Remote Sensing and GIS Applications for Geomorphological Characteristics in Parts of Singrauli District, Madhya Pradesh, India

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Abstract
Geomorphology is a scientific discipline that focuses on the study of the form and structure of the earth's surface. Geomorphological characteristics play a crucial role in understanding topography, landforms, and hydrological parameters. Remote sensing and GIS are widely used and popular to analyse morphological parameters. The spatial distribution of topographic attributes can often be used as an indirect measure of the spatial variability of these processes and they can be mapped using relatively simple techniques like digital elevation models. The Cartons-1 satellite image and data from various sources were used for the creation of such models. The digital elevation model has been applied to the area lying between latitude 24^0 24' and 24^0 28' and longitude 82^0 15' and 82^0 21' in the Singrauli district of Madhya Pradesh to decipher the geomorphological characteristics. Using the models created from remote sensing and GIS from the maps of NRSC the spatial distribution of the geomorphological characteristics in the Singrauli district of Madhya Pradesh have been clearly demarcated.

Keywords: Geomorphology, Remote sensing, Satellite data, Cartoast-1, DEM.

1. Introduction

Geomorphology is a scientific discipline that focuses on the study of the form and structure of the Earth's surface. Geomorphology is the scientific investigation of earth's physical land surface features, encompassing various landforms such as rivers, hills, plains, beaches, dunes, and many others. Geomorphometry is a field of geomorphology that focuses on the quantitative analysis of landform morphology, specifically the shape of the earth's surface. The reinvention of this technology has occurred with the introduction of remotely sensed photos and Geographical Information Systems (GIS) software has reinvigorated this technology. Geomorphometry's numerous contributions to the field of geomorphology and related disciplines are extensive. Geomorphometry plays a crucial role in the investigation of terrain and the creation of surface models (Huggett, et al. 2019). Furthermore, the advancements in remote sensing technologies, supercomputing techniques, and processing software such as ArcGIS and ERDAS have significantly accelerated and enhanced the laborious task of creating extensive maps. Many spatial forms can model surface topography commonly known as Digital Elevation Models (DEMs). A Digital Elevation Model (DEM) is a structured collection of numerical values depicting elevations above a chosen reference point in a geographical area (Moore et al. 1991).

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2. Location of the Study area

The Singrauli district falls in the northeastern region of Madhya Pradesh and spans a geographical area of 567,200 ha, with latitudes 23^0 49' and 24^0 42', and longitudes ranging from 81^0 18' to 82^0 48'. Rewa and Sidhi districts border the district in the north, Uttar Pradesh in the east, Sarguja in the south, and Shahdol districts in the west.

The study area (Figure 1) is located in the NE part of the Singrauli district, covering 62.3 square kilometers falls in the toposheet no. 63L/7 of the survey of India. The study area encompasses the north latitudes of 24^0 24' and 24^0 28', as well as the east longitudes of 82^0 15' and 82^0 21'.

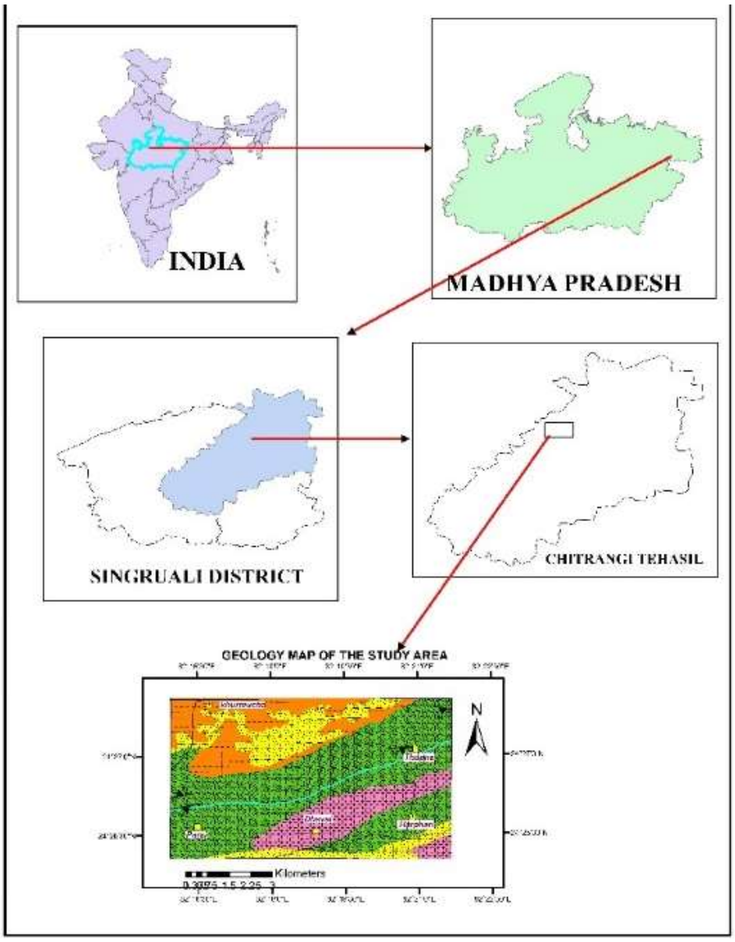

Figure 1: Location of the study area in Singrauli district of Madhya Pradesh

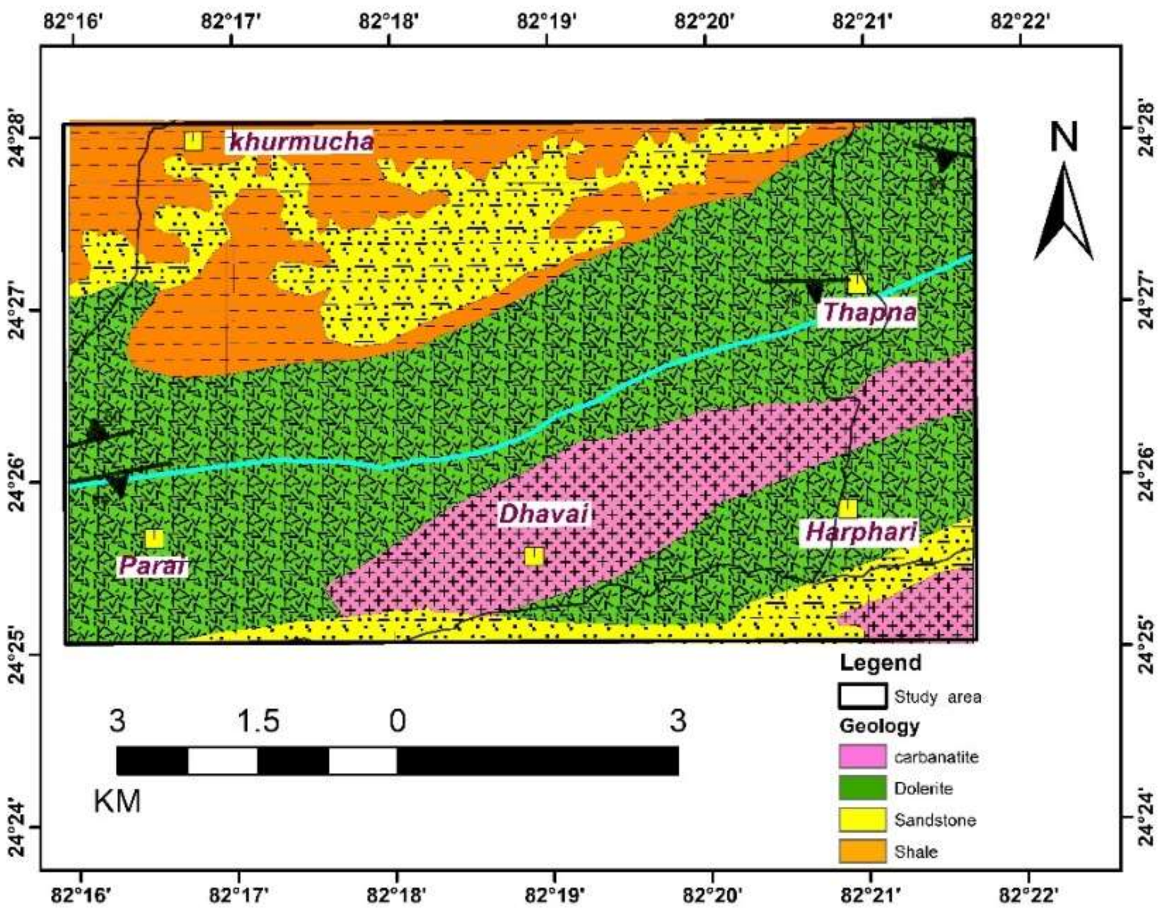

Figure 2: Geology map of the study area in Singrauli district of Madhya Pradesh

3. Geology of the study area

The detailed geology of the study area is shown in Figure 2. The geological composition of the Singrauli district includes a range of rock types, spanning from ancient Archean granites to younger alluvium deposits. Other significant geological formations visible in the districts include the Deccan traps, which formed during the Cretaceous-Eocene period. The Gondwana's, composed of sandstone from the Palaeozoic to Mesozoic era and various layers of Vindhyans and phyllites, quartzites, schists, gneisses, and granites of Archean age. The area is occupied by four major rock types- dolerite, carbonatite, shale, and sandstone. The majority of the area is occupied by the intrusive rock dolerite.

4. Materials and Methods

The preliminary information was collected from the survey of India (SOI) toposheet of number 63L/7 in 1:50000 scale. The satellite data was acquired from the Bhoonidhi portal of the National Remote Sensing Centre (NRSC), Hyderabad, which is downloaded from the NRSC website ("https://bhoonidhi.nrsc.gov.in/"). The Cartosat-1 image of satellite-5, sensor type PAN, specification P5-PAN-CD-30m, and sensor specification scheme of Satellite-Sensor-Imaging mode-resolution was used for the Digital Elevation Model (DEM) and preparation of drainage map of the study area. For geomorphology characteristics, data collected from the Bhukosh is a gateway to all geoscientific data of the Geological survey of India (GSI) ("https://bhukosh.gsi.gov.in/Bhukosh/Public").

CARTOSAT-1 is the first Indian Remote Sensing Satellite with the ability to capture stereo images while in orbit. Cartographic applications utilised the photos to meet global demands. The cameras on this spacecraft had a resolution of 2.5 m, enabling them to discern objects as small as a compact vehicle. The Cartosat-1 satellite supplied the necessary stereo pairs to create digital elevation models, orthoimage products, and value-added goods for a range of Geographic Information System (GIS) applications. ("https://bhuvan-app3.nrsc.gov.in/data/download/tools/document/Cartosat_1_brochure.pdf").

The satellite image (Figure 3) was georeferenced and processed by using Arc GIS 10.4 software with a spectral band of 0.5-0.85 microns. The swath width of this image was 29.42 km. Standard products are generated after accounting for all necessary correction was carried out. Ortho-rectified products are corrected for terrain distortions and camera tilt effects with the help of control points and using Stereo Strip Triangulation (SST) based DEM (only for Indian region). All Cartosat -1 data products are supplied with 10-bit radiometry for PAN Fore and Aft (Panchromatic Aft-pointing) cameras.

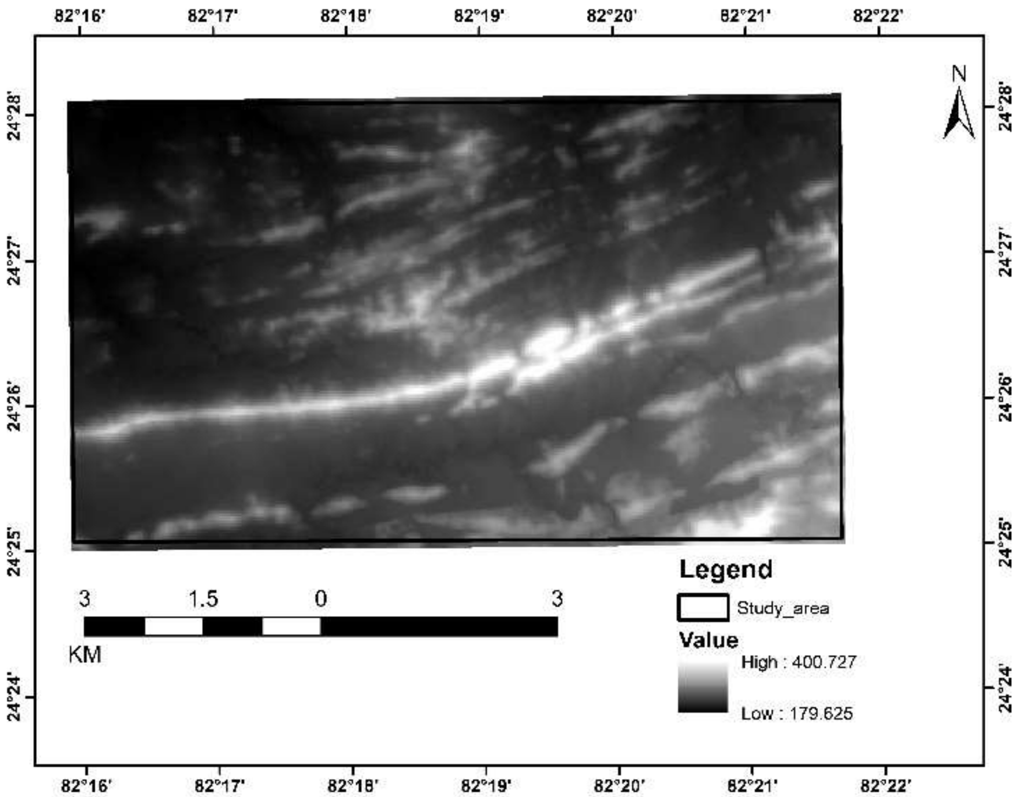

Figure 3: Cartosat-1 satellite image of the study area in Singrauli district of Madhya Pradesh

To PAN the fore camera is oriented towards the front and the aft camera towards the rear, following the direction of the velocity vector. Then the standard enhancement techniques are applied, such as image translation, image enhancement, image contrast adjustment, and spectral and spatial filtering. (Miller and Pearson, 1971; Short, 1982; Price, 1995).

We obtained data of the earth's surface using the Cartosat-1 data user's manual from 2005 ("https://bhuvan-app3.nrsc.gov.in/data/download/tools/document/Cartosat_1_brochure.pdf"). We employed various techniques such as stratification, directed filtering, layered approaches, composition, aggregation, and improvements as needed to enhance the quality of mapping.

Conventional techniques were used to categorise terrain analysis, including factors such as topography, land form, land use, and land cover. The ground control locations that were taken into account consist of road intersections. The convergence of the drainage lines and constructed objects enabled the visualisation of the process. Process, examine, and generate raster and vector data for diverse applications.

The present study region was geographically referenced, digitally manipulated, and visually examined to analyse terrain elements such as topography and landforms, drainage patterns, stream order, and land use/land cover (Rao, 1995). Identifying the topography and landforms in an area is useful for understanding the underlying lithology, as different rock types frequently have unique topographic features. The spectral response of a rock type is determined by the kind and composition of minerals present in it (Priyanka, T. et al., 2024; Jogu, L. S. et al., 2022; Price, 1995; Singer, 1981; Goetz, 1975; Miller and Pearson, 1971). In general, rocks that have a limited ability to reflect light at shorter wavelengths will gradually increase their ability to reflect light as the wavelengths go longer, eventually reaching the highest level of reflectance between 1 and 3 gigametres (Hunt et al., 1979).

5. Results and Discussion

5.1 Digital Elevation Model

A Digital Elevation Model (DEM) is commonly understood as the primary representation of the Earth's terrain, providing essential data for creating raised-relief maps (Guth 2006). DEM, or Digital Elevation Model, is a crucial parameter that needs to be evaluated in any operation involving topography analysis. This includes examining its derived properties such as slope, curvature, roughness, drainage area, and network. The technology has found applications in scientific fields such as hydrology, geology, geomorphology, urban planning, and surveying. These applications have been well documented in earlier studies (Pakoksung and Takagi, 2015; Lee et al., 2009; Weibel and Heller, 1990, and Fraser et al., 2002).

Figure 4 shows the DEM map of the study area. The study area is a very undulating surface with the lowest point region 179.6m in the NW part and gradually increases towards the NE part with an elevation of 400.7m.

The hill-type topography in the centre of the study area striking in the NE-SW direction divides it into two parts, the upper part dominates with low elevation and vice versa.

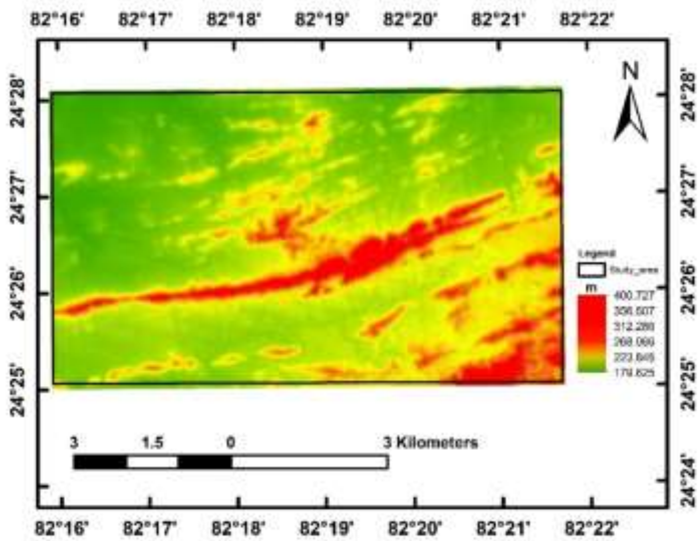

Figure 4: Digital Elevation Model (DEM) Map of the study area in Singrauli district of Madhya Pradesh

5.2 Drainage pattern

As a result of the significantly elevated terrain in the central portion of the research area (Figure 4), the drainage pattern becomes fragmented and produces separate patterns on each side of it. The majority of the studied area exhibits dendritic to sub-dendritic drainage patterns (Figure 5). Figure 5 displays various stream orders, each represented by a different colour code. The stream orders range from 1 to 4. The majority of the research region is characterised by first and second order streams, which is the primary factor contributing to the absence of identifiable watersheds in the area.

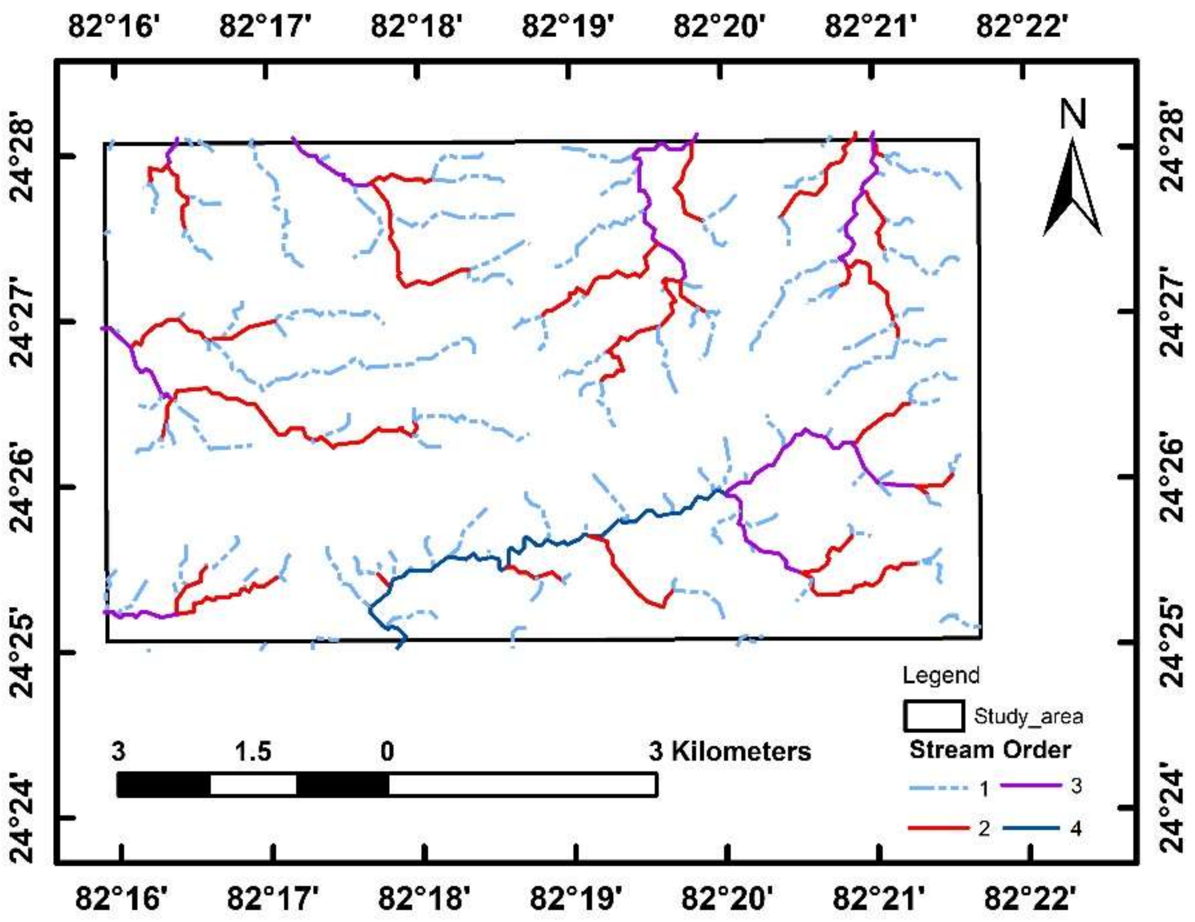

Figure 5: Drainage Map of the study area in Singrauli district of Madhya Pradesh

5.3 Geomorphology

The Kaimur hilly ranges cover the majority of the district, which is characterized by hilly terrain. There are three physiographic divisions within the district. Kaimur hills, central hilly, and the southern hills. Three main rivers flow along with several tributary rivers. The major rivers are the Son, Gopal, and Rihand. The Kaimur ranges stretched from NE to SW and covered most of the district. The central part of the district forms a series of hill ranges. The area's general slope is toward the northeast ("District groundwater information booklet, Singrauli District, Madhya Pradesh, Ministry of water resources, CGWB, North Central region Bhopal", 2013). Figure 6 illustrates the geomorphology of the study area. The pediment—the core stone of the tor composite—constitutes the majority of the area in the northern part, with the southwest region following suit. The southeastern region is distinguished by extensively fragmented hills and valleys. The central research region consists of hills and valleys that are moderately dissected. The remaining space is filled with strike ridges. There was only one significant water body found in the Singrauli district of Madhya Pradesh.

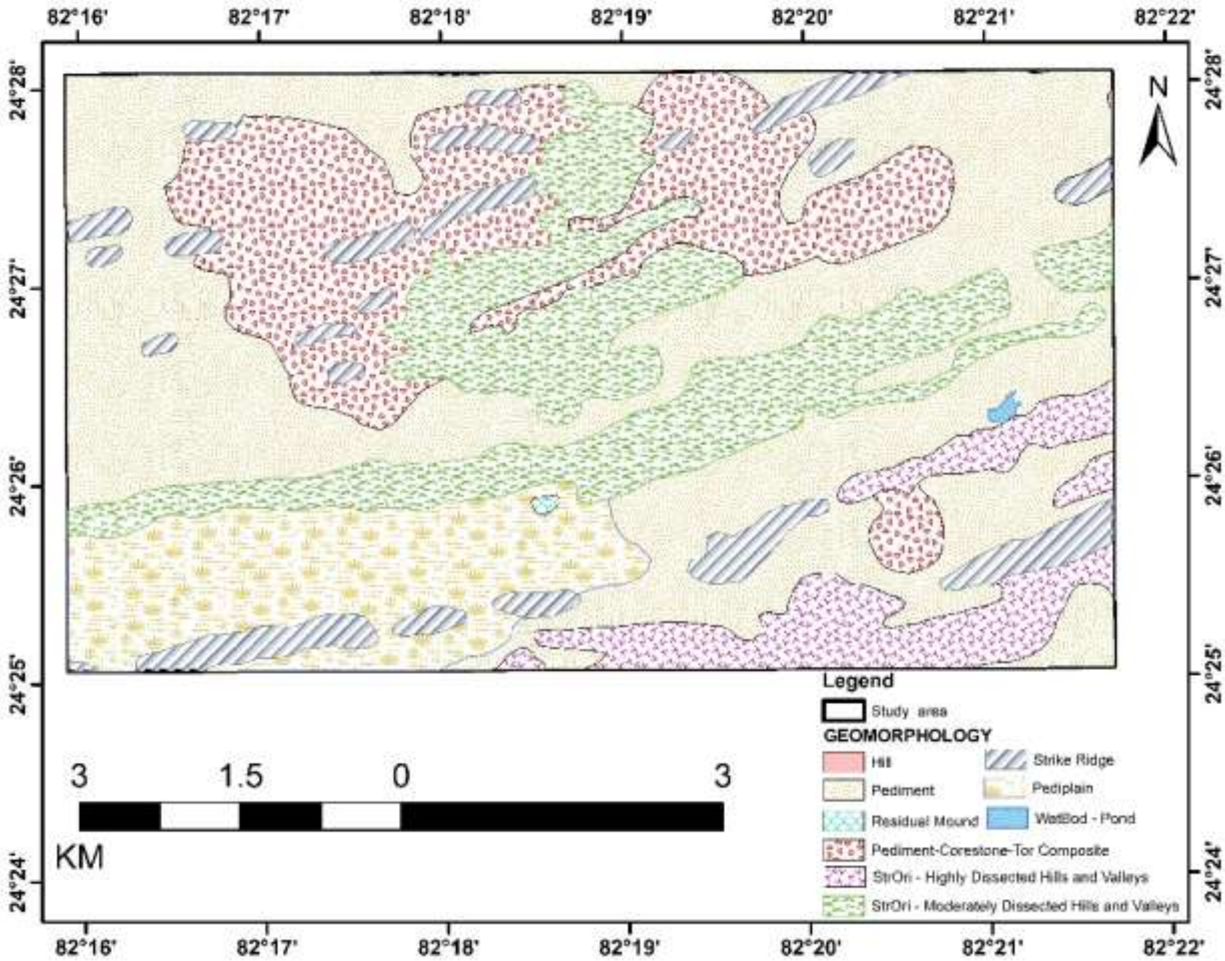

Figure 6: Geomorphology Map of the study area in Singrauli district of Madhya Pradesh

5.4 Lineaments in the study area

The current study utilizes visual interpretation of lineaments using data gathered from the Bhukosh web portal to discover the characteristics of these lineaments (Moore and Waltz, 1983; Drury.,1987; Veeraiah et al., 2006; Subhash Babu et al., 2014). The lineament map (Figure 7) was created by combining geological data with remote sensing techniques at a scale of 3km. The lineaments were classified further based on variations in tone and the arrangement of dykes, quartz veins, fracture joints, and faults. These classifications were then verified against the actual conditions on the ground. A limited number of lineaments were identified in the research area, with the majority of them following a northeast-southwest direction and exhibiting geomorphic characteristics. An individual fault and a fold that runs down the axis were found in the northern region of the area. Only one joint/fracture was observed in the southernmost point of the study area.

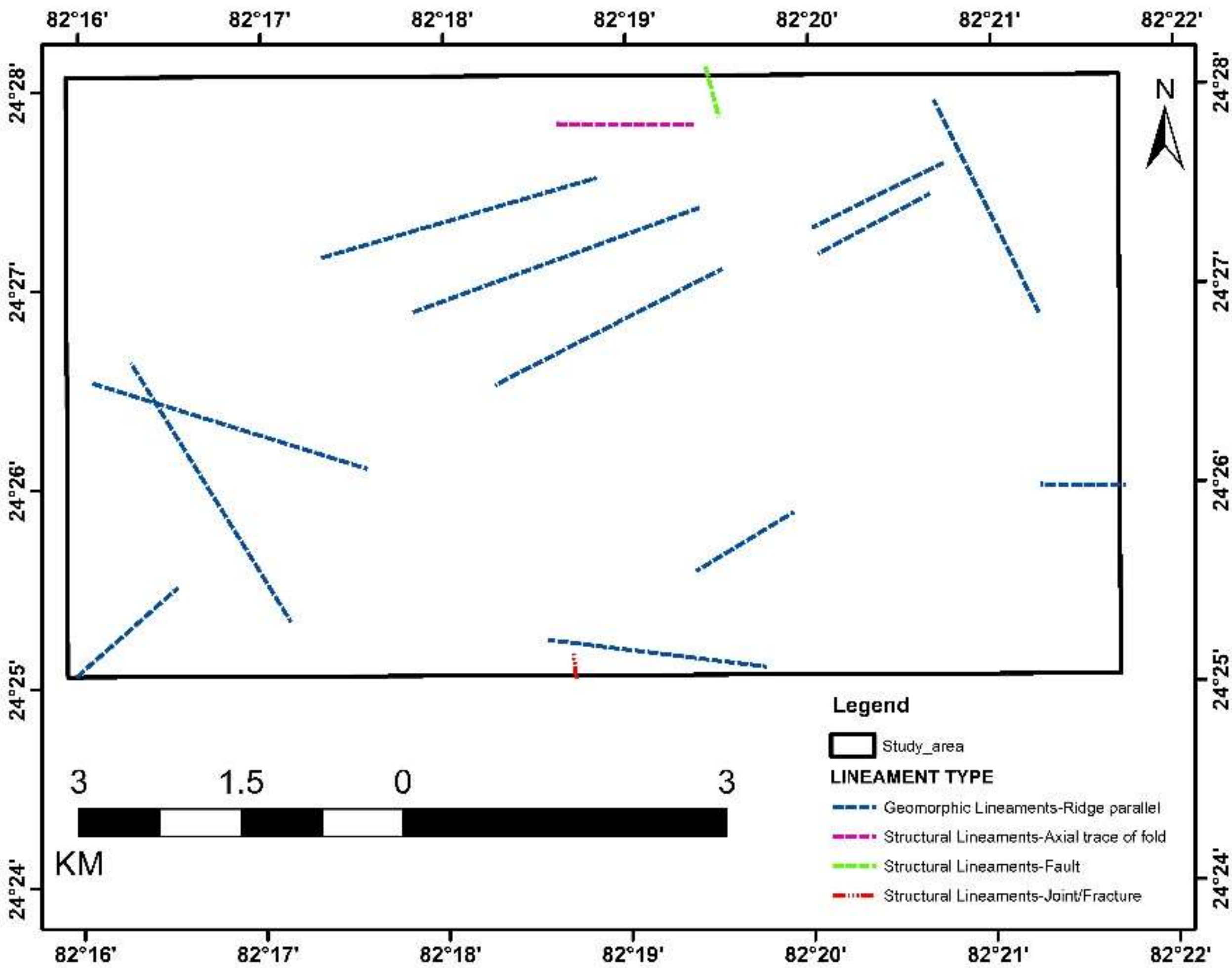

Figure 7: Lineament Map of the study area in Singrauli district of Madhya Pradesh

5.5 Land use and Land cover (LU/LC)

Land Use (LU) pertains to the activities and diverse applications conducted by humans on land. Land Cover (LC) encompasses the various components of the earth's surface, including natural flora, bodies of water, rock and soil, constructed structures, and other features that arise from changes to the land. Land use and land cover are closely connected and can be used interchangeably, however land use is typically determined based on the cover. The land use/land cover (LU/LC) of the current research region was derived from satellite data obtained from the NRSC website (https://bhuvan.nrsc.gov.in/home/index.php). The utilisation of remote sensing and GIS proved vital in this investigation. The land use/land cover map comprises five distinct classifications (Figure 7). Approximately 90% of the research area was covered by crops and trees. Approximately 9% of the area is comprised of rangeland, while 1% is occupied by manmade structures and minor bodies of water.

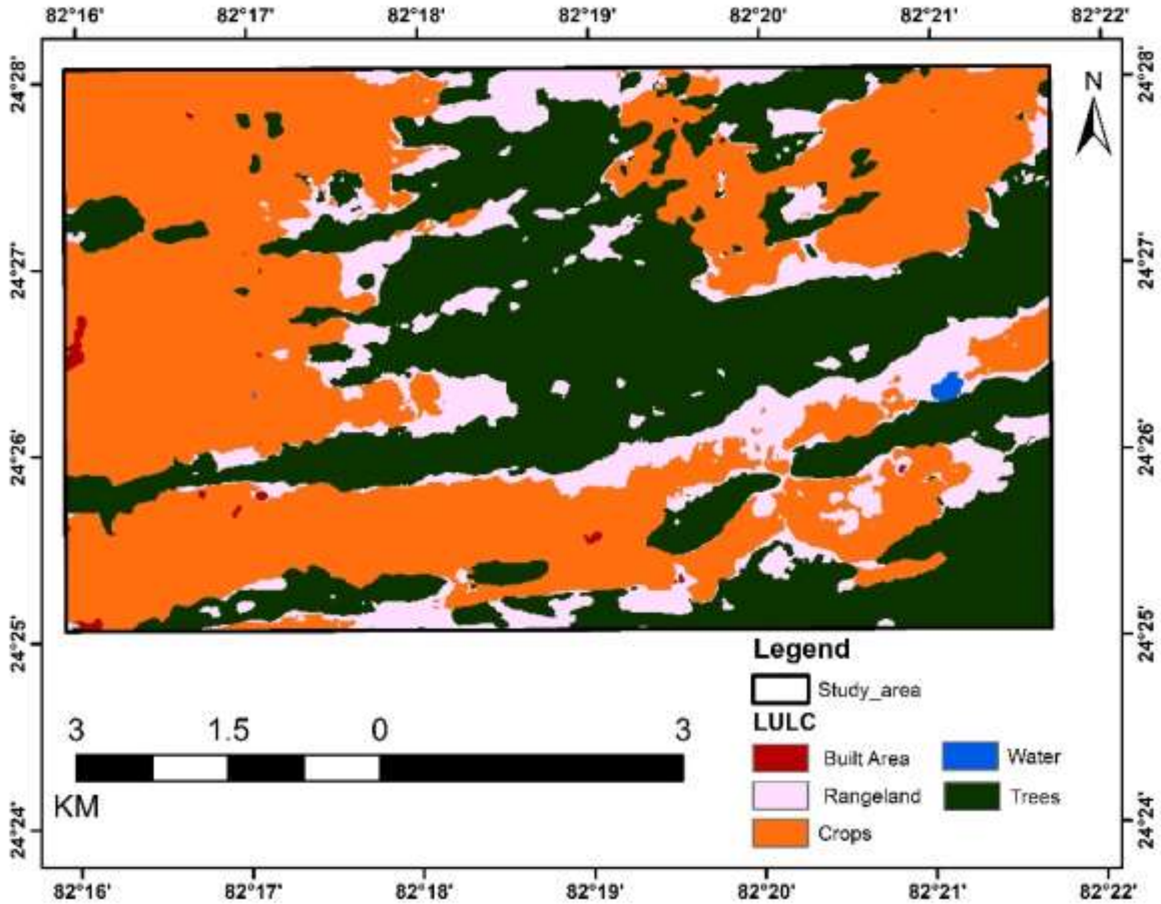

Figure 8: Land Use and Land Cover (LU/LC) Map of the study area in Singrauli district of Madhya Pradesh

6. Conclusions

The use of GIS and remote sensing techniques has demonstrated their accuracy and effectiveness in mapping the geomorphological features in the investigated region. The use of satellite images has enabled the identification and delineation of lithological, drainage, and soil units, as well as the demarcation of their boundaries. The structural fabric was achieved by digitally processing and interpreting satellite pictures using Arc GIS. A comprehensive land use-land cover map has been prepared following the merging of all the units. The Digital Elevation Model (DEM) and the drainage map indicate that the area is characterised by a significant presence of surface water depletion. The analysis of geology, geomorphology, and land use/land cover indicates that the majority of the research region is comprised of forested lands, making it suitable for mineralogical investigations.

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