

Landslide susceptibility mapping using GIS and Remote Sensing: A case study of the Rangamati District, Bangladesh

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Abstract

The landslide is a natural phenomenon and one of the most commonplace disasters in the Rangamati Hill tract area which appeals for better forecasting and specify the landslide susceptible zonation. This research work examines the application of GIS and Remote Sensing techniques based on different parameters such as altitude, slope angle, slope aspect, rainfall, land-use land-cover (LULC), geology and stream distance by heuristic model to identify the landslide susceptible zones for the study area. Among the parameters, rainfall, steep slope, geology and LULC are the dominant factor that triggering the landslide. Clayey or silty soils of the study area during heavy and prolong rainfall behave a flow of debris due to water pressure within the soil, resulting landslides. Steep slope has greater influences for weather zones of the rock-masses for susceptible landslides. Result and field observation indicate that the population density and LULC has a vital effect on landslide within the study area. However, landslide susceptible zones were created based on the susceptibility map of the study area which shows that about 19.43% of the area are at low susceptible zone, 56.55% of the area are at medium susceptible zone, 19.19% of the area are in the high susceptible zone and 4.81% of the area is at the very high susceptible zone.

1. Introduction

The landslide is a common natural phenomenon which a slope collapses abruptly due to weaken self-retain the capability of the earth under the influence of the gravitational force. It causes for the orientation of bedding planes, slope steepness, water and drainage, soil composition, vegetation, joints and fractures and by the sudden tremors (Islam and Rahman 2019). Some other reasons that contribute to the slope failure are the high shear stress, lack of lateral support or removal of support, weathering and low intergranular force due to seepage pressure (Islam and Rahman 2019). A series of landslide in the Rangamati area in the recent years indicated that there was a progressive time of occurrence between two consecutive landslides. However, surprisingly, in the recent past, the trend and frequency of landslides in this region are found to be increased within a short while, which were triggered by extensive rainfall (Khan 2008, Islam, Hussain et al. 2014). Spatial variability in landslide susceptibility can be influenced by topography and forest cover characteristics (Daniel and Kelly 2007). It also controlled by numerous factors such as soil depth and geotechnical properties (Hammond 1992, Wu 1996) and spatiotemporal variability in landslide triggered by the rainfall intensity (Mark and Newman 1988, Daniel and Kelly 2007). Usually, spatial variations in soil type, slope angle and initial water content on rapid rainfall induced shallow landslide at the hill slope (Fan, Lehmann et al. 2016). In the most cases in the study area, flow-type failures occur within a slow-moving landslide mass due to the generation of excess pore water pressure, which may be the result of deformation of the landslide body during motion (Asch and Malet 2009). Moreover, the rapid population growth and eventually rapid urbanization fosters, unplanned land use practices and obviously illegal hill cutting which is the collective facts for enhancing the vulnerability of landslides in this locality (Khan, Lateh et al. 2012, Islam, Hussain et al. 2014, Islam

and Rahman 2019). In 2017, there were hundreds of homes have been buried in mud and rubble, including over 5,000 homes in the Kawkhali Upazila of Rangamati District (Islam, Islam et al. 2017).

Over the last few decades, Geographic Information System (GIS) has become an essential tool in landslide hazard and risk assessment. Landslide susceptibility mapping can make available much of the basic information needed for hazard mitigation through proper project planning and implementation. Landslide susceptibility can be defined as the probability that a landslide will occur in a specific area in the future and can be measured by the correlation between responsible factors and the spatial distribution of landslides (Brabb 1984, Dai and Lee 2002). Usually the landslide susceptibility maps have been inaugurated using different GIS based methods and statistical analysis, such as the analytical hierarchy process (AHP), frequency ratio, bivariate, multivariate, Logistics regression, fuzzy logic, and artificial neural network (Matori, Basith et al. 2012). However, landslide susceptibility mapping could projection the causes of landslide. In order to forecast and specify the region where future land failure is likely to happen, it is necessary for mapping the landslide prone areas (Althuwaynee, Pradhan et al. 2012).

Away from the influence of aforementioned major factors on the spatial distribution of landslides, land use and land cover (LULC) are also a significant factor in the landslide susceptibility assessment (Guillard and Zezere 2012). It is a proxy variable, is very dynamic over time and is influenced by climate-driven changes and direct anthropogenic impacts (Promper, Puissant et al. 2014). Now-a-day, the use of remote sensing and geographic information system techniques are valuable tools for spatiotemporal analysis of LULC (Wang, Zhang et al. 2014, Nampak, Pradhan et al. 2018). Definite LULC changes (e.g., deforestation, slope ruptures to road construction, steep slopes) surges the number of unstable slopes (Reichenbach, Busca et al. 2014), i.e., supporting the tendency for landslide occurrence, and can have an important impact on landslide movement (Glade 2003, Beguería 2006, van Westen, Castellanos et al. 2008, Mugagga, Kakembo et al. 2012, Persichillo, Bordoni et al. 2017, Meneses, Pereira et al. 2019). Considering the extreme causalities occurred in recent time in the Hill tracts, especially in the Rangamati area due to landslide, this study aims to assess the high susceptible zone for landslide and analyze the multifarious issues involves in a landslide using GIS and remote sensing technique.

2. Study Area

The Rangamati is a district located in southeastern part of Bangladesh (Fig. 1). The study area a part of the Arakan Yoma anticlinorium produced by eastward subduction of the Indian plate beneath Burmese sub-plate within the Bengal Basin (Steckler, Mondal et al. 2016). The eastern part exhibiting more folding and thrusting than west. Area-wise, the Rangamati is the largest district of the country which is bounded by the Tripura State of India on the north, Bandarban district on the south, Mizoram State of India and Chin State of Myanmar on the east, Khagrachhari and Chittagong Districts on the west. The Rangamati District is located between 22°27' and 23°44' northern latitudes and in between 91°56' and 92°33' east longitudes.

3. Methodology

Heuristic model is used to establish the susceptibility mapping of landslide. To prepare the landslide susceptibility mapping following 9 data layers have been used to complete the whole work (Table 1).

For landslide susceptibility mapping, two techniques have followed:

3.1 Analytical Hierarchy Process

The Analytic Hierarchy Process (AHP) is a chronic process to operate intangible criteria in the decision making process (Saaty 2008). It is a multi-objective, multi-criteria decision making approach that is based on the idea of pairwise comparisons of alternatives with respect to a criterion. The primal factors are coming out while conducting the pairwise comparison matrix.

3.2 Weighted Overlay Method

Weighted overlay is a technique (resources.esri.com) where multifarious raster data layers are integrated in such a way where rasters can be grouped into different ranges and the reclassify tool allows for such rasters to be reclassified. The output rasters can be weighted by importance and added to produce an output raster. Reclassified data layer is multiplied by the weighted value and thereby final overlay mapping has done.

In AHP, for making comparisons, we need a scale of numbers that indicates how many times more important or dominant one element is over, another element with respect to the criterion or property with respect to which they are compared (Tables 2 and 3).

This method combines the following steps:

- Cell values of each reclassified criteria have multiplied by the raster's weight of importance
- The resulting cell values are added together to produce the output raster

$$\text{Output} = (\text{Reclass_Rainfall}) \times (.302) + (\text{Reclass_Slope}) \times (.254) + (\text{Reclass_Altitude}) \times (.208) + (\text{Reclass_LULC}) \times (.076) + (\text{Reclass_Aspect}) \times (.062) + (\text{Reclass_Geology}) \times (.062) + (\text{Reclass_Stream_Distance}) \times (.042)$$

4. Result

4.1 Rainfall

Upper north and central west and lower part of the study area have high precipitation (Fig. 2). From the analysis of GIS data, 22% of the area is at very high risk and about 53% of the area are at high risk of landslide. The average precipitation is high in the study area compared to the normal range of precipitation. The weight value of rainfall is 30.2 indicates that rainfall is highly significant for landslide (Table 4).

4.2 Geology

The rock materials of the area covered by Siltstone with subordinate shale and sandstone, Silty and sandy shale Sandstone and sandy shale (Rank 5) based on geological time scale named as Bhuvan formation which is more susceptible to landslide. The Boka Bill formation (Rank 2) which has resisted rock materials like well bedded siltstone and shale with subordinate sandstone which is less risk for landslide (Fig. 3). Results (Table 5) show that about 34% of area covered by Bhuvan formation which is highly risky of landslide. Only 20% of the study areas are less susceptible of landslide in terms of geological formation. Most of the area is medium susceptible of landslide according to the geological formation of the study area (Table 5).

4.3 Slope angle

From the analysis of GIS it is revealed that the southeastern part of the Rangamati District like Belaichari, Juraichari and the north and northeastern region like Baghaichari which shows a higher degree of slope than the rest of the area (Fig. 4). It has found that 26% area having slope of $< 10^\circ$. About 31% area has slope of 10° to 25° . 23.91% of area having 26° to 30° , 17% of the area having slope of $> 35^\circ$ slope. The weight value of the slope is 25.4 means, among of criteria slope is highly significant in landslide vulnerability (Table 6).

4.4 Altitude

Based on GIS data it has found that the altitude of the study area varies from 50 m to 900 m and average altitude of Rangamati District is about 610 m. Nearly 44% of the study area has altitude about 146 m to 576 m or more in range (Fig. 5). It has revealed that about 31.30 percent of the area having greater than 73 meters Altitudes. About 10 percent area has greater than 576 meter high altitudes. It is said that about two-third of the area having medium to high risk of landslide (Table 7).

4.5 Aspect of the slope

The aspect map above is west facing slope is dominated. The nature of the slope is down slope movement. That's why the shades in the map are mostly light green (Southeast), light blue (South) and blue (Southwest). Soil temperature was only slightly higher in the west facing slope, and warmer soil only partly explained the large difference in soil respiration between east and west facing slopes (Fig. 6). The result of the study shows that 14.61% of the area is flat means no slope. However, about 29% of the area northwest and northeast facing slope of higher degree which is risky for a landslide. The weight value of aspect is 6.2 indicates aspect is medium significance for landslide (Table 8).

4.6 Stream Distance

The drainage density reveals the closeness or spacing of stream channels. The density of river/stream plays an important role in the occurrence of landslide incidence. Most of the landslide is found near to river valley caused by the steepness of river valley due to erosion work of the river. Stream Distance classes are divided into five categories (Fig. 7; Table 9).

4.7 LULC

From the analysis of GIS (Fig. 8), it is revealed that the middle part of the Rangamati District like Kaokhali, Kaptai, Rangamati Sadar are densely populated area and the north and northeastern region like Baghaichari which shows high susceptibility of landslide than the rest of the area (Fig. 8). It is found that (Table 10) 8% of the total area covered by water and dense hill forest area are about 12%. Fallow land with light vegetation is covered by 53.07% and about 22% of area are agricultural land and 6% area is highly populated area. Out of 100, weight value of LULC is 7.6 indicates LULC is medium significance for a landslide.

4.8 Susceptibility map

The percentage of area under each susceptibility class in the district is displayed in (Table 11). It is shown that areas with very high landslide vulnerable zones in the northern, central west and southern parts of the Rangamati district (Table 11). Comparatively eastern and central eastern parts are very low vulnerable areas. Moreover, risk zones created from the susceptibility map of Rangamati district implies that 19.43% of the area are at very low risk zone, 24.79% of area are at low risk zone, 31.76% of the area are at medium risk zone, 19.19% of area are at high risk zone and 4.81% of the area are at very high risk zone (Fig. 9). About 43% areas are characterized by steep slopes (more than 30° slopes) which are more vulnerable to landslide.

Approximately 60% area of the study is poured with more than 2500 mm rainfall annually, which is a leading factor of landslide. From landslide susceptibility map it has found that most risky area is the urban area of Rangamati Sadar where the density of population and number of settlements is high. Another risk area is Kaptai due to having high altitude, soil properties having favorable characteristics for landslide, high rainfall and stream distance is very low.

5. Discussion

Different literary works have been done on landslide susceptibility of the Chittagong metropolitan area, Rangamati and some parts of the Chittagong Hill tract area. Several methods and causative factors have also been considered by authors to find the high risk area of landslide. Landslide in Rangamati District triggered by several factors such as rainfall, slope angle, slope aspect, vegetation, land use, geology, elevation, distance from the drainage and road (Huq and Hoque 2012). Major findings of (Huq and Hoque 2012) are that Kawkhali, Rajasthali, kaptai, and Rangamati Sadar Upazilla, are the most landslide hazard-prone upazilla as 44% of its area are highly susceptible to landslide occurrence. Kaptai Upazila, Vedvedi, Amtali Union, Manikchari, Reserve Bazar areas of Rangamati Sadar Upazila are landslide prone, caused by the hill cutting (22%), weak soil structure (1%), de-vegetation (4%), heavy rainfall (21%), steeper hill (4%), house construction (6%), earthquake (12%) (Kafy, Hasan et al. 2017). Moreover, field observation indicated that human life was ruined due to landslide in Rangamati district, which is very alarming. Several causative factors and geotechnical properties of soil has been taken to assess the susceptibility of landslide in Rangamati from previous study (e.g., (Kafy, Hasan et al. 2017)). However, this research

work done by an analytical hierarchy process, whereas the various data layers overlaid through weighted overlay method based on primary data (rainfall, slope angle, aspect, geology, altitude, distance from the stream and LULC).

Since the soil movements are influenced by numerous parameters, however, scientific and technical studies (e.g., (Xie, Esaki et al. 2004, Chang, Chiang et al. 2008, Pradhan and Lee 2010) suggest that rainfall is one of the important triggering factor that causes landslides. The effect of rainfall infiltration on slope could result in the changing soil suction and positive pore pressure, as well as raise the soil's unit weight, reducing anti-shear strength of rock and soil (Wilson and Dietrich 1987, Premchitt, Brand et al. 1994, Iverson 2000, Hengxing, Chenghu et al. 2003). The main causes of such phenomenon seem to be prolonged rainfall events of medium intensity or extreme intensity. Rainfall data (**Appendix 1**) show that the rainfall (About 3000 mm/yr) in the study area is greater than the average rainfall of the country (1030 mm/yr). Moreover, frequency of rainfall (Fig. 10) in the past decades evident the influence of landslide by rainfall. However, rainfall distribution within the study area is unique. Almost 60% area of the study is poured with more than 2500 mm rainfall annually, which seems a leading factor of landslide. Most of the landslide movements were reported in the study area during monsoon rainfall. The rainfall in the upper north and central west and lower part of the study area has higher precipitation than the rest of the areas (Fig. 2). GIS data analysis indicates that about 22% of the area is at very high risk and about 53% of the area are at high risk of landslide (Table 4).

The present study indicates that about 34% of area covered by the Bhuban Formation, consisting of siltstone with subordinate shale and sandstone, silty and sandy shale, sandstone and sandy shale (Reimann 1993) which is highly risky of landslide (Fig. 3). A significant portion of the study is exposed with the Boka Bill Formation, which has resisted rock materials like well bedded siltstone and shale with subordinate sandstone (Reimann 1993) which is less risk for landslide (Fig. 3 **and** Table 5).

The steep slopes are usually susceptible for landslide and considered as a life-threatening. This kind of slope surface occurs when a mixture of soil and slope factors produce a high potential for slope face failure and successive erosion simultaneously (Islam, Hussain et al. 2014). Over-steepened or troubled slopes are considered critical when resistance to surface erosion is low and shear strength, resistance tolerances are exceeded (David 2008, Islam, Hussain et al. 2014). The potential for slope face failure of the slope can be compounded with poor slope face compaction under super saturated conditions. The study area is comprised of semi-consolidated to consolidated soil of the Bokabil and Bhuban Formation with numerous joints and faults. These two formations consisting of a huge amount sand and shale (clay). The shale is very hard and show greater cohesion at dry condition while it shows the flow like nature in wet condition. Due to the steep slope angle, the study area is prone to landslide during the rainy session. Another reason is that while interbedded clay layer within the sandy Bokabil Formation, might induce rockfall/slide the greater volume of rock-masses/chunks causing devastating landslide. However, the weathered zones with steeper slope (greater than the angle of internal friction) is always susceptible to landslide. Visual inspection confirmed that Chittagong-Rangmati road-cut section near Manikchari due to barred after hill cutting. In some areas, where faults or joints are exposed above the toe of slope is also

vulnerable for sliding. Our analysis using GIS technique is revealed that the southeastern part of the Rangamati District like Belaichari, Juraichari and the north and northeastern region like Baghaichari having a higher degree of slope than the rest of the area (Fig. 4). Field observation indicates that most of the locations of previous landslide have slopes greater than 65°. Analyses are also evident that 26% area having slope of < 10°. About 31% area has slope of 10° to 25°. 23.91% of area having 26° to 30°, 17% of the area having the slope angle of > 35° (Table 6).

The soil of higher altitudes has highly susceptible to weathering and erosion. Due to the higher altitude less vegetation cover than the lesser part of the hill. In this instance, less root coverage within the soil, reducing the shear strength of soil resulting produces many cracks/fractures in the rock-masses. Areas of higher altitude have less moisture/water content influences the lowering of cohesive force within the soil resulting landslide. Soil type and soil depth are both closely connected to landscape positions. The upslope area is generally associated with coarser textured material, whereas fine textured material is more likely to accumulate at lower landscape positions (Kleiss 1970, Malo, Worcester et al. 1974, Roy, Jarvis et al. 1980, Ovalles and Collins 1986). When regions of high initial water content overlap with coarse soil, the possibility of the formation of weak spots is enriched and landslide triggering is accelerated; whereas imposing a dry condition of coarse soil, the probability to form weak spots are reduced and landslide initiation will be postponed (Fan, Lehmann et al. 2016). GIS data indicate that the altitude of the study area varies from 50 m to 900 m and average altitude of Rangamati District is about 610 m. Nearly 44% of the study area has altitude about 146 m to 576 m or more in range (Fig. 5). About 31.30 percent of the study area having greater than 73 meters Altitudes and about 10 percent area has greater than 576 meter altitude. Based on the map of altitude, about two-third of the area are assigned as having medium to high risk of landslide (Table 7).

Slope aspect is also an influencing parameter for slope failure within the study area. The slope aspect map (Fig. 6) shows that the hill's slope of the study area is mostly west facing. Due to west-facing, slopes experiencing higher temperature resulting the large difference in soil respiration and heavy rainfall during the southwesterly monsoon in the subcontinent (Fig. 6). Moreover, about 29% of the area (Table 8) northwest and northeast facing slope of higher degree which is risky for a landslide (Fig. 6).

The drainage density map reveals the closeness or spacing of stream channels (Fig. 7). The density of river/stream plays an important role in the occurrence of landslide incidence. Most of the previous landslide occurred in the study area are found near to river valley caused by the steepness of river valley due to erosion work of the river.

The LULC is a very dynamic variable over time and is influenced by climate-driven changes and direct anthropogenic effects (Promper, Puissant et al. 2014). In this regard, it is an important influencing factor in the landslide susceptibility assessment. For this reason, accomplishment a landslide susceptibility analysis with a historical inventory over long periods (e.g., decades) demands the use of a permanent set of influencing factors, along the landslide inventory timeline. GIS analysis revealed that the middle part of the Rangamati District like Kaokhali, Kaptai, Rangamati Sadar are densely populated area. The

inhabitants of the study area live on Jhum cultivation and timber harvest from the hills influencing deforestation. However, the timber harvest and road building can alter landslide characteristics (Swanson and Dyrness 1975, Montgomery, Schmidt et al. 2000), with potentially adverse effects on environment with increased landslides (Hicks, Hall et al. 1991, Hartman, Scrivener et al. 1996, Daniel and Kelly 2007). Topographic attributes (i.e., slope gradient and convergence) are recognized as primary factors controlling susceptibility of shallow soils to landslides (Hack and Goodlett 1960, Reneau, Dietrich et al. 1990, Niemann and Howes 1991, Daniel and Kelly 2007, Chen and Jan 2003). The north and northeastern region like Baghaichari (Fig. 8) which shows high susceptibility of landslide than the rest of the area (Fig. 8) due to the high Jhum cultivation potential. There are about 8% of the total areas covered by water and dense hill forest area is about 12% (Table 10). Fallow land with light vegetation is covered by 53.07% and about 22% of area are agricultural land and 6% area is highly populated area.

A susceptibility map is created for showing the landslide vulnerability zones in the study area. Overall result shows that about 25% area is in high susceptible zone where Rangamati Sadar, Khawkhali, Kaptai and Bilaichari in high risk. The result of the susceptible area of the present study is consistent with others research works (Huq and Hoque 2012, Islam, Hussain et al. 2014, Kafy, Hasan et al. 2017)(Kafy et al., Haque.et al., Islam et al.,) that had carried out on the susceptibility of landslide in Rangamati Hill tracts. To validate our work, we compared the landslide susceptibility map with recent landslide from 2015 to 2017 (Table 12) which overlapped and consistence. It was seen that most of the previous devastating landslides were identified on the distribution of high landslide susceptible zone identified by the GIS techniques.

6. Conclusion

Among all the parameters accounted for landslide rainfall has triggered influences for a landslide. The study reveals that about 53% of the study area has experienced more than 260 cm rainfalls annually, which is as an essential indicator for a landslide. Devastating landslide mostly depends on slope angle of an area, whereas about 20% of the Rangamati district has greater than 30°. Slope angle some cases of > 70°. The study it has revealed that 28% of the study area has west facing slope aspect which intends to high susceptibility of landslide. Although a vast portion of the study area is densely vegetated area, the vegetated area has not enough landslide protective plants. About 34% of area is covered by moderately compacted the Bhuban and Bokabil Formation composed of siltstone with subordinate shale and sandstone, silty and sandy shale, sandstone and sandy shale which is a predominant factor for a landslide. GIS analysis revealed that the middle part of the Rangamati District like Kaokhali, Kaptai, Rangamati Sadar are densely populated area. The inhabitants of the study area live on Jhum cultivation and timber harvest from the hills influencing deforestation leads landslide movements. A Susceptibility map is created for showing that about 25% area is in high susceptible zone where Rangamati Sadar, Khawkhali, Kaptai and Bilaichari in high risk. The GIS result of the susceptible area of the present study is consistent with other recent research works and also coincide the latest landslide locations which justify the findings.

Declarations

Ethics approval and consent to participate

“Not applicable”

Consent for publication

“Not applicable”

Availability of data and materials

Data is given in the Appendix

Competing interests

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Authors' contributions

1st author- Miss Afruja Begum 40%

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Tables

Table 1 Data layers used in research work

Data	Parameters	Format	Source
Landsat 5 TM (05/10/2016) 30 m		Raster	USGS
Digital elevation model (30 m)	Slope angle, aspect, altitude	Raster	USGS
Rainfall	Rainfall	Excel	Bangladesh Meteorological Department
Lithology	Lithological unit	Raster	GSB
Soil erodibility	Soil erodibility index	Raster	GSB
Land form map	Landform characteristics	Raster	Arc GIS 10.3
Distance from Stream	Stream buffer	Raster	Arc GIS 10.3
USGS earthquake (point)	Earthquake magnitude	Raster	USGS
Previous landslides	Landslide location	Vector	Literature Review

Table 2 Criteria and Fundamental Scale for Pair-wise Comparison

Criteria used in AHP	Intensity of Importance	Definition
Altitude	1	Equal Importance
Slope	3	Moderate Importance
Aspects	5	Strongly Importance
Land Use Land Cover	9	Very Strongly Importance
Stream Distance	2,4,6,8	Intermediate Value
Rainfall		
Geology		

Table 3 Weight for the Criteria based on Comparison

Criteria	Priority (Weight)
Rainfall	30.2%
Slope	25.4%
Altitude	20.8%
LULC	7.6%
Aspect	6.2%
Geology	5.6%
Stream Distance	4.2%

Table 4 Assigned Rank, Area and Weight value for Rainfall

Rainfall (mm)			
Class	Rank	Area (Percentage %)	Weight
Low	2	7.84	30.2
Moderate	3	11.24	
High	4	53.07	
Very High	5	21.64	

Table 5 Assigned Rank, Area and Weight value for Geology

Geological Description			
Class	Rank	Area (Percentage %)	Weight
Girujan Clay	1	21.45	5.6
Boka Bill Formation	2	10.80	
Lake	2		
Tipum Sandstone	3	9.25	
Dihing and Dupi Tila Formation	4	14.41	
Dupi Tila Formation	4		
Valley Alluvium and Colloivium	4		
Bhuvan Formation	5	33.96	

Table 6 Assigned Rank, Area and Weight value for Slope

Slope Angle (°)			
Class	Rank	Area (Percentage %)	Weight
<10	1	25.63	25.4
10-25	2	31.19	
26-30	3	23.91	
31-35	4	14.59	
>35	5	4.68	

Table 7 Assigned Rank, Area and Weight value for Altitude

Altitude (m)			
Class	Rank	Area (percentage %)	Weight
<73	1	31.30	20.8
73-146	2	24.43	
146-244	3	27.52	
244-380	3		
380-576	4	7.14	
>576	5	9.58	

Table 8 Assigned Rank, Area and Weight value for Aspect

Aspect			
Class	Rank	Area (Percentage %)	Weight
Flat	1	14.61	6.2
East	2	16.55	
South East	2		
South	3	27.27	
South West	3		
West	3		
North West	4	29.05	
North East	4		
North	5	12.53	

Table 9 Assigned Rank, Area and Weight value for Stream Distance

Stream Distance			
Class	Rank	Area (Percentage %)	Weight
572-754	1	13.20	4.2
429-571	2	16.11	
287-428	3	31.11	
144-286	4	34.13	
0-114	5	10.21	

Table 10 Assigned Rank, Area and Weight value for Aspect

Land Use Land Cover			
Class	Rank	Area (Percentage %)	Weight
Water Body	1	7.84	7.6
Hill Forest	2	11.24	
Fallow Land	3	53.07	
Agricultural Land	4	21.64	
Populated Area	5	6.18	

Table 11 Assigned Rank, Area and Weight value for Susceptibility

Landslide Susceptibility Mapping		
Class	Area (Percentage %)	Rank
Low Susceptible Zone	19.43	1
Medium Susceptible Zone	56.55	2
High Susceptible zone	19.19	3
Very High Susceptible Zone	4.81	4

Table 12 Previous landslides in the study area

No	Location of Previous landslides	Date	Causalities	Based on Susceptibility model classes
1	Manikchori	June,2017	152	High Susceptible Zone
2	RangamatiSadar	July 2018	11	Very High Susceptible Zone
3	Kolabagan, Kaptai	June,2019	3	Very High Susceptible Zone
4	Kolabagan, Kaptai	July,2019	2	Very High Susceptible Zone
5	Kaptai-Chndraghuna road	1968	-	High Susceptible Zone
6	Ghaghra, Rangamati	1970	-	High Susceptible Zone
7	Jagharbeel, Rangamati	1990	-	Moderate Susceptible Zone

Figures

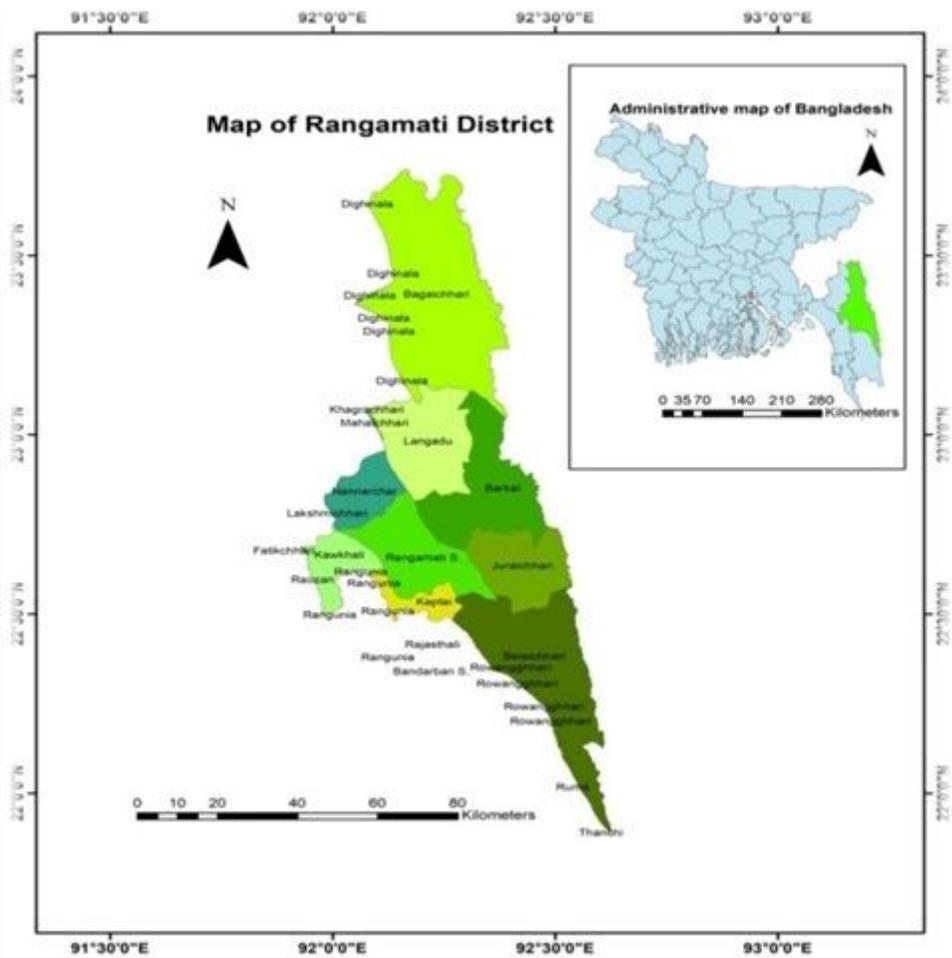


Figure 1

Map of Study Area (Ref??)

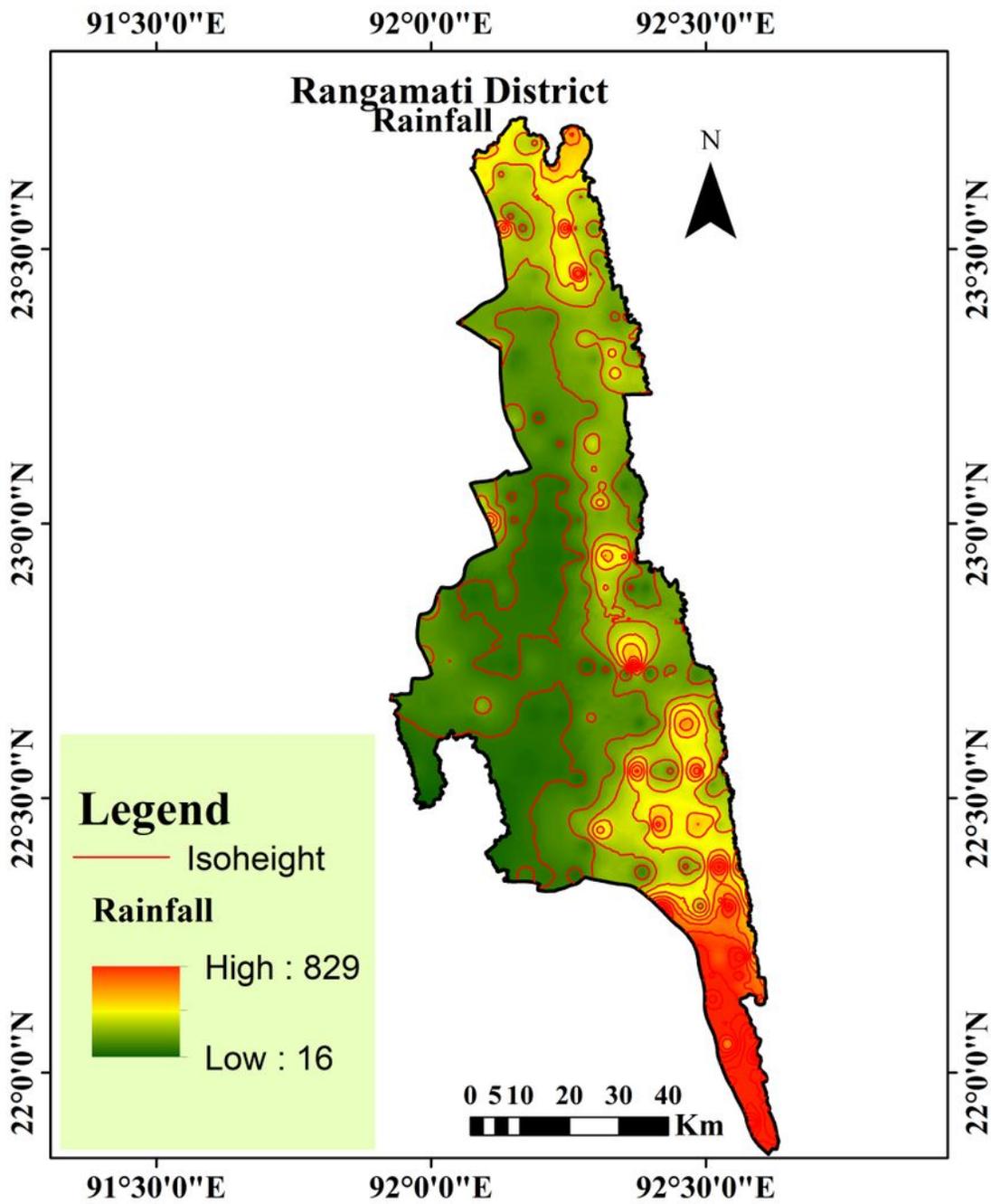


Figure 2

Rainfall distribution of Rangamati District using GIS

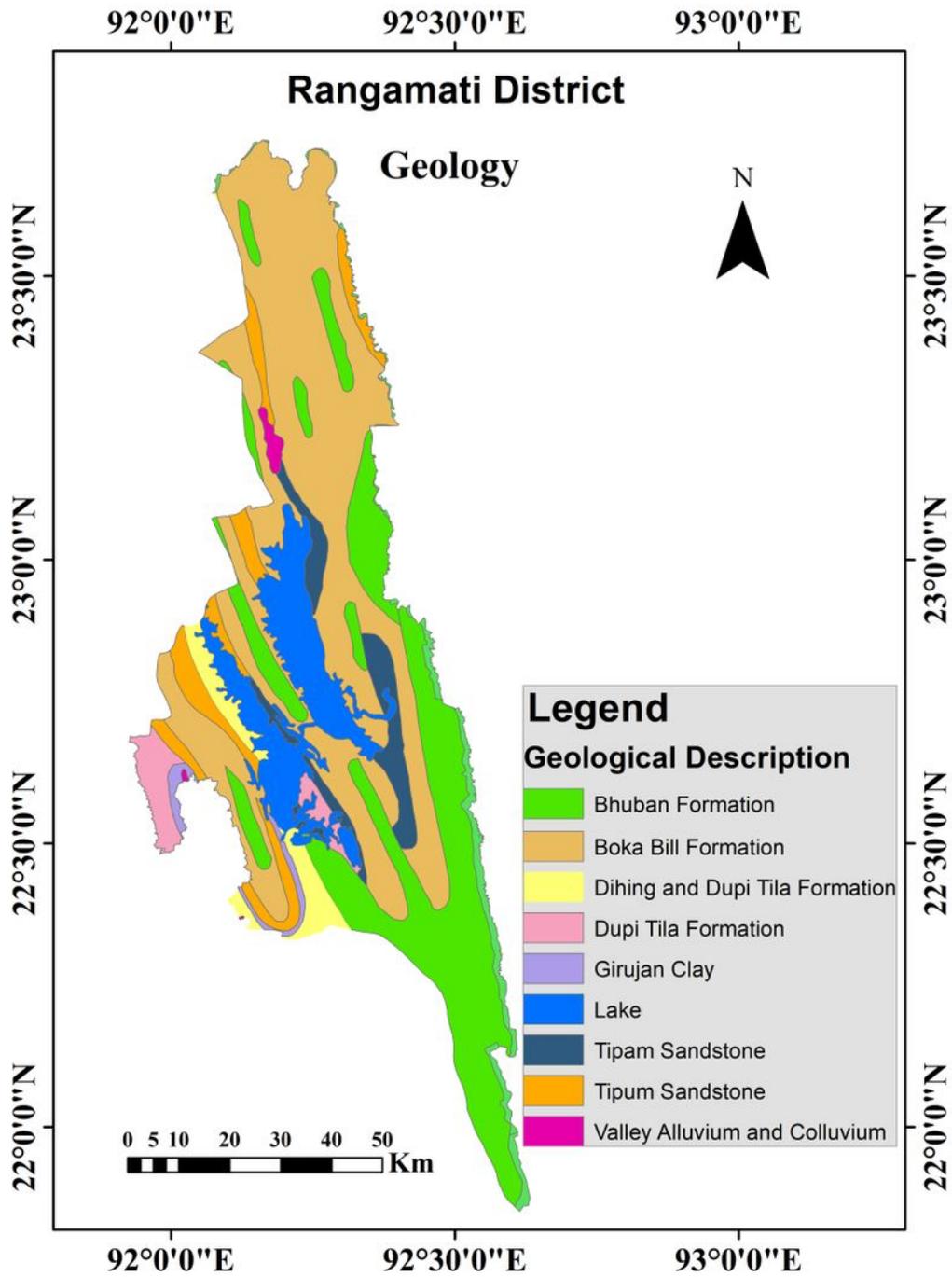


Figure 3

Geologic map of Rangamati District showing different rock formations

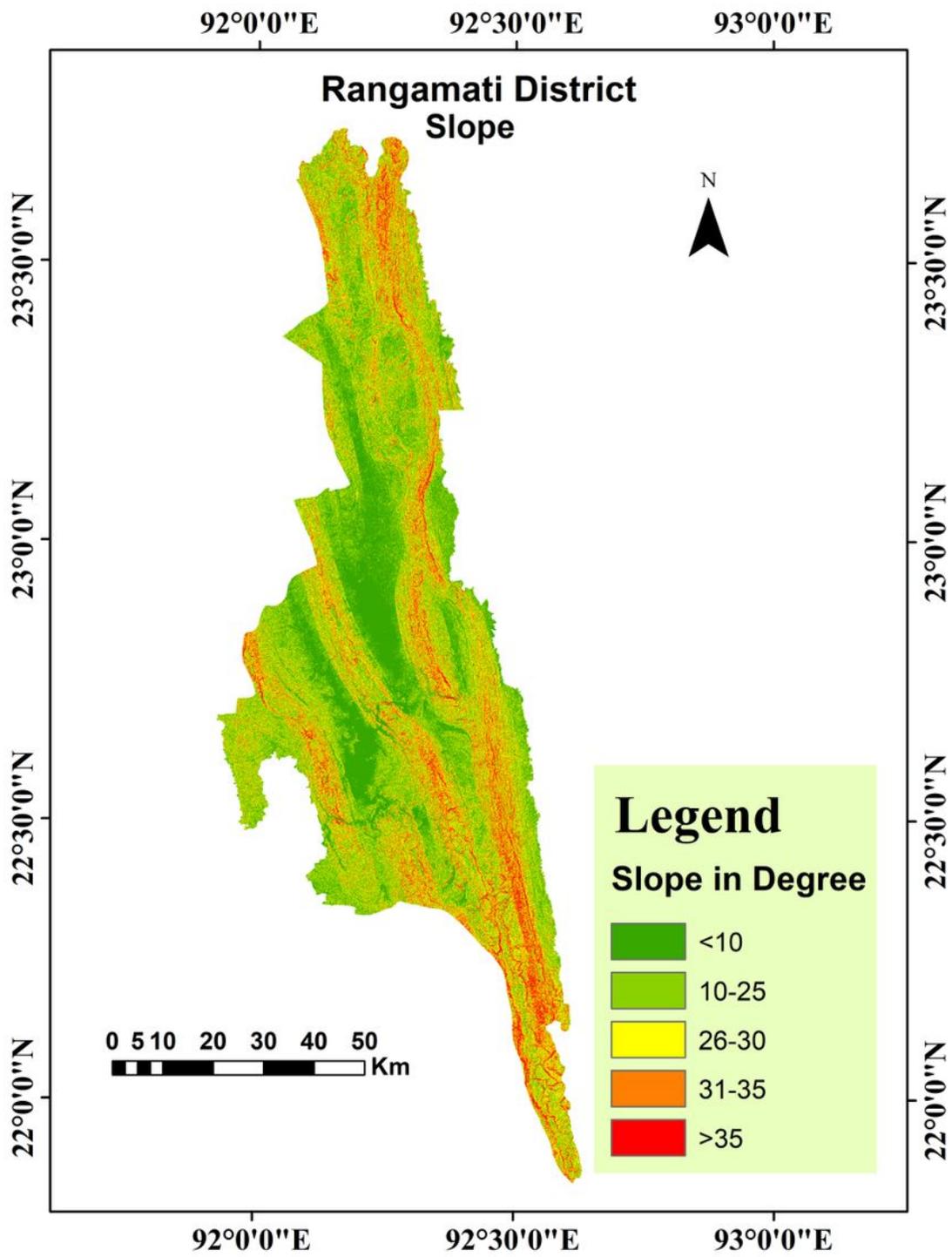


Figure 4

Map showing the angle of slope of Rangamati District

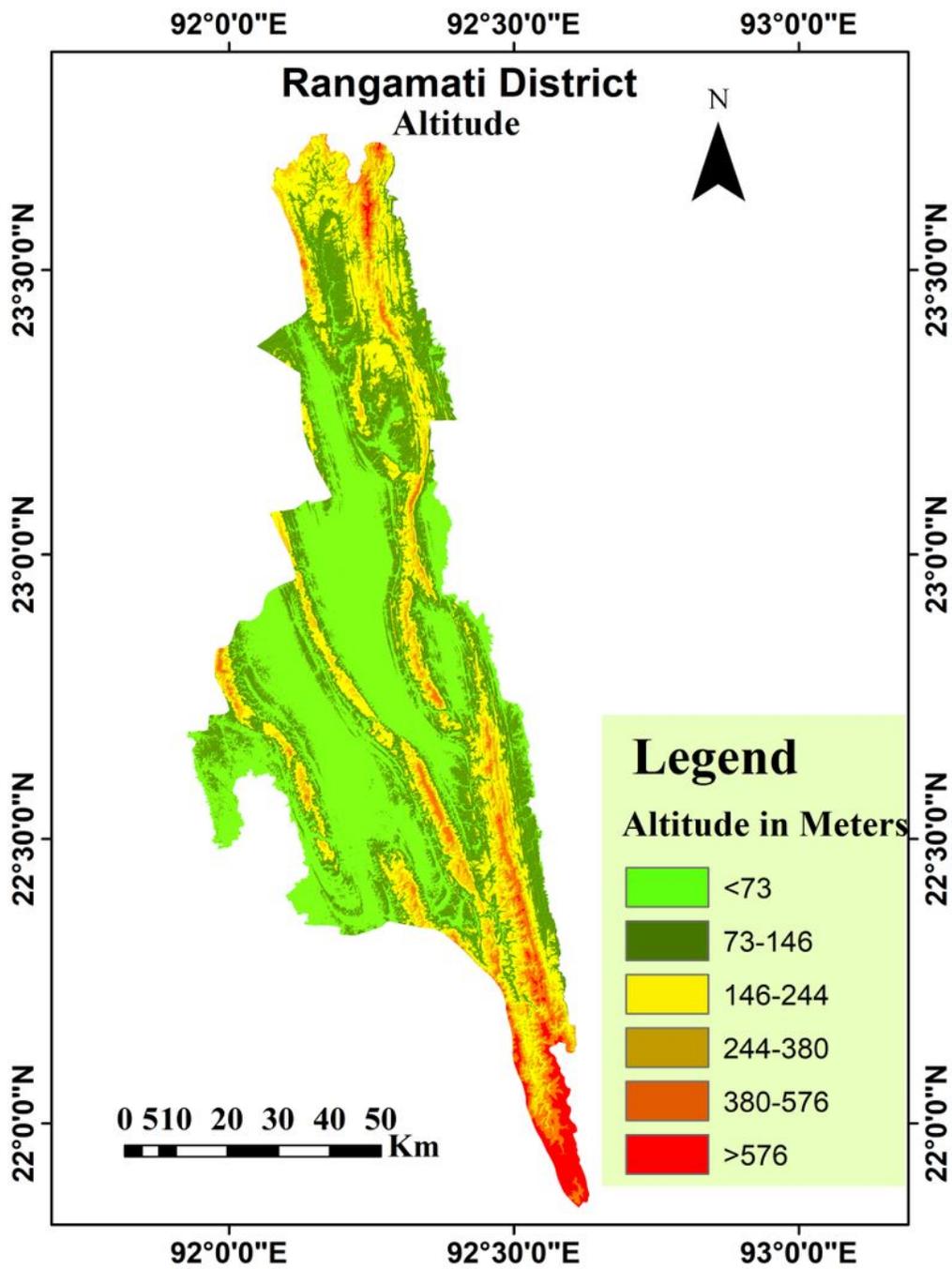


Figure 5

Map showing the altitude of Rangamati District

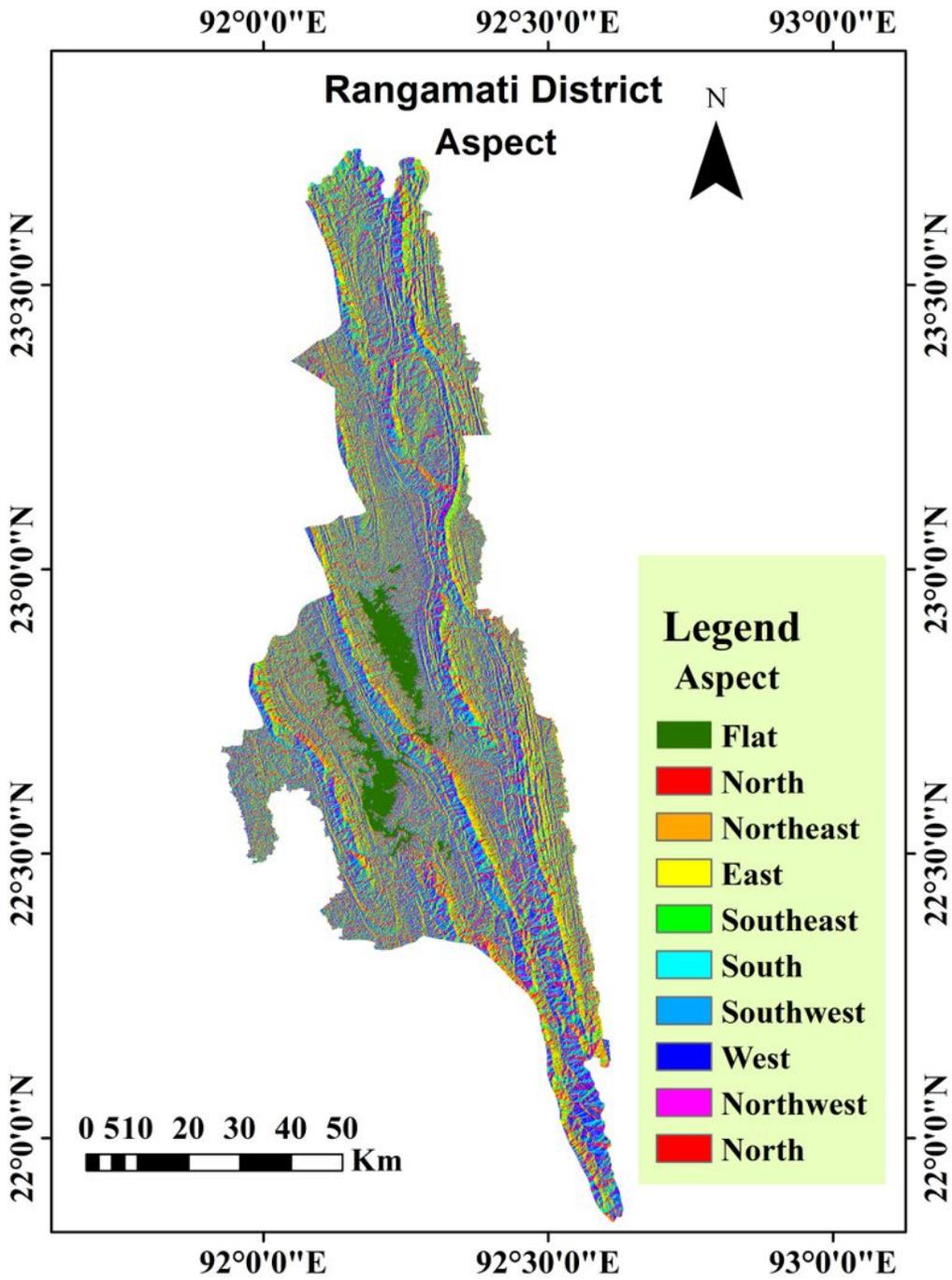


Figure 6

Map exhibiting the aspect of slopes of Rangamati District

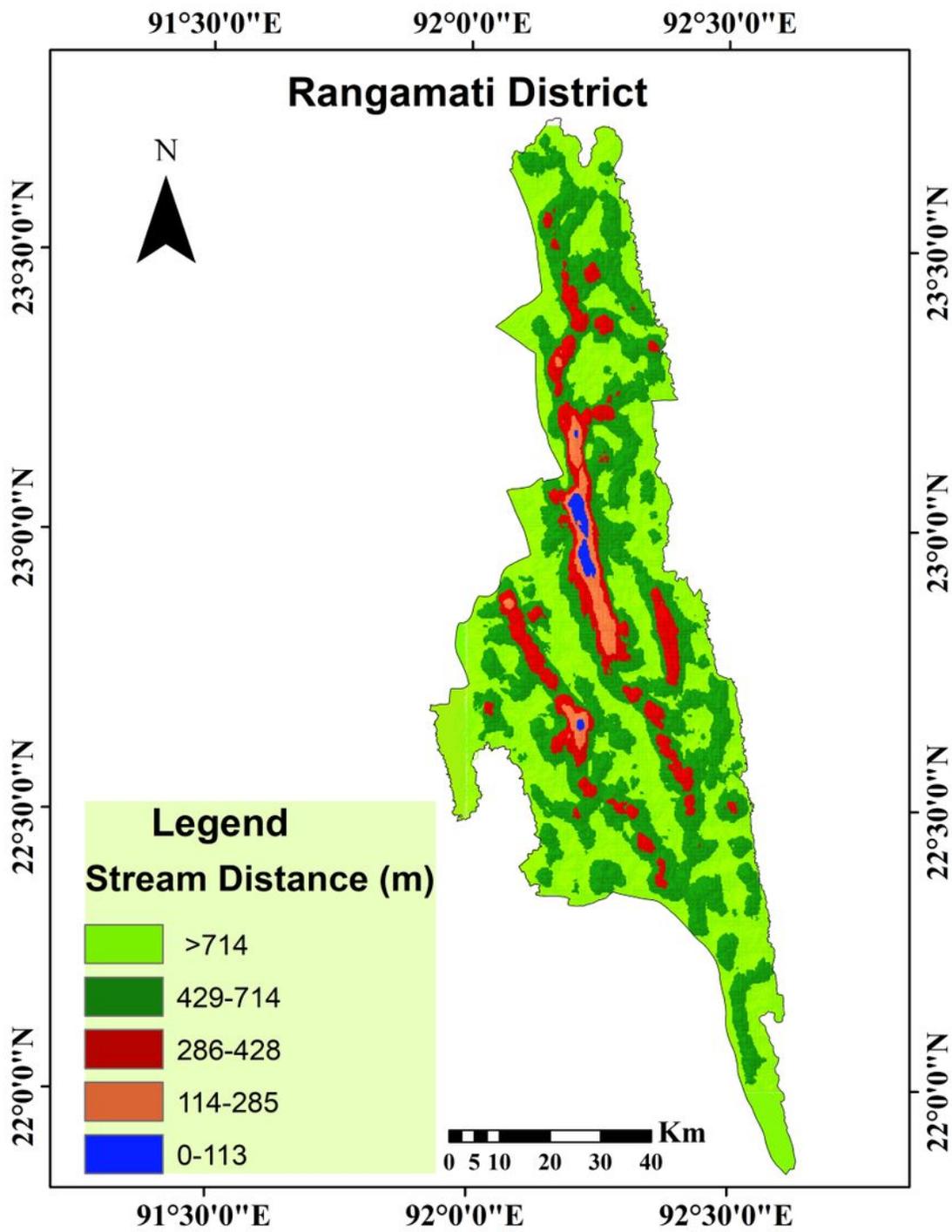


Figure 7

Map illustrating the distance from the streams of Rangamati District

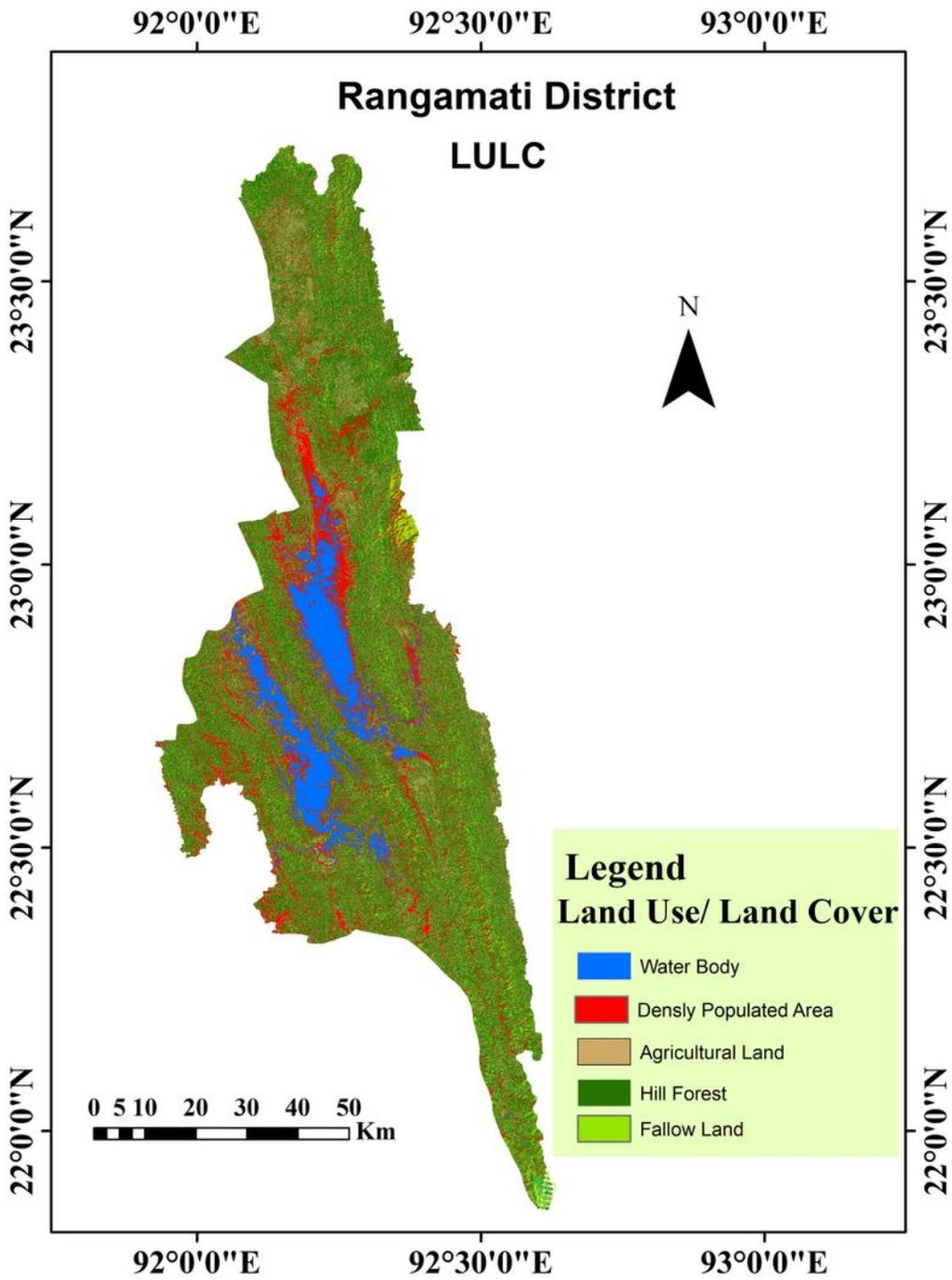


Figure 8

Map showing the LULC of Rangamati District

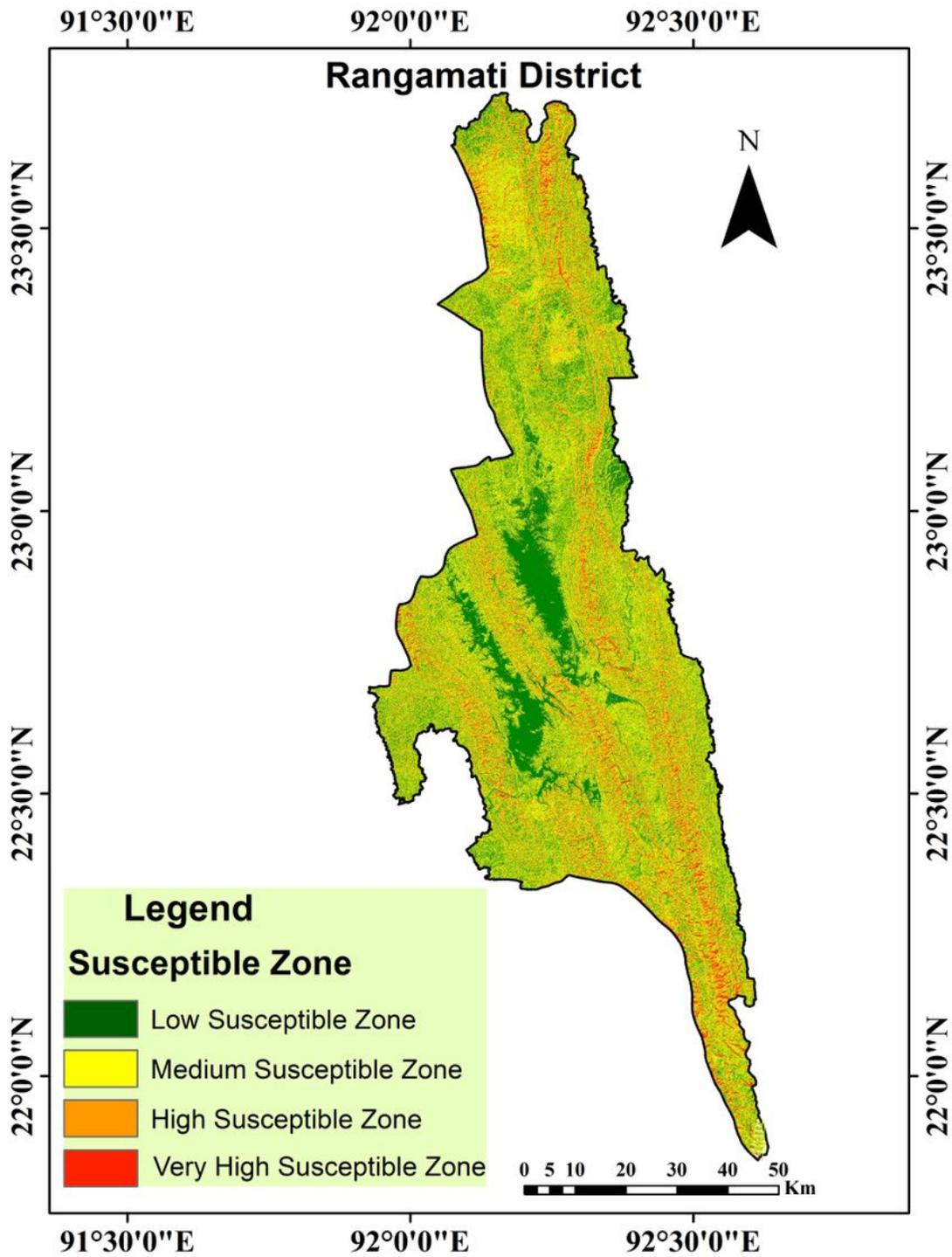


Figure 9

Landslide Susceptibility map of Rangamati District

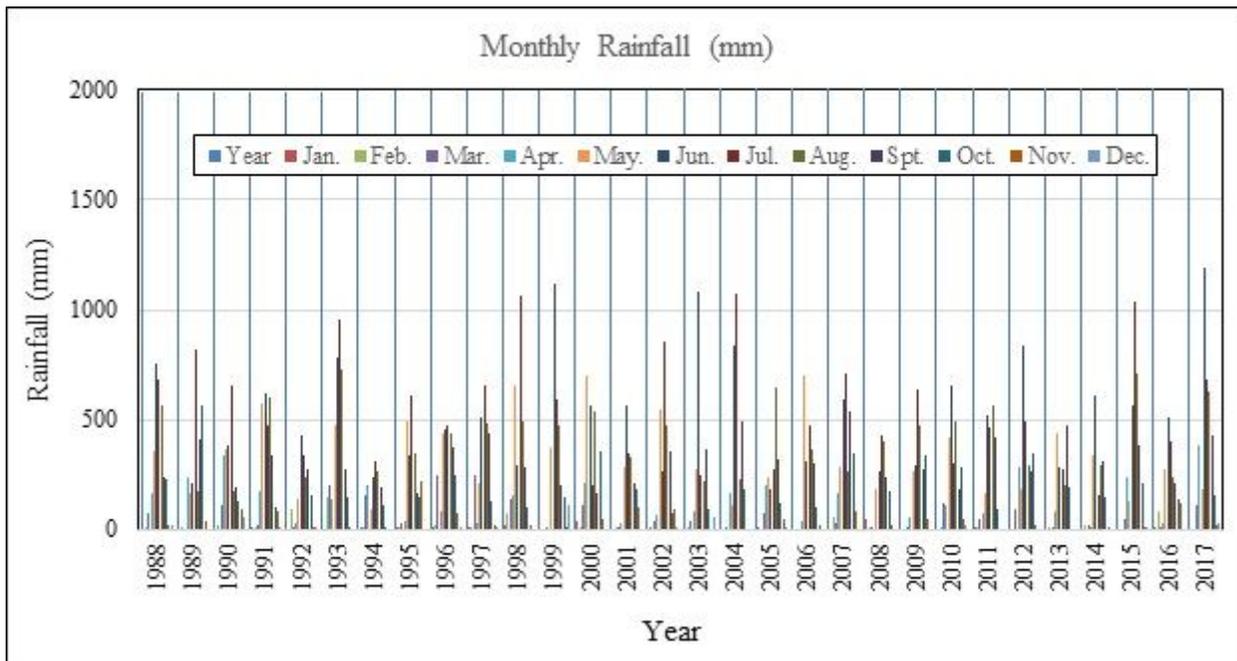


Figure 10

Monthly Rainfall records of Rangamati for years of 1988 to 2017 (Source: Bangladesh Meteorology Department)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Appendix.docx](#)