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Relief and Drainage Analysis of the Great Ganga River and Daur River Basin in Pratapgarh District

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Abstract:

The analysis of relief and drainage characteristics is an essential component of geomorphological and hydrological studies, as it helps to understand the structure, evolution, and hydrological behaviour of river basins. The present study examines the relief and drainage characteristics of the Great Ganga River and Daur River basin in Pratapgarh, which forms part of the Indo-Gangetic Plain. The study utilizes geospatial techniques including Digital Elevation Model (DEM) data obtained from the United States Geological Survey and drainage data extracted from India-WRIS to analyze the geomorphological and hydrological characteristics of the basin. Relief analysis indicates that the study area is characterized by low elevation variations and gentle slopes typical of the alluvial plains of northern India. The drainage analysis reveals a well-developed dendritic drainage pattern consisting of major rivers such as the Sai, Bakulahi, Loni, and the Daur River, along with numerous smaller tributaries and drainage channels that ultimately drain into the Ganges River system. Morphometric interpretation of the drainage network shows the presence of multiple stream orders, reflecting active surface runoff processes particularly during the monsoon season. The results demonstrate that relief conditions significantly influence drainage development, sediment deposition, and surface water flow in the basin. The study highlights the importance of relief and drainage analysis in understanding watershed characteristics and provides valuable insights for sustainable water resource management, flood control, and regional planning in the basin area.

Keywords: Relief Analysis, Drainage Pattern, Morphometric Analysis, GIS and DEM, Ganga Basin, Pratapgarh District.

Introduction:

The analysis of relief and drainage is an important aspect of geomorphological and hydrological studies, as it helps to understand the structure, evolution, and functioning of river basins. Relief represents the variation in elevation and slope of the earth's surface, while drainage refers to the pattern and organization of streams and rivers that collect and transport surface runoff within a basin. The study of these parameters provides insights into watershed

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characteristics, erosion processes, landform development, and water resource management. In geographical research, relief and drainage analysis is widely used to evaluate basin morphology, drainage density, stream order, and slope conditions that influence the hydrological behaviour of a region. Such studies are particularly significant in alluvial plains where subtle variations in relief strongly affect river flow, sediment transport, and flood patterns.

The Ganga River system is one of the largest and most significant drainage systems in the Indian subcontinent. Originating from the Himalayan region and flowing approximately 2,500 km eastward to the Bay of Bengal, the Ganga and its numerous tributaries drain a vast portion of northern India and form the largest river basin of the country. The basin covers about 8,61,404 km², extending across several states including Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, and West Bengal. The river system supports dense human settlements and agricultural activities due to its fertile alluvial plains and abundant water resources. Because of its extensive network of tributaries and distributaries, the Ganga basin plays a crucial role in shaping the geomorphology, hydrology, and socio-economic landscape of northern India.

Within this broader fluvial system, the river basins of the Great Ganga River and the Daur River in Pratapgarh district (Uttar Pradesh) represent an important local drainage unit of the middle Gangetic plain. The region is characterized by a low-lying alluvial surface with gentle slopes, seasonal streams, and tributaries that ultimately contribute to the Ganga drainage network. Relief conditions, soil composition, and monsoonal rainfall significantly influence the drainage pattern and hydrological dynamics of these basins. Analysing the relief and drainage characteristics of the Great Ganga and Daur River basins is therefore essential for understanding watershed morphology, surface runoff patterns, erosion processes, and sustainable land-use planning in the district. Such studies also provide valuable information for flood management, agricultural development, and regional environmental planning.

Literature Review:

Horton (1945) conducted one of the earliest quantitative studies of drainage basins and developed fundamental laws related to stream numbers, stream lengths, and drainage density. His work introduced the concept of stream ordering and emphasized that drainage networks can be analyzed mathematically to understand the erosional development of river basins. Horton demonstrated that the structure of drainage systems reflects geomorphological processes and basin characteristics, providing a scientific basis for morphometric analysis of river basins.

Strahler (1957) further refined Horton's approach by introducing a modified stream-ordering system and by establishing quantitative methods for analysing watershed geometry. He emphasized that drainage basin characteristics such as stream order, bifurcation ratio, and drainage density are essential indicators of basin morphology and hydrological behaviour. His method made morphometric analysis more systematic and widely applicable in geomorphology and hydrology.

Schumm (1956) contributed significantly to the understanding of drainage basin morphometry by analyzing relationships between slope, relief, and channel characteristics. He highlighted

that basin relief and slope strongly influence runoff, erosion, and sediment transport within a watershed. His research demonstrated how morphometric parameters can be used to interpret geomorphic evolution and hydrological response of river basins.

Chorley, Malm, and Pogorzelski (1957) introduced new approaches for estimating drainage basin shape and emphasized the role of basin geometry in hydrological processes. Their study demonstrated that basin shape influences runoff concentration and flood potential, thereby contributing to the understanding of watershed hydrology and geomorphological development.

Singh (1996) analysed the geomorphology of the Ganga Plain and explained the formation of alluvial landforms, drainage patterns, and fluvial processes in northern India. The study highlighted that the drainage systems of the middle Ganga plain are largely controlled by gentle slopes, alluvial deposits, and monsoonal hydrology, which shape the drainage characteristics of many tributary basins in Uttar Pradesh.

Shukla and Raju (2008) examined the geomorphic characteristics of river basins in the central Ganga plain using topographic and satellite data. Their work emphasized the role of geomorphological parameters such as slope, relief, and drainage pattern in understanding basin evolution and fluvial processes in alluvial plains.

Prakash (2016) carried out morphometric analysis of the Varuna River basin, a tributary of the Ganga River, using remote sensing and GIS techniques. The study showed that morphometric parameters such as stream order, drainage density, and relief characteristics are useful in evaluating watershed development and fluvial geomorphology in the middle Ganga plain.

Mukherjee (2016) analysed the topographic characteristics of the Ramganga River basin using Digital Elevation Model (DEM) and GIS techniques. The study demonstrated that relief, slope, and drainage network characteristics significantly influence watershed planning, river utilization, and flood management.

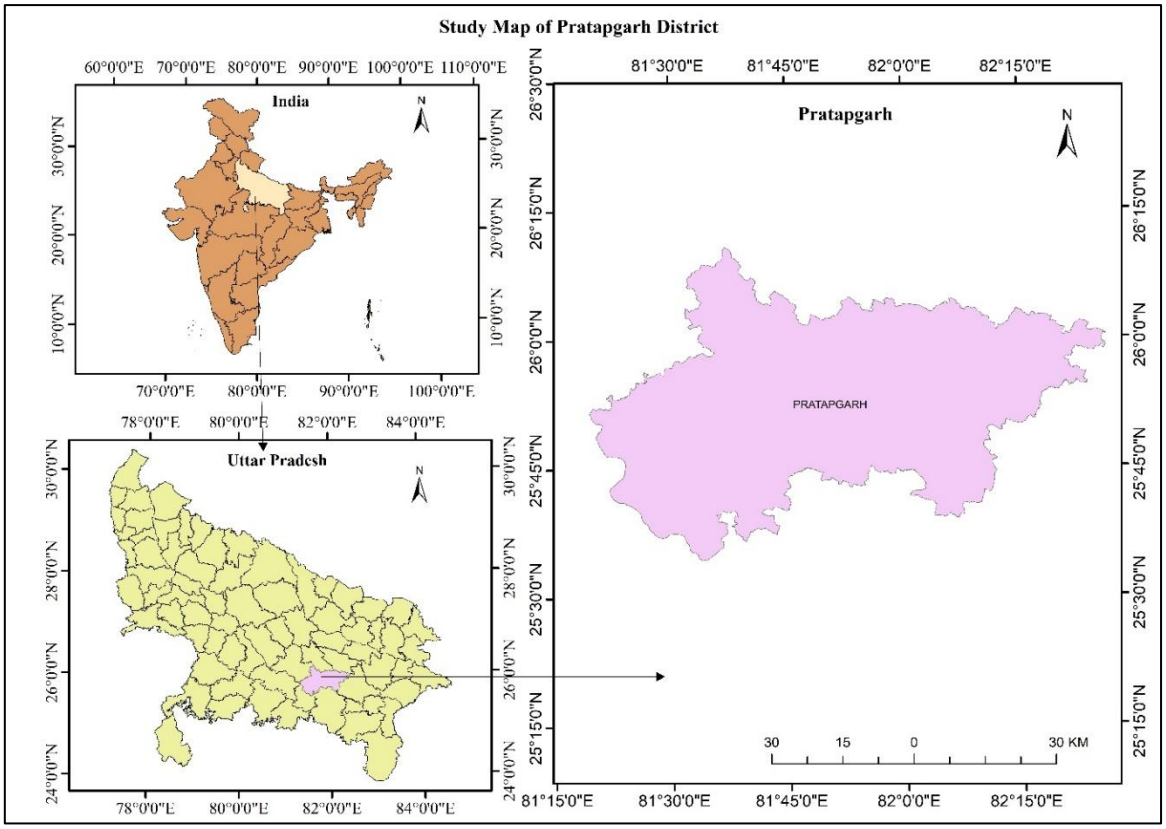
Chowdhury et al. (2024) conducted morphometric analysis of the Halda River basin using modern geospatial techniques. The study emphasized that morphometric analysis involves evaluating linear, areal, and relief aspects of a drainage basin to understand the geometry, structure, and hydrological behavior of watersheds.

Study Area:

The study area comprises the basin of the Great Ganga River and the Daur River located in Pratapgarh district, which forms part of the middle Ganga Plain in northern India. Geographically, the district extends approximately between 25°34′ N to 26°11′ N latitude and 81°19′ E to 82°27′ E longitude and covers an area of about 3,730 km². It is bounded by Sultanpur in the north, Prayagraj in the south, Jaunpur in the east, and Raebareli in the west. The region is characterized by a low-lying alluvial plain with gentle slopes formed by the long-term deposition of sediments brought by the Ganges River and its tributaries. The Daur River is an important local tributary that contributes to the regional drainage network and ultimately drains into the Ganga system. The climate of the region is tropical monsoonal with hot summers, a humid rainy season from June to September, and mild winters. Annual rainfall is mainly concentrated during the southwest monsoon, which significantly influences river

discharge, surface runoff, and drainage characteristics in the basin. The soils are predominantly fertile alluvial soils that support intensive agricultural activities, particularly the cultivation of rice, wheat, pulses, and oilseeds.

Fig: 01, Study Area Map



Source: Prepared by Author

In terms of population dynamics, Pratapgarh district had a total population of 3,209,141 persons according to the 2011 Census of India, including 1,606,085 males and 1,603,056 females, indicating a relatively balanced sex ratio of about 994–998 females per 1000 males. The district recorded a population density of about 854 persons per square kilometre and experienced a decadal population growth rate of around 16.2–17.5% between 2001 and 2011, when the population increased from about 2.73 million in 2001 to over 3.20 million in 2011. The literacy rate of the district is around 70–73%, with male literacy significantly higher than female literacy. The population distribution is predominantly rural, with only about 5–8% of the population living in urban areas, reflecting the agrarian nature of the district. Scheduled Castes constitute about 22% of the total population, while the majority of residents speak Hindi and Awadhi as their primary languages. These demographic characteristics indicate a high dependence on agriculture and natural resources, making the relief and drainage conditions of the Ganga and Daur river basins particularly important for regional livelihood, settlement patterns, and sustainable land-use planning.

Objectives:

1. To analyse the relief characteristics and drainage pattern of the Great Ganga River and Daur River basin in Pratapgarh district.
2. To evaluate the morphometric parameters of the basin using GIS and DEM techniques for understanding watershed characteristics and drainage development.

Data Sources:

The present study is based on both primary and secondary data sources. Topographical information and drainage network data have been obtained from Survey of India (SOI) topographic sheets, which provide detailed information regarding elevation, river courses, and settlement patterns in the basin area. Satellite imagery and spatial data have been acquired from United States Geological Survey through the Earth Explorer platform, particularly the SRTM (Shuttle Radar Topography Mission) Digital Elevation Model, which is widely used for terrain analysis and watershed delineation. Administrative boundary data have been collected from the Survey of India and other government sources. Demographic information related to population characteristics has been obtained from the Census of India (2011). Additional information regarding geomorphology, drainage analysis, and morphometric techniques has been collected from relevant books, research papers, journals, and government reports.

Table: 01 Rivers of Pratapgarh District

Sr.No.	River Name	Length in KM
17	Sai	151.19
1	Bakulahi	134.11
10	Loni	76.15
6	Duar	56.45
20	Tambura Nala	52.02
15	Patti Nala	35.38
14	Paraya Nala	33.37
24	Naiya Nala	31.56
8	Hiraganj Drain	27.71
4	Chamraura	23.51
23	Naiya Nala	21.53
26	Pili	19.78
7	Ganga	19.12
19	Sutia Nala	15.32

18	Sakarni	12.98
21	Umri Drain	12.20
5	Dhansari Drain	11.91
13	Naudiha	7.99
12	Nariyanwa Drain	7.64
9	Hisampur Drain	7.16
11	Narayanpur Drain	6.34
16	Ranikund Nala	5.72
2	Baragaon Drain	5.68
22	Gomati	4.67
3	Birsinghpur Drain	3.72

Source: Extracted From India-wirs

Methodology:

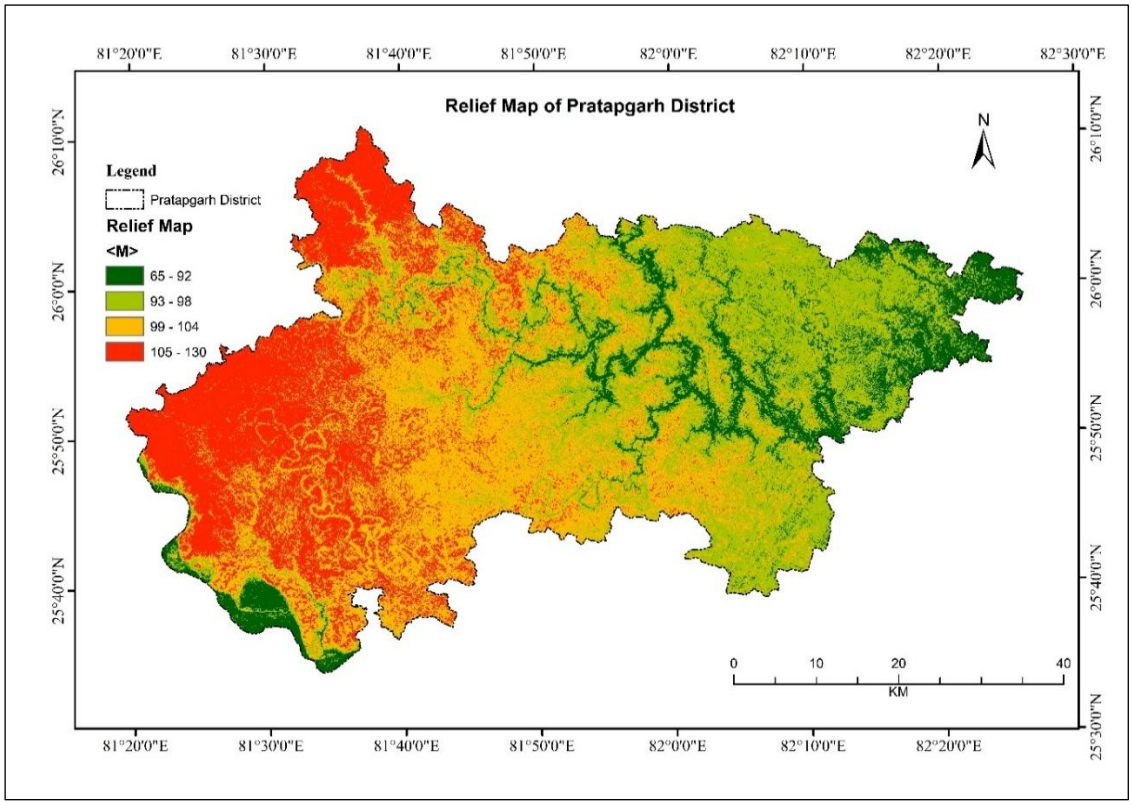
The present study adopts a quantitative geomorphological and geospatial approach to analyse the relief and drainage characteristics of the Great Ganga and Daur River basin. Initially, the boundary of the basin was delineated using Digital Elevation Model (DEM) data obtained from the SRTM dataset, which provides elevation information with suitable spatial resolution. The DEM data were processed and analysed using ArcGIS to generate slope maps, relief maps, and drainage networks of the study area. The drainage system was extracted using hydrological tools such as flow direction, flow accumulation, and watershed delineation. Subsequently, the drainage network was classified into different stream orders following the Arthur Newell Strahler stream-ordering method. Various morphometric parameters were calculated, including linear aspects (stream order, stream length, bifurcation ratio), areal aspects (drainage density, drainage frequency, basin shape), and relief aspects (basin relief, slope, and relative relief). These parameters help in understanding the geomorphological evolution, hydrological behaviour, and watershed characteristics of the basin. The results were interpreted to evaluate the relationship between relief conditions and drainage development and to assess their implications for watershed management and regional planning.

Result and Discussion:

The analysis of relief and drainage characteristics of Pratapgarh district reveals important geomorphological and hydrological features of the basin of the Ganges River and the Daur River. The relief conditions derived from the SRTM Digital Elevation Model obtained from the United States Geological Survey indicate that the study area belongs to the middle Indo-Gangetic Plain, which is characterized by a generally low and gently sloping terrain. The elevation across the district shows minor variations, reflecting the depositional nature of the alluvial plains formed by the long-term sedimentation processes of the Ganga and its

tributaries. The relief map (Fig. 02) illustrates that the terrain gradually slopes towards the southern and southeastern parts of the district, facilitating the natural flow of surface water into the regional drainage system. The relatively low relief and gentle gradients favour the development of an extensive drainage network and also contribute to seasonal waterlogging and flood susceptibility in certain low-lying areas.

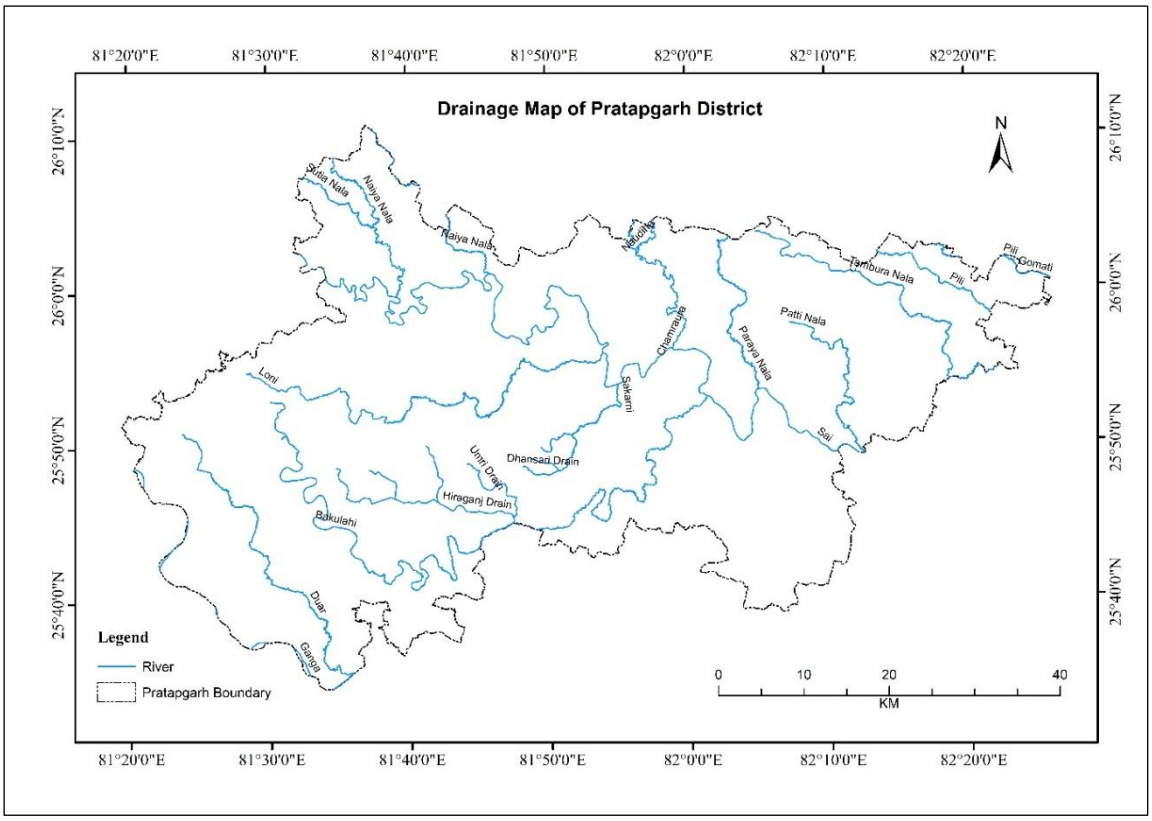
Fig: 02 Relief map of Pratapgarh District



Source: Prepared by author using USGS data.

The drainage map of the district (Fig. 03), prepared using river data extracted from India-WRIS, demonstrates a well-developed drainage network composed of major rivers, minor tributaries, and several seasonal streams. The most prominent river in the district is the Sai River, which has a recorded length of 151.19 km within the district, followed by the Bakulahi River (134.11 km) and the Loni River (76.15 km). Among the smaller tributaries, the Daur River has a length of 56.45 km, making it an important contributor to the local drainage system. Other streams and drainage channels include Tambura Nala (52.02 km), Patti Nala (35.38 km), Paraya Nala (33.37 km), Naiya Nala (31.56 km and 21.53 km segments), Hiraganj Drain (27.71 km), Chamraura (23.51 km), Pili (19.78 km), and the Ganga River segment within the district measuring approximately 19.12 km. Additional smaller drainage channels such as Sutia Nala, Sakarni, Umri Drain, Dhansari Drain, Naudiha, Nariyanwa Drain, Hisampur Drain, Narayanpur Drain, Ranikund Nala, Baragaon Drain, Gomati, and Birsinghpur Drain further contribute to the overall drainage structure of the district.

Fig: 03, Drainage map of Pratapgarh district



Source: Prepared by Author using India wirs Data.

The spatial distribution of these rivers and streams indicates a dendritic drainage pattern, which typically develops in regions with homogeneous geological structures and gentle slopes. Such a drainage pattern is characteristic of the alluvial plains of northern India where the underlying lithology offers minimal structural control on river courses. The drainage network extracted through ArcGIS and analyzed using the Arthur Newell Strahler stream-ordering method reveals a hierarchical organization of streams ranging from first-order seasonal channels to higher-order perennial rivers. The presence of numerous first- and second-order streams indicates active surface runoff processes during the monsoon season, while the larger rivers function as the main drainage channels that transport water and sediments towards the Ganga system.

Relief conditions strongly influence the development and distribution of the drainage network within the basin. Areas with slightly higher elevations act as watershed divides from which several smaller tributaries originate, while the lower elevation zones serve as the main drainage corridors where rivers converge. The gentle slope of the terrain allows for slow water flow and sediment deposition, contributing to the formation of fertile alluvial soils that support intensive agricultural activities. However, the same low relief conditions may also increase the susceptibility of certain parts of the district to flooding during periods of heavy monsoonal rainfall. Overall, the relief and drainage analysis demonstrates that the geomorphological characteristics of the basin play a crucial role in shaping the hydrological behavior, land-use patterns, and environmental conditions of the region. The integration of geospatial data and

morphometric analysis provides valuable insights for watershed management, flood mitigation, and sustainable regional planning in the basin of the Ganga and Daur rivers.

Conclusion:

The analysis of relief and drainage characteristics of the Great Ganga River and Daur River basin in Pratapgarh reveals that the study area forms an integral part of the Indo-Gangetic Plain, characterized by low relief, gentle slopes, and an extensive alluvial surface. The relief analysis based on DEM data indicates that the terrain exhibits minor elevation variations, which significantly influence the direction and development of the drainage network. The drainage analysis shows a well-developed dendritic drainage pattern consisting of major rivers such as the Sai, Bakulahi, Loni, and the Daur River, along with numerous smaller tributaries and drainage channels that ultimately contribute to the Ganges River system. The presence of a large number of first- and second-order streams indicates active surface runoff processes during the monsoon season, while higher-order streams function as major drainage channels transporting water and sediments across the basin. The low relief conditions combined with fertile alluvial soils support intensive agricultural activities and dense rural settlements, although these characteristics also make certain parts of the region vulnerable to seasonal flooding and waterlogging. Overall, the study highlights that the relief and drainage configuration of the basin plays a significant role in shaping the geomorphological processes, hydrological behavior, and land-use patterns of the region, and the use of GIS and DEM-based analysis provides valuable insights for effective watershed management, flood mitigation, and sustainable regional planning in the basin area.

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