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An appraisal of geomorphic characteristics and flood susceptibility zone using remote sensing and GIS: A case study North 24 Parganas District, West Bengal, India

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Abstract:

Floods are a recurring hazard in the North 24 Parganas district of West Bengal, India. The district is known for its complex geomorphology and dynamic hydrology. Out of all the North 24 Parganas districts, two subdivisions are mainly affected by floods, namely Basirhat subdivision and Bangaon subdivision. This study assessed the geomorphological features and identified flood susceptibility zones using remote sensing and GIS. Important geomorphological factors such as elevation, slope, land use and land cover were analyzed to assess their impact on flood risk. By integrating satellite data, digital elevation model (DEM) and GIS, we have developed a flood susceptibility map for targeted flood management. This study highlights the value of geomorphological and remote sensing information for understanding flood risk and guiding sustainable land use planning. Remote sensing and GIS are known to be very important and useful tools in identifying flood-affected areas and accurately understanding the causes of floods. In addition to the causes of floods and affected areas, remote sensing and GIS help in knowing and understanding flood management, flood prevention, and dynamics.

Keywords: North 24 Parganas district, Flood disasters, GIS, Remote sensing

1. Introduction:

1.1 Background:

Any disaster makes the normal life of people miserable. A disaster is called a disaster only when it harms people and animals and affects populated areas. Floods are one of the most common disasters. Floods are mainly seen in flat areas. Due to the low slope of the land in flat areas, the speed of the river decreases, due to which a lot of sediment accumulates on the riverbed. During heavy

rainfall during the rainy season, the river cannot carry this excess water and overflows its banks, flooding populated areas, resulting in floods. Floods cause loss of life, death of various animals, extensive damage to residential areas, closure of highways, damage to rail lines, power outages, disruption of telecommunication systems, closure of schools and colleges for a long time, etc. There are many factors behind the occurrence of floods, such as landforms, land slopes, climatic features - especially rainfall, river density, river flow, etc. Apart from natural factors, there are also indiscriminate human activities such as hastily building settlements, settling in low-lying areas along the river banks, building brick kilns on both sides of the river, building embankments around the river, building bridges over the river, etc.

Floods are one of the most devastating natural disasters in India, especially affecting low-lying areas like North 24 Parganas in West Bengal. The district's proximity to the Bay of Bengal and the presence of numerous rivers, canals and wetlands make it highly susceptible to floods. The seasonal monsoons exacerbate these risks, resulting in regular floods that affect agriculture, settlements and infrastructure.

Remote sensing and GIS technologies have proven essential for identifying flood-prone areas by providing spatial information on landforms, soil types, drainage and more. This study focuses on understanding the geomorphological features of North 24 Parganas and creating a flood susceptibility map, which aims to assist in efficient flood management and risk mitigation.

1.2 Study Area:

North 24 Parganas is a district located near the coast of West Bengal, India, with a geographical area of about 4,094 square kilometers. North 24 Parganas is a border district of the Indian state of West Bengal, extending between 23°15'2"N and 22°11'6"N latitude and 89°5'E and 88°2'E longitude. It is bordered by Bangladesh to the east, Nadia district to the northwest, Hooghly and Howrah districts to the west, and South 24 Parganas to the southwest (Figure 1).

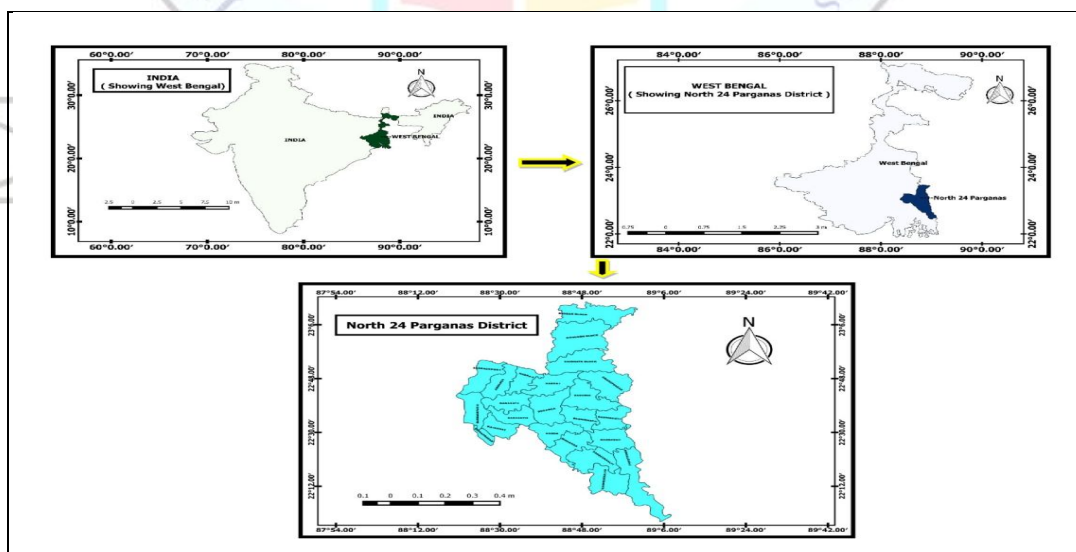


Figure1: Location map of the study area

The climate of North 24 Parganas district is humid, tropical, and characterized by a variety of landforms, including coastal plains, riverine areas, and wetlands. The district has a population density of about 2182 people per square kilometre and a population of 10,009,781, making flood risk particularly significant for a densely populated area. North 24 Parganas district is mainly made up of five subdivisions namely Bangaon, Basirhat, Barasat, Barrackpur and Bidhannagar. The district consists of a total of 199 gram panchayats, 1606 mouzas, 25 municipalities and 1527 villages.

North 24 Parganas district is a part of the lower Gangetic delta, through the west of which the Bhagirathi river flows. The main rivers of this district are Betna, Betrabati, Bhagirathi, Bidhyadhari, Dantbhanga, Haroagong-Kultigong, Ichhamati, Jamuna, Kodalia, Naobhanga, Nonagong, Padma, Sarat Khali, Sealdagong, Sonai, Suti, Tentulia, Kalindi, Raimongal, Dasna, Betni. The water of these rivers is used for agriculture, fishing, brick kilns and various other purposes in the settlement areas of this region. Among all the above rivers, the Ichhamati river has the greatest impact on this district. The Ichhamati river originates from the Mathabhanga river near Majhdia in Nadia district and merges with the Kalindi river near Hasnabad after passing a long distance of 208 km. On this course, the Ichhamati river flows through three municipalities (bongaon, basirhat, taki) and several villages. The Ichhamati River is largely responsible for the floods that have occurred in North 24 Parganas district in recent years.

The maximum temperature of North 24 Parganas district is 43°C, which occurs in May and the minimum temperature is 8°C in January. The weather of this district can be observed as Relative Humidity Between 50% in March & 90% in July and the average rainfall throughout the year is approximately 1579mm.

The soil of this district varies from Sandy to Clayey Loam. Due to occasional floods, the riverside areas of this district are covered with fertile silt from the rivers. As a result, the soil of the riverside areas is more fertile than other areas.

1.3 Objectives of the Study:

The objectives of this study are:

- To examine the geomorphologic features affecting the flood susceptibility of North 24 Parganas district through remote sensing and GIS.
- To use remote sensing and GIS to map flood-prone areas.
- To analyze the flood-prone areas of this district to assist in disaster management planning.

2. Literature Review:

Geomorphic studies combined with flood susceptibility analysis have proven effective in identifying high-risk areas. Research indicates that factors like elevation, slope, drainage, and land use significantly impact flood behavior. Recent studies also emphasize the advantages of integrating DEMs and satellite imagery with GIS for flood mapping, particularly in regions where field data

collection is challenging. Currently, various studies are focusing on the use of open source GIS software. These open source software can be used to easily create maps of flood-prone areas and also to create various geomorphic maps to determine the causes of floods. For example, GIS-based flood vulnerability maps, elevation maps, geomorphology maps, river networks, river catchments, watershed delineation, stream ordering, etc. can be created to understand flood vulnerability.

3. Data Used:

- First of all, shp file of our country India has been collected from Global Administrative Areas (GADM) portal.
- Then DEM data has been collected from SRTM through QGIS to create elevation map.
- DEM data has been collected from SRTM through QGIS to create slope map.
- Data has been collected from Bhuban portal to create geomorphology map.
- Data has been collected from Bhuban portal to create Land use land cover (LULC) map.
- Data has been collected from Survey of India Topographical sheet and updated with Landsat8 OLI satellite data to create drainage map.
- To create flood risk zoning map through QGIS, information about where floods have occurred in different years and gauge data of various gauge stations have been taken from "District Disaster Management Plan" of North 24 Parganas district.

4. Methodology:

To analyze the flood vulnerability, we used GIS-based Multi-Criteria Assessment (MCE). The open source software QGIS 3.28 was used to assess and define the flood intensity and flood-prone areas. To understand the geomorphologic factors behind the floods in North 24 Parganas district, elevation map, slope map, geomorphic map, LULC map and river network map were generated using QGIS 3.28 software. All the maps mentioned above were created using the Universal Transverse Mercator (UTM) coordinate system and the WGS84 spatial reference system using QGIS software.

To get the shp file of the research area North 24 Parganas district, the shp file of India was downloaded from the Global Administrative Areas (GADM) portal. The India shp file was included in QGIS 3.28 open source software and from there only the shp file of the research area North 24 Parganas district was kept and the rest were deleted.

Then, DEM data was collected from SRTM (Shuttle Radar Topography Mission) through QGIS 3.28 and superimposed on the shp file of the research area North 24 Parganas district. The maximum value or height of the collected DEM data is 48 mt and the minimum value or height is -23 mt, the height range is 71 mt, and the average value or height is 6.26 mt. This time, the DEM data of the research area has been clipped from raster to clip raster by mask layer to clip the research area. Then, the symbology of the clip DEM data has been changed and the land slope has been represented

according to the difference in color density with the appropriate color of the land slope (Figure 2). Elevation maps of important subdivisions of this district such as Bangaon subdivision (Figure 3), Basirhat subdivision (Figure 4), Barasat subdivision (Figure 5) and Barrackpur subdivision (Figure 6) have been prepared in the same process.

In conducting flood research in any region, the geomorphology of the region should be reviewed. Bhuvan Portal has been used to collect the geomorphology map of North 24 Parganas district. Geomorphology map has been created by collecting the geomorphology data of this study region from bhuvan.nrsc.gov.in and connecting it to Bhuvan Portal through its WMS layer in QGIS 3.28 software (Figure 8).

To create the river network map, data was collected from the Survey of India Topographical sheet and updated from Landsat8 OLI satellite data (Figure 9).

The help of Bhuvan Portal has been taken to create the LULC map of North 24 Parganas district. Similarly, the LULC map has been created by connecting Bhuvan Portal with QGIS 3.28 (Figure 10).

We used a weighted overlay analysis to develop the flood susceptibility map. Each raster layer was reclassified based on susceptibility (low, moderate, high, and very high), then weighted to reflect the combined influence of geomorphic features on flood risk. The final flood susceptibility map was validated using historical flood data and local reports. To create a flood map of North 24 Parganas district and identify the flood-prone areas, information has been collected from the "District Disaster Management Plan". This information has been collected on which year's floods have occurred in each village of the entire district and it has been seen that which areas of North 24 Parganas district are most flood-prone, moderately flood-prone, less flood-prone and some areas are very less flood-prone. With this information, a flood map of North 24 Parganas district has been created through digitization in QGIS 2.10.1 software (Figure 11).

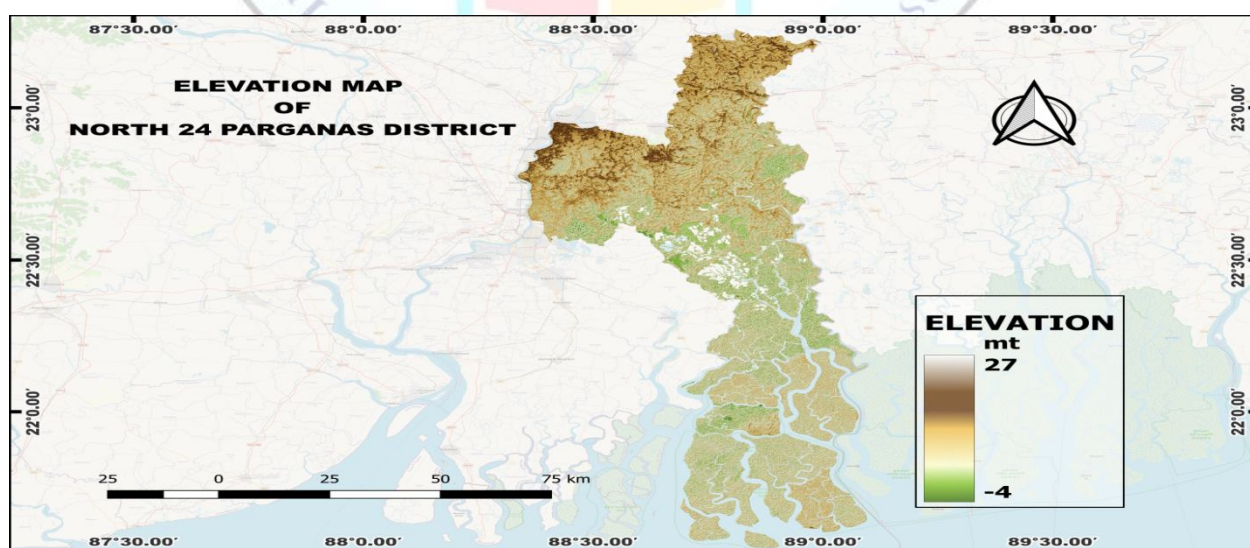


Figure 2: Elevation map of North 24 Parganas District

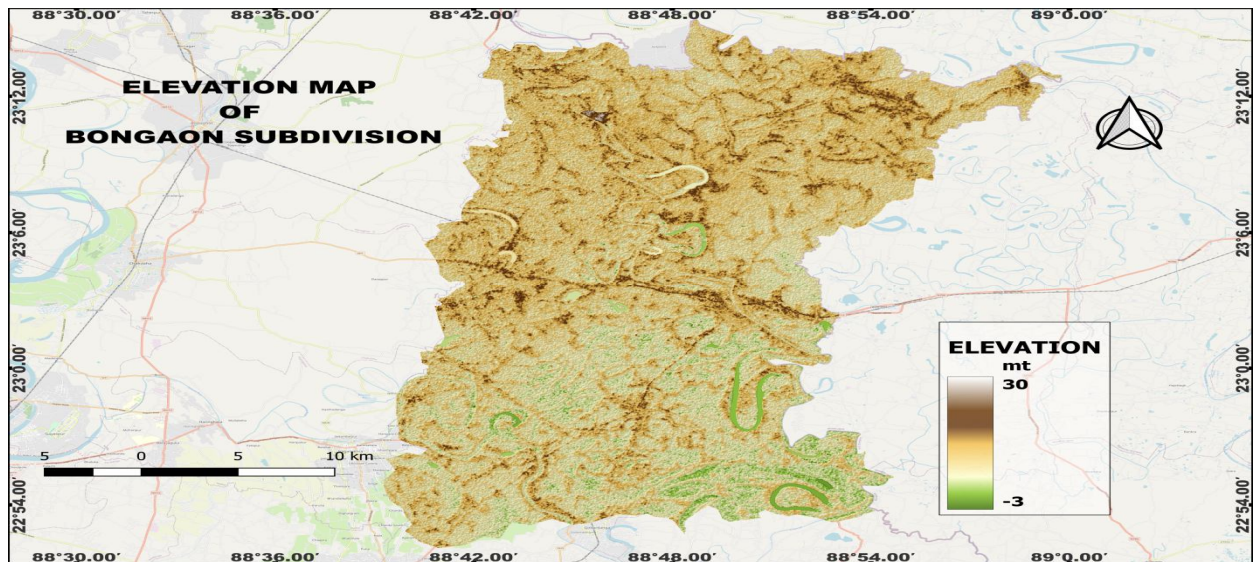


Figure 3: Elevation map of Bongaon subdivision

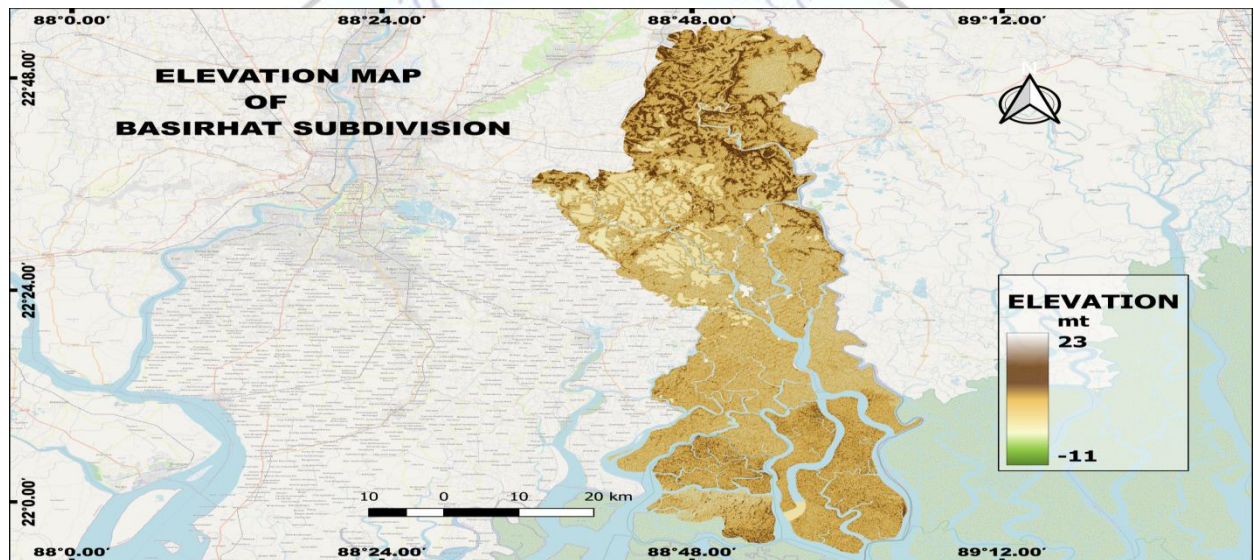


Figure 4: Elevation map of Basirhat subdivision

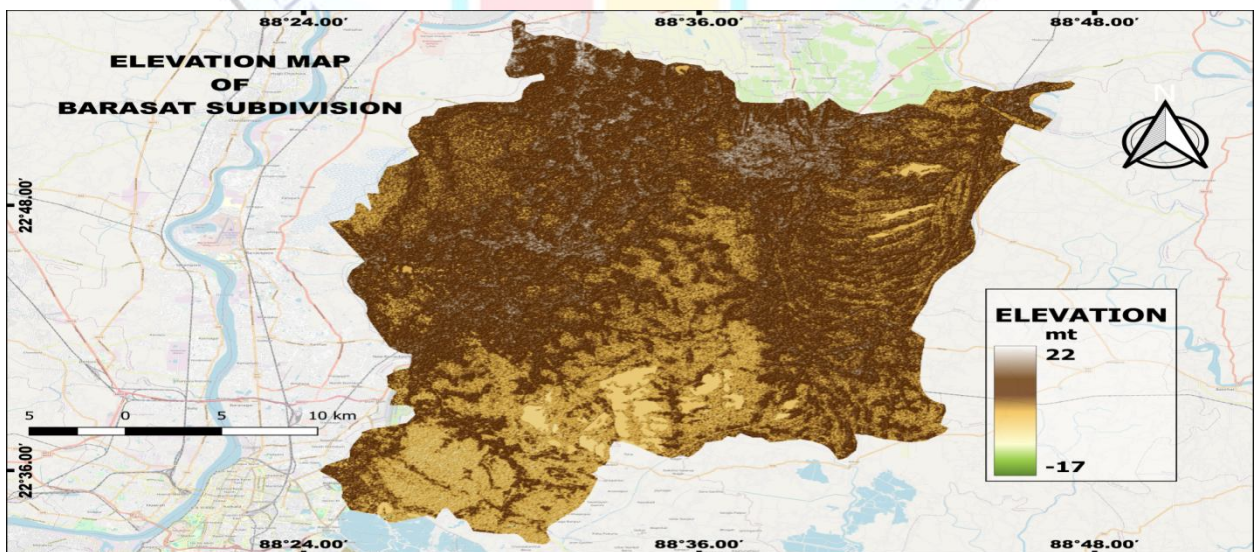


Figure 5: Elevation map of Barasat subdivision

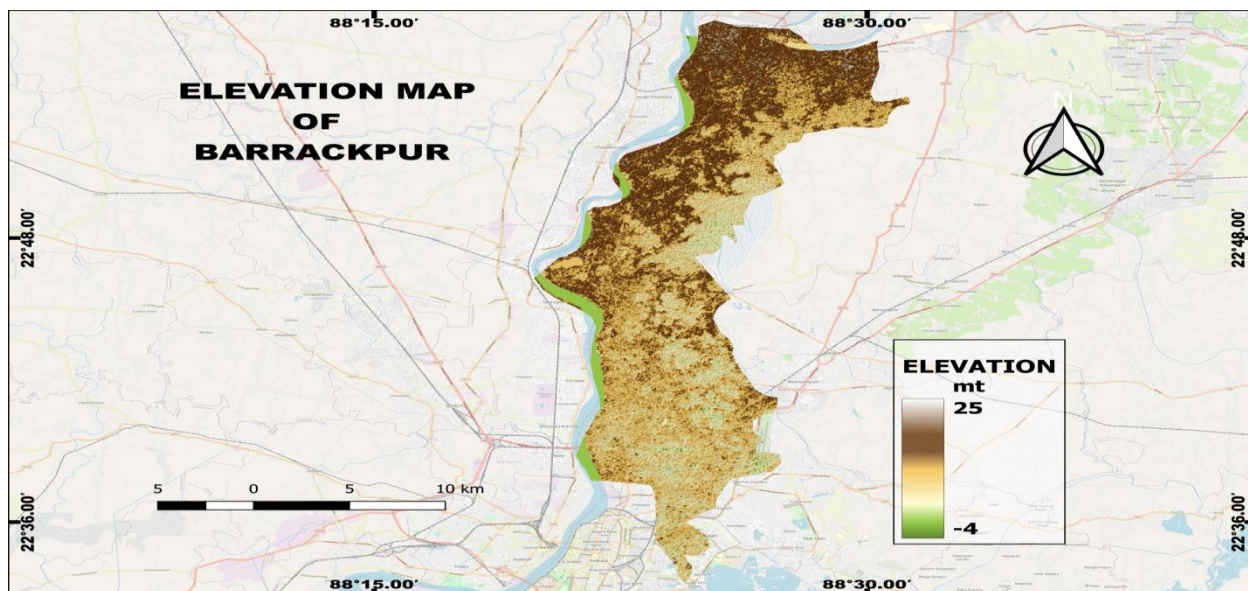


Figure 6: Elevation map of Barrackpur subdivision

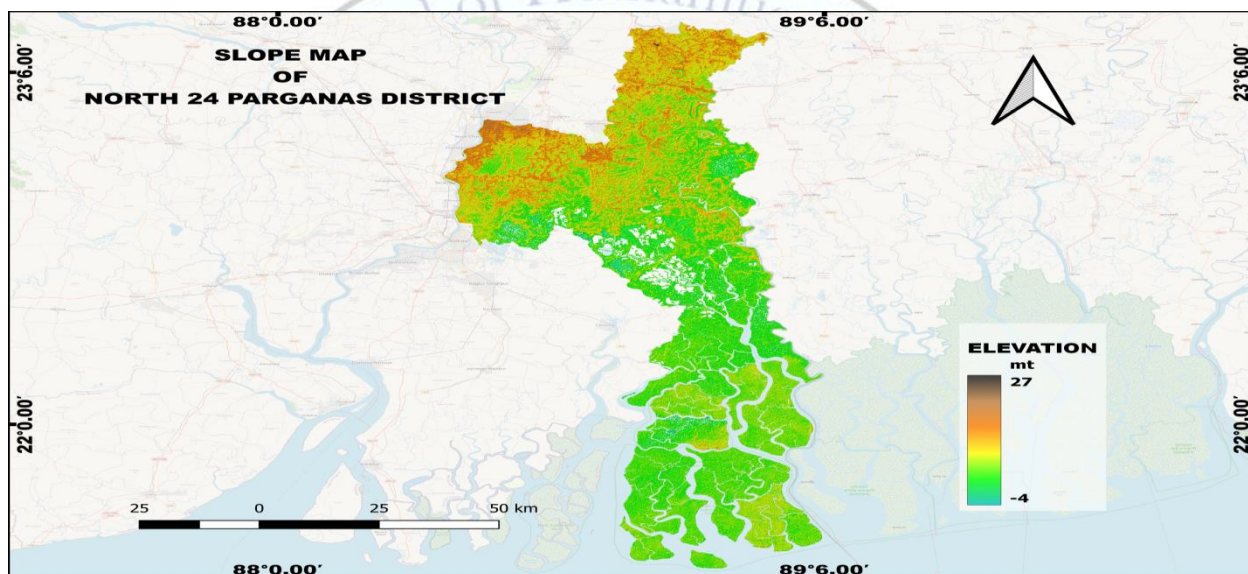


Figure 7: Slope map of North 24 Parganas District

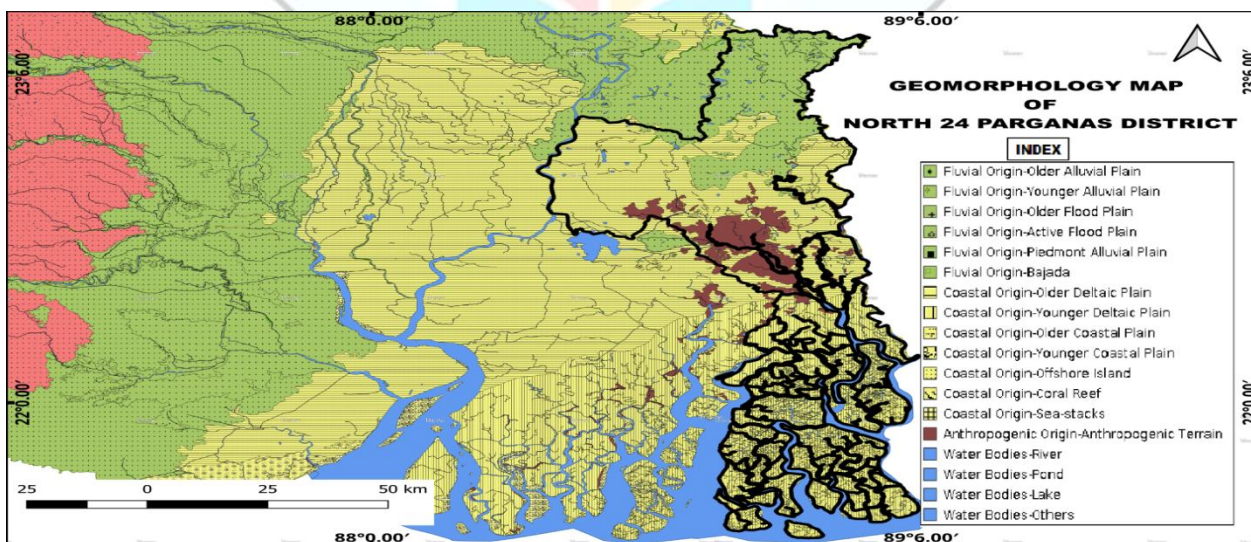


Figure 8: Geomorphology map of North 24 Parganas District

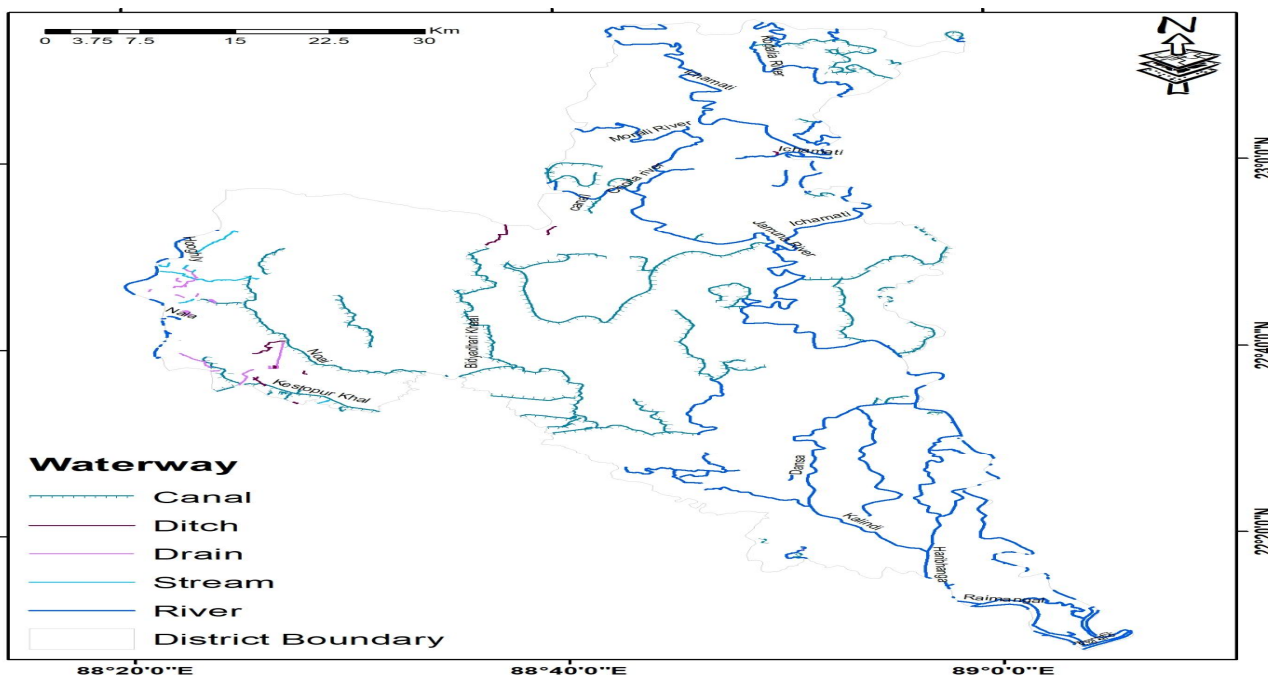


Figure 9: River map of North 24 Parganas district

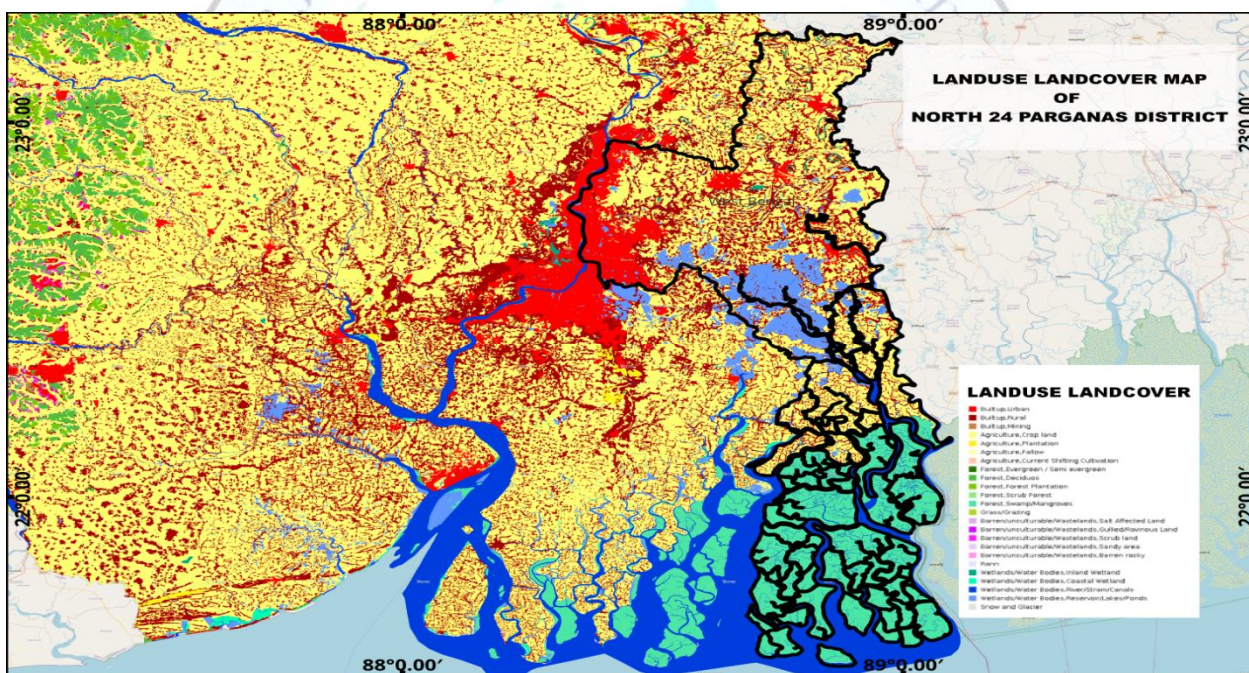


Figure 10: Land use Land cover map of North 24 Parganas District

5. Flood Susceptibility Zone Identification:

Identification of flood-sensitive areas is very important for disaster management and planning in regions like North 24 Parganas of West Bengal. The district is highly vulnerable to floods due to its proximity to the Ganga-Brahmaputra delta, numerous rivers and low-lying areas. Topographic Data like Digital Elevation Model (DEM) from SRTM, elevation map (Figure 2) and slope map (Figure 7) helps to know the slope of the entire district, which areas are low and which areas are high, where water accumulates and gets stuck during monsoon, etc.

North 24 Parganas district has been identified with various geomorphological parameters, such as fluvial origin(older alluvial, younger alluvial plain & older flood, younger flood plain), coastal origin(older and younger deltaic plain), active river channels, abandoned river channel, channel bar, back swamp, deep depression, meander scar, water body, ox-bow lake, paleochannel and shallow depression, anthropogenic terrain.

In this study area, all the river groups are classified as active channel and abandoned channel. Active river channels play an important role in sediment transport, but gradually these rivers are getting filled up due to sediment accumulation. Ganga and Ichamati river are two important active river channels of this region, which are playing an active role in sediment accumulation in this region, which is playing an effective role in increasing the probability of flooding in this region. Abandoned river channels are seen scattered all over this region especially in the north-eastern and southern regions. These abandoned river channels are isolated from the main river and store water in low-lying areas throughout the year and these areas get flooded quickly during the monsoon.

Among fluvial origin, older alluvial, younger alluvial plain & older flood, younger flood plain help to identify flood-prone areas. In younger flood plains, flooding continues actively, due to which younger alluvial plain is formed here. In older flood plains, floods occur after a long period of time; as a result, older alluvial plain can be seen here. The entire Bangaon subdivision located in the north of North 24 Parganas district and some parts of the northern part of Basirhat subdivision belong to older flood plain, only the areas along the Ichamati river with active river channel over these areas belong to younger flood plain. In the areas along the Ichamati river, the river water overflows its banks every year during the rainy season, as a result, new sediment is deposited in these areas along the river every year. Since these areas along the Ichamati river are very fertile, people do agriculture here. Every year during the rainy season, this agricultural area is flooded with floodwaters.

The central part and the upper part of the southern part of the North 24 Parganas district are entirely covered by the older deltaic plain of coastal origin, and the lower part of the southern part is covered by the younger deltaic plain of coastal origin. Almost the entire part of Basirhat subdivision is covered by this coastal origin. Being a part of the coastal origin, the elevation of this region is very low, in many cases even below sea level. Therefore, this region is the most flood-prone in the entire North 24 Parganas district (Figure 8).

The river map of North 24 Parganas district shows that many rivers flow from the north-east to the south-east of the district. Some canals are visible in the central and western parts of the district and some ditches are present in the western part of the district. Due to the high density of rivers, the incidence of floods is highest in the north-east and south-east of this district (Figure 9).

The severity of floods in a region largely depends on the land use of that region. Uncontrolled

and indiscriminate use of land by humans, especially in low-lying areas along the river banks for settlement, cultivation, and communication, increases the severity of floods. A lot of information about the current land use has been obtained from the LULC map of North 24 Parganas district. The LULC map shows the dangerous development of settlements in flood-prone areas of this district, the amount of agricultural land in flood-prone areas, the use of low-lying areas, etc (Figure 10).

The North 24 Parganas district is prone to floods due to its low elevation, proximity to the Bay of Bengal, and presence of several rivers like the Ichamati, Bidyadhari, and Hooghly. Factors like storm surges, monsoonal rainfall, and tidal effects also contribute to flood risk.

6. Results and discussion:

The main objective of this study is to assess the geomorphological features and flood susceptibility areas of North 24 Parganas district using remote sensing and GIS. For this study, various maps such as elevation map, slope map, geomorphology map, LULC map and flood zoning map have been prepared using QGIS software using various remote sensing and GIS data. By reviewing the above GIS based maps, various aspects of flood tendency and identification of flood zones of the study area have been known.

The land slope and elevation map gives an overall picture of the elevation of a region. The land slope and elevation map of North 24 Parganas district shows that the district is entirely flat and the variation in land slope in this district is very low (Figure 2 & 7). The highest elevation of this district is 27 meters, which is seen in the northern part of Barrackpore subdivision located in the west of this district. The lowest elevation of this district is -4 meters, which is seen in the southern part of Basirhat subdivision located in the south of this district. Therefore, the land slope and elevation map of North 24 Parganas district shows that the land height of the entire district is very low and the land slope of the district gradually decreases from the north-west to the south and drops below 0 meters. Detailed information about the land slope and elevation of this district is also available from the land slope and elevation maps of various subdivisions of North 24 Parganas district (Figure 3, 4, 5 & 6). Geomorphology map highlights the landform features of a region. The geomorphology map of North 24 Parganas district shows that the northern part of this district, i.e. the entire Bangaon subdivision, is under the older flood plain. Active river channel (Ichamati river) along with many abandoned river channels, back swamp, meander scar, ox-bow lake, paleochannel and shallow depression can be seen in different parts of Bangaon subdivision. The southern part of the district is under the older and younger deltaic plain. Much of this southern part is covered by anthropogenic terrain, many active river channels, water deposits, meander, ox-bow lake (Figure 8).

The river map of North 24 Parganas district shows that many rivers flow from the north-east to the south-east of the district. Some canals are visible in the central and western parts of the district and there are some ditches in the western part of the district (Figure 9).

The LULC map of North 24 Parganas district shows that the highest population density of this district is in the western and central parts, urban settlements are the most in this part. Mainly in this part, land use is highest in the areas of city-centered communication system, business, industry, education, entertainment, etc. Apart from this, dense village-centered settlements are seen in this part. In the north of North 24 Parganas district, Bangaon subdivision is densely populated, but rural settlements are more here than urban. The population density is lowest in the south of the entire district. In the southern part, land use is mainly village-centered. However, since this region belongs to coastal origin, agricultural work is not good due to the intrusion of salt water into the soil. Most of the land here is used for making fish ponds. A large part of the land of the entire North 24 Parganas district is occupied by rivers, canals and wetlands (Figure 10).

The flood hazard susceptibility map of North 24 Parganas district has identified the flood risk zones of this district. The flood hazard susceptibility map has been divided into 5 categories according to the intensity of the flood, namely very high risk, high risk, moderate risk, low risk, very low risk.

Very high risk zone: Sandeshkhali-I, Sandeshkhali-II, Hasnabad and Hingalganj blocks of Basirhat subdivision located in the south of this district belong to this zone (Figure 11). This zone covers a total area of 770.28 square kilometers which is 18.81% of the total district. This zone is crossed by the active river channels of Dansa, Kalindi, Haribhanga and Ichhamati, which make this zone very high risk. This zone belongs to older and younger deltaic plain. Most of the elevation of this zone is below sea level. For these reasons, this area belongs to the Very high risk zone.

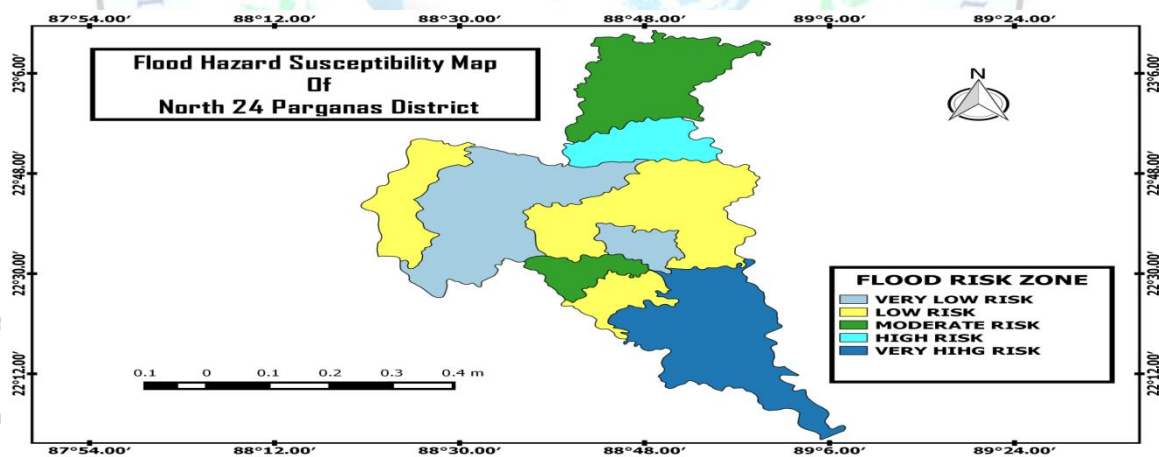


Figure 11: Flood hazard susceptibility map of North 24 Parganas District

High risk zone: This high risk zone includes Gaighata block which is located to the south of Bangaon subdivision. This region covers an area of 243.30 square kilometers, which is 5.94% of the total district (Figure 11). The elevation of this zone is less than 0 m above sea level in the south-eastern part and 0 m in many places in the central part. The average elevation of the zone is 11 m. Abandoned river channels, paleochannels, oxbow lakes, back swamps and deep depressions are scattered in this area.

Moderate risk zone: This moderate risk zone includes Bagdah and Bangaon blocks, north of Bangaon subdivision and Haroa block of Basirhat subdivision. This region covers an area of 1224.37 square kilometers, which is 30% of the total district (Figure 11). The average elevation of the zone is 15 meters. The zone belongs to older alluvial plain. Abandoned river channels, oxbow lakes and active river channels are found here.

Low risk zone: This zone is located in the central part and extreme west of North 24 Parganas district. Deganga, Baduria, Swarupnagar, Minakhan and Basirhat-I blocks of Basirhat subdivision and entire Barrackpur subdivision are in this Low risk zone. This region covers an area of 1203.40 square kilometers, which is 29% of the total district (Figure 11). The average elevation of the zone is 20 meters.

Very low risk zone: This zone consists of Barasat Subdivision and Bidhannagar Subdivision located in the west of this district. This region covers an area of 729.68 square kilometers, which is 17.82% of the total district (Figure 11).

7. Conclusion:

The main objective of this study was to conduct a geomorphological discussion on the most important disaster flood of North 24 Parganas district through geospatial techniques. From the maps prepared through remote sensing GIS, it is understood that the entire region is flat land. The height of the land here is very low, in some places the height of the land is below sea level. The northern part of the region mainly belongs to older flood plain & younger flood plain. Excluding the northern part, the rest of the part belongs to older and younger deltaic plain. Although the height of the land in the northern and western parts of the region is a little higher, the height of the land in the southern part is very low, in some places the height is below sea level.

There are many active river channels throughout the region, including the Dansa, Kalindi, Haribhanga and Ichhamati. The Ichhamati River is the longest river in the district, and has deposited a lot of sediment along its banks. The Ichhamati River is one of the main causes of flooding in the district. North 24 Parganas district is densely populated, with a large portion of the population living on the fertile land along the banks of various rivers, which increases the risk of flooding. The southern part of Basirhat Subdivision in the south of the district is most vulnerable to flood. In addition, the areas along the Ichhamati River in Bangaon Subdivision in the north of the district are also affected by floods. Only a few areas in the western part of the entire region are protected from the severity of floods.

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