Migration Letters

Volume: 20, No: S5 (2023), pp. 1302-1312

ISSN: 1741-8984 (Print) ISSN: 1741-8992 (Online)

www.migrationletters.com

The Geomorphology Class Mapping Of The Selected Area Of Bundelkhand Massif Based On DEM Using GIS And Remote Sensing Techniques

Surendra Pal Singh[1], Prashasti Ashok[2*], M. Kartic Kumar[3], Ashish Kaushal[4], Marga Tashale Amanu[5], Tibebu Manaye Mihrete[6]

ABSTRACT:

The district Jhansi covers a 5024 sqkm area under three tehsils and eight blocks of Bundelkhand massif on a survey of India toposheet 54K and 54O. This research investigates the effectiveness of using Indian Remote Sensing (IRS) data with Geographic Information Systems (GIS) and remote sensing techniques for geomorphology classification based on slope and elevation in the Jhansi district, India. The study utilizes freely available Cartosat-2 Panchromatic and Cartosat-1 Multispect[1]ral imagery processed in ERDAS and ArcMap software. Digital Elevation Models (DEMs) extracted from Cartosat-1 data are employed to calculate slope and elevation attributes. Slope classes are established, and geomorphology is categorized based on slope and elevation combinations. The research assesses the accuracy of the geomorphology classification through ground truth verification and evaluates the potential applications of the results in diverse fields like disaster risk management, resource exploration, and agricultural planning. The findings aim to contribute to a deeper understanding of Jhansi's geomorphology and serve as a valuable resource for various applications, including land-use planning, environmental management, and disaster risk assessment.

Keywords: *Geomorphology classification, slope, elevation, GIS, remote sensing, Jhansi, India.*

1. INTRODUCTION

Geomorphologies represent diverse morphological features resulting from geological processes and are crucial for understanding an area's geomorphology, hydrology, and environmental characteristics. Accurate geomorphology classification plays a vital role in various fields, including resource management, disaster risk assessment, and infrastructure development. Traditionally, geomorphology classification relied on field surveys and topographic maps, which were time-consuming and lacked spatial detail. Advancements in GIS and remote sensing technologies have revolutionized geomorphology analysis, enabling automated and objective classification at larger scales and higher resolutions. Recent advances in remote sensing, geographic information system (GIS) and availability of satellite-based digital elevation models and developments in numerical modelling capabilities enhance the

[1,5]Department of Surveying Engineering, Wollega University, Nekemte City- 395, Ethiopia.
[2*]Department of Geology, Institute of Earth Sciences, Bundelkhand University, Jhansi, India.
[3,6]Department of Geomatics Engineering, Wachemo University, Hossana, Ethiopia.
[4]Jindal Global Business School, O P Jindal Global University, Sonipat, Haryana.

ability to understand the surface processes more clearly in the field of geomorphology [1]. Given that each of the landform units have different characteristics (soil, slope, elevation, vegetation etc.), classification of landforms is importance [2,4]. Remote sensing and GIS comprise powerful tools that can be used for the fast valuation of natural reserves. The method is cost-effect and can be effectively used for groundwater exploration [5,7]. The evaluation found that locally produced, extremely high-resolution digital elevation model (DEM) products are becoming more widely available and used in landform categorization studies. The SRTM dataset is still the most widely utilised in the field among the worldwide DEM datasets available. Most landform delineation investigations rely on specialist knowledge. While object-based analysis has lately gained traction, pixel-based analysis is both prevalent and rising. Whereas validation approaches appeared to be mostly focused on expert knowledge, most research did not include validation techniques. These findings indicate that a systematic evaluation of landform delineation may be required. Other issues that may require examination include comparing various DEMs for landform delineation, doing more object-based studies, and investigating the efficacy of quantitative validation methodologies and data-driven analytical methods [6].

This research focuses on classifying geomorphology in Jhansi, India, based on slope and elevation derived from remotely sensed data. Jhansi lies in the Bundelkhand region, characterized by a diverse topography comprising plateaus, valleys, hills, and riverine plains. Understanding the distribution and spatial configuration of these geomorphology is crucial for managing natural resources, mitigating erosion, and planning for sustainable development in the region. Traditional geomorphology mapping methods are often time-consuming and expensive. This research explores the potential of IRS data coupled with GIS and remote sensing techniques for efficient and cost-effective geomorphology classification based on slope and elevation in the Jhansi district.

2. STUDY AREA

This study encompasses a district encompassing 5,024 square kilometers with a perimeter of approximately 425 kilometers. The area spans six toposheet numbers: 54K6, 7, 10, 11, 14, and 15 from the Survey of India (SOI) series, and additionally 54 O. Situated across a georeferenced map, the region falls within the bounds of 78°10'E to 79°25'E longitudes and 25°10'N to 25°45'N latitudes. Administration-wise, it comprises four tehsils (administrative subdivisions): Jhansi, Moth, Garautha, and Mauranipur, further divided into eight blocks - Baragaon, Chirgaon, Babina, Moth, Gursarai, Bamour, Ranipur, and Bangra. Jhansi, serving

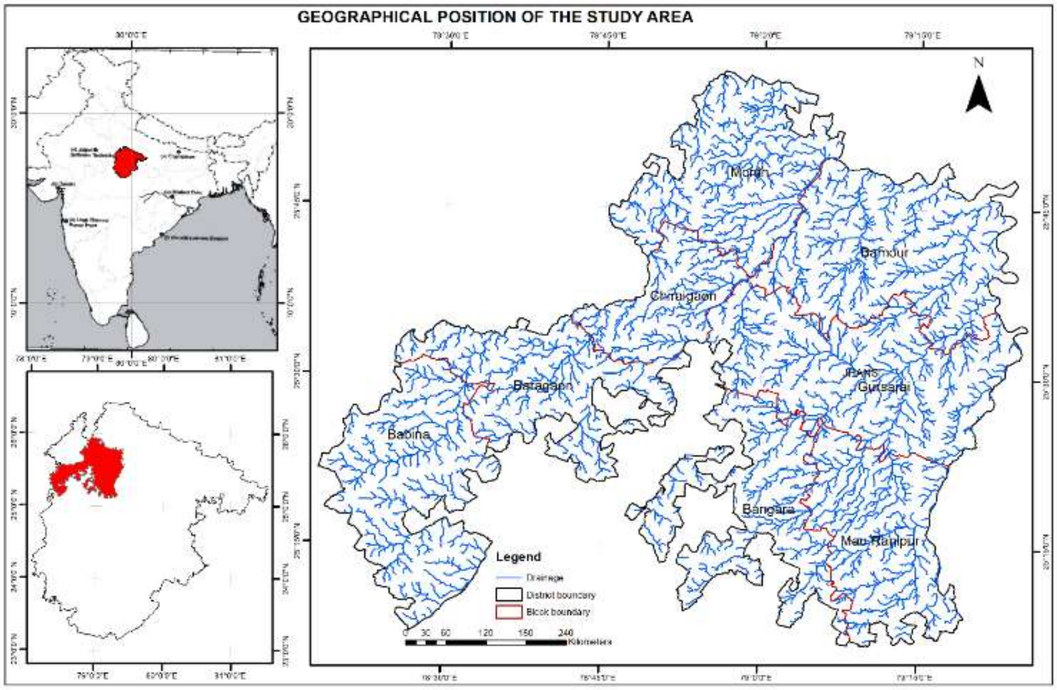


Fig 1: Location map

as the district headquarters, rests within the northern sector of the Bundelkhand massif [2,8]. Notably, the dominant slope direction runs from south to north. The Bundelkhand region, despite forming part of the Yamuna's watershed on its northern boundary, faces significant challenges accessing groundwater due to its predominantly hard granitic rock geology. This makes water infiltration and storage difficult, leading to frequent droughts every four years.

While the average rainfall during the monsoon (June-September) exceeds 91%, most recharge occurs during this limited period. Therefore, identifying viable groundwater zones is crucial for developing and implementing effective recharge strategies. Integrating geological data with other influencing factors like topography and land cover can aid in pinpointing these potential areas.

The maximum average monthly temperature goes 32.59 0C and the average minimum temperature falls 19.21 C.

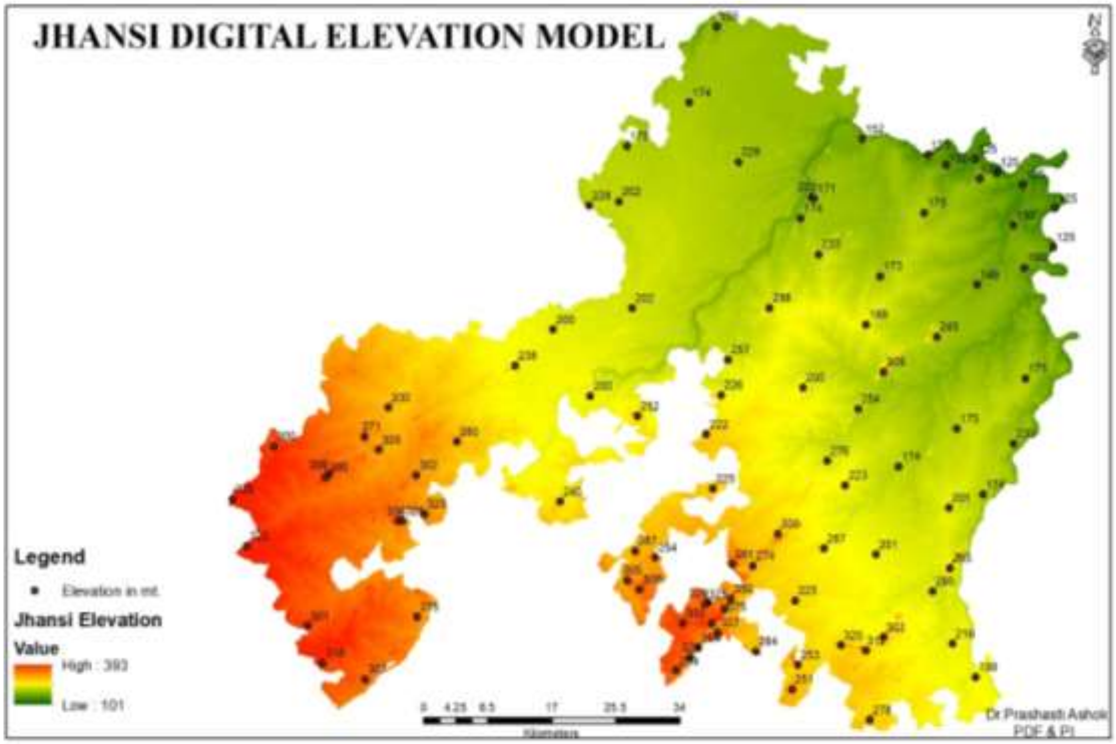


Fig 2: SRTM DEM Jhansi after processing

3. MATERIAL AND METHODOLOGY

Every dataset underwent resampling and georeferencing. The study made use of IRS pre-monsoon photographs from March 20016, post-monsoon images from October 20018, and Bhuvan images. The satellite imagery features multispectral bands in the visible and near-infrared spectrum, captured by the LISS 3 sensor with a 24 m spatial resolution. Arc GIS and ERDAS software have been used to augment and extract information from the visual interpretation using a variety of typical digital image pre-processing procedures. To get the intended outcome, preprocessing of the photos was carried out, and supervised classification was used to create LULC thematic layers. From the SOI topographic sheet, an elevation profile map was taken from the DEM and high points database created by the Arc GIS digitizing tool. layer of contours created every 25 meters. Surface drainage layer created for cross-verification, using satellite imagery and the SOI toposheet. SRTM DEM with a resolution of 30 meters was used to construct the stream order, slope, drainage density, and lineaments layers. The drainage strata were identified using hydrology methods, such as stream order, watershed, flow direction, and flow accumulation. Groundwater report, Bhukosh database, soil layer generation, and geology based on Bhukosh categorization and geomorphology come next. Utilizing visual interpretation approaches in accordance with the National Remote Sensing Centre India (NRSC) categorization, thematic layers such as Landuse/Landcover (LULC), water body and drainage, geology, slope, geomorphology, lineament density, drainage density, and soil (Figure) were generated**.** This comprehensive analysis culminated in the successful classification of geomorphology across the Jhansi region[12].

This work uses a geospatial methodology to classify geomorphology by combining remote sensing and GIS technologies. The following stages can be used to define the methodology:

3.1 Pre-processing:

- Cartosat datasets were geometrically corrected using ground control points identified in high-resolution imagery.

- Radiometric corrections were applied to Cartosat-1 Multispectral bands to address atmospheric and sensor effects.
-

3.2 DEM Generation:

- A SRTM DEM downloaded from free source.
- The DEM was further refined through spatial filtering and interpolation to enhance accuracy.

3.3 Slope and Elevation Analysis:

- Slope maps were derived from the DEM using the Spatial Analyst tool in ArcMap.
- Slope classes were defined based on existing geomorphological classifications (e.g., gentle, moderate, steep) and local terrain characteristics [19].
- Elevation values were extracted from the DEM and categorized into distinct elevation zones.

3.4 Geomorphology Classification:

- A geomorphology classification scheme was developed based on combinations of slope and elevation classes.
- Visual interpretation of satellite imagery and integration with reference data aided in assigning specific geomorphology types (e.g., hills, plateaus, valleys, plains).
- Other than overlay analysis and weightage assignment, application of k-means fuzzy logic for the purpose of automated landform classification with high resolution data is another option to get the accurate result[15].

3.5 Accuracy Assessment:

- Ground truth verification points were collected using GPS and compared with the classified geomorphology.
- Producer's and User's accuracies, along with overall Kappa coefficient, were calculated to evaluate the classification accuracy.

3.6 Feature Extraction:

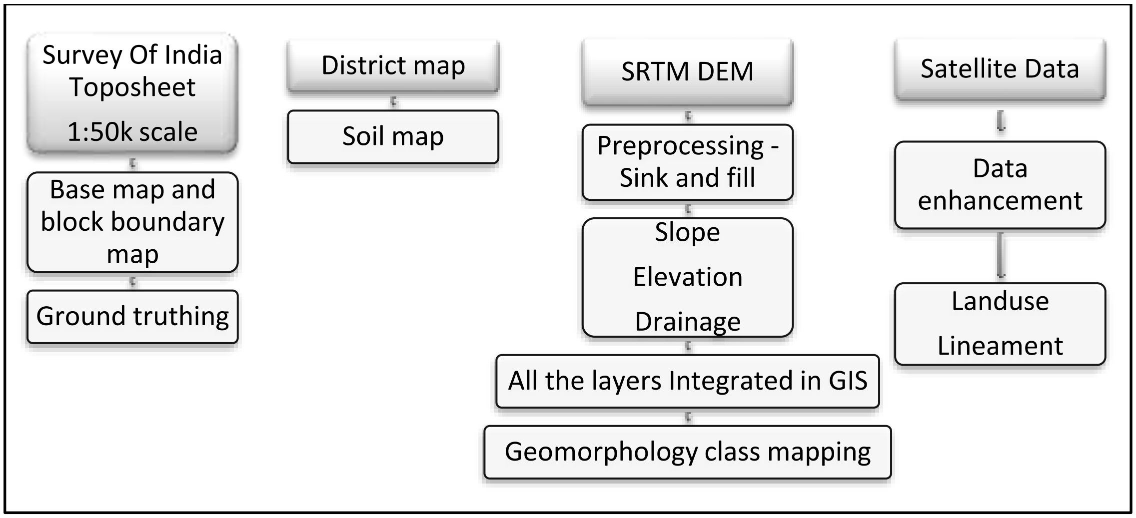
- Slope and elevation derivatives generated from the DEM using GIS tools. Slope calculated using various methods, such as gradient, hill shade, or slope aspect. Elevation categorized into discrete classes based on geomorphological significance.
- Additional features, such as texture and land cover information, extracted from the satellite imagery for enhancing classification accuracy.

3.7 Geomorphology Classification methods:

- Two approaches are available to explore:
  - **Supervised classification:** Training data collected through visual interpretation of high-resolution imagery and field verification. Supervised algorithms were employed to classify geomorphology based on their slope, elevation, and potentially other features.
  - **Unsupervised classification:** Unsupervised algorithms, such as K-means clustering or ISODATA, used to group pixels with similar slope and elevation characteristics into distinct geomorphology classes.

3.8 Data Acquisition:

- Cartosat-2 Panchromatic and Cartosat-1 Multispectral satellite imagery covering the Jhansi district were downloaded from the Bhuvan portal.
- Additional resources like geological maps and topographic sheets were obtained for reference and validation.



Flow Chart 1: Methodology Used For The Geomorphology Class Mapping

4. RESULTS AND DISCUSSION:

The area is characterized by the rugged topography where the elevation ranges from 120 m to 407 m near the lineaments. The landcover consists mainly of a mixture of deciduous forest with patches of agricultural land. The SRTM DEM was analysed, and 20 m contour lines generated with the help of Toposheet verification. Drainage pattern and triangulated irregular network maps were integrated for the relief analysis. Highest peaks/ spot elevation was digitized separately. There are lineaments which show highest elevation in digital elevation map and the northern portion indicates lowest elevation. The slope goes southwest to northeast in the study area.

- The terrain map of the area has a beautiful pattern of lineaments and elevation when it is integrated with DEM it has shown a topographic 3D map of the study area and the highest elevation was in southern side of the study region with 360 m elevation The classified geomorphology map depicted prominent geomorphology in the Jhansi district with good visual clarity[16].
- Slope classes effectively captured the variations in terrain steepness, and elevation zones differentiated between higher and lower lying areas.
- The influence of different slope and elevation derivatives on classification accuracy has been investigated. In Jhansi district runoff rate is higher due to existence of Granite hard rock and number of first order tributaries is more compared to other districts because almost all of them are seasonal and influenced by granite rock and number of reservoirs are very few in the district. Major portion of land of the study area was classed as upland plateau, undulating plain, intermontane basin and low land. It was predominantly covered with hard rock.

4.1. SLOPE

A crucial component of geomorphology class mapping is the slope. The Jhansi district exhibits a common slope orientation of north-easterly. The southern plateau has a height range of 200 meters above mean sea level overall, with the southern portion being around 345 meters above mean sea level. Consider the (a) pediplain province of southern Bundelkhand and (b) province of severely degrading composite plain in the north. SRTM data and an India Toposheet survey were used to create a slope map using spatial analyst tools. There is a range of 0 to 31 degrees of slope in the region. Six slope subclasses may be distinguished within the research region based on slope.

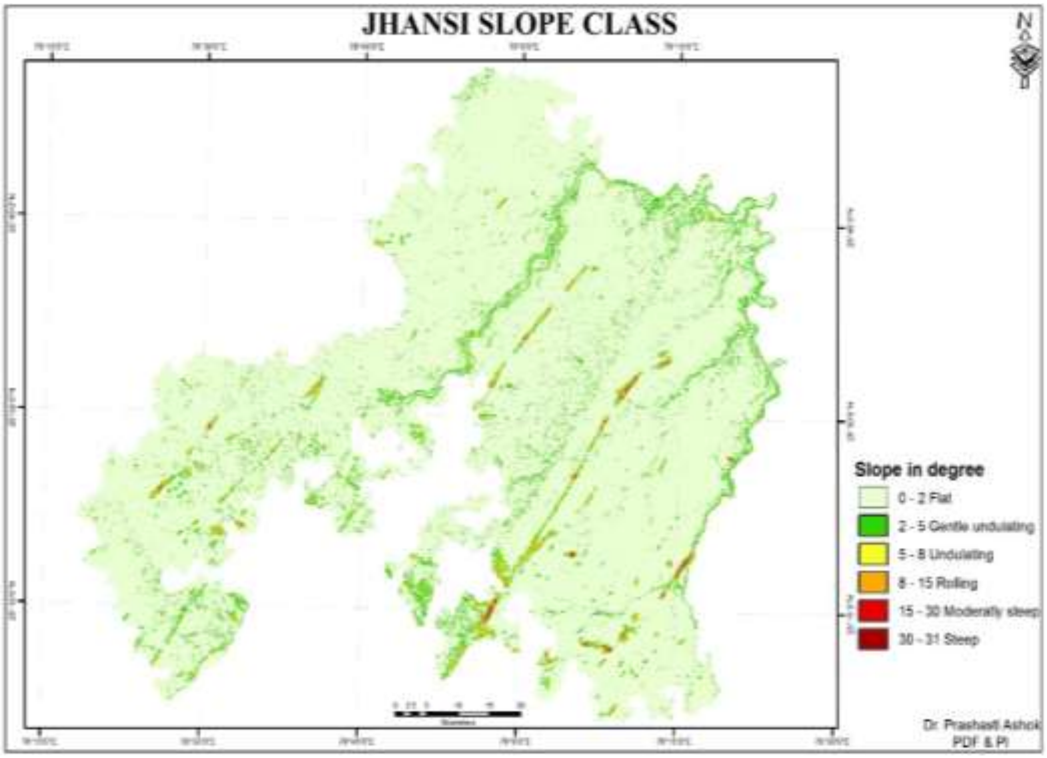


Fig 3: Jhansi slope classification

The region with a 0–2-degree slope is classified as having "good water potential" because of its practically "flat" topography and high rate of infiltration. This category includes the maximum area. A 2.5–5% slope is seen as having gently undulating landscape with some drainage. Mostly gentle undulating slope found along the river and in patches. Apart from this, a small portion comes under the ‘Undulating’ and ‘Rolling’ slope category which covers 5–15-degree slope and high runoff and low infiltration. A small portion of the whole area comes under the moderately steep and steep category (15-31 degrees).

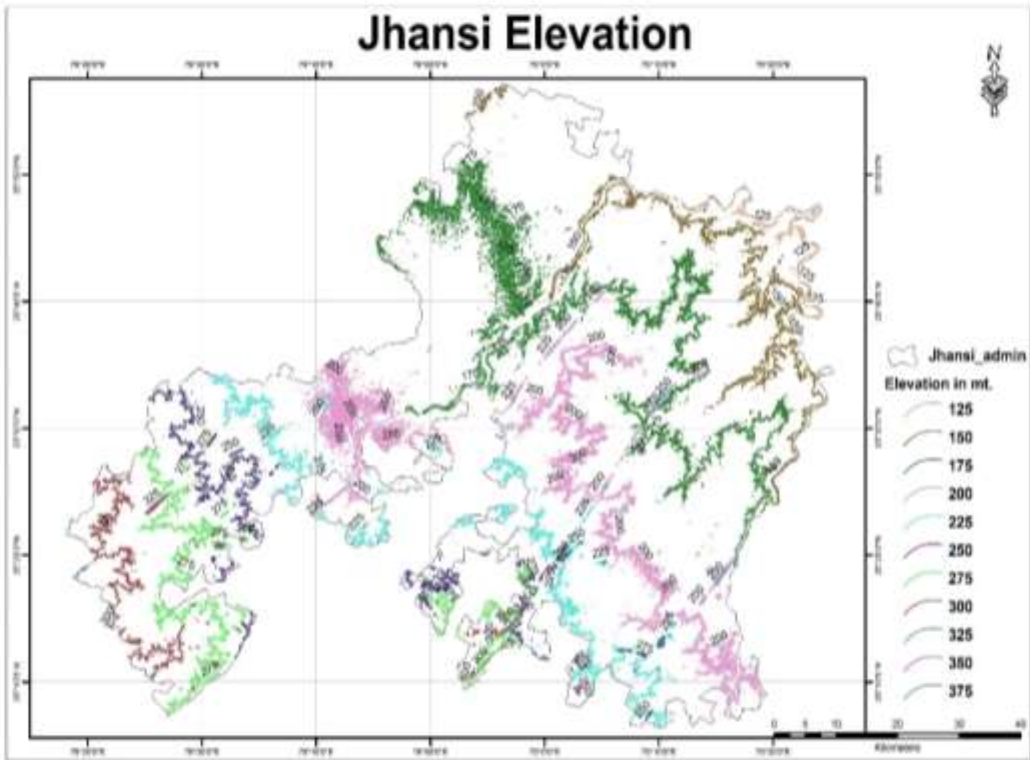


Fig 3: Jhansi Elevation map with the help of SRTM and Toposheet

4.2. GEOMORPHOLOGY

Geomorphological characteristics are determined by the structure and geological formations. During ground water analysis, the geomorphology layer has the largest weight in the research region, with a normalized weight of.190. The geomorphology of the Bundelkhand region is divided into two main areas: the intermountain fertile valleys and the hill ranges. The granite masses that comprise the hill ranges are resistant, hard, and compact, with quartz reefs intruding on them. As one moves south, the alluvial fill's thickness changes from 10 to 16 meters. The large region has been categorized according to its geomorphology, which includes rivers, wash plains, pediplain, pediments, linear ridges, ravines, and badlands. The Jhansi's overall geomorphology is undulating, with degraded hills made of rough rocks. Jhansi is beneath the highly elevated Bundelkhand plateau in the north, and the region descends southward with little hillocks that are depressed portions of the Vindhyan range, according to an examination of Toposheet(s) and satellite images. Jhansi may be largely classified into two groups: denudational and fluvial geomorphology and water bodies with limited structural geomorphic features. Findings show that most of the area falls under the pediplain category.

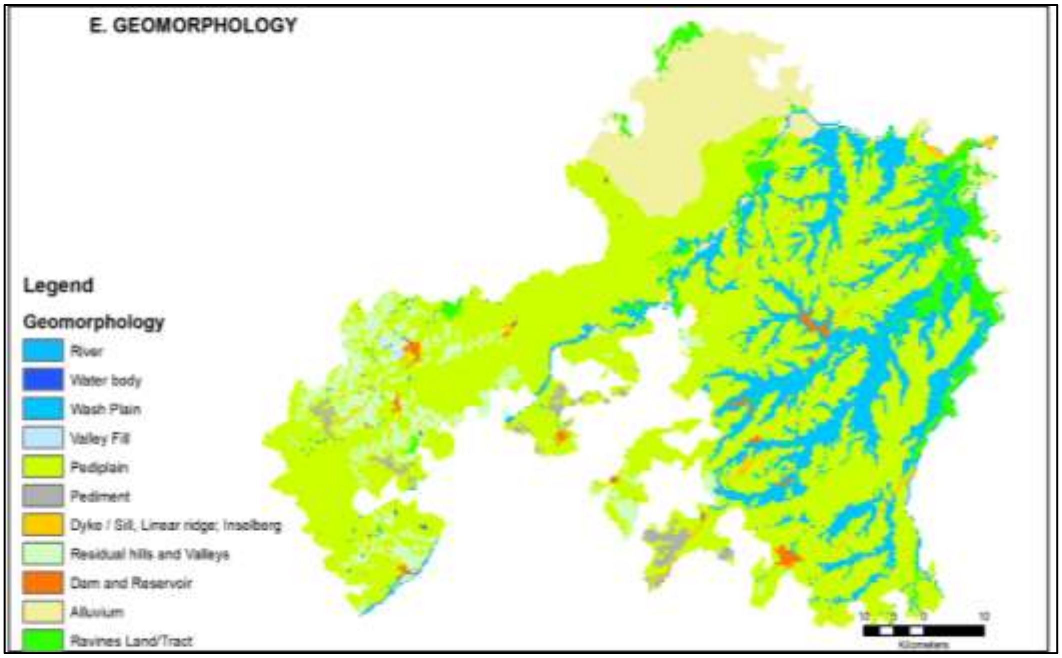
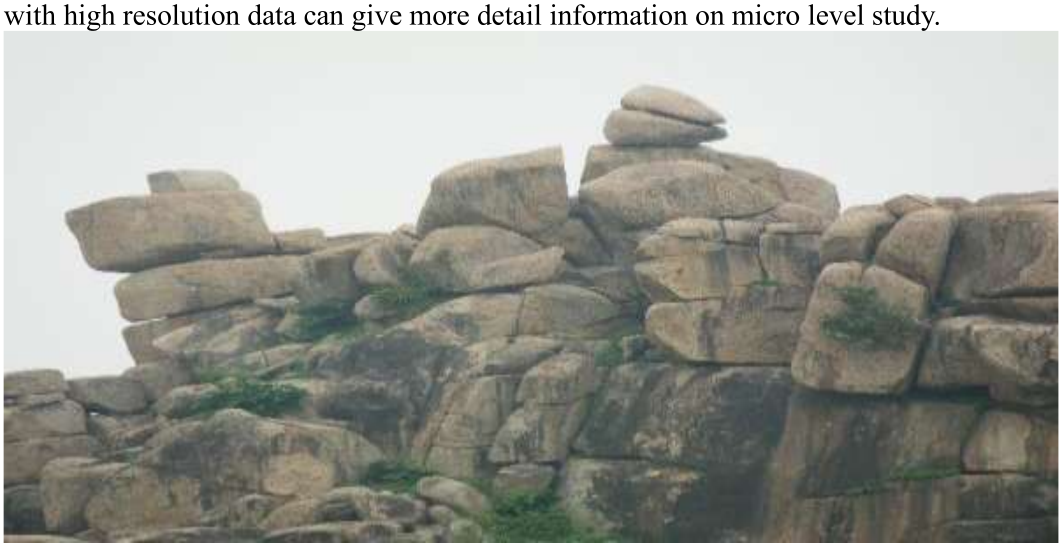


Fig 4: Geomorphology classification of Jhansi

The district comes in north of Vindhyan range. Landscape is a part of Bundelkhand massif which developed by the intrusion of one rock underneath the other and lineaments and fractures mapping verified it. The data that has been used have its own limitations but further studied with high resolution data can give more detail information on micro level study.



Pic 1: Granite hard rock structure Jhansi

4.3. Applications and Future Scope:

• The geomorphology classification map can be utilized for:

o Disaster risk management: locating places where floods, landslides, and other natural disasters are likely to occur.

o Resource exploration: Using geomorphology features to identify possible mineral and water resources.

Planning for agriculture involves zoning land according to its slope and soil type to make it ideal for different types of farming.

o Infrastructure development: Deciding on the best places to build roads, irrigation systems, and other infrastructure.[18]

4.4. Future research could:

o Combine data from other sources, such as LiDAR, to improve terrain analysis.
o Use cutting-edge machine learning methods to classify geomorphology automatically.
o Use multi-temporal satellite images to investigate the temporal variations in geomorphology throughout time.

5. Conclusion:

The geomorphology of Jhansi has been classified mainly into 11 classes. The water and hard rock play a vital role with human interference. Vindhyan Hard rock hill range is a widely spread geomorphologic feature which is covered by the granite hard rock and have steep slope. Vindhyan Slope is determining the numbers and amount of flow in streams. This study shows how well IRS data, which is publicly available, can be used with GIS and remote sensing methods to classify the geomorphology of the Jhansi district, India, according to slope and elevation. The produced geomorphology map offers useful data for a range of uses and lays the groundwork for more research on the dynamics of geomorphology and resource management in the area. In Jhansi Geomorphology and Geology both plays a vital role to determine the direction and flow of drainage. Third order tributary is flowing in between two lineaments, and first order is more in eastern and western direction and all rivers flow in northeast. Some third order and almost all 2nd order tributaries and directed by the lineament. Erosional process worked on these lineaments and rivers crossed lineaments on very few places which show that the origins of these hills are very new in the Bundelkhand.
Furthermore, the study will contribute to the development and enhancement of remote sensing-based geomorphology classification methods applicable to various environments. Techniques for mapping geomorphology are always evolving in the fields of application and analysis investigations. It was once based on the demarcation approach, but with the use of GIS, automated, semi-automated, and fuzzy logic techniques are now highly helpful and need less time and money. Subsequent research endeavours may be undertaken to facilitate more planning across many industries. The study's relationship to geology, slope, and elevation is significant in and of itself. Planning and ground water availability are impacted by the study. Landforms may alter in the future as a result of human influence and rapidly expanding development plans and initiatives.

Acknowledgement:
My cordial thanks to B.U. Jhansi to provide the lab facility and to the UGC New Delhi for financial support. I express my gratitude towards NIC Jhansi and NRSC to provide data.

6. References

[1] Reddy, G. P. O. (2012). Geomorphological processes and evolution of landforms. Remote sensing and GIS in digital terrain analysis and soil-landscape modelling. National Bureau of Soil Survey and Land Use Planning, (152), 26-35.
[2] Ashok P., et al., AHP and GIS Techniques for the Demarcation of Groundwater Potential Zones in a Part of Granitic Bundelkhand, India- A Case Study of District Jhansi" International Journal of Mechanical Engineering, ISSN:0974-5823, Vol.7 No.2 (February 2022), Copyrights @Kalahari Journals, Scopus indexed. Chrome extension://efaidnbmnnnibpcajpcglclefindmkaj/https://kalaharijournals.com/resources/FebV7_I2_136.pdf
[3] Jagannathan, K. (2009). Manual for National Geomorphological and Lineament Mapping on 1: 150,000 scale. Report number NRSC/RS&GIS-AA/GEOM. Indian Space Research Organization and Geological Survey of India. National Remote Sensing Centre, Hyderabad.

[4] Mokarram, M., & Sathyamoorthy, D. (2018). A review of landform classification methods. Spatial Information Research, 26, 647-660.
[5] Ashok P., Singh S.P., Saxena S., "Geomorphic classification using GIS and Remote sensing tools in western part of Bundelkhand massif on Kali Sind River, International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 8, Issue 6, June 2018), (IJETAE), Vol. 8, issue 6, June 2018.
[6] Mashimbye, Z.E., & Loggenberg, K. (2023). A Scoping Review of Landform Classification Using Geospatial Methods. Geomatics.
[7] Solomon, S., Quiel, F. "Groundwater study using remote sensing and Geographic Information Systems (GIS) in the central highlands of Eritrea", June 2006, Hydrogeology Journal 14(5):729-741(2006).
[8] Ashok P., Singh S.P., Saxena S, Singh D., (2012), "Slope Identification with GIS & Remote sensing on a part of Bundelkhand Plateau – A micro level case study of Central Sind Catchment", Indian Cartographer, Vol XXXII, 2012, Page no. 61, Dehradun. (Peer review)
[9] MacMillan, R.A.; Shary, P.A. Chapter 9. Landforms and Landform Elements in Geomorphometry. In Geomorphometry; Hengl, T., Reuter, H.I.B.T.-D., Eds.; Elsevier: Amsterdam, The Netherlands, 2009; Volume 33, pp. 227–254. ISBN 0166-2481.
[10] Ashok P., Singh P, Saxena S., Singh D. (2011), "Role of GIS and Remote Sensing for the demarcation of groundwater potential zones near to Central Upper Sind Catchment", National conference on Geology of Bundelkhand, April 21-23, 2012, held at Bundelkhand University, Department of Earth Science, Jhansi (U.P.), Journal of Economics Geology and Georesource Management (JEGGM) Vol. 8 No.(1-2), (2011), pp. 57-64.
[11] Verhagen, P.; Drăguţ, L. Object-Based Landform Delineation and Classification from DEMs for Archaeological Predictive Mapping. J. Archaeol. Sci. **2012**, 39, 698–703.
[12] Ashok P., Saxena M., Saxena S., Singh D. (2011), "Geomorphology Analysis and Classification with Geographic Information System & Remote Sensing - A micro level study," International Journal of Earth Sciences and Engineering (IJESE), ISSN 0974-5904, Volume 04, No 06 SPL, October 2011, pp 330-333.
[13] Manfre, L.A.; de Albuquerque Nobrega, R.A.; Quintanilha, J.A. Regional and Local Topography Subdivision and Landform Mapping Using SRTM-Derived Data; a Case Study in Southeastern Brazil. Environ. Earth Sci. **2015**, 73, 6457–6475.
[14] Singh, S.P., Singh, M.M., Srivastava, G.S. and Bundelkhand area, Central India. Journal of Himalayan Geology,28:79-101
[15] Mithan, H.T.; Hales, T.C.; Cleall, P.J. Supervised Classification of Landforms in Arctic Mountains. Permafr. Periglac. Process. **2019**, 30, 131–145.
[16] Ashok P., (2023) Assessment of Ground Water for Sustainable Utilization of Water Resources In Bundelkhand Region., Post Doctoral research, B.U. Jhansi.
[17] Demek, J., & Embleton, C. (Eds.). (1976). Guide to medium-scale geomorphological mapping. International Geographical Union, Commission on Geomorphological Survey and Mapping. Demek, J. (1972). Manual of detailed geomorphological mapping. (No Title).
[18] Ashok P., Singh S.P., Kumar M.K., Amanu M.T. "Natural Hazards and Disaster Management,"1st ed., ISBN- 978-93-93682-09-3, AKN Learning, Delhi, 2022.
[19] Burrough P.A., Van Gaans P.F.M., MacMillan R.A., (2000). High-resolution landform classification using fuzzy k-means. Fuzzy Sets and Systems. Volume 113, Issue 1, 1 July 2000, Pages 37-52.
[20] Mashimbye, Z.E.; Loggenberg, K. A Scoping Review of Landform Classification Using Geospatial Methods. Geomatics 2023, 3, 93-114. https://doi.org/10.3390/geomatics3010005