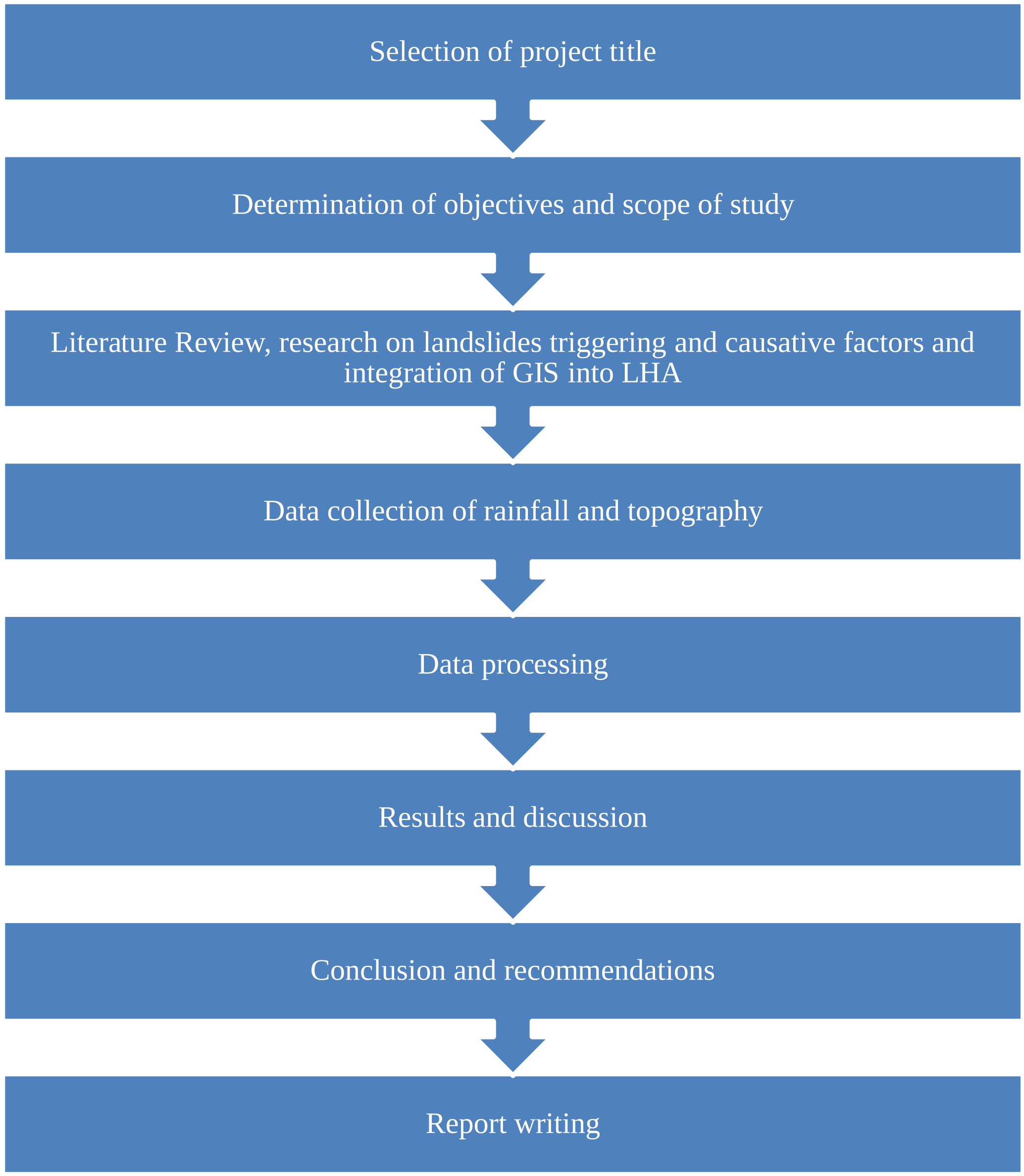
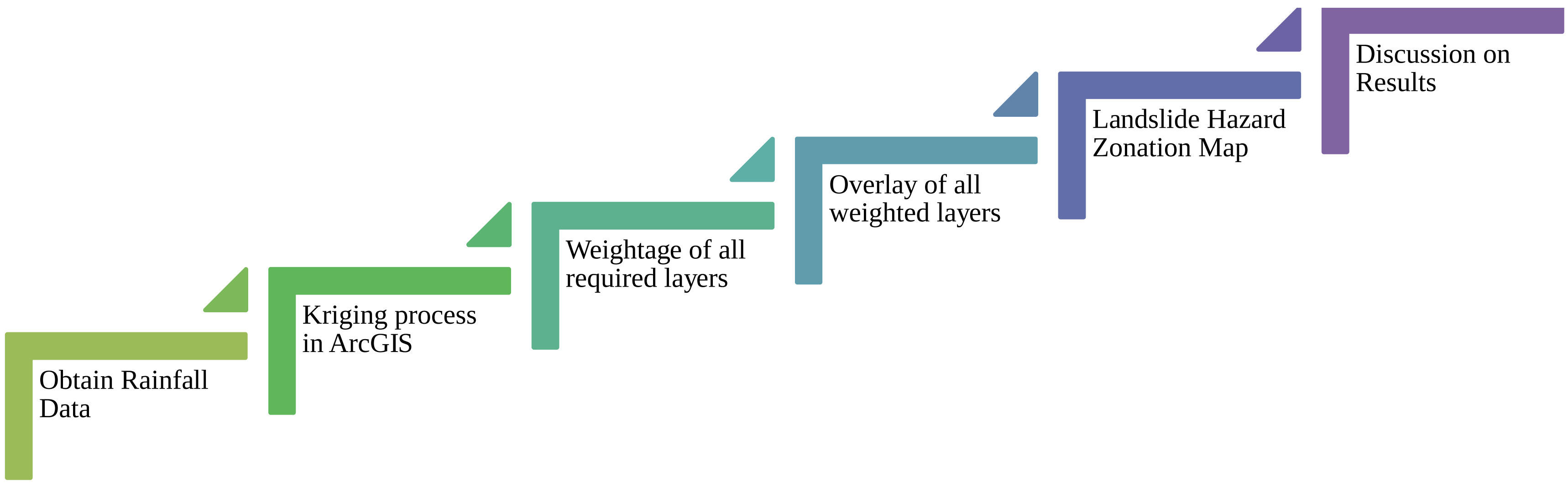


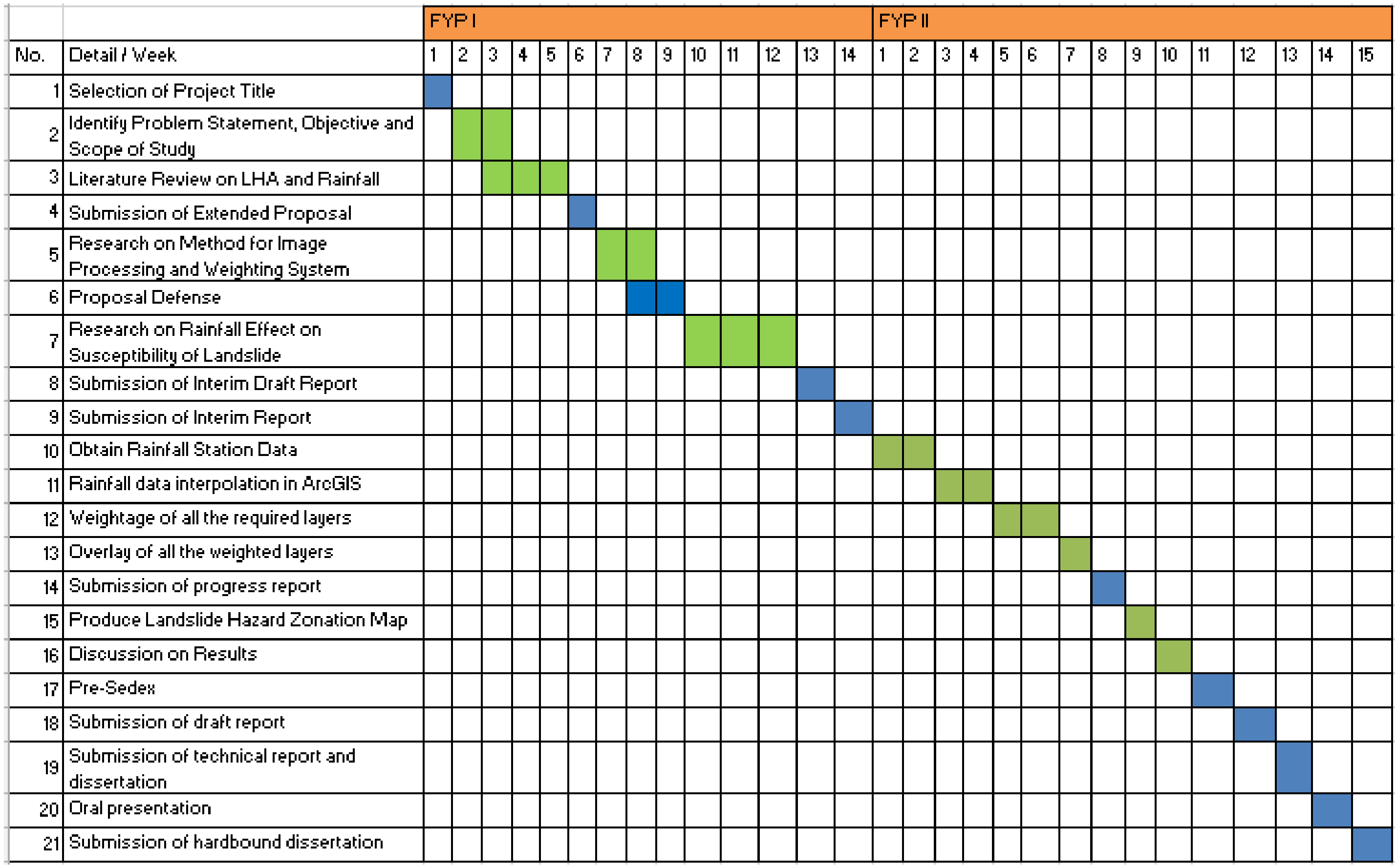
Figure 7: Research activities

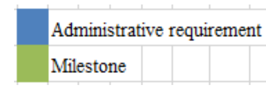
3.4 KEY MILESTONE FOR FYP 1

3.4 KEY MILESTONE FOR FYP 2



3.5 GANTT CHART





3.6 TOOLS REQUIRED

Software Use
• **Laptop pre-installed with Windows, Microsoft Office, Adobe Reader and ArcGIS 10**

3.7 LANDSLIDE HAZARD ASSESSMENT (LHA)

The title selected in Week 1 was "GIS based Determination of Landslide Location" to research about the Landslide Hazard Assessment (LHA). Based on the final output of this research, the objectives and the scope of work of this study was formed and after research through online journals and research papers, methodology was formed. The author determined the method for data processing which will be weighted and a color coded zonation map will be mapped, which will then be overlaid with other layers that has been weighted according to their characteristics that are susceptible to slope failure (Table 1). All the layers overlaid will be categorized according to the weightage system and a final output which is a hazard map will be developed. Based on the hazard map, the author will discuss about the results obtained and correlate the relationship between rainfall characteristics and landslide in Cameron Highlands.

3.7.1 Obtaining relevant data

Rainfall data are to be obtained from Department of Irrigation and Drainage (DID) and spatial data of Cameron Highlands. In order to be accurate, increasing the number of rainfall stations will increase the reliability of the results of this study. These data will be provided in text file which will be then put into excel spreadsheet with known coordinates that can be imported into ArcGIS software. These spatial reference must be provided with known coordinate reference system (CRS) in order to display the data in the correct location.

Another set of data that needs to be in place will be the Cameron Highlands topography data provided by JUPEM. Previously, studies have been conducted at the same place and so this study will reuse this set of data as the coverage area is the same. From this topography data, all the relevant layers in table 1 will be created.

3.7.2 Kriging

In the ArcGIS software, there are various mathematical model that can be chosen which includes spherical, exponential, Gaussian, linear etc. The rainfall count on 22 October 2013 was chosen to be processed in ArcGIS. This particular date was chosen because there was a heavy rain which caused mudflow in Cameron Highlands. This layer was processed using ArcToolbox available in the software.

Figure 8: ArcToolbox with Kriging option

3.7.3 Relevant layers weighted according to factor

In the table below shows the list of data that are going to be used in this study which also includes the sources of the data. All the data will be weighted according to Table 1 before being overlaid to develop the landslide hazard zonation map.

Type of data	Detail data	Scale/Resolution	Source
Topographic map	Slope Slope Aspect Road Map River lake map Curvature	1:25,000	Department of Survey and Mapping Malaysia
Geology Map	Rock type map Lineament map	1:100,000 1:100,000	Department of Geoscience and Mineral
SPOT 2 Images	Land use land cover (for updating land use land cover map)	20 m	MACRES
Land Use Land Cover Map (old version)	Land use land cover map	1:25,000	Department of Agriculture Malaysia
Rainfall Data	Point feature		Department of Drainage and Irrigation (DID)

Table 2: Type of data and Sources[8]

3.8 SUMMARY

This chapter has presented the methodology used in this research. Research methodology and project activities involved were elaborated earlier of this chapter. In addition, this chapter also outlined key milestone, Gantt chart and tools required. Detailed steps to conduct this study are also elaborated in this chapter. The results will be further discussed and recommendations on landslide hazard assessment and future work to be done will be proposed in the following chapter.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

In this chapter, the results from rainfall interpolation by kriging are discussed. The layers that are created from topography shape files are also included in the results section. In the last part of this chapter, the author will discuss future work that are to be done.

4.2 RESULTS AND DISCUSSION

Rainfall stations with their respective coordinates are first computed in excel spreadsheet in order to be able to be imported in ArcGIS. The latitude and longitude of each of the station must be converted into degrees, minutes and seconds into decimal by a simple calculation which is A+ (B/60) +(C/3600), where A is the degree, B is the minute and C is the second. The conversion of each station location are shown in table 3.

This table is then imported into ArcGIS and the station locations projected in Kertau Rectified Skew Orthomorphic (RSO) Malaya Grid (meters) due to the data set provided by JUPEM in that coordinate reference system (CRS). Figure 9 shows the JUPEM data that is provided with the station location overlaid on the layer.

The point data shows the rainfall station data that are provided by DID. The square shaded area shows the topography map provided by JUPEM. From this figure, the station location are of some distance from the JUPEM data set. Kriging will be done based on these locations of rainfall stations.

No	Location	Stn Id	Latitude	Longitude	Latitude (decimal)	Longitude(decimal)	Rain_22Oct (mm)
1	LDG. BOH (KAWASAN KILANG)	4414036	4 27 05	101 25 30	4.45138888889	101.425	69.5
2	LDG. BOH (BHG. BOH)	4414037	4 26 30	101 26 40	4.44166666667	101.4444444	80
3	LDG. BOH (BHG. SELATAN)	4414038	4 26 55	101 27 10	4.44861111111	101.4527778	52
4	MARDI C HIGHLANDS	4414040	4 27 00	101 25 12	4.45000000000	101.42	51
5	GUNUNG BRINCHANG di C.HIGHLANDS	4513033	4 31 00	101 23 00	4.51666666667	101.3833333	0
6	LDG. TEH SG. PALAS di CAMERON HIGHLANDS	4514032	4 31 00	101 25 00	4.51666666667	101.4166667	66
7	SRK S. KIJANG CNDRIANG at PERAK	4212128	4 16 00	101 14 20	4.26666666667	101.2388889	40
8	KUALA MEDANG at PAHANG	4218042	04 17 50	101 48 40	4.29722222222	101.8111111	47
9	KG. SAHOM at KINTA, PERAK	4312001	4 23 09.05	101 12 52.49	4.38584722222	101.2145556	25.6
10	KOLAM TAKONGAN at AIR GOPENG, PERAK	4411001	04 28 45	101 10 15	4.47916666667	101.1708333	50.5
11	GUA TEMPURUNG at KINTA. PERAK	4411120	4 26 03.40	101 11 26.99	4.43427777778	101.1908306	23.3
12	POLITEKNIK UNGKU OMAR at IPOH, PERAK	4511111	04 35 20	101 07 30	4.58888888889	101.125	16.5
13	BROOK at KELANTAN	4614001	04 40 35	101 29 05	4.67638888889	101.4847222	48.6
14	LOJING at KELANTAN	4614002	04 36 00	101 24 00	4.60000000000	101.4	33

Table 3: Stations Location and Coordinates with Rainfall Data

4.2.1 DATA PREPARATION

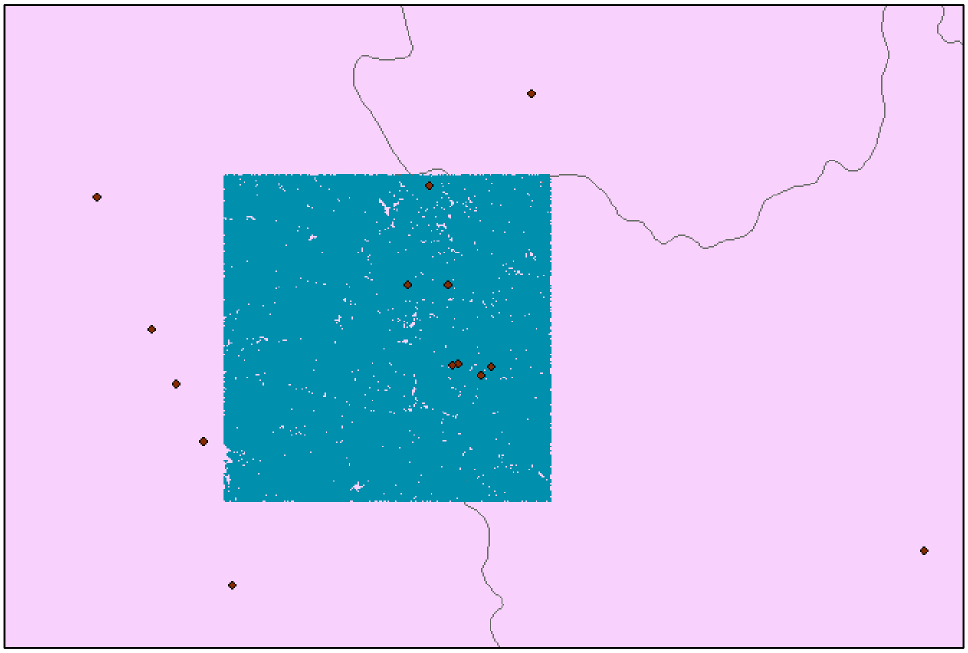


Figure 9: Station Location with JUPEM data

Figure 9 shows the rainfall stations data obtained from the DID together with the contour area provided by JUPEM. There are some rainfall stations located outside the square area. This is to ensure the interpolated area of rainfall will be within the intended covered area.

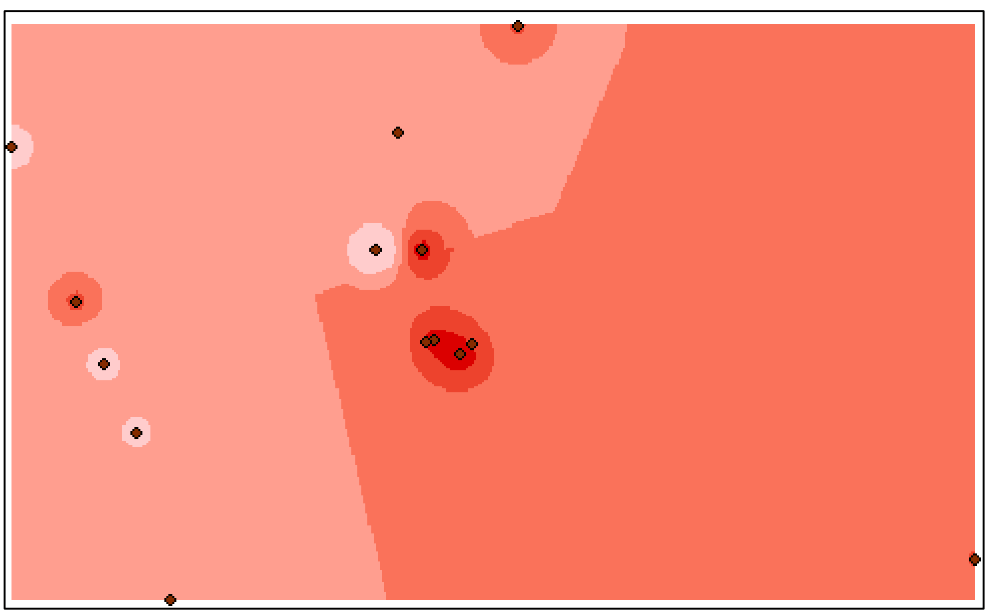


Figure 10: After Kriging of Rainfall Stations

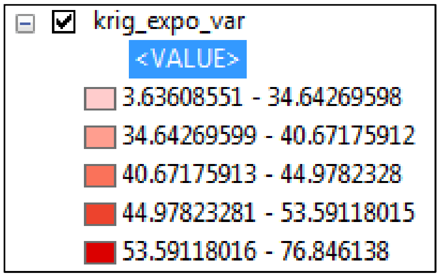


Figure above shows the color coded zones after kriging process in ArcGIS. The figure on the left explains the color and the values of each of the color represented in Figure 11**.** As observed, most of the covered area are ranges between approximately 35 to 45 mm.

Figure 11: Color Code and Value

Layers are also created from the topography data sets provided by JUPEM by extracting the contour lines.

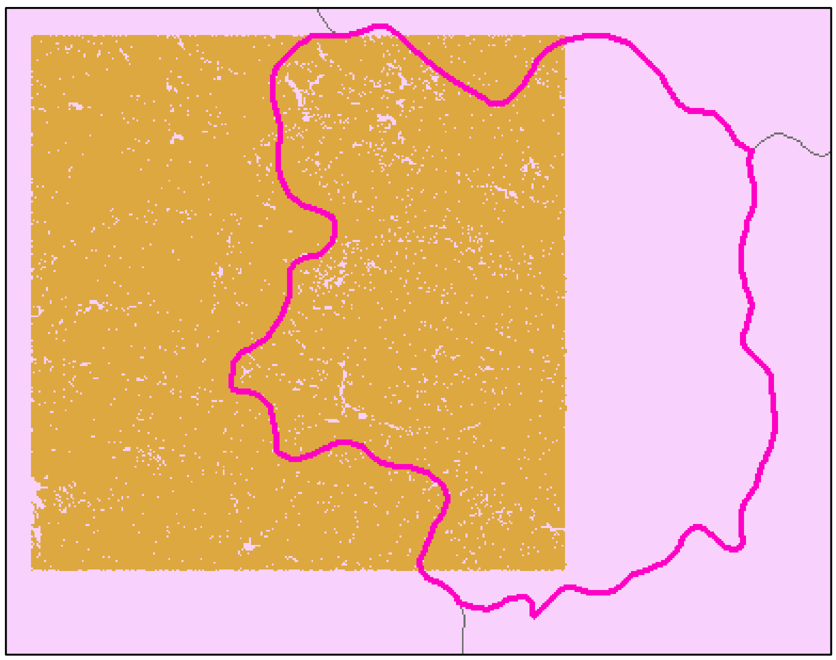


Figure 12: Contour lines

With the contour extracted, slope aspect, slope, curvature, elevation layers can be processed by using the ArcToolbox available in ArcGIS which is categorized under the Spatial Analyst Toolbox.

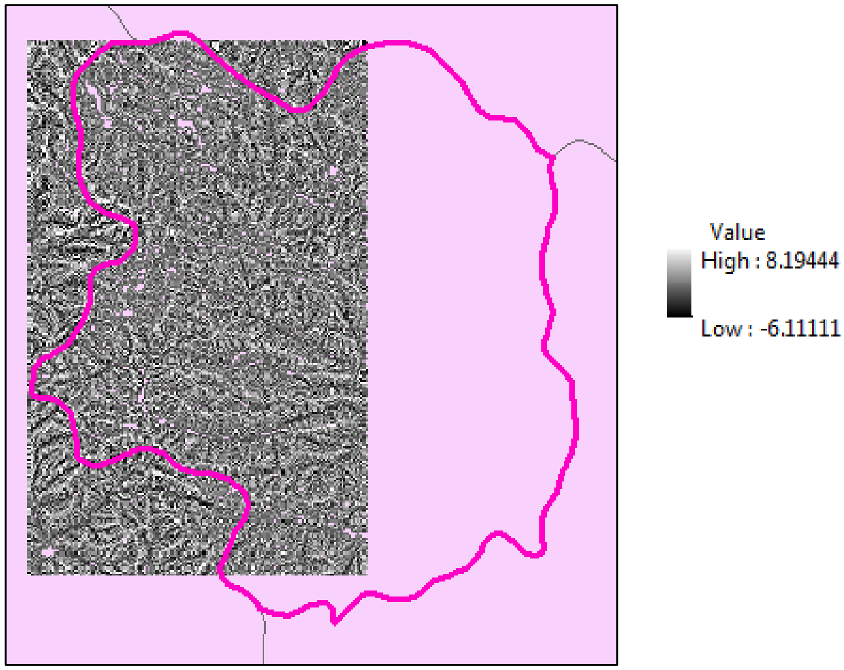


Figure 13: Curvature layer

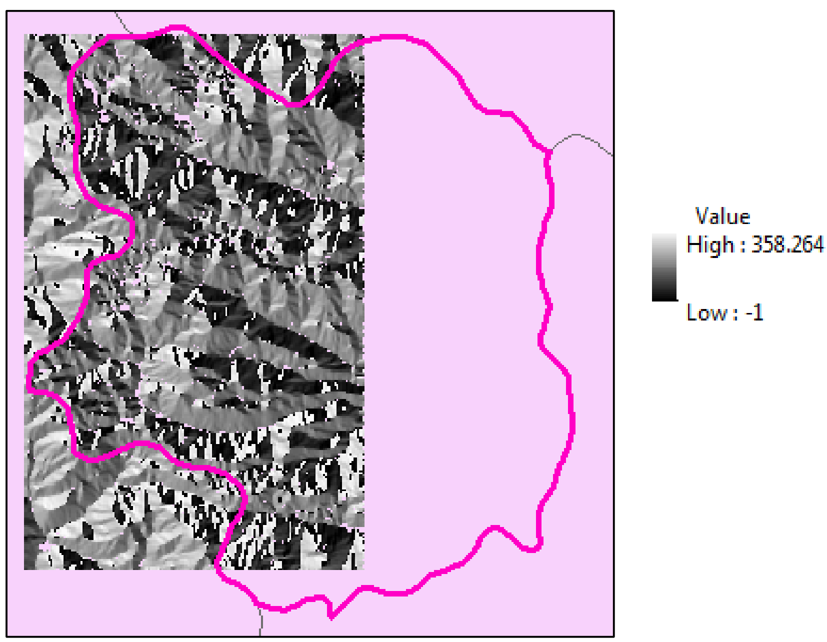


Figure 14: Slope Aspect Layer

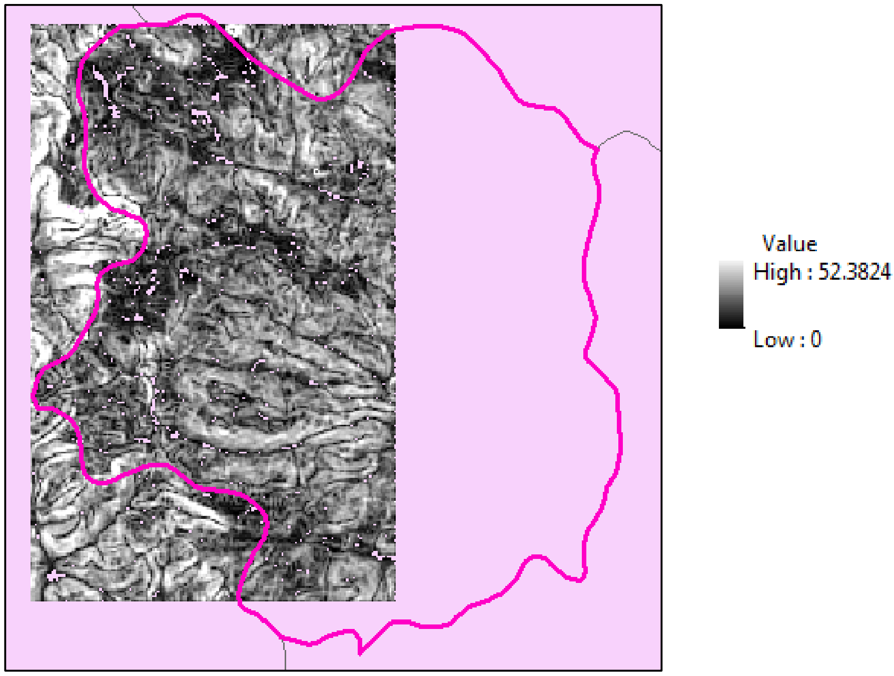


Figure 15: Slope Layer

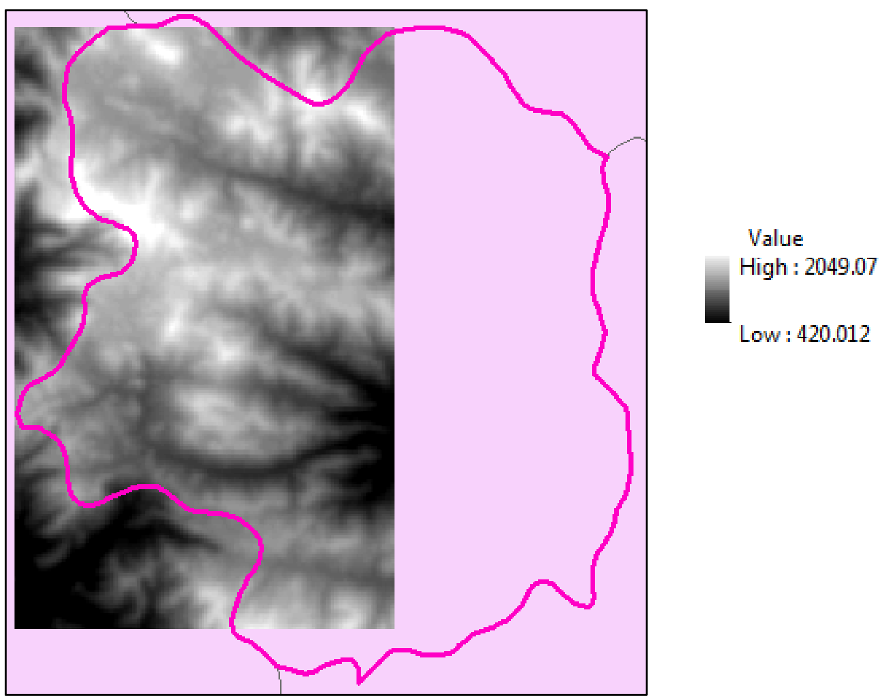


Figure 16: Elevation Layer

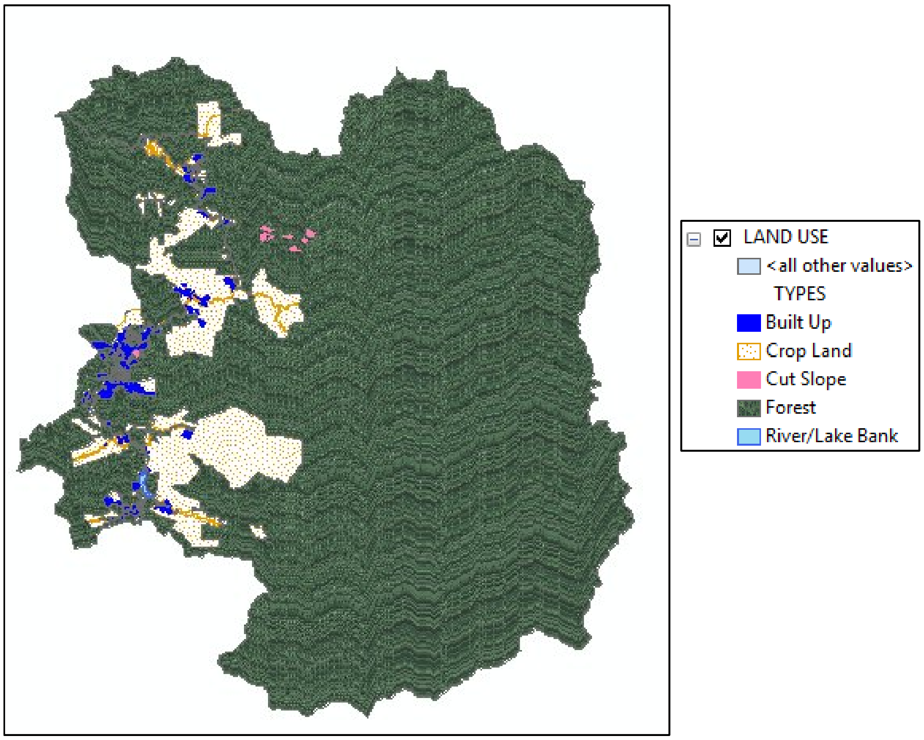


Figure 17: Land Use Land Cover (LULC) Layer

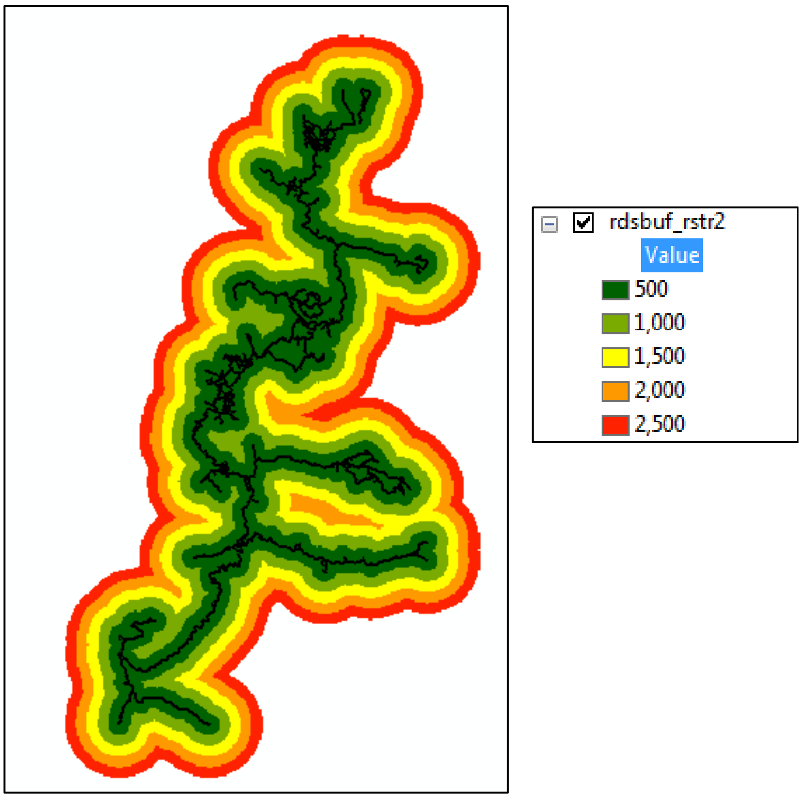


Figure 18: Roads after Buffer

The main roads of Cameron Highlands were buffered for 500 m, 1000 m, 1500 m, 2000 m and >2000 m. This buffer is considered as a code of practice in the industry to not build anything within the buffer zone in order to prevent slope cutting and man activities.

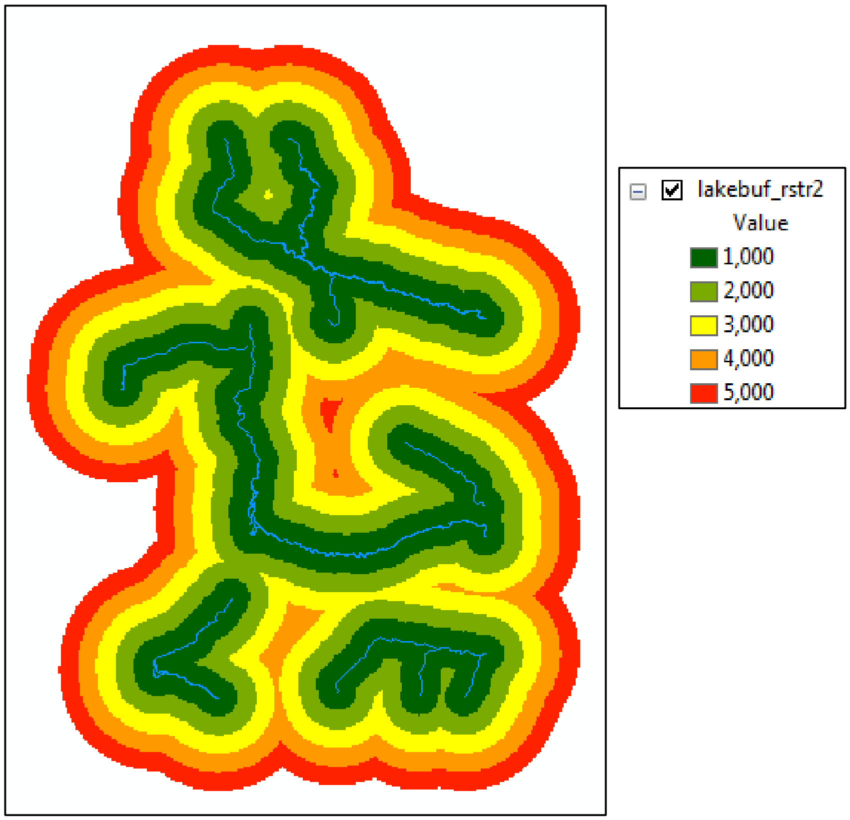


Figure 19: River/Lakes after Buffer

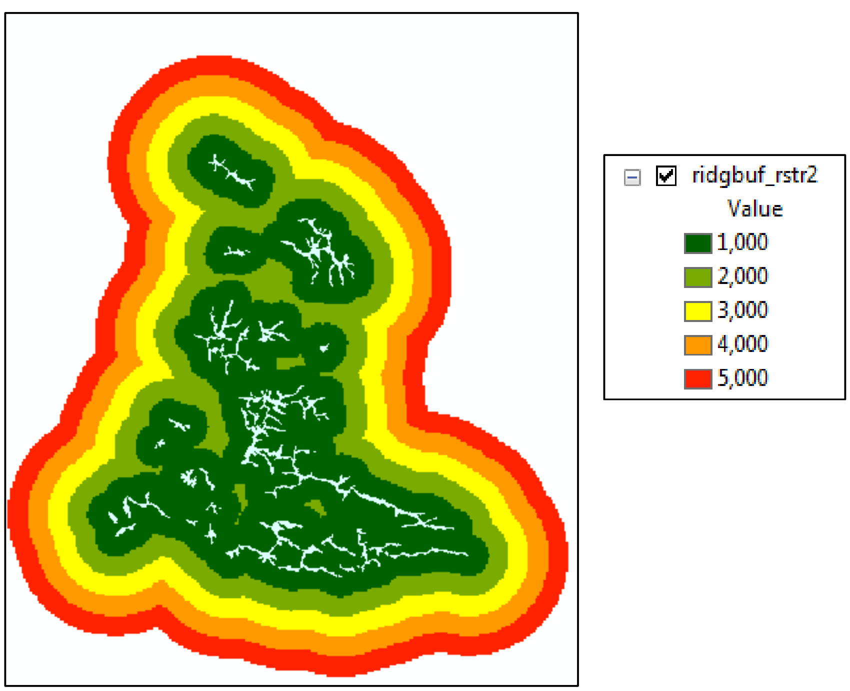


Figure 20: Lineament after Buffer

The same processes were done to river/lakes and lineament layers except the buffer distance was increased to 1000 m for every increment. It is most important in the first 1000 m from the rivers because it is where usually soil erosion and slope failures occurs. As the distance gets further away from the lineament or rivers/lakes, the risk decreases.

4.2.2 WEIGHTED OVERLAY ANALYSIS (ARCTOOLBOX)

After preparing all these data that are needed to be used for the overlay function in the ArcToolbox, the overlay action is then performed. In this analysis, all the factors involved are set to be of equal influence and the evaluation scale is of 1 to 5 as the weighting system involves five classes.

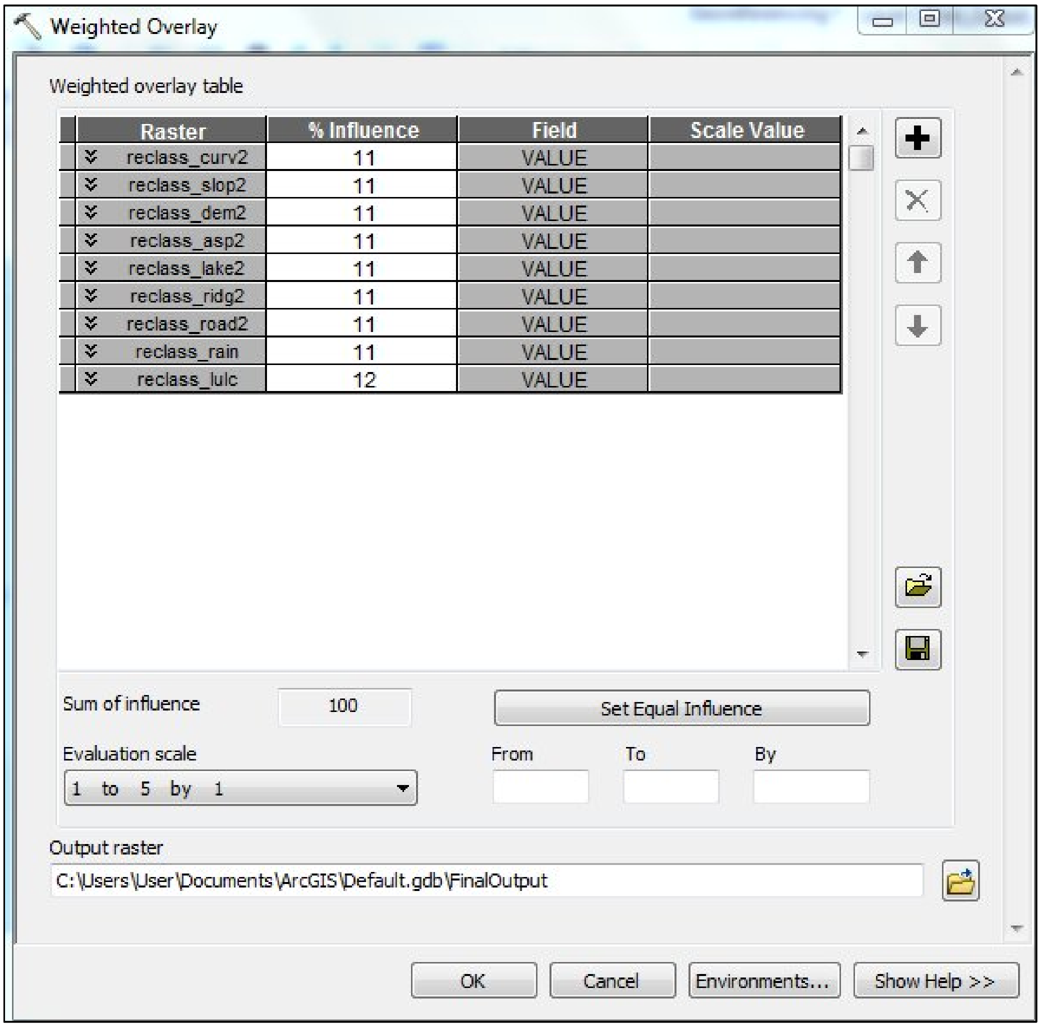
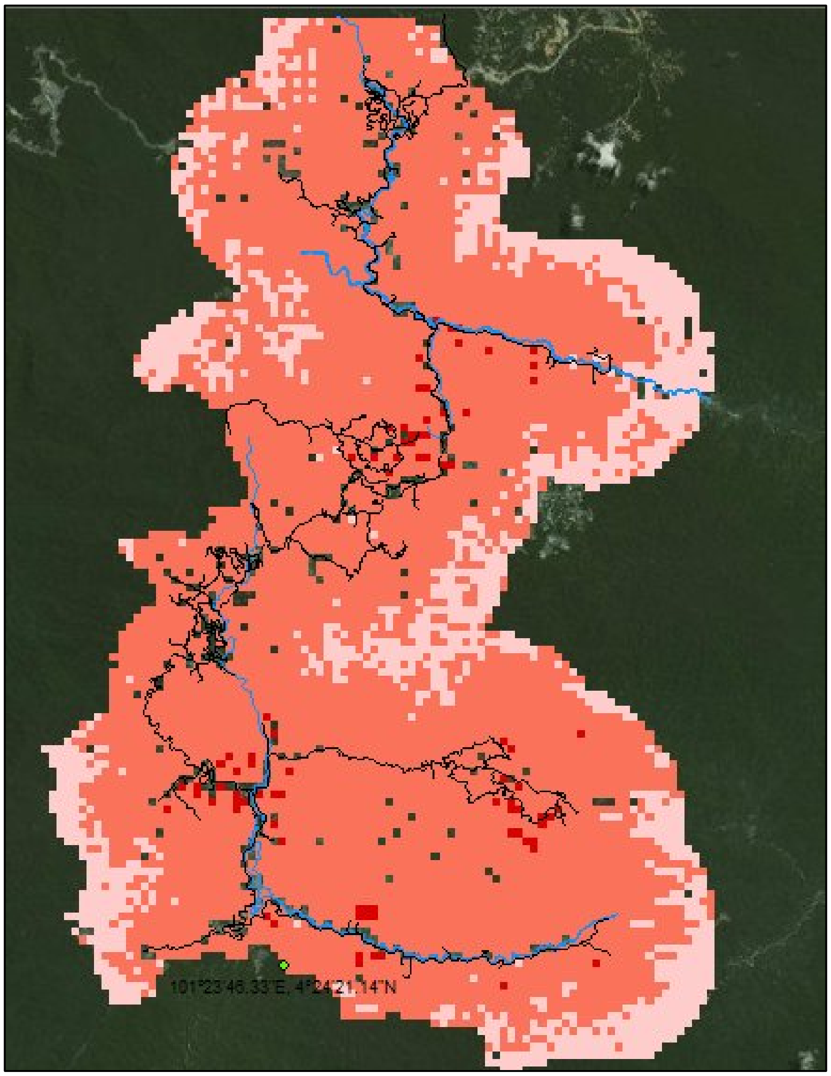


Figure 21: Weighted Overlay Toolbox

It is important to note that this tool only accepts raster as input, thus all data processed need to undergo another operation of conversion into raster. The influence of each factor can be set according to the user's command as long as the sum is 100 in percentage. If the sum of influence does not equal to 100, the system will show a warning to the user to change in order to proceed for analysis. There are a few scale values available in the system such as 1 to 9 by 1, 1 to 3 by 1 and -10 to 10 by 2. In this study, it is only set to 1 to 5 by 1. Nonetheless, users are free to assign the scale by themselves as seen in Figure 21.

4.3 FINAL



OUTPUT

Figure 22: Final Output

Figure 22 shows the final output of the weighted overlay with roads and rivers added to the figure. The full map is shown in the appendix. The system only takes into account the areas that are covered by all the factors and disregards the areas that are of no data. There are mainly categories of susceptibility to landslides, which are light pink (low risk), peach (medium risk) and bright red (high risk). From the figure, it can be clearly seen that the medium risk dominated most of the areas in Cameron Highlands. This final output is mapped based on the rainfall data on 22nd October 2013 when there was a mudflow to have reportedly happened. The highest rainfall amount recorded was 80 mm whereas the lowest amount was 0 mm. This is a significant difference given the period of recording and day were the identical.

On the mapped area also is observed to contain a green point (coordinates: 101°23'46.33"E, 4°24'21.14"N) which is the area of Bertam Valley where the reported mudflow has happened. Despite the confirmed news that there was a mudflow, the system did not manage to detect the high risk area susceptible to landslide. This could be due to the extra water released from a nearby Sultan Abu Bakar dam on the same day. Given the heavy rainfall amount and water released from dam, the mudflow was triggered.

The rainfall characteristic which is the amount (mm), is generally a triggering factor for a landslide to happen when the rest of the factors are constant. The bright red indicating high risk to landslide were focussed on areas where there are high amount of rainfall.

4.4 RECOMMENDATIONS

4.4.1 RAINFALL INTERPOLATION

In appendix, there are maps of inventory list of rainfall gauges installed in Perak, Kelantan and Pahang. From the maps, there are lower number of rainfall gauges installed around Cameron Highlands.

In order to improve rainfall interpolated values, the number of data must be increased. However, this is not the effort of a researcher alone. The data must be made available. Having known the study area is a hilly and sloppy area, it is understood that the gauges are difficult to install in these places. For further researches to be conducted in Cameron Highlands, it is recommended to get as much details and information on rainfall from the DID.

Another improvisation on the rainfall interpolation is more research should be done on the suitable semivariogram model for Cameron Highlands. As mentioned in the literature review, Kriging is divided into two main branches, namely Ordinary and Universal Kriging. Since Ordinary Kriging was used, recommendations will be done according to the Ordinary Method only. In Ordinary Kriging, there are various semivariogram models made available which includes exponential, spherical and linear.

It is advised that in order to find the suitable semivariogram model that should be used in Cameron Highlands, researches should be conducted and to compare with real time data that is collected from DID. In this manner, the method can be verified and future works that are related to this common area or characteristics can adapt the same methodology of interpolation.

4.4.2 RAINFALL PREDICTION USING IMAGE PROCESSING

Obtaining rainfall over the area can be done through many ways. This is just one of the way. There is also another method of predicting rain by using image processing. The images that are being used in this particular method is consecutive radar images captured by the radar at every interval depending on the radar operation. These consecutive images could be used to predict the rainfall amount and to use these figures to simulate if landslides will occur at these amount of rainfall.

However, in this method, the data provided plays an important role as coding would not manage to read each of the pixels if there are disturbances underlying the images such as the state boundary. It is important that only base reflectivity of radar to be read in the images. These images are considered as raw images before being processed.

4.5 SUMMARY

This chapter has presented the results from overlay analysis and the results were further discussed and elaborated. Besides that, the author has proposed several measures to improve future work to be done in this research. The following chapter will contain conclusions of this research and recommendations proposed by the author.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter presents conclusions of this research that includes recap of problem statement, objectives, methodology and results from overlaying analysis in GIS. The later part of this chapter presents measures and recommendations proposed by the author to improve future work to be done in overlaying analysis.

5.2 CONCLUSION

Landslide has always been one of the natural disaster that takes lives and destroys properties. It could be triggered by certain factors and in tropical countries such as Malaysia, rainfall would be assumed as the triggering factor of a landslide. This research focuses on developing a qualitative landslide hazard map in Cameron Highlands.

The author also discussed the causative and triggering factors of a landslide, and also particular factors that are included in this research which includes rainfall, slope, slope aspect, elevation, curvature, distance from road, distance from river/lake, distance from lineament and land use land cover. The triggering factor in this study will be mainly rainfall[6].

It was then followed by determination of method for data processing which will be weighted and a color coded zonation map was mapped, which was produced after overlaid with other layers that has been weighted according to their characteristics that are susceptible to slope failure as presented in Table 1. The results were presented and discussed followed by recommendations suggested by the author. This work could serve as a basis for future researches to be done on this area.

GIS is a powerful tool that engineers should utilize in order to conduct hazard assessment such as landslides. With the advancement of technology, GIS made work done on paper in the past, possible to be done on computers and a database could be kept for updating and control.

5.3 SUMMARY

This chapter has presented conclusion including recaps from previous chapters. This research examined the application of GIS in LHA; identified the problems and defined main objectives for this study; determined the methodology to use for rainfall interpolation; discussed the results and lastly proposed recommendations to improve for future work. The findings from this paper could serve as a basic framework to be used in the near future to conduct LHA and produce LHZ map for Cameron Highlands, Pahang.

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APPENDIX

Location	Station ID	Rainfall on 22 October 2013 (mm)
LDG. BOH (KAWASAN KILANG)	4414036	69.5
LDG. BOH (BHG. BOH)	4414037	80
LDG. BOH (BHG. SELATAN)	4414038	52
MARDI C HIGHLANDS	4414040	51
GUNUNG BRINCHANG di C.HIGHLANDS	4513033	0
LDG. TEH SG. PALAS di CAMERON HIGHLANDS	4514032	66

SRK S. KIJANG CNDRIANG at PERAK	4212128	40
KUALA MEDANG at PAHANG	4218042	47
KG. SAHOM at KINTA, PERAK	4312001	25.6
KOLAM TAKONGAN at AIR GOPENG, PERAK	4411001	50.5
GUA TEMPURUNG at KINTA. PERAK	4411120	23.3
POLITEKNIK UNGKU OMAR at IPOH, PERAK	4511111	16.5
BROOK at KELANTAN	4614001	48.6
LOJING at KELANTAN	4614002	33

Table showing the rainfall amount at each rain gauge station