GIS Based Landslide Hazard Zonetion of Guwahati Region

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Abstract - Landslide is generally defined as a wide variety of down slope movements of earth materials that result in the perceptible downward and outward movement of rocks, soil, vegetation, artificial fills or combination of all these under the influence of gravitational force. Landslide, one of the major geo-environmental hazards has annually affected the Guwahati city, causing huge damage to life and property. The present study is an attempt to classify the settlement areas of Guwahati city based on its slope angle to identify the potential landslide risk zones. The study utilized different types of data including Survey of India topographic maps, geological (lithological and structural) maps, IRS-1B and -1D multispectral and field observations. The processing of multi-geo-datasets was carried out in a raster GIS environment. The various data layers generated and co-registered were: landuse/landcover, lithology, map of drainage, slope angle and relative relief. Data integration was carried out using the arc gis through overlay analysis to prepare the landslide risk zonation map. It is interpreted that the distribution of landslides is largely governed by a combination of geo-environmental conditions like presence of massive crystalline rocks is highly susceptible to seepage pressure, barren or less-vegetated areas and Toe cutting of the natural slopes for construction of dwelling houses.

Key word **- Landslide, Hazard, Risk, Thematic Map**

I. INTRODUCTION

Among the various natural hazards, landslides are the most widespread and damaging hazard. They cause loss of life and property, damage to natural resources (e.g. vegetation, land and soil) and hamper developmental projects like roads, bridges and communication lines, etc. It has been estimated that, on average, the damage caused by landslides in the Himalayan range costs more than US$ 1 billion besides causing more than 200 deaths every year, which overall is considered as 30% of such types of losses occurring world-wide (Naithani 1999).

An area of about 0.49 million sq. km out of the total area of India is vulnerable to landslide. About 0.098 sq km of an area in Northeast is vulnerable to landslide (Phukon, P., 2012, GIS, 2006). The

other regions vulnerable to landslide in India include the Himalayas, Nilgiris, Ranchi Plateau and Eastern and Western Ghats of India (GSI, 2006).

According to a survey conducted by the State Soil Conservation Department, 8 out of the 18 hills of the city has been declared unfit for the human inhabitant.3000 hectares of land out of total 7,023 hectares of city land has been suspected to be landslide prone. The first major landslide in Guwahati took place in 1972 in Nabagraha (Kharghuli Hills). Over the last eight years, 60 people have lost their lives in landslide. Eight people lost their lives in 2000, 6 during 2002, 17 during 2003, 18 people in 2004 and eleven people in 2007 due to landslide incidence on the hills of city.

II. AIM AND OBJECTIVES

The main aim of the research is to demarcate the potential landslide risk zone and prepare a landslide hazard zonation mapping of Guwahati region. The objectives of the research are as follows-

- To identify the area prone to landslide with respect to slope.
- To analyse the factors and processes that trigger landslides in the region.
- To give remedial measures for mitigation and prevention of landslide.

III. OVERVIEW OF STUDY AREA

Guwahati city, situated on both the bank of the mighty Brahmaputra River and the foothills of Shillong plateau is said to be the City of Eastern Light. It is also known as the gateway to the north eastern region of India and of the major commercial nerve centre of the Northeast. Geographically, the city is located between 26 0 4' 45"N-26 0 13'33"N and 910 34'14"E-910 52'06"E). The Guwahati city is more extended in east west ward trend with spreading between Narengi in the East, Lokpriya Gopinath Bordoli (LGB) International Airport in the West with an area of about 45 km and between the southern bank of the mighty Brahmaputra River and the foothills of the Shillong Plateau for about 15 km. The Guwahati city covers an area of about 264 sq.km comprising Guwahati Municipal Corporation area, and North Guwahati Town Committee, Amingaon. The population of Guwahati has increased from 500,000 in 1991 to 8, 14,575 (Census of India, 2001) and to 963,429 in 2011 (Census of India, 2011). The city is well connected with road, rail and airway network. The present study area of Guwahati Municipal Corporation covers an area of about 216 sq. km. The city has experienced a rapid rate of urbanization with a growing rate of 131.60 in 1971 and 38.59 in 1991-

2001. The total area of the city was 43.82 sq. Km in 1971, which has expanded to 216 sq. Km in 2011. The density of population in the city is very high of about 3735 person per sq. Km in 2001 (Census of India). The city is enriched with high vegetation cover in the form of forest and several wetland and waterbodies are located within the city. Figure 1.1 shows the information and study area of Guwahati region, Assam. Fig. 1 shows the location of study area.

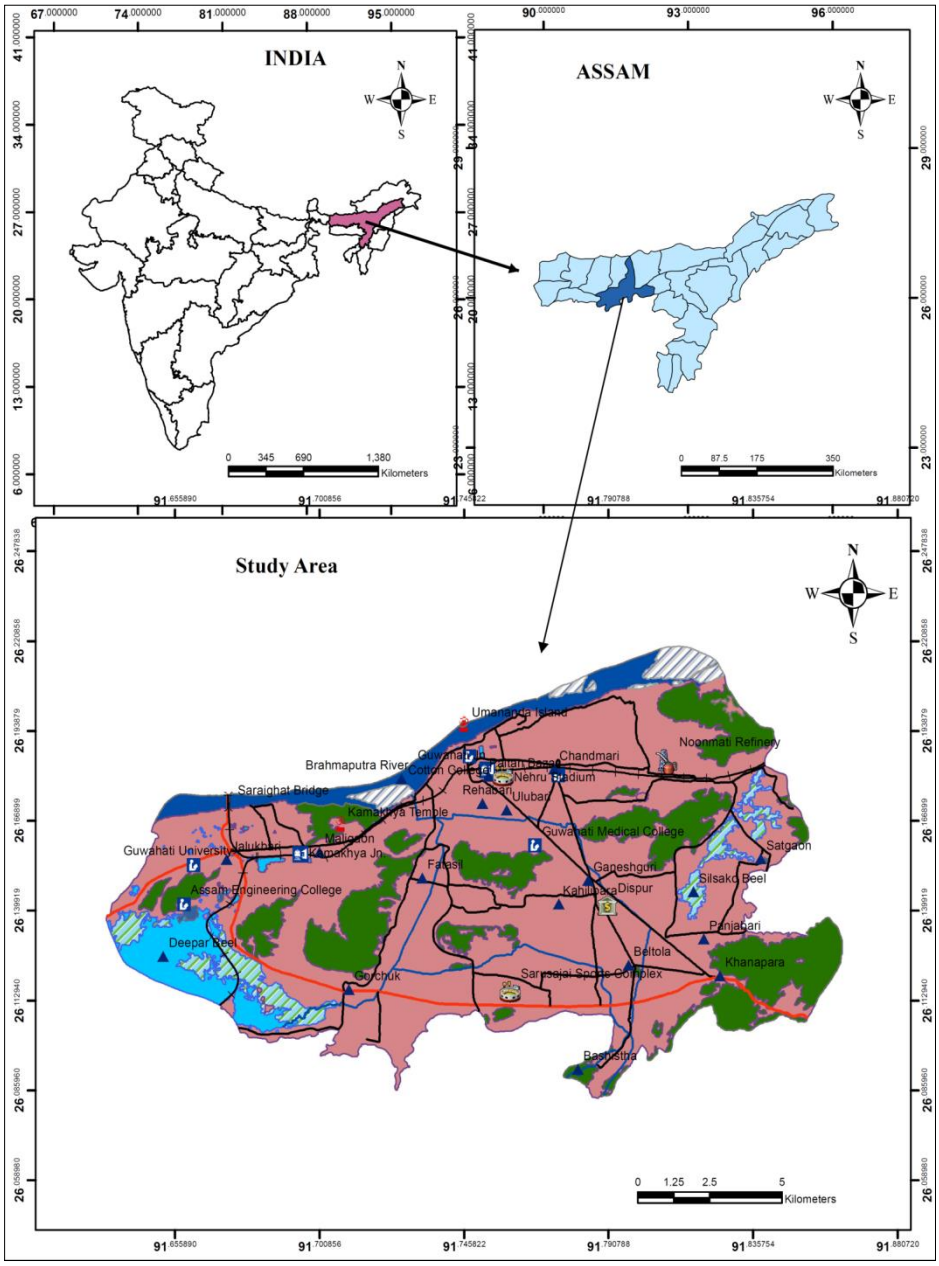


Fig. 1 shows the location of study area

Physiography of the Area

The Guwahati city is geologically an extension part of the shillong plateau of the Pre Cambrian Age. Geologically, the city is characterized by Precambrian granite gneissic complex composed of granite gneiss, biotite schists, gneiss and quartzite. The Precambrian granite gneissc complexes are directly overlain by Pleistocene-Holocene Sediments. The highland in and around Guwahati city are primarily made up of the gneisses and granite bodies with quartzites, amphibolites and biotic schists; with the intermountain valleys are filled with Pleistocene-Holocene sediments (Maswood,1981). The Precambrain basement occupies an area of about 68.49 per cent. The Shillong group of rocks occurs as inselbergs in alluvium plain of the Guwahati city and hill ranges in southern boundary of the district with Meghalaya. These rocks covers an area of about 1500 sq. Km, south out of Brahmaputra River and 100 Sq. Km (10%) in North Bank. They rocks mainly constitute of Schists and geisses of varied nature and composition. Migmatites, granites, veins and basic rocks of different composition are embedded in these schists and gneisses. Physiographically, the city can be divided into three parts-

- The hilly region in the south,
- The alluvial plains in Central part, and
- The Western parts and the swamps along Brahmaputra flood plains.

The average elevation of the low lying area is about 49m and the lowest being 41.16m above the mean sea level in the Guwahati region. A maximum elevation of 575m is found in the southern part of the city where extended part of Khasi and Jayantia hills is located. The maximum elevation in the eastern part of the city is about 216 m in the Kharghuli and Nabagraha hills. Nilachal

(303m) act as a barrier for the continuous extension of plain areas toward western direction. There are several dissected residual hills located all over the city. The southern part of the city is highly surrounded by the extended part of the Jayantia hills of Meghalaya state. The other major hill located in the city are Nabagraha hill (217m), Nilachal hill (193m), Tetelia hill (221m), Khanapara hill (303m), Fatasil hill (385m), Chandrapur hill (205m), Buragohain Pahar (500m), Narakasur (264m) and Narengi hill (168m). The hills located in the city are mostly covered by scrub land with or without scrub. Most of the hills located in the city are covered by the thinly populated residential area. Geomorphologically, a larger part of the area is covered by the alluvium plain. Alluvium plain is basically formed by the Brahmaputra River and its several palaeochannels.

The most unique feature of the Guwahati landscape is the presence of number of partially silted water bodies, which is locally named as 'Beel'. The largest Beel in the city is the Deepar Beel which is located in western fringe of the city, covering an area of about 5.7 sq. km. The Deepar Beel has been listed in the Ramsar Convention list of Wetland of international importance. The other important wetland (Beel) located in the city are Soru Sola Beel and Bor Sor Beel, which provide beauty to the landscape of Guwahati.

Apart from the mighty Brahmaputra River flowing through the city, the other two rivers, the Basistha and the Bharalu form the main drainage within the city. Residual hills occupy the major part of the Guwahati city with about 68.49 per cent, the alluvium plain occupies about 31.51 per cent and the water bodies with Paleochannels occupy 7.82 per cent of the total area. The city also have several river island, the largest being the Umananda Island.

IV. DATABASE AND METHODOLOGY

The different types of datasets used were as follows:

1. A toposheet map of Guwahati was used made by the US Army Map Service (1955) of the scale 1:250000. The details of the toposheet are as follows- Series-U502, Sheet NG 46-6, Edition 2-AMS.
2. Geological map representing litho logical and structural units.
3. 3. Satellite sensor data of ETM multispectral digital data in seven band with 30m ground resolution and SRTM dem has been used to dive the slope, aspect, contour.
4. Field data involving observations on landslides, geology, structure and landuse/landcover.

The GIS and image processing were carried out using PC-based software Eradas Imagine 9.2 and Arc Gis 10.1. Broadly, the data manipulation can be considered in two stages: pre-processing and processing. Pre-processing involved digitization of toposheets to serve as the base map. The digital multispectral data were corrected for atmospheric path radiance by the dark-object subtraction technique (Chavez 1988) and registered over the topographic map to form an input into the GIS database. Digitization of all the relevant data maps, namely geology structural and drainage maps was carried out and all the datasets were georeferenced.

Processing involved various advanced digital image processing and GIS techniques, such as edge enhancement, colour compositing, Generation of slope, Aspect layer, Landuse/Landcover identification, overlay and logical operations. Interpretations were made from these processed images.

V. DATA LAYER PREPARATION AND INTERPRETATIONS:

For analysing landslide hazard of a particular region various thematic maps based on different themes are to be generated with the help of ERDAS & ArcGIS software. Various thematic maps were generated based on different theme like drainage, geomorphology, geology, slope, Landuse/Landcover etc for the study purpose.

Base Map

A base map is an essential outline on which geographical and topographical data's are plotted for general information of the area. Topographical features like boundaries, transportation, river, landmarks etc are plotted on the map to get an overview idea of the study area. Fig. 3.4 shows the Base map of Guwahati City.

Drainage Map

Drainage map mainly shows the pattern of drainage network available in the area. It is usually defined as the natural pattern formed by the streams, rivers and lakes in a particular drainage basin (Kessarkar, P.M., et al., 2011). Drainage network plays a very major role in the identification of landslide prone areas. It reflects the slope formation of the region and its erosional aspects. It helps in identifying the area where the chances of landslide occurrence is higher. The Guwahati city has major 3 drainage network flowing across the city. The area also has several numbers of wetland (Beel) and water bodies in and around the city. The streams flowing through the city has been encroached by the human settlement which has disturbed the natural flow of the stream in the city. Most of the drainage network over the hills have been disturbed and encroached by the human settlement which has resulted into blockage of rainfall water on the hills. Thus, inappropriate drainage system has resultant into higher frequency of landslide in the region.

Geomorphology Map

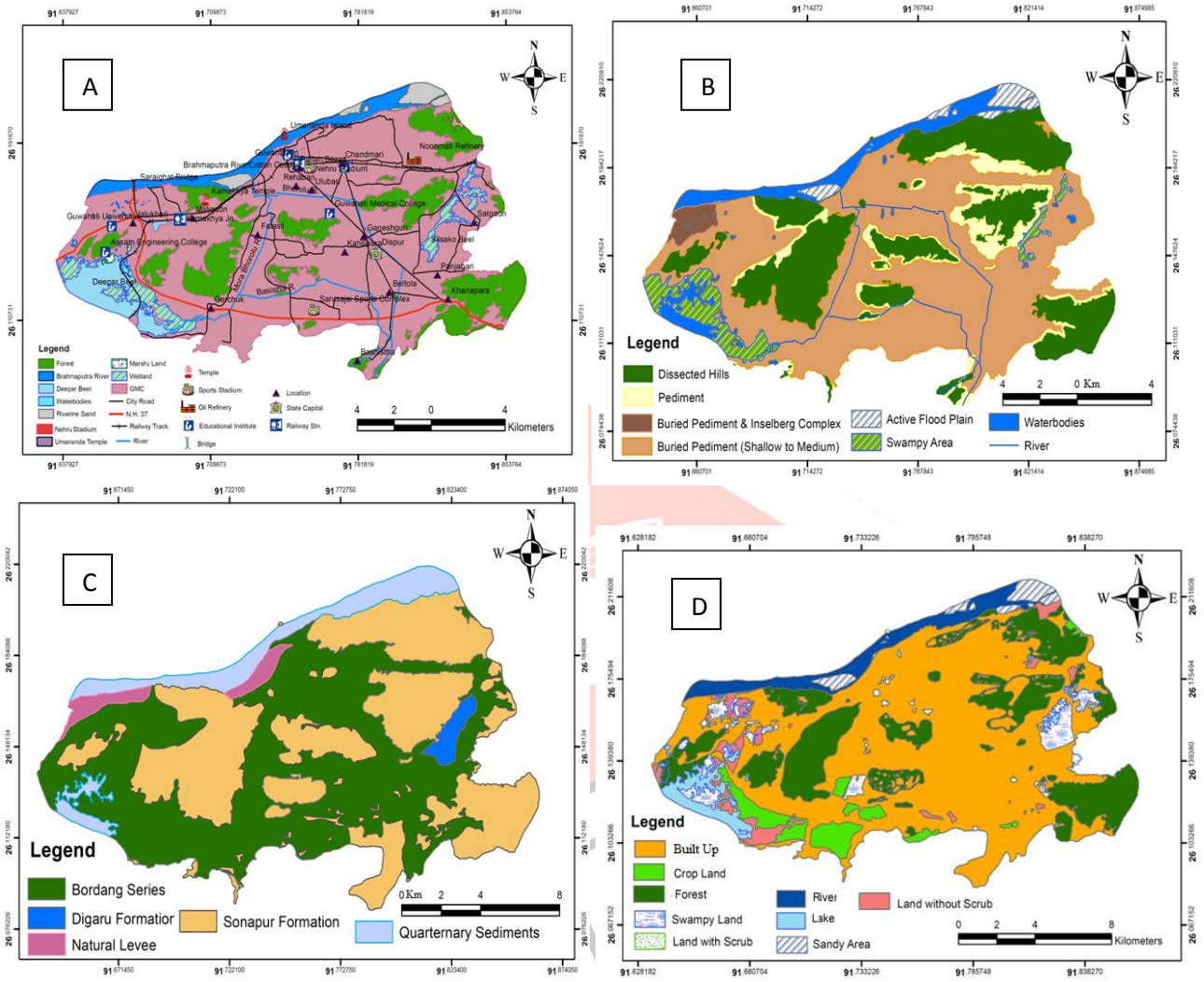
Geomorphology maps helps in showing the spatial distribution of different landforms, surface and near surface deposits and the processes and time that act on the formation of these landforms. It helps in understanding the landscape development of the region. Geomorphologically, the study area was divided into seven categories- (a) Dissected Hill, (b) Pediment, (c) Buried Pediment & Inselberg Complex, (d) Buried Pediment (Shallow to Medium) (e) Active Flood Plain, (f) Swampy Area and (g) Water bodies.

The area has a large number of dissected hills located across the city. Most of these hills are without vegetation cover which has resulted into much weathering and erosion process on the hills. Weathering and erosion has lead to break down of rocks and soil

over these hills. During monsoon season, heavy rainfall act as a triggering factor for landslide occurrence in the region. The rocks and soil over these hills gets easily eroded during the monsoon season.

Geology Map

Geology is the scientific study which studies the origin, history, rock composition and structure of the solid earth crust. Geological map of an area shows the origin, composition and relationship among rock and sediment at and near the earth's upper surface. Geological maps are helpful in understanding the rock composition and structure within a study area and their role in the causes of landslide in the region. Geologically, the Guwahati region was divided into five categories- (a) Bordang Series, (b) Digaru Formation, (d) Natural Levee, (e) Quarternary Sediments and (f) Sonapur Formation.



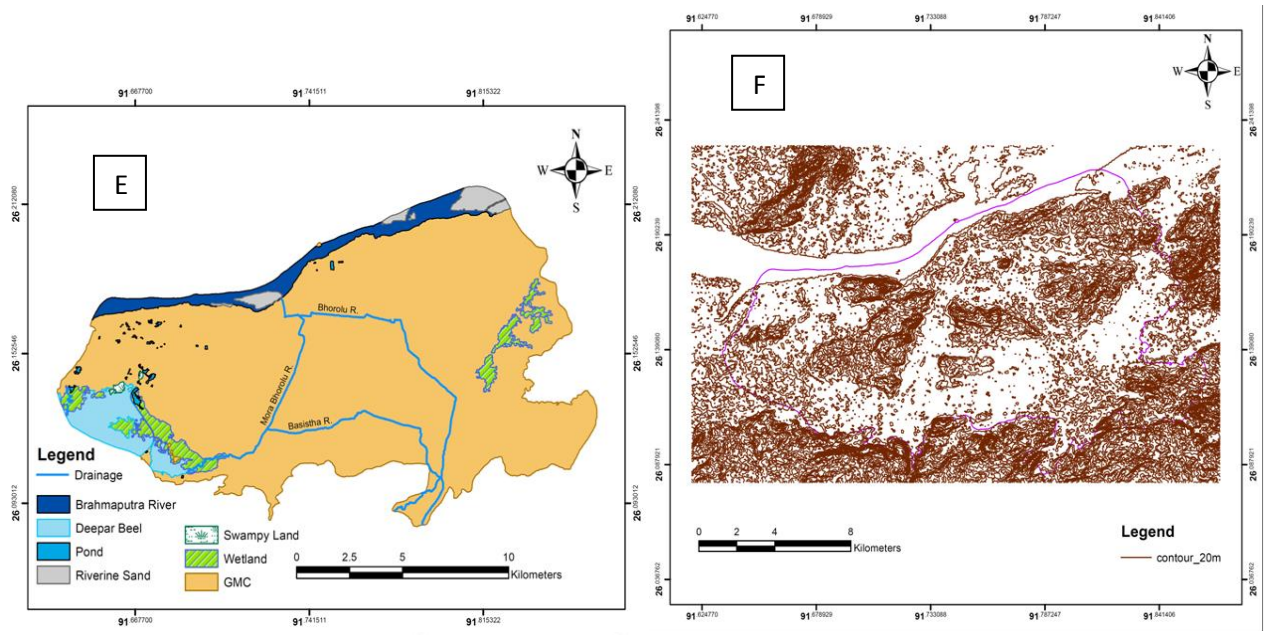
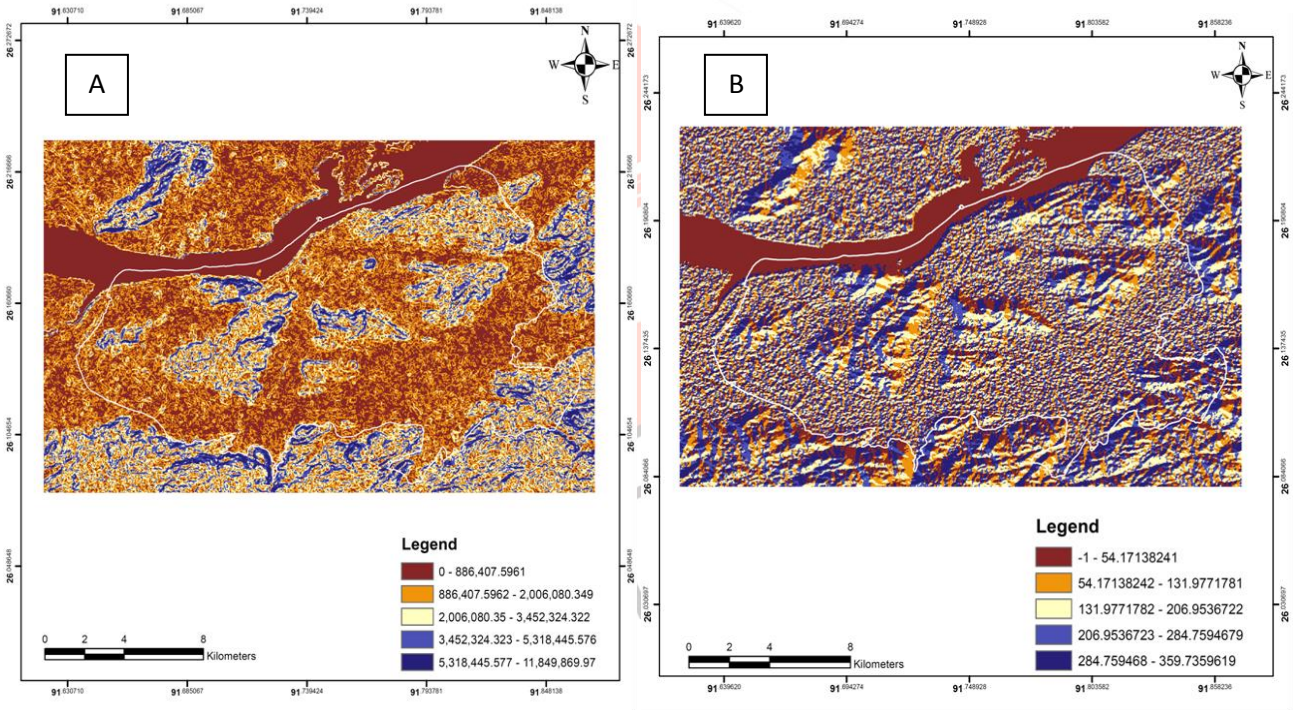
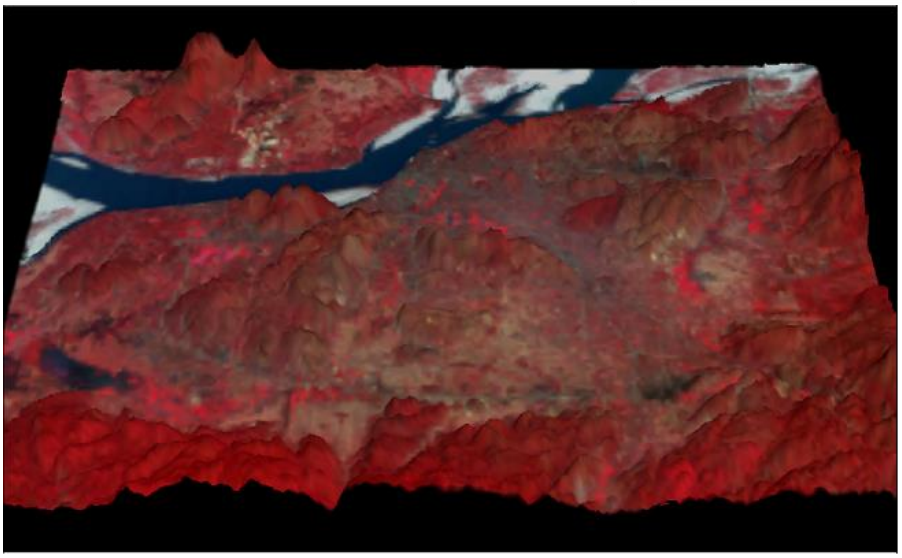


Fig 2.0: (A) Base Map, (B) Geomorphology Map, (C) Geology Map, (D) LU/LC Map, (E) Drainage Map, (F) Contour Map of Guwahati City.





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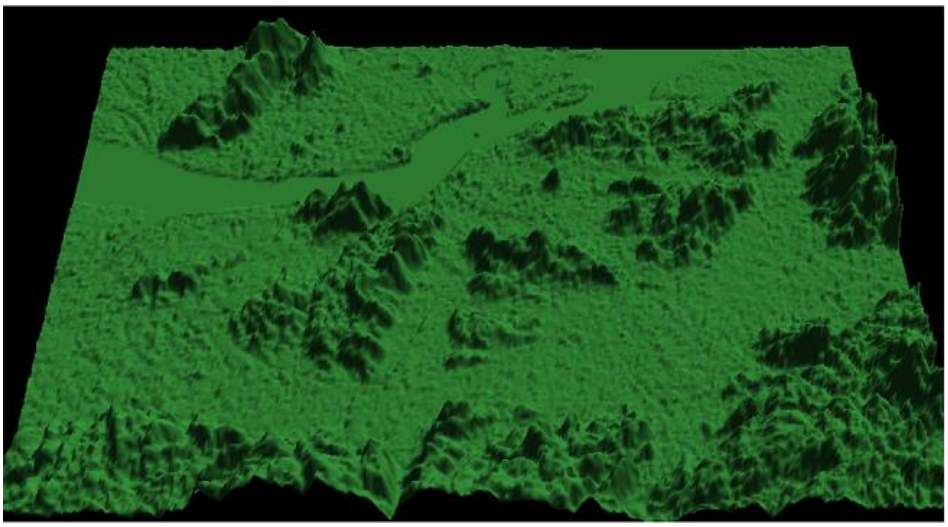

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Fig.3: (A) Slope Map, (B) Aspect Map of Guwahati Region. (C) DEM with FCC of Guwahati region, (D) DEM of Guwahati region

Landuse/Landcover Map

A Landuse/landcover maps are very useful for identifying the different classes of land. It is most important in analyses of the landslide hazard in relation to change in landuse pattern of the study area over a different period. A landuse/landcover map generated through satellite image clearly shows the area increased under residential zone. A large number of areas about 8090.19 hector (41%) under Guwahati city are occupied by the Built Up Area. Settlements over hills also have increased recently due to higher migration in the city. A large number of settlement patches in haphazard manner is demarcated on satellite image. This has caused decrease in forest and vegetation cover over the hills resulting into slope instability in the region. The density of forest has decreased over a period and is mainly covered with scrubs. The areas without scrubs on the hills are more exposed to erosion agent causing slope failure in the region.

Digital Elevation Model

Digital Elevation Model (DEM) is the three dimensional representation of the earth's topography through remote sensing technique. DEM is very essential technique for knowing the relief feature of an area. DEM is used for generate contour, slope, aspect map. DEM was later superimposed with FCC image of the study area to get a better look of the hilly terrain.

Contour Map

A contour line, also known as isoline or isopleths is an imaginary line that joins points of equal elevation on the earth surface. All the points on a given contour line are at the same height. It is one of the most important ways of showing the relief feature of earth on the map. It is a two dimensional representation of the earth relief on the sheet of paper. It mainly shows the height of an area above Mean Sea Level (MSL).

The contour line of the Guwahati region was generated using DEM of the study area with a 20 mt interval in ArcGIS software.

Slope Map

Slope is one of the major factors which plays an important role in identification and mapping of the landslide susceptibility zone. Movement of slope helps in predicting future landslide (Carrara et al., 1998). The stability of hilly terrain is highly influenced by the angle of the slope. Slope is defined as the degree of inclination of a feature relative to the horizontal plane. . It was observed that the slope angle calculated from the DEM had a range of 0°–45°. Most of the hills have moderate slope but without much vegetation cover. Development work carried throughout the city has resulted into instability of slopes in the region. Moreover, construction of large number of settlement over the hills without any appropriate measure has also played a crucial role in the slope failure in the region. Slope facing the northern side is more vulnerable to landslide.

Slope Aspect Map

A slope aspect map shows the direction and steepness of hilly terrain slope. Slope aspect is an isoline map with selected aspect categories e.g. northeast, northwest, southeast, southwest etc. Slope aspect shows the direction a slope is facing towards. The direction of the slope in respect to sun has huge influence on its structural and chemical composition of the soil slope. Slope aspects are basically constructed on the basis of contour line data of the area.

Union Map

A union map was generated by imposing different thematic maps for the analysis and preparation of new map for the desired data. Here, geology, geomorphology and landuse/landcover map was superimposed for generating a union map of this through integrating in the GIS environment. It helps in finding out the area vulnerable to landslide in respect to landuse/landcover element when superimposed with geology and geomorphology aspect of the area. Fig. 4.0 shows the Union Map of LU/LC, Geology and Geomorphology.

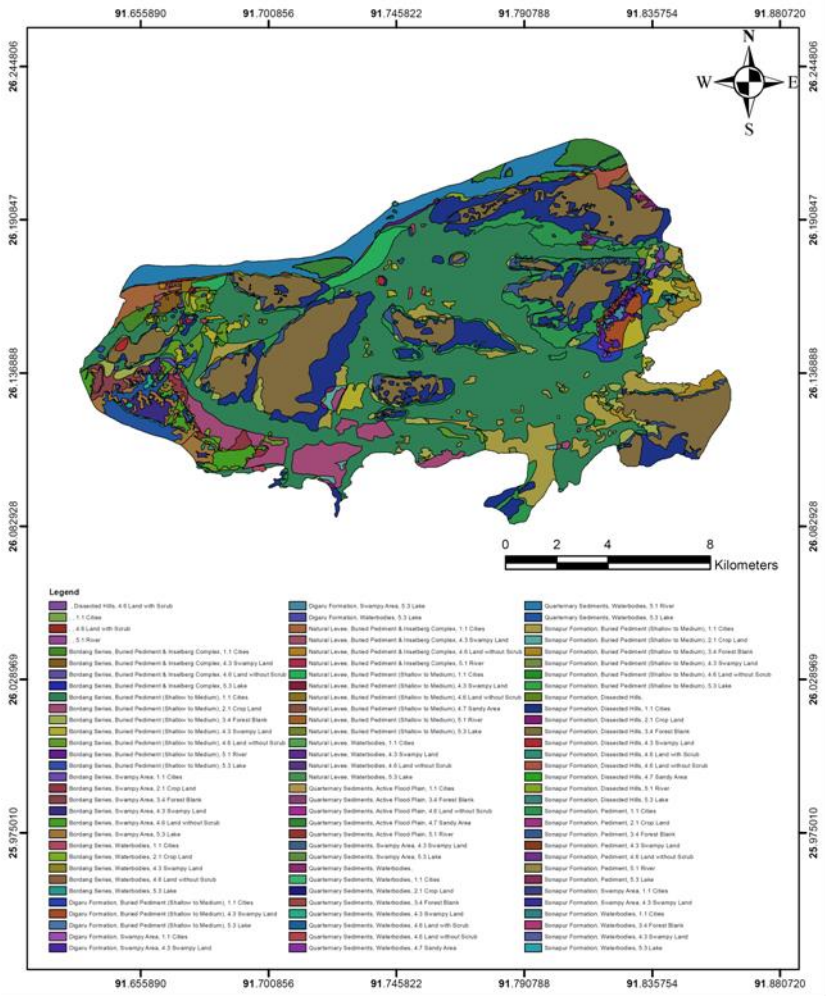

Fig. 4.0 shows the Union Map of LU/LC, Geology and Geomorphology

VI. RESULT AND DISCUSSION

Landslide Hazard Zonation mapping helped in identifying the area prone to landslide in Guwahati city. It also helped in identifying the type of landslide occurring in the city depending on the geographical feature of the area. The final landslide hazard zonation map was generated by analyzing landuse/landcover area in aspect to geological and geomorphologic features of the region. Through this, the first objective of the study was achieved. Fig. 5.0 shows the Landslide Hazard Zonation Map.

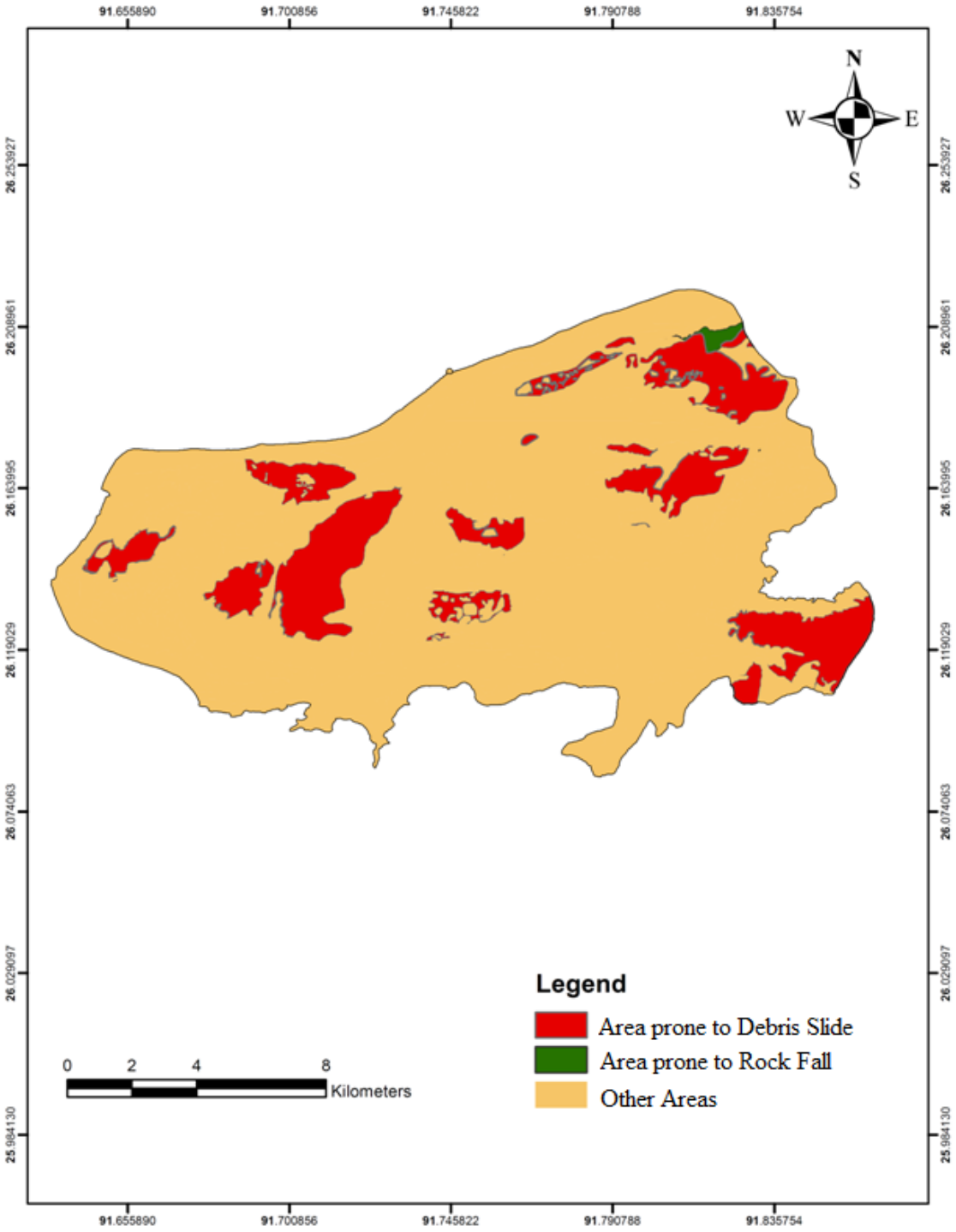

Fig. 5.0 Landslide Hazard Zonation Map oGuwahati city

The area prone to landslide was demarcated on the basis of geological and geomorphology features of landuse/landcover area. The area having dissected hills and falling under Sonapur geological formation zone is more prone to landslide in Guwahati region. Rockfall occurring in the region was also identified through analyzing union map of LU/LC, geology and geomorphology map. It is found that out of the total geographical area 28.9% are under prone to land slide, 16.6% area come under rock fall and 57.3% come under the category of others. Rock fall occur in the area where the slopes are steep. The eastern part of the Guwahati region is exposed to rock fall due to steep slopes and low vegetation cover as the forest cover in the area has declined and most of the forests are blank. The area is also prone to seismic activities which lead to instability of slope in the region. Seismic activity and rainfall plays a major role in the occurrence of landslide in the region.

Fig:6. (A)Hill without vegetation cover (Lokhra) (B) Cutting of hills for construction of road in khanapara (C) Debris landslide occurred at Lalungaon (D) Rockfall landslide at Sonaighul

Geomorphologically, the Guwahati city has large number of dissected hills across the city. These hills are highly erosive in nature, which has resulted into occurrence of landslide in the region. The slopes of these hills are moderate but are highly vulnerable due to low vegetation cover. The forest cover in the region has got decreased and falls under Forest Blank categories of NRSA classification. These forests have very low vegetation cover which has exposed the upper surface to agent of erosion. The lands without scrubs are also vulnerable to rock fall landslide. Rainfall is one of the most important triggering factors which has resulted into occurrence of landslide in the region.

VII. RECOMMENDATION AND REMEDIAL MEASURES

Guwahati is the most premier urban centre of northeast India. It is the nerve centre of all the economic activities taking place in the extreme northeastern part of India. The city is increasing at a very rapid rate. Rise in population has resulted into encroachment of forest and hilly areas of the city. Haphazard construction of settlement without any necessary measures has resultant into instability of slopes in the region. Deforestation, illegal settlement construction, inappropriate drainage system, construction work and supported by intense and prolonged rainfall in the city has cause to slope failure in the Guwahati region. Recently frequency and intensity of landslide incidence has increased in the region. There has been lot of casualty and damage of property due to this geological hazard. So, in order to minimize the impact of landslide, necessary steps should be taken in advance for protection and prevention. Here are the few recommendation and remedial measures to be taken for landslide in Guwahati region. These measures are fully based on the field observation and study done through various journal and articles for landslide hazard and its mitigation measures.

1. The most important measures to be taken is the preparation of standard guidelines for landslide management and mitigation for the entire city. These guidelines should be shared with the entire administrative department as well as all the stakeholders involve in disaster management. These guidelines should also be in local language and should be shared with the community.
2. Area falling under high risk zone should be completely avoided for any construction work or for human settlement.
3. Retrofitting of the houses built on the hills should be done so that it can withstand the impact of landslide to some extent. It was observed that most of the houses built on the hills are kuttcha or the walls are made up of single brick. Such kind of housing structure could not withstand impact of any kind of landslide event.
4. Slope identified as vulnerable to landslide must be corrected in advance to avoid any slope failure in the region. Slope which is more than 20 degree angle should be corrected in advance using technical method.
5. The city lacks proper drainage system. Moreover the natural drainage systems have also been affected by human interference. The drainage system of the city should be corrected so that the water can flow freely through a channel without affecting slope.
6. People located at the most risky zone should be rehabilitated to a safer and plain area through any government development scheme like JNNURM.
7. Mining and any quarrying activities on in and around the hills must be strictly banned.
8. An awareness programme among community must be created in the region about the causes and impact of landslide. Community must be taught about natural way of mitigating landslide. The community must be informed about the impact of houses created on steep slopes due to landslide.

9. Biotechnical slope protection measures can be used for increasing the strength of the soil as it is environment friendly.
10. Slope on the hills should be monitored regularly and assessment of the slopes must be done annually. A task force must be made to monitor and identify the area vulnerable to landslide.

VIII. CONCLUSION

Disasters are inevitable, but the disaster caused due to human negligence can be avoided to some extent in future. Landslide in Guwahati city is mainly caused due to interference of human by disturbing the surrounding environment. Due to rise in population, the area under forest cover has decreased, which has exposed the top surface to weathering. Rainfall and seismic activity has acted as a triggering factor in most of the event of landslide in Guwahati city. People have been living in the high risk zone of landslide. So in order to minimize the impact Landslide Hazard Zonation mapping is one of the most important exercise which helps in identifying the area at higher risk to landslide. This will help the planner to take necessary step to overcome the problem and will also help in future development project. Landslide Hazard Zonation will also helps in taking preventing measures in advance to minimize the impact of landslide in the region.

IX. ACKNOWLEDGMENT

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