Applications of Remote Sensing in Geomorphologic Mapping: A Case Study from the Karur District, Tamil Nadu, India

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Abstract: ***The study of landforms, or geomorphology, provides an understanding of surface and subsurface processes that carved landforms on the Earth's surface over time. Geomorphology and ancillary information on geology, soil, vegetation, and hydrology help plan development in numerous fields. Geomorphological mapping and its applications have been carried out using satellite-based geospatial technology for the last five decades. Using satellite remote sensing's synoptic and temporal capability, different landforms can be depicted. The use of remote sensing enables rapid and systematic geomorphological mapping at a low cost and allows the detection and mapping of landforms in dynamic landscapes at various scales. Geomorphological mapping is discussed in this paper, along with remote sensing mapping techniques. IRS-P6 LISS-III (23.5 m) satellite images were used as the primary data source for the mapping. Additionally, ancillary data such as geological maps, topographic maps, digital elevation models (DEMs), field data collected by GPS systems, and web portals for image visualization were employed in the mapping process. Structural hill, linear ridge, inselberg, piedmont zone, colluvial fill, rocky pediment, buried pediment, older flood plain, and younger flood plain are the major geomorphological units found in the present study area. This study's output will help the geologist, water resources managers, and administrators to plan and administrate resources sustainably.***

Keywords: False color composite, geomorphologic mapping, remote sensing, Karur district, Tamil Nadu

1. Introduction

Geomorphology is the exterior architecture of Planet Earth. The exposed rocks in the Earth's crust undergo physio-chemical breaking down called weathering processes due to various pressure-temperature variations [1-2]. The agents like rivers that flow on them erode, transport, and deposit them in different parts of the Earth's surface and develop erosional and depositional features on the Earth's surface. Similarly, various other geomorphic agents such as sea, air, and glaciers and their processes, viz: the coastal processes, aeolian processes, glacial processes, etc., operate on the Earth's surface and create different geomorphic landforms/ features [3].

Landform mapping, geomorphic process analysis, and its applications have opened new vistas because of advances in geospatial technology, such as high and very high-resolution satellite data and the availability of high-resolution DEMs new data-driven techniques and algorithms for remote sensing data analysis. For floods and landslides, geomorphology is widely used in hazard zonation [4-6]. It can be applied to geoengineering to assess the site before building dams, roads, or railways. Oil and gas exploration uses geomorphological guides to detect mineral occurrences. Also, they are essential in delineating hydro-geomorphic units [7]. Management of coastal zones requires it. The study of geomorphic anomalies is also widely used in archaeology and anthropology. Climate change can be studied by studying the imprints of geomorphic processes on any landscape [8-10].

It is possible to obtain information about landforms, surface/subsurface composition, and surface elevation using remote sensing. The present context for the application of remote sensing in geomorphology is presented with a particular focus on the impact of new technologies, primarily: (1) the widespread availability of digital elevation models; and (2) the introduction of hyperspectral imaging, radiometric, and electromagnetic [11-12]. Developing advanced computational techniques and image-processing algorithms also revolutionized remote sensing techniques. From the use of hard-copy images to the processing of digital data, remote sensing has advanced. Through the application of corrections to raw image data to improve radiometry of remote sensing images, information extraction from remote sensing images was enhanced, geometric corrections of images were performed for tying the images precisely to any geographical location on the Earth's surface, and area-specific enhancements were applied to the images and mosaics were generated to create seamless databases of large areas [13].

The geomorphology map of the Karur district was compiled in a GIS environment by interpreting IRS-P6 LISS-III images on the screen. When mapping the geomorphology of the present study area, a digital elevation model (DEM) was also used, which provides valuable insights into landforms in hilly terrain. Using a global positioning system (GPS), the landform boundaries were checked and updated during fieldwork. Based on image tone, texture, and association, satellite data were used to map the geomorphology of the present study area, displaying slope, relief, and differential vegetation growth.

2. Materials and Methods

2.1 Study area description

The study area, Karur district, is located in the Central part of Tamil Nadu state, India, bounded in the North by Namakkal district, in the West by Tiruppur district, in the Southeast by Dindigul district, and in the East and Northeast by Tiruchirappalli district (Fig. 1). The study area is located in between North latitudes 10o 30' 00" and 11o 05' 00" and East longitudes 77°45' 00" and 78°35' 00". The Karur district covers an area of 2,900 sq. km.The major part of the Karur district is drained by the Cauvery River flowing from west to east along the district boundary in the northern part. Amaravathi, Nanganjiar, Kodavanar, and Pungar are the other important rivers and tributaries to the Cauvery River. Amaravathi, Nanganji, and Kodavanar drain in the district's western part, and the river Pungar drains in the eastern part of the district. The drainage pattern is generally dendritic. All the rivers are seasonal and carry substantial flows only during the monsoon period. Several irrigation canals have water from the river Cauvery flowing towards eastern agricultural lands for seasonal crop cultivation.

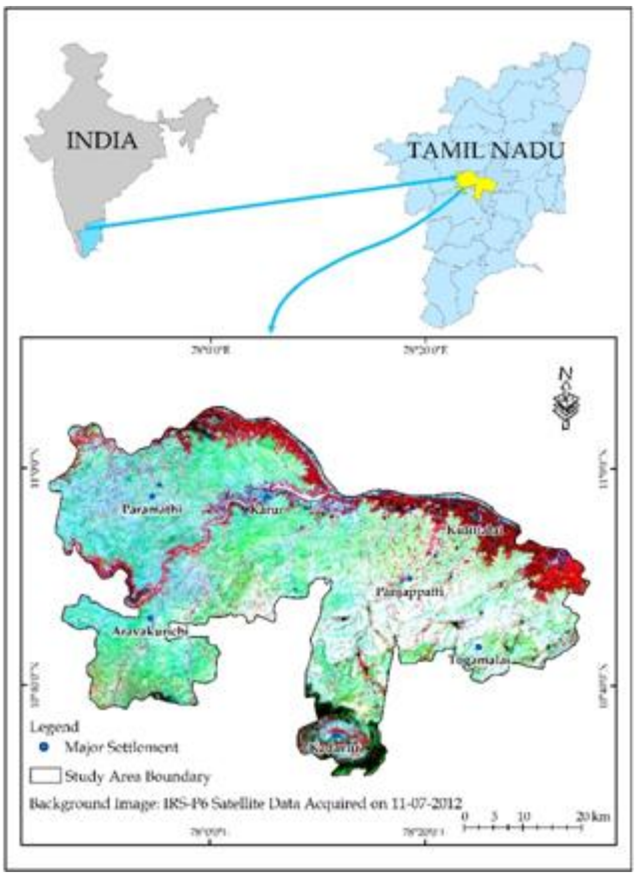

Figure 1: Study Area Map

2.2 Materials used

Geomorphological mapping of the present study area was conducted using the following data.

1) LISS-III images from IRS-P6 with four bands (3 Visible and 1 SWIR), with a spatial resolution of 23.5 m and a swath width of 141 km.
2) Downloaded ASTER DEM with a resolution of 30 meters.
3) A geological and mineral map of the Karur district published by GSI at a scale of 1:125,000.
4) A survey of India's toposheets at 1:50,000 scale with contour intervals of 20 meters was used.

2.3 Methods

Onscreen image interpretation techniques were used to carry out the geomorphologic mapping. By increasing contrast among various features, image enhancement was performed to improve the images' interpretability. We understood the relief and dissection patterns using the ASTER DEM and toposheets[14]. Hillshade, derived from the ASTER DEM with different azimuth and sun elevation angles, was used to identify faults, fractures, and joints in this region. Various bands were combined to generate false color composite images, and landforms were identified based on the tone, texture, and association, as well as additional information derived from toposheets and GSI geological maps.

3. Results and discussions

The geomorphology map was prepared using the elevation details from the Survey of India topographic sheets, interpreting the IRS P6 LISS – III satellite imagery and enhancing and visualizing the digital satellite data using digital image processing techniques (Fig.2&3). The geomorphic units represented in the study area are Structural Hills, Linear Ridges, Inselbergs, Piedmont Zone, Colluvial Fills, Rocky Pediments, Buried Pediments, Older Flood Plain, and Younger Flood Plains. The corresponding vectorized GIS layer is shown in Fig 4. The Karur District generally has an undulating topography with a gentle slope towards East–North–East (ENE). This district has a few major and minor detached patches of hill ranges: Kadavur, Ayyarmalai, and Rangamalai hills. The following sections discuss about the detailed geomorphologic mapping of the present study area.

3.1 Structural Hills

These are the broad undulating hills of considerable elevation showing structural linearity/curvilinearity and steeply sloping in all directions. From the groundwater point of view, the structural hills serve as high run-off zones. Recharge is poor and restricted mainly along the joints, fractures, and faults. Therefore, groundwater occurrence is limited with the availability of joints, fractures, and fault planes in the structural hills. In the satellite FCC, processed and enhanced satellite FCC image, these structural hills are identified by long and linear alternating ridge and valley topography with or without different forest cover types (Fig. 2 D).

3.2 Linear Ridges

They exhibit linear shape and positive relief in satellite images. In the Karur district, the linear ridge is identified in the southern part of the study area, and it appears in the satellite image with light brown to dark tone and coarse texture. The N-S trending linear ridge was developed over quartzite. Extremely shallow to moderately shallow soils have formed due to mechanical weathering, with scanty or no vegetation and sparse drainages with relatively steeper slopes in the south than in the north. This hydro-geomorphic unit acts as a run-off zone; hence, groundwater potential is very poor. The digital satellite data has been processed through Principal Component Analysis (PCA) technique, and FCC has been created using the results of such PCA-1, 2, and 3. This PCA FCC image showsa linear ridge (Fig. 3 A).

3.3 Inselbergs

Inselbergs are isolated hill that stands above plains. The occurrence of inselbergs implies immense variations in the rates of degradational activity on the land surface. The PCA-processed FCC image shows such Inselbergs(Fig. 3 B).

3.4 Piedmont Zone

A piedmont zone is an area at the base of a mountain or mountain range. And alluvium deposited along the foothill zone due to sudden loss of gradient by streams. Alluvium forms a good shallow aquifer depending on its thickness, composition, and recharge conditions. The PCA-processed FCC image shows Piedmont Zone (Fig. 3 C).

3.5 Colluvial Fills

The materials eroded from the catchments and routed by the drainages get trapped along their paths in the downstream plains wherever their velocity decreases. Hence these sediments are typically found as unconsolidated dumps of varying-sized particles such as pebbles, cobbles, rock fragments, sand, silt, and clay. These are similar to the valley fills found between hills. Such zones of colluvial fills can hold good groundwater due to their good porosity, permeability, and poor consolidation level. Hence, groundwater tapping will usually be possible along them for agricultural purposes. Due to such unconsolidated nature, moisture retention, related biomass growth, and irrigation along them on either side of drainages, these colluvial fills showed a contrasting linear shape and red signature in IRS P6 FCC data (Fig. 2 C).

3.6 Rocky Pediments

Clear rock cut surfaces were found over hard rock exposures in different parts of the study area. When exposed or covered with thin veneer of soil cover, such rock-cut characters are called pediment or rocky pediments. These rocky pediments were well seen in IRS P6 FCC digitally processed images. Such rocky pediments are widely scattered in the study area (Fig. 4). As far as groundwater prospects are concerned, generally, the rocky pediments own poor water prospects because of their crystalline nature. However, if the rocky pediments are highly fractured or crisscrossed with lineaments, then such zones will have little groundwater prospects along these fractured zones over pediments.

3.7 Buried Pediment

In the larger part of the study area, the Hornblende Biotite Gneiss formed vast and smooth plains, i.e., the pediment is covered with thick soil to a minimum of 10m. Hence, it is named buried pediment (Fig. 4). Owing to the appreciable soil thickness over such buried pediments, the groundwater prospects would be generally better than the pediments. It is identified on remotely sensed data by its light red to red tone with irregular boundary outline, elongated shape, gentle slope, and moderate relief. The thickness of this hydrogeomorphic zone varies from place to place and favors a good amount of water to circulate within this zone before reaching the deeper zones. The drainage pattern is sub-parallel to parallel, with low drainage density. Land use is mainly agricultural activity with small patches of natural vegetation, but scrubland is also found in some places. Groundwater potential is moderate to good and suitable for dug and bore wells. These buried pediments were well seen in IRS P6 FCC image (Fig.2B).

3.8 Older and Younger Flood Plains

The river systems form the flood plain by dumping sediments. These usually have sand, silt, and clay, bear good moisture content, and support wet agriculture. The river Cauvery has developed an excellent floodplain in the study area. This floodplain is the best prospect zone for groundwater (Fig. 2A). All the geomorphic features thus interpreted by the above satellite data analysis were vectorized using ArcGIS. The final output was generated, which is shown in Fig,4. The areal extent of various geomorphologic units is shown in Table 1.

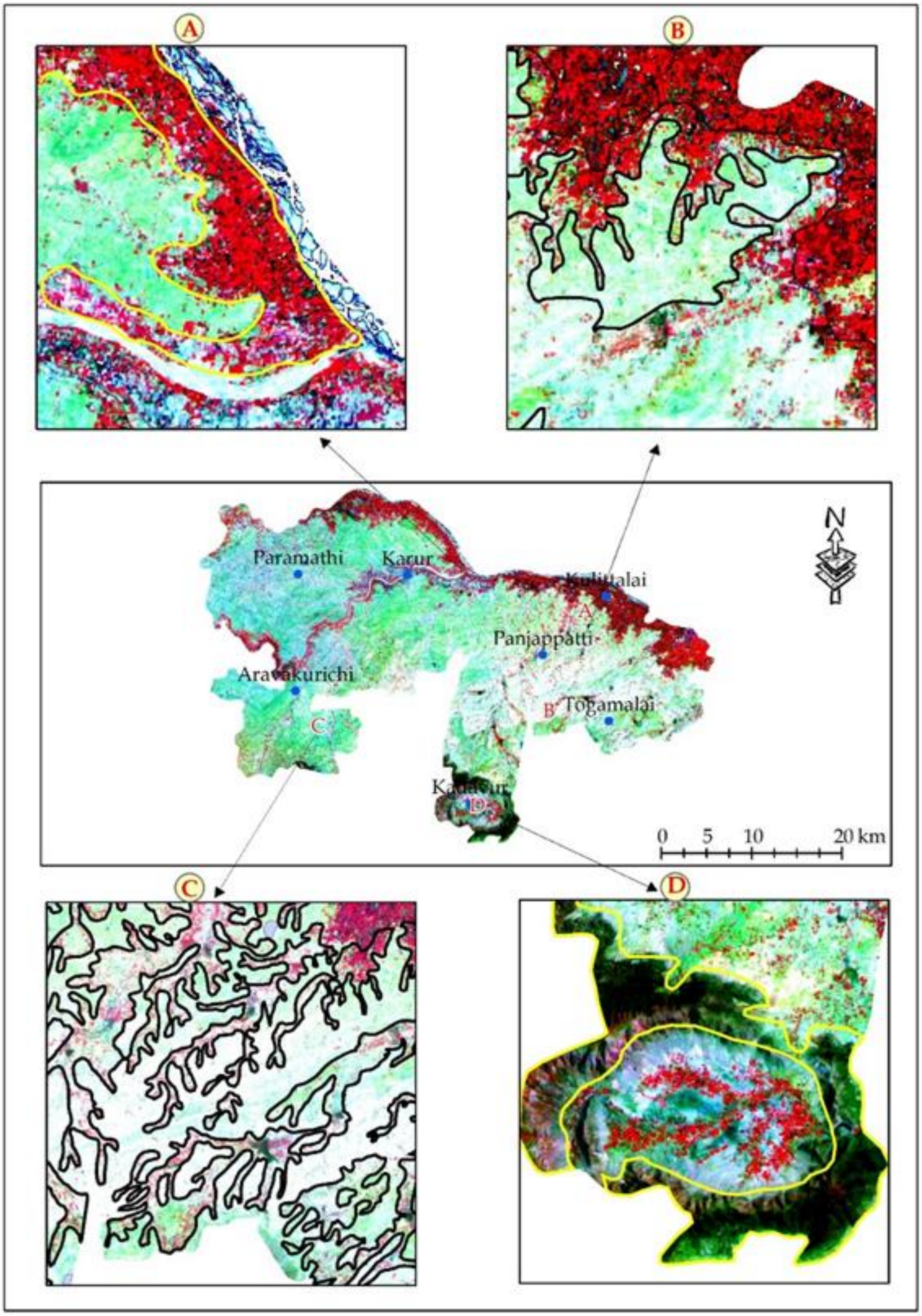

Figure 2:IRS P6- Standard FCC Image Showing:
A. Younger Flood Plain, B. Buried Pediment, C. Colluvial Fill and D. Structural Hill

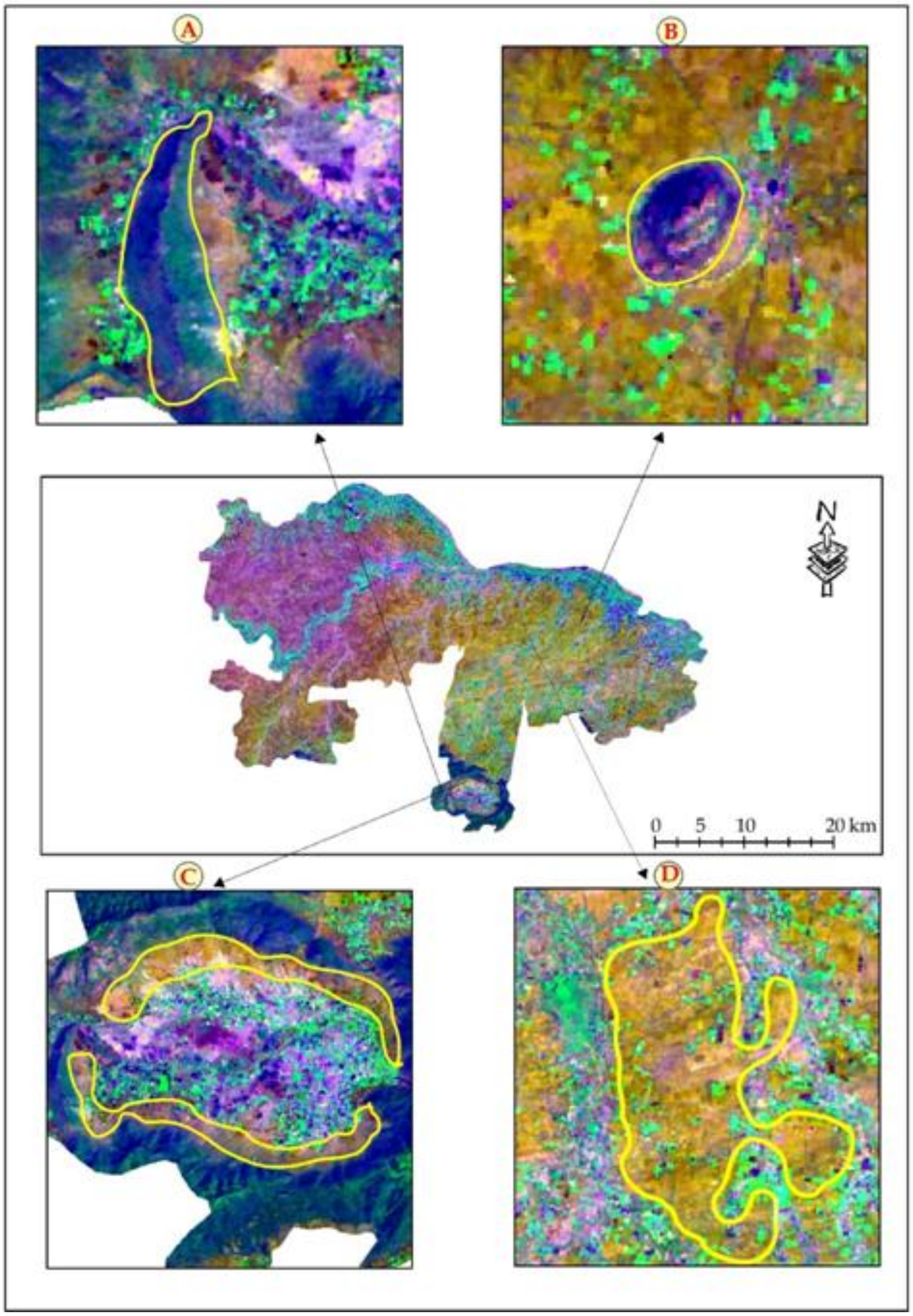

Figure 3: Processed IRS P6 User-defined FCC Image generated with a combination of PCA - Linear Ridge (A) Inselberg, (B) with blue colour, Piedmont Zone (C) with green colour and Rocky Pediment (D) with Red colour

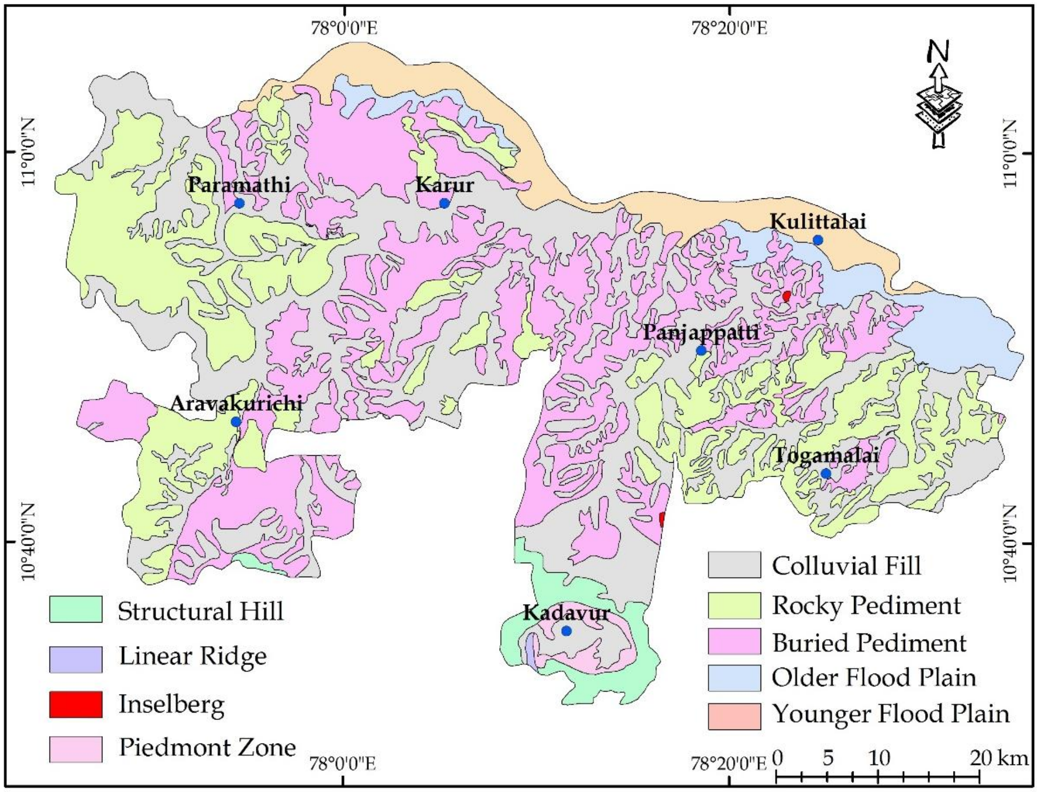

Figure 4: Geomorphology map

Table 1: Areal Extent of Geomorphology

S.No	Geomorphology	Area (sq.km)	Area%
1	Structural hill	74.82	2.56
2	Linear ridge	2.30	0.08
3	Inselberg	1.00	0.03
4	Piedmont Zone	26.25	0.90
5	Colluvial fill	1061.74	36.27
6	Rocky pediment	640.43	21.88
7	Buried pediment	802.66	27.42
8	Older flood plain	132.91	4.54
9	Younger flood plain	185.18	6.33

4. Conclusions

It was estimated that nine different landforms were present in the area under study. This paper illustrates how geospatial technologies such as remote sensing, DEM, GPS, and GIS can be combined with geological and topographic maps and Google Earth to create geomorphology. The LISS-III images were suitable for identifying landforms in the present study area. Similarly, hill shade images derived from DEMs helped identify structural trends in the area. Several areas of interdisciplinary science have benefited from geomorphology. These applications significantly solve society's intricate problems, support developmental planning, and contribute to developing the study area's natural resources. Among these are disaster risk reduction, geoengineering infrastructure development, groundwater management, conservation, and management of mineral deposits; several other activities are involved.

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