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Research Paper

Hydrogeological Investigation of Nirguna (Bhikund) River Watershed, Using Remote Sensing and Geographical Information System Techniques for Watershed Management in Akola and Washim District, Maharashtra, India

[1]Mahesh D. Phalke*, [2]Khadri SFR
[1,2](PG Department of Geology, SGBA University, Amravati-444602 (MS) India)
*Corresponding Author: [1]Mahesh Devidas Phalke**

ABSTRACT: *Technological improvements in Geographic Information Systems (GIS) have been critical to many aspects of watershed management, including assessing the state of watersheds, modelling the impact of human activity on water quality, and visualizing the results of various management scenarios. Using geospatial technologies like remote sensing, image processing techniques, and GIS is crucial for the efficient acquisition of surface water availability data for watershed management. This study employed GIS and remote sensing methods to in-depth hydrogeological investigations and watershed management for the Nirguna (Bhikund) River watershed in the Akola & Washim districts of MS, India. A number of morphometric analysis and watershed management techniques were used in the creation of the database. From operational aids like inventory control and educational maps, to descriptive modelling and tactical or strategic decision support systems, the application of GIS in watershed management has developed throughout time. For many reasons, groundwater is a vital water supply source. The drainage map was produced by using Arc Map software to digitise Survey of India toposheets using publicly available satellite imagery. Using supervised and unsupervised classification techniques, the land use/land cover map is created in the Arc GIS 10 versions and the ERDAS Imagine application. Geomorphology, ecology, and soil are among other theme levels. DEMs, slopes, land use, land cover, and drainage density are all produced using Arc Map software. The mathematical computation of parameters, including drainage density, bifurcation ratio, and stream order, is known as morphometric analysis. Geographic information system methods and the stream ordering strategy proposed by Strahler (1964) was used to perform morphometric analysis. Explore hydrogeological features, soil map, land cover cultivation map, slope map, geomorphological parameters, drainage density map, drainage pattern, morphometric analysis, digital elevation model studies and water treatment response, the study's findings were important. In this work, geographic information system (GIS) and remote sensing (RS) analytical techniques were used to examine the hydrogeological features of the Nirguna (Bhikund) River watershed in Akola & Washim district for the purpose of watershed management.*

KEYWORDS: *Watershed, Remote Sensing, GIS, Groundwater, Morphometry, Hydrological.*

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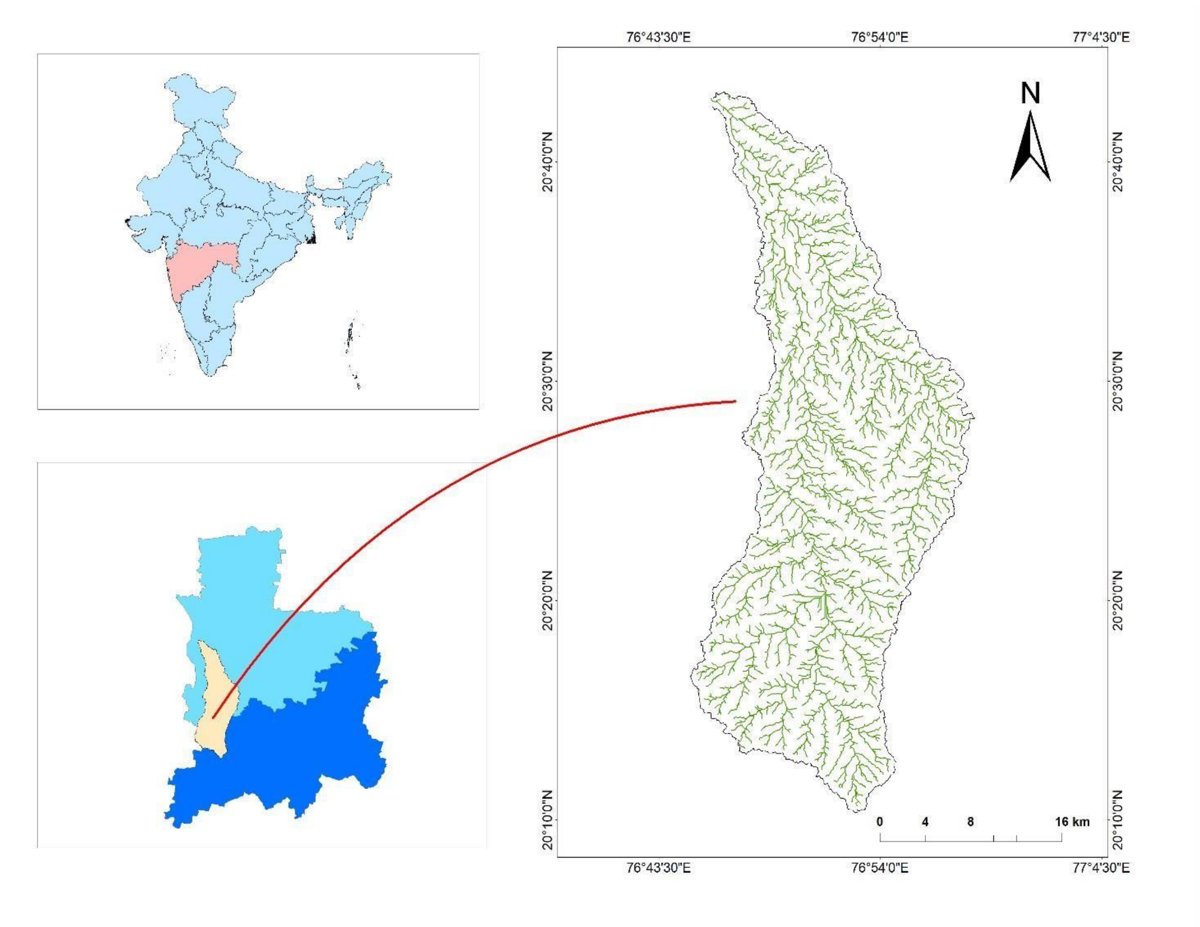
I. INTRODUCTION:

Enhancing and maintaining a watershed's function through the creation and execution of strategies, programmes, and initiatives which has an influence on the lives of people, animals, and plants in a watershed catchment region, constitutes the bulk of watershed management. Watershed management is difficult without a full system evaluation. Groundwater has played and will continue to play an important part in agricultural and livestock production, water for consumption supply, drought mitigation, and the country's economic growth. Because groundwater is an occult and subterraneous resource, it must be studied using subsurface groundwater exploration techniques. As the basis of all life, land and water are invaluable and essential resources that are used in every aspect of economic activity, from industries to agriculture (Rokade et al 2004). Morphology is the measurement and mathematical analysis of landforms and land layout. (Agarwal, 1998; Reddy et al. 2002). Arc GIS is a suite of computer decision making tools that facilitate integration, processing, analysis, and presentation of geographical data from several sources (Anji Reddy, 2001). A thorough understanding of a drainage basin's characteristics requires creating a drainage map and calculating the drainage morphometric variables (Krishnamurthy et al. 1996; Kumar et al. 2000; Reddy et al. 2002; Nag and Chakraborty 2003; Nooka Ratnam et al. 2005). The Purna basin has a size of 7,500 square kilometres, of which 3,500 square kilometres are covered by salty ground water, indicating a catastrophic drinking water condition. The basin has a complicated geological structure, with east-west and north-south faults running across it. Based on picture features including tone, texture, shape, size, position, and association, one could see the geomorphic landforms represented visually in the satellite imagery. Physiographic, how landforms developed, the makeup of the rocks and sediments, and related geological structures. In Survey of India, topography data is used to analyse satellite pictures. Based on physiographic and relief factors, there are three main geomorphic units such as plateaus, hills, piedmont zones, and plains (Khadri et al. 2013). Due to the areas dependency on agriculture and the minimal presence of surface water resources, as well as the growth of the population and the unpredictability of rainfall patterns, the water table has dropped to deeper levels, necessitating the sustainable development of the watershed in terms of groundwater as well as surface water resources (Khanday et al.2017).

II. STUDY AREA:

The Nirguna (Bhikund) river watershed is a tributary of the Mun River that rises in the Washim hills and the Patur reserve forest region close to Bhildurga Village in the Washim district. The study area of the the Nirguna (Bhikund) River watershed is in the Maharashtra state's Akola & Washim District and is delineated by Survey of India topo sheet nos. 55D/14, 55D/15, and 55D/16. It has a perimeter of approximately 187 km and a surface area of 726 sq. km, and it is scaled at 1:50000. Lava flows from the Deccan Trap are present in the research region. The soils in region primarily come from alluvial deposits and basaltic lava flows.

Figure 1: Location map of Niguna (Bhikund) River Watershed.



III. METHODOLOGY:

When analysing and interpreting linear, aerial drainage basins, the LISS-III Open Source satellite picture was employed (Fig. 2). Factors of picture interpretation like tone, texture, form, size, pattern, and association used to complete the maps of the Nirguna (Bhikund) River watershed area, basic information and local information were combined Using Arc GIS 10, the maps were georeferenced, digitalized, and attributes were applied to generate the digital database. The spatial analyst tool from Arc Map software is used to create the slope map using SRTM data. Using a base map, several thematic layers can be extracted for the various analytical components, such as drainage, roads, and water bodies. An image of the geomorphology is formed using a visual interpretation technique and interpretation criteria such as size, shape, texture, tone, pattern and shadow relationship. Line maps are used for visual understanding of land use/cover categories; depending on the terrain, the categories mapped may vary from map sheet. The free source LISS III satellite picture is used to analyse Land Use/Land Cover. The ground truth verification method, supervised and unsupervised classification approaches, and land use/cover map were created. Using an interpretation key and a visual interpretation technique, several aspects are recognised and discriminated.

This studies watershed management and morphometric analysis of the Nirguna (Bhikund) River watershed in the Mun tributary were prepared using a multi-criteria overlay analysis. Many sources were used to construct the topics of slope, drainage, geomorphology, land use/cover and soil texture. To comprehend the Nirguna (Bhikund) River watershed areas detailed nature, the above-mentioned DEM is used (Fig. 2). The Nirguna (Bhikund) River watershed has an average elevation that varies from 256 to 563 metres. The study areas top sheet map and open source satellite data with ground truth typically reveal a variety of geomorphic features, including ridges, basins, valley fill, alluvial plains, and flood plains as well as highly dissected plateaus, moderately dissected plateaus, and lower dissected plateaus.

IV. MORPHOMETRIC ANALYSIS:

The movement and distribution of water on Earth, as well as its chemical and physical characteristics as well as how it interacts with the environment, particularly with living things people, are the subject of hydro science. Evaluation of the watershed areas drainage system and watershed management programmes relies heavily on morphometric analysis. Depositional landforms such as lava plateaus, lava plains, linear ridges, conical hills, mesas, and buttes, as well as erosional landforms including lava cones, alluvial fans, and Bajada deposits, predominate in the examined region. A catchment area is the region where precipitation collects and radiates into a focal point that has internal water drainage, such as a lake, larger stream, or the sea. A key component of geomorphology is the catchment area for a variety of reasons. Water flows at or close to the surface of the earth. Sediments and dissolved matter are also transported, and the catchment region is normally a well-defined area that is easily separated from one another by a water divide (Suresh S. et al. 2022). Because most land and water resource planning and management challenges arise from the use of traditional data collection techniques, Remote Sensing (RS) and Geographic Information System (GIS) approaches were used in order to identify drainage patterns and provide excellent solutions to overcome these challenges. (Khadri et.al, 2013). Morphometrics is the quantitative study and measurement of the landforms' dimensions and configuration on Earth (Thornbury, 1969). The last feature that sets apart the watershed region and makes it In geomorphology, one crucial analytical unit is the fact that numerous of these significant attributes can be measured, which enables watersheds to be compared to one another—a process that was first carried out by Horton (1945) and Strahler (1957). This quantitative description, called "catchment area morphometry," is applicable to the features of the catchment area's stream channel system as well as its surfaces and curves. Stream ordering has made use of the Strahler (1964) technique due of its simplicity. A statistical analysis was conducted to evaluate the drainage basin of the Nirguna (Bhikund) River watershed in the Mun tributary. Aerial views, relief view characteristics, and linear aspects were all included in the analysis. Stream length ratio, mean stream length ratio, bifurcation ratio, length, and order of streams are all studied in the linear aspects (Table 1). Geographic Information Systems (GIS), Arc GIS, and remote sensing techniques were used to calculate metrics related to the basin geometry, including basin size, total stream length, stream length ratio, and basin perimeter (Fig. 3).The drainage density (Dd) of a basin, according to Horton (1932), reflects the degree of proximity between the streams. In square kilometres, the drainage density (Dd) is the total length of all streams within a drainage area. The research areas subsurface appears to be highly permeable based on a low drainage density. A weak or weakly impermeable underlying material is indicated by a high drainage density. (Fig. 4). The drainage density of 2.3 in the study region implies that the subsoil is highly porous and must have a thick vegetation cover.

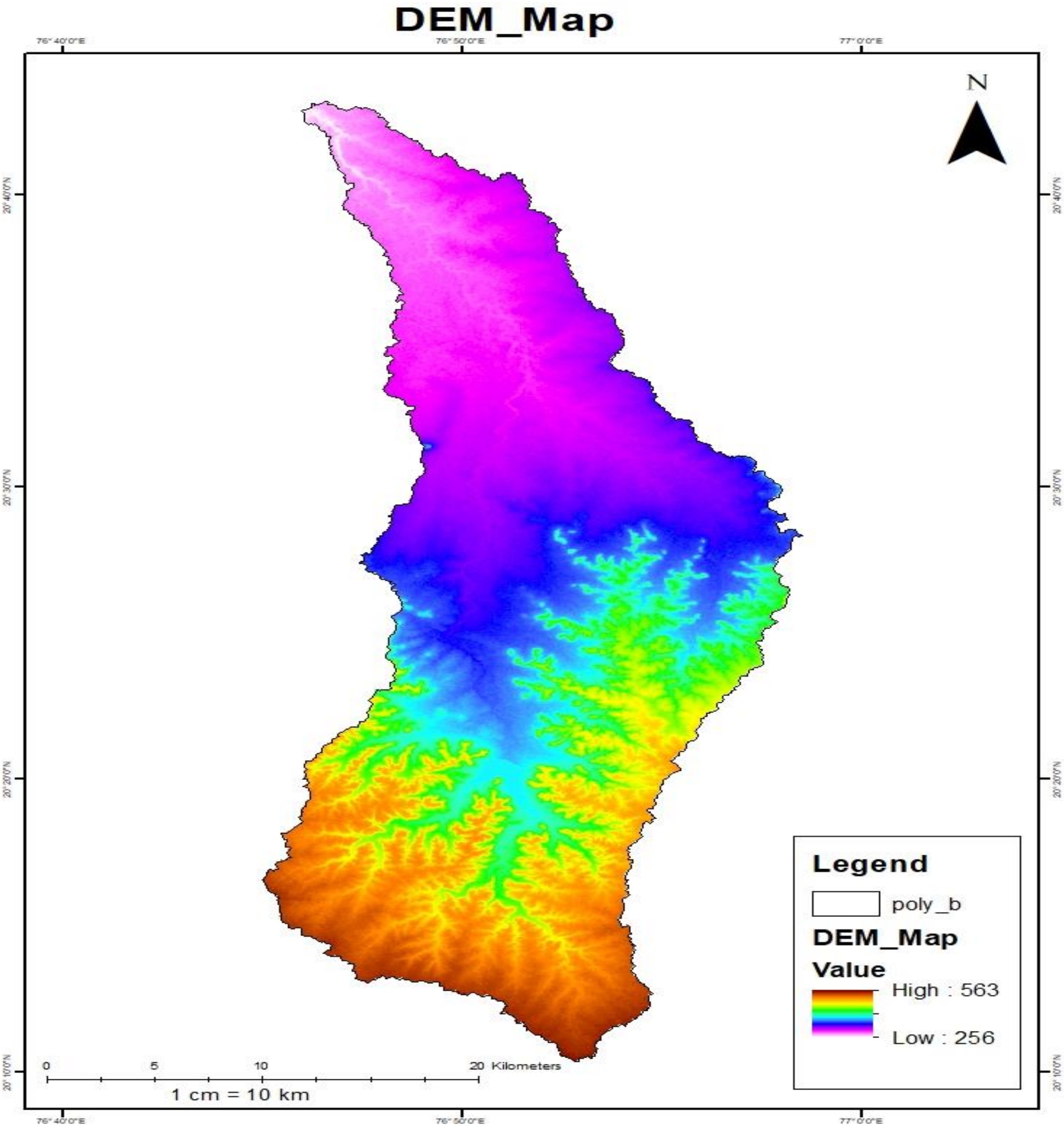


Figure 2: Digital Elevation Model (DEM) Map of Nirguna (Bhikund) River watershed.

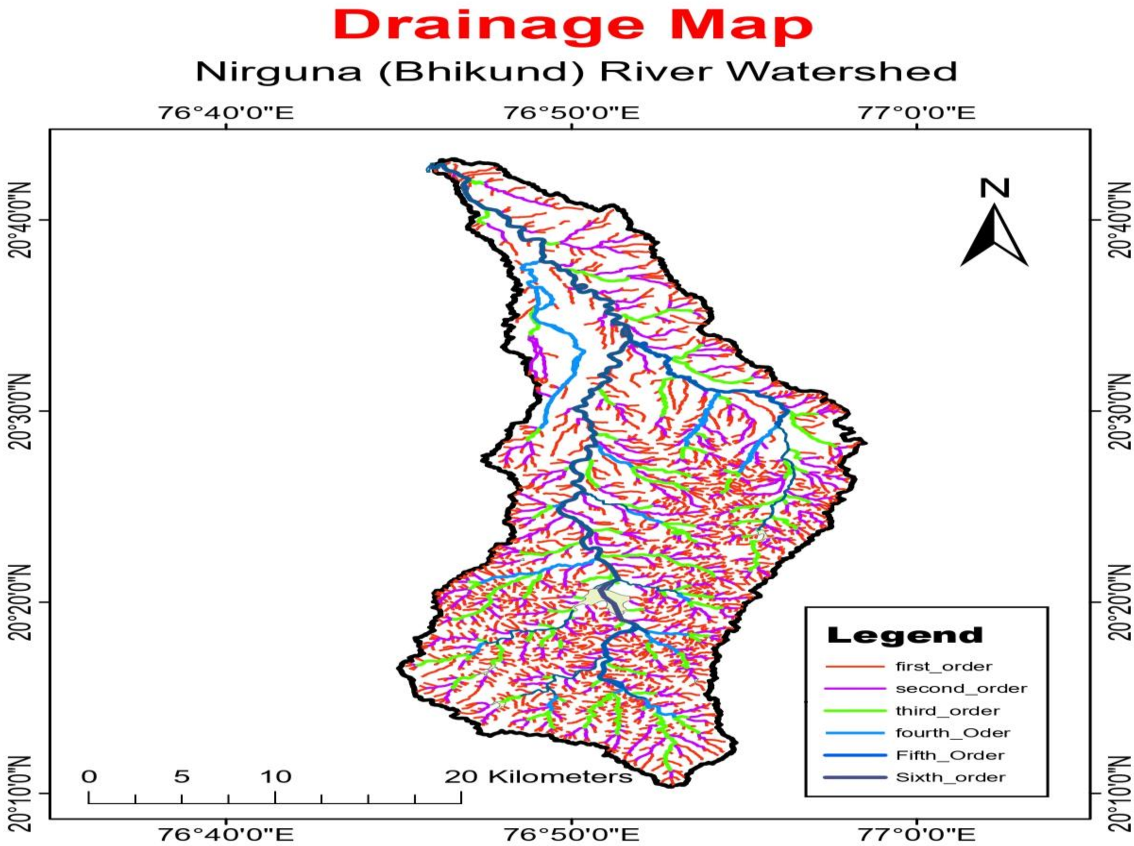


Figure 3: Morphometric Analysis map of Nirguna (Bhikund) River watershed.

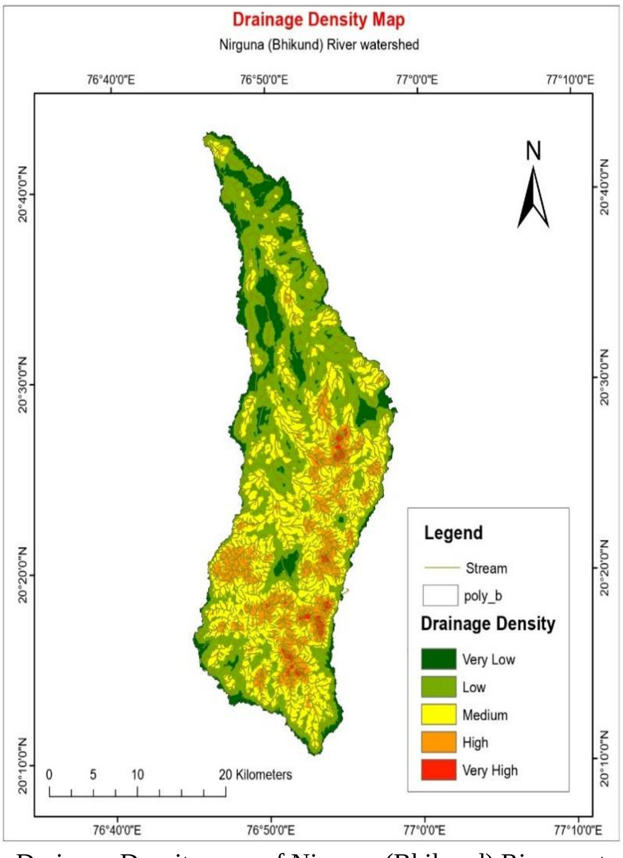


Figure 4: Drainage Density map of Nirguna (Bhikund) River watershed.

IV.1 THEMATIC LAYERS:

The study has made use of a number of layers, including soil, slope, drainage, drainage density, geomorphology, land use, and cover. Digital image processing software, along with spatial and non-spatial datasets, were used to construct these thematic layers using ARC GIS Desktop 10. To choose the best locations, a GIS-based method is taken into account. The creation of thematic layers involves the usage of appropriate data.

IV.2 LAND USE/LAND COVER:

Land use refers to the numerous activities and uses that occur on the land. "Natural vegetation" land covers are defined on rock/soil created by human's covers and other lands in aquatic bodies (NRSA 1989). The way land resources are used by humans creates "land use," which varies according to the purpose it fulfils, including the production of food, the provision of housing, leisure activities, the material extraction and processing, as well as the biophysical attributes of the land itself. The degradation of natural resources that results from biological and chemical pollutants from industry and agriculture is a persistent danger to tropical ecosystems. Reached catastrophic proportions (Benidick, 1999). Due to increases in population and the need to inhance production from available resources. Land cover is the term used to describe the biological and physical cover that is present above the top layer of land and includes things like plants, water, bare soil, and/or man-made structures (Ellis, 2007). In terms of the research areas land use pattern, the majority of the region is covered by agricultural land, while the southern half of the study area, which is part of the Washim district, is occupied by forest and some water bodies.

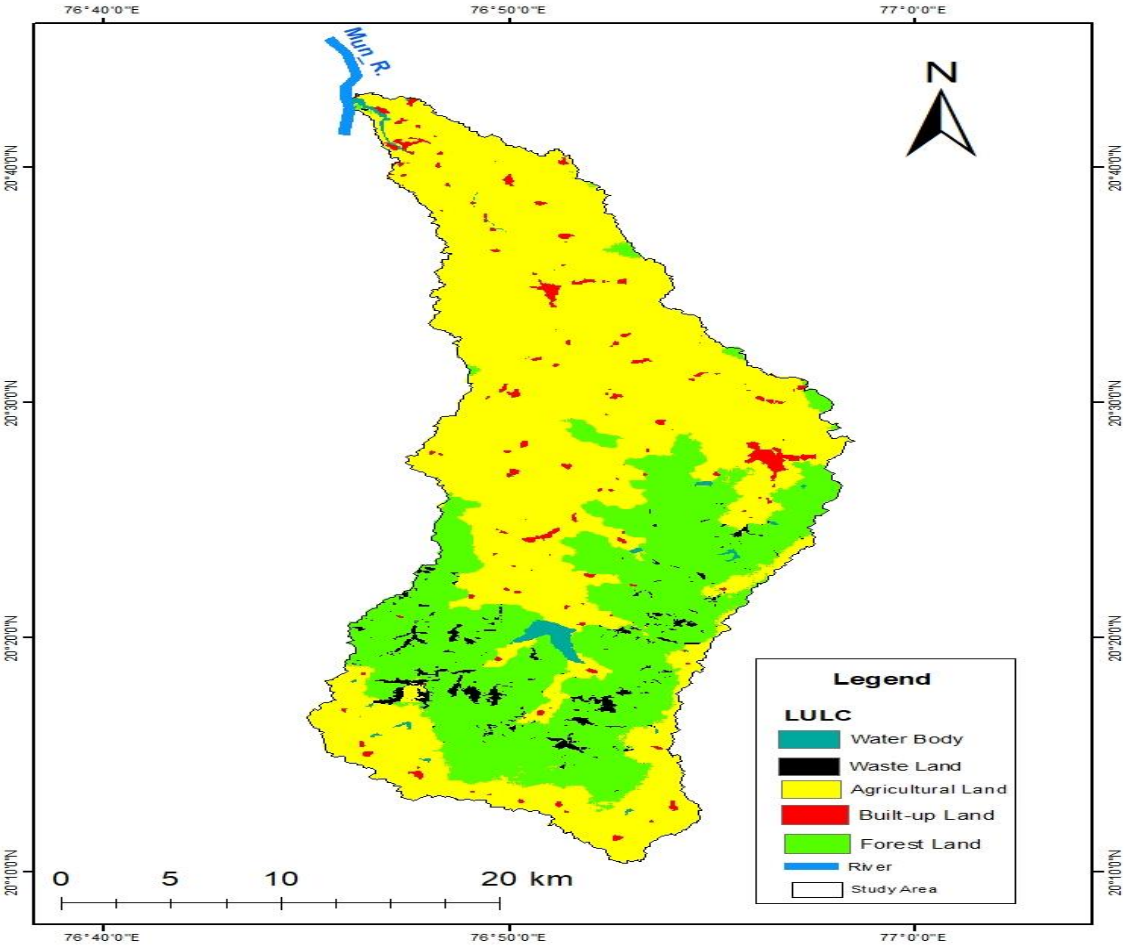


Figure 5: Land Use/Land Cover map of Nirguna (Bhikund) River watershed.

IV.3 DRAINAGE:

The watershed areas drainage network is principally determined by the Nirguna (Bhikund) River watershed and its tributaries. However, the pattern is dendritic mainly to sub dendritic in nature which is a network of numerous tributaries of varying orders and magnitudes that connect the master stream, resembling the branches and roots of a tree. In accordance with the importance of contour, slope, relief, DEM, and drainage network, local patterns have also formed. In the research region, the highest level of stream is sixth order. First and the second-order streams have a connection with higher elevations with high relief and slope, leading in more runoff and less recharge.

IV.4 WATERSHED SOIL CHARACTERISTICS:

The soils in the Akola and Washim areas are generated by the weathering of Deccan Trap and are widely recognised for their fertility and good yields. The soils are divided into two types: i) medium black soil and ii) deep black soil. The medium black soil is seen in the district's Balapur and Wadegaon, in the centre of the research area. This soil is medium dark in colour with a subangular texture. It is also medium drained with a low water holding capacity. The research area is the portion of the Purna basin and a tributary of the Mun River is the Nirguna (Bhikund) river watershed, encompassing parts of the Maharashtra districts of Akola and Washim. Black dirt with a deep character may be found in the talukas of Balapur and Akola. The soil in these locations is dark in colour, with a heavy texture and a subangular blocky structure in the subsurface horizon. It is moderately drained and has a low to medium water holding capacity. The southern section of the research area, which is in the northern region of the Washim district, contains good black soils. Furthermore, the soils found in plateau locations are shallow, with worn material at the subsurface. In terms of Balapur tahasil, deep black soils dominate the most part of the area. It is critical to note that the most productive soil in both districts is black cotton soil. The coarse shallow soil may be found in Balapur and Patur talukas. This soil has a low to medium black hue, a subangular texture, and a poor to average water carrying capability.

IV.5 SLOPE CHARACTERISTICS:

The amount of slope compared to the horizontal surface is specified as a basin or watershed slope. The ArcGIS programme were utilised to build the slope map. The watershed of the Nirguna (Bhikund) river has a variable slope, according to study. The slope values in the research region range from 0^o as a very low to 33^o very high while the hillshed values range from 0 to 180 (Fig.6). The steep scarp and fast discharge are shown by moderate slope variation.

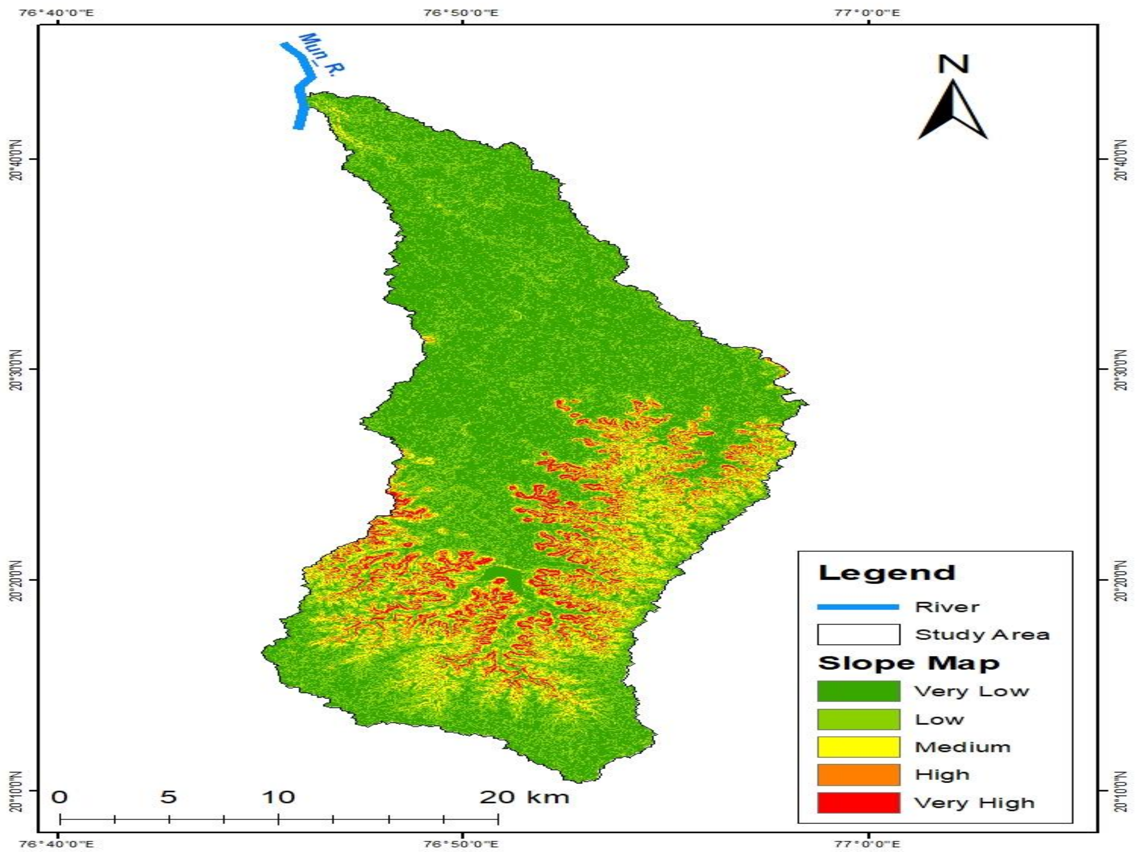


Figure 6: Slope map of Nirguna (Bhikund) River watershed.

IV. 5: GEOMORPHOLOGY:

Water bodies, pediment and pediplain complex, highly dissected plateau, low dissected plateau, moderately dissected plateau, flood plain, dam and reservoir, and alluvial plain are the eight distinct landforms found during geomorphologic investigations. The key features of the low dissected plateau's thick weathered mantle, which ranges from 5 to 8 metres, are the lack of dissection and lineaments suggesting a probable storage zone. The depth to sea levels varies from 16 to 19 metres in strongly dissected places. The topography is divided into several scarps on the southern side and low-lying plains on the northern side. The majority of the research region is made up of the pediment and pediplain complex, alluvial plain, and moderately dissected plateau (fig.7).

V. WATERSHED MANAGEMENT:

There are essentially three sorts of various water bearing horizons are discovered in the Deccan Traps viz. Massive or compact basalt, which includes jointed, cracked, vesicular, and weathered basalt, as well as some amygdaloidal basalt. Porosity and permeability are vary for the various lithological units found in the research region. In general, groundwater in basaltic deposits occurs unconfined. The physical properties of basaltic rocks govern groundwater potential, weathering degree, and weathered products. The presence and distribution of groundwater in basaltic terrain is strongly influenced by lithological, geomorphological, structural influences on climatic conditions beneath conditions that are semi-confined, unconfined, and that of the water table. It is crucial to note that basaltic lava flows have unique characteristics, particularly on the upper layers, that allow the basaltic rock to store and transport groundwater, which is known as porosity and permeability. It is also crucial to note that basaltic lava flows have secondary porosity and permeability rather than primary porosity and permeability. The degree of weathering, particularly spheroidal weathering in compact basalts, jointing, fissuring, and fracturing, all contribute to the development of secondary porosity or space to store groundwater. It is critical to note that rainfall is a highly essential element or key factor for groundwater recharge in the research region (Huang et al. 2013).

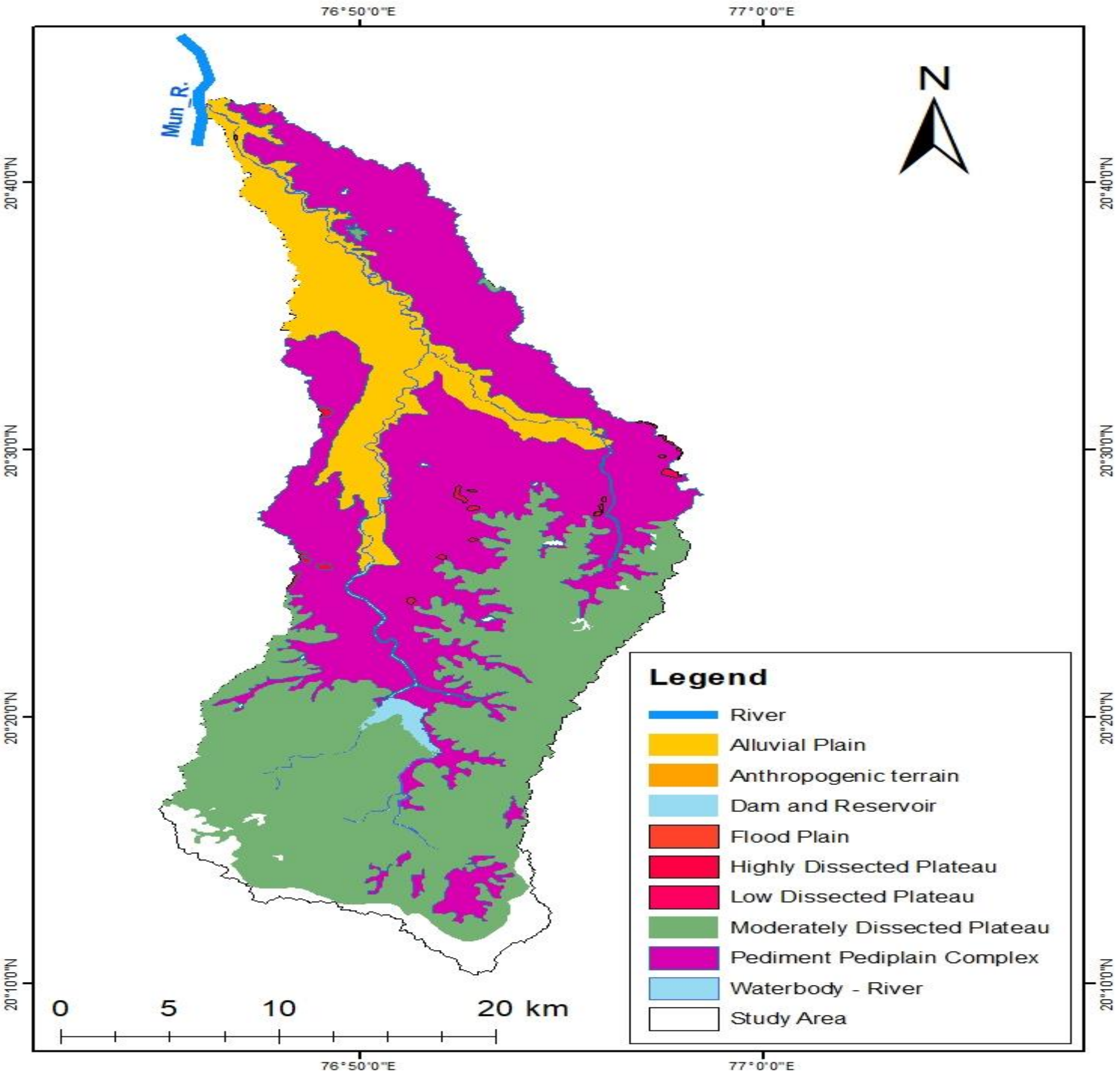


Figure 7: Geomorphological map of Nirguna (Bhikund) River watershed.

VI. RESULTS AND DISCUSSION:

A drainage basins morphometric study provides essential data on the geography, runoff, geological features, and hydrogeological properties of the underlying rock, as well as an analytical approach to defining drainage pattern characteristics. It is also essential for understanding hydrologic research on a river basin or watersheds (Bhavana N. Umrikar, 2017). The data for all linear, ariel, and relief parameters has been displayed in attribute form. It might be argued that examining watershed morphometry is inadequate for characterising and prioritising sub-watersheds. As an alternative, an integrated plan that takes runoff, changes in land use, and changes in land cover and sediment discharge estimates, is required. (Gadisa Chimdesa Abdeta, et. al. 2020). There is a clear correlation between erodibility and the linear parameters Bifurcation Ratio and Stream Length: the higher the value, the more erodible the material. As a result, for watershed prioritisation, the greatest value of Bifurcation ratio and other linear, Areal, and Relief parameters Stream Frequency, Drainage Density & First Order Streams, Circulatory Ratio, Form Factor, Overland Flow Length, Ruggedness, Relief Ratio, and Basin Relief Number was given a rating of rank 3, the second greatest value was evaluated as rank 2, and the lowest value was rated as rank 1.

Sr. No.	Parameters	Nirguna (Bhikund) River Watershed
1	Basin area (A) (km^2)	726
2	Basin perimeter (km)	187

3	Basin length (km)	85
4	Drainage density (Dd) (km/ km^2)	2.3
5	Stream frequency (Sf) (No/ km^2)	2.87
6	Drainage texture (T)	6.6
7	Circularity ratio (Rc)	0.26
8	Elongation ratio (Re)	0.38
9	Form factor (Ff)	0.1
10	Relief (R)	563
11	Relief ratio (Rh)	6.63

Table 1: Findings from the Nirguna (Bhikund) river watershed's drainage network attributes.

Sr. No.	Stream order (u)	Number ofStream (Nu)	Total Length of Stream in km (Lu)	Mean StreamLength (Km)	Bifurcation ratio (Rb)	Mean Bifurcation ratio(Rbm)
1	I	1552	946	0.61	4	
2	II	388	363	0.94	3.6	
3	III	108	168	0.64	3.6	
4	IV	30	71	2.37	10	
5	V	3	26	8.67	3	
6	VI	1	65	65	--	
Total		2082	1639			4.9

Table 2. Results showing morphometric properties of Nirguna (bhikund) River watershed.

VII. SUMMERY AND CONCLUSION:

The process of developing and implementing policies, initiatives, and programmes to protect and improve watersheds is known as "watershed management." Watershed functions that affect the communities of humans, animals, and plants that are contained inside a watershed. The remote sensing combination of sensor data and fieldwork survey data can produce a one-of-a-kind and composite database for optimum planning and Watershed management. Remote sensing from space technology is a one-of-a-kind instrument for providing spatial and multi-spectral data and knowledge that is repeated in order to prepare effectively. The property other factors are gradient of slope and relief intensity. Criteria that will be used to decide the kind of water collection and structures for water saving. Data from this study have been made available on the following topics: morphometric analysis, drainage pattern, digital elevation model, soil map, land use, land cover, slope, and watershed management. Studies and responses in the Nirguna (Bhikund) River watershed in the Maharashtra state districts of Akola and Washim. The presence and distribution of groundwater in basaltic terrain is strongly influenced by lithological, geomorphological, and structural influences on climatic conditions beneath the water table, semi-confined and unconfined circumstances. It is quite important to observe that the flows of basaltic lava have peculiar features, particularly on the upper layers, that allow the basaltic rock to store and transport groundwater, which is known as porosity and permeability. It is very important to note that the secondary porosity as well as permeability are mainly found in the basaltic lava flows rather than primary porosity and permeability. The degree of weathering, particularly spheroidal weathering in compact basalts, jointing, fissuring, and fracturing, all contribute to the development of secondary porosity or space to store groundwater.

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