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Manuscript ID:
IJWGAFES-2025-020403

DOI: 10.5281/zenodo.15854237

DOI Link:
<https://doi.org/10.5281/zenodo.15854237>

Volume: 2

Issue: 4

April

Year: 2025

E-ISSN: 3066-1552

Submitted: 05 Mar 2025

Revised: 20 Mar 2025

Accepted: 10 Apr 2025

Published: 30 Apr 2025

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How to cite this article:

Shinde, S. D., Powar, S. K., & Kalekar, S. V.
(2025). Identification of Groundwater Potential
Zone of Kasari Basin Using Gis Technique.
International Journal of World Geology,
Geography, Agriculture, Forestry and
Environment Sciences, 2(4), 26–36.
<https://doi.org/10.5281/zenodo.15854237>

Identification of Groundwater Potential Zone of Kasari Basin Using Gis Technique

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Abstract

Groundwater is the most important resource contributing significantly to in the total annual supply. The purpose of the present study is to use Geographical Information Systems (GIS) for determining the best areas having ground water potential zones in „Kasari River Basin“. Assessing the potential zone of groundwater recharge is extremely important for the protection of water quality and the management of groundwater systems. Groundwater potential zones are demarked with the help of remote sensing and Geographic Information System (GIS) techniques, in which this present study a combination of Geographical Information System and Analytical Hierarchical Process (AHP) techniques is used. A composite map was generated using GIS tools. Accurate information to obtain the parameter that can be considered for identifying the groundwater potential zone, a total of eight thematic layers, such as Rainfall, Slope, Elevation, land use/land cover, Drainage Density, Lineament Density, Geomorphology, Geology, etc., are generated using the satellite data. A probability-weighted approach was applied during the AHP process, and for the various geomorphic units, weight factors were determined based on their capacity to store groundwater. This procedure is repeated for all other layers, and the resultant layers are classified. The groundwater potential zones are classified into five categories: very low, low, moderate, high, and very high potential zones. The use of the suggested methodology is demonstrated for a selected study area, the Kasari River Basin, which lies in the Kolhapur district of Maharashtra. This Groundwater potential zone will be very useful for the effective identification of suitable locations for the extraction of water.

Keywords: AHP, GIS, Remote Sensing, Ground Water

Introduction

Groundwater is the water located beneath the Earth's surface, occupying soil pore spaces and fractures in rock formations. It constitutes a crucial part of the hydrological cycle, where a portion of the precipitation infiltrates the subsurface and percolates downward until it reaches a saturated zone, commonly known as groundwater recharge (Todd & Mays, 2005). This saturated zone, or aquifer, serves as a vital source of water source for domestic, agricultural, and industrial purposes, particularly in areas lacking perennial surface water bodies (CGWB, 2020).

In India, and specifically in the Kolhapur district of Maharashtra, villages such as Panhala rely heavily on groundwater extracted from the Kasari River Basin for their water needs. In both urban and rural India, groundwater provides nearly 50% of the total water used, with agriculture being the dominant consumer (World Bank, 2010). However, the availability and distribution of groundwater are largely governed by natural factors, such as geology, geomorphology, topography, and anthropogenic activities, such as unregulated extraction (Ravi & Sreekesh, 2011). Aquifers are composed of permeable materials such as sand, gravel, sandstone, or fractured rocks, which allow water to move through their interconnected pores (Fetter, 2001). Traditionally, groundwater potential zones have been identified using hydrogeological surveys and geophysical techniques, which are often labor-intensive and costly (Krishnamurthy et al., 1996). In contrast, modern geospatial technologies, such as Remote Sensing (RS) and geographic information systems (GIS), offer efficient, cost-effective, and accurate means of mapping and managing groundwater resources (Jha et al., 2007).

Remote sensing facilitates the indirect identification of groundwater potential by analyzing surface features such as geomorphology, landforms, slope, and lineaments, which are features that often correlate with subsurface hydrogeological conditions (Chowdhury et al., 2009). GIS, when integrated with decision-making models such as the Analytical Hierarchy Process (AHP), enables the multi-criteria evaluation of groundwater zones by assigning weights to different thematic layers, including geology, slope, drainage density, land use/land cover, and soil type (Saaty, 1980; Rahmati et al., 2015). The growing demand for groundwater, particularly in India over the past two to three decades, has led to significant over extraction, especially for irrigation in regions with limited surface water availability.

Terrain characteristics, such as high relief and steep slopes, promote surface runoff, whereas flat terrain and topographical depressions encourage infiltration and recharge (Singh et al., 2013). Increasing the surface runoff in areas with a high drainage density limits the natural recharge. Consequently, surface water bodies such as rivers and ponds act as important recharge zones. Unregulated and unsustainable groundwater extraction has resulted in declining water tables and increasing water stress conditions. Hence, integrating geospatial tools with hydrogeological assessments is essential for sustainable groundwater management and planning (Muralidhar et al., 2020). Thus, the main objectives of this research were to generate the thematic layers that influence the groundwater potential zone and to map the groundwater potential zone using the Analytical Hierarchy Process.

Study Area:

The Kasari River, a tributary of the Panchaganga River, is located in the Kolhapur district of Maharashtra and extends from latitude 16°39'51"N to 16°55'13"N and longitude 73°42'51"E to 74°42'51"E. The river basin, covering an area of approximately 631.7 sq. km, was mapped on the Survey of India toposheet numbers 47L/1, 47L/2, 47H/9, 47H/13, and 47H/14 at a 1:50,000 scale. Originating in the Sahyadri ranges near the village of Gajapur in Malkapur, the river flows southeast towards Dhargarwadi for about 10 miles, then continues eastward for another 25 miles until it merges with the united waters of the Kumbhi and Tulsi Rivers at Padali, located about 3 miles west of Kolhapur. The river, which is broad in its middle and lower courses, is fed by several minor streams and drains a large triangular area between the Vishalgad range in the north and the Waghajai range in the south, making it a vital component of the local river system.

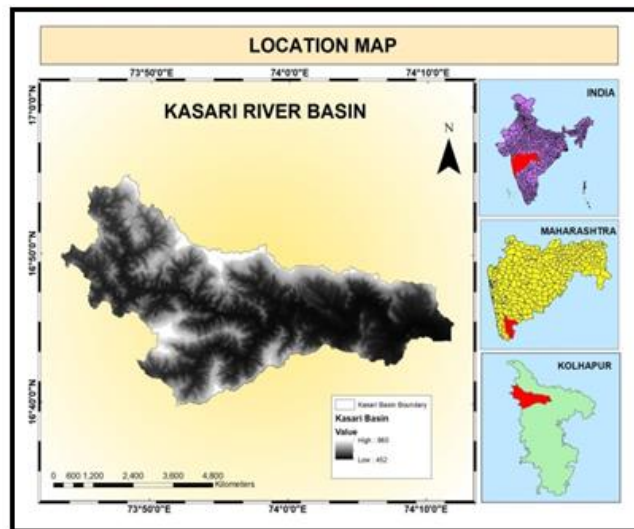


Fig. no. 1- Location Map of Study area

Database and Methodology:

In this study, data acquisition was performed carried out using various remote sensing and GIS techniques to support different analytical functions. Satellite imagery plays a crucial role with data sourced from multiple open-access platforms. Landsat-8 imagery, obtained from the United States Geological Survey (USGS Earth Explorer), was used to generate a Land Use and Land Cover (LULC) map. SRTM-DEM (Shuttle Radar Topography Mission – Digital Elevation Model (SRTM-DEM) data were utilized to derive slope, elevation, and drainage density maps. Additionally, satellite data from Bhuvan, the Indian geo-platform developed by ISRO, were employed to extract lineament and geomorphological information for the study area. All datasets were integrated into a GIS environment to facilitate the spatial analysis required for this research.

To develop groundwater resources in a given area, an integrated methodology combining remotely sensed data with other relevant datasets can be effectively employed. One such approach is the Analytical Hierarchy Process (AHP), a multi criteria decision-making technique developed by Prof. Thomas L. Saaty in 1980. AHP enables the derivation of priority scales through pairwise comparisons using quantitative data, such as weights and prices, and qualitative judgments. In this study, eight key parameters were utilized to delineate groundwater potential zones: drainage density, elevation, lineament density, geology, geomorphology, land use/land cover (LULC), rainfall, and slope. Digital Elevation Model (DEM) data were used to generate slope and flow accumulation maps, while LANDSAT 8 imagery aided in land use classification. Drainage density maps were created using ArcGIS, and all thematic layers were prepared within a GIS environment where appropriate weights were assigned to each class using AHP. The spatial features were digitized in QGIS, converted to a raster format, and further processed to derive weighted thematic layers. Based on the integration of these layers and their assigned weights, the study classified groundwater potential zones into five categories: Very Low, Low, Moderate, High, and Very High.

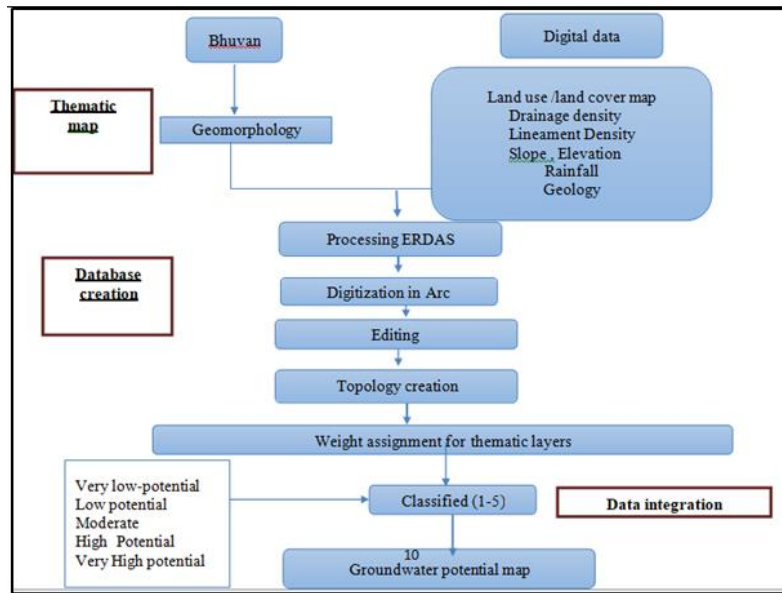


Fig. No. 2: Methodology

Result and Discussion

Different thematic layers were prepared to determine find out the ground water potential zone land Use and Land Cover Map.

Land Use and Land Cover Map

The main factor in any kind of study the major parameter is LU/LC mapping. We performed LULC mapping in the Kasari River Basin we done that LULC mapping, and we know that our study area is fully dependent on agriculture. In our land use land cover mapping, we performed have done five classifications, and which those are important for obtaining any information from any area. These classes are Water body, Settlements, Agriculture, Scrub and Forest. With the help of this information, we can classify all manmade and natural things, and over the last two centuries, economic development and population growth have triggered rapid changes into the earth's land cover, and there is an indication that the pace of these changes will accelerate in the future. This output was obtained get from ERDAS Imagine software. We performed classification on Landsat 8 and some other tools and methods we used to obtain getting this output. We performed Supervised Classification and then recoded and obtained then we get good quality LU/LC data.

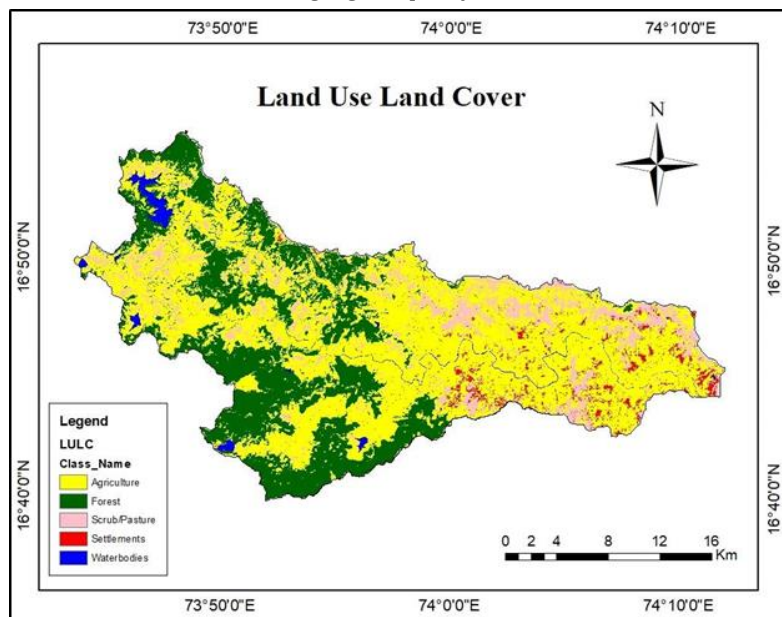


Fig. No.3: Land Use Land Cover Map of Kasari River Basin

Geomorphology

Geomorphology is the study of landforms, their processes, forms, and sediments on the Earth's surface. It is a branch of earth science that which has grown since the advent of aerial photographs and satellite data. Geomorphology, along with information on the soil, water, and vegetation, has become one of the essential input for planning for various developmental activities. The geomorphology of an area depends upon the structural evolution of the geological formations. Geomorphology reflects various forms of land form and its structural features. Many of the features are a favourable for the

occurrence of a groundwater and are classified in terms of groundwater potential. In our study area, we can see different types of geomorphological features. The features those we obtained in our study area are anthropogenic origin, structural origin, denudation, and water bodies. Geomorphology is very important for the extraction of groundwater, and geomorphology will reveal tell us all geological and geographical conditions of our study areas land. We can tell This is a very important parameter for determining the groundwater potential zones.

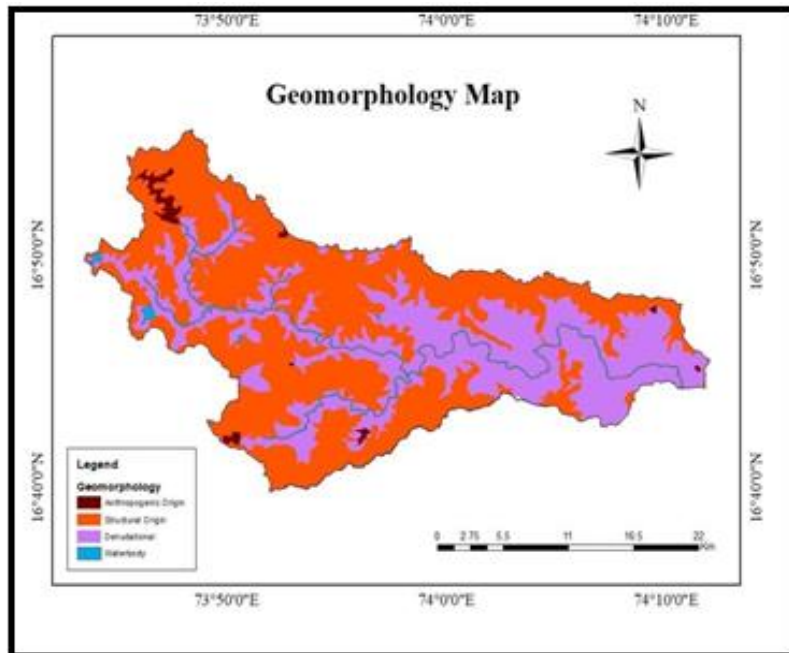


Fig No. 4: Geomorphology of Kasari River Basin

Slope

The slope plays a significant role in the groundwater availability because since infiltration is inversely related to the slope. The steeper the slope, the greater will be the runoff and, therefore, the lesser is the groundwater recharge. By Using DEM, a slope map was generated, and five classes were prepared. The slope map is given, and the slope must be shown have to show in degrees in anywhere.

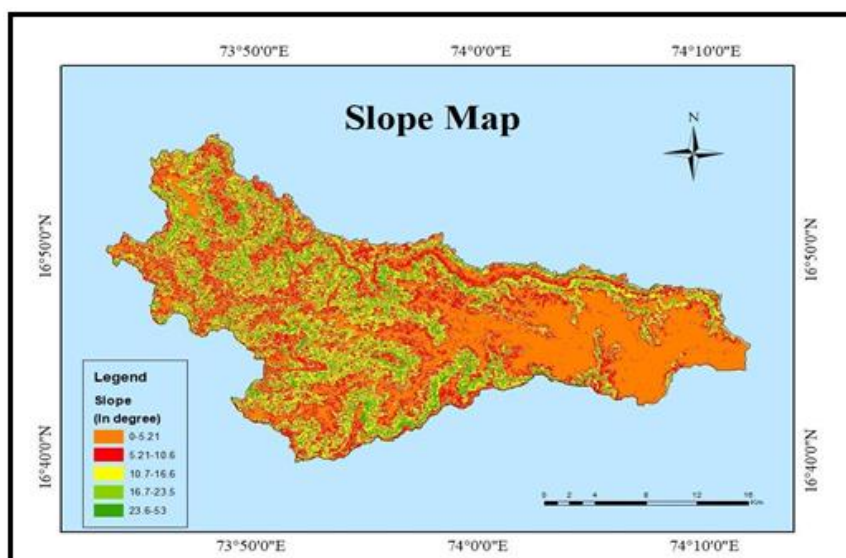


Fig. No. 5: Slope Map of Kasari River Basin

Drainage Density

The drainage density is an inversely related to the permeability of aquifers and plays a very important role in the run-off dispersal and level of infiltration.

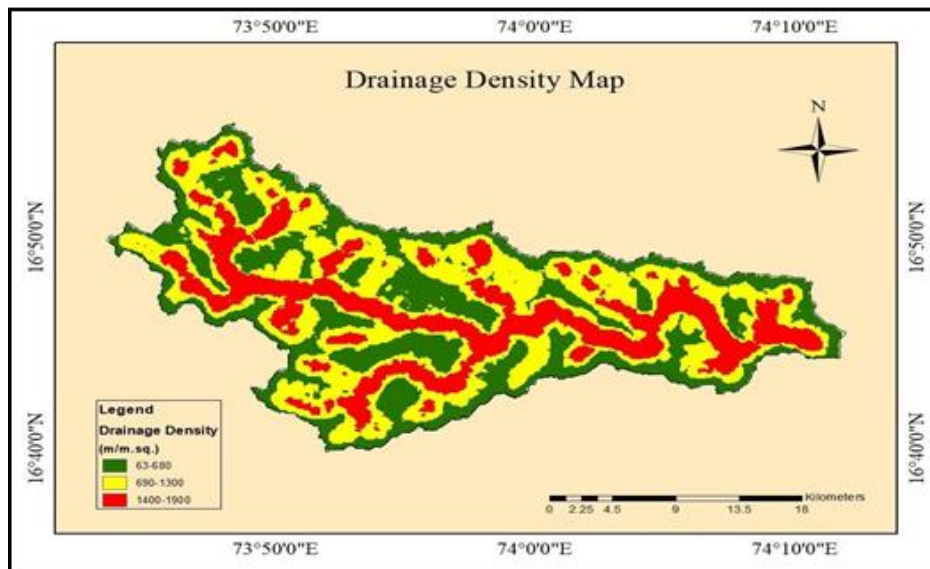


Fig. No: 6: Drainage Density Map of Kasari River Basin

Lineament Density

The lineaments present in the field of analysis had varying thicknesses. A linear density map was prepared based on the concentration and the length of the lineaments. Bhuvan was used to digitize the lineaments in the study area. Lineaments are large-scale linear features that express themselves in terms of topography, which is an expression of the underlying structural characteristics in itself. From the point of view of the groundwater these features include valleys regulated by folding, faulting and joining, hill ranges and ridge lines, abrupt truncation of rocks, straight stream segments and right-angled offsetting of stream course. Given that these linear characteristics are commonly associated with dislocation and deformation, they provide groundwater pathways.

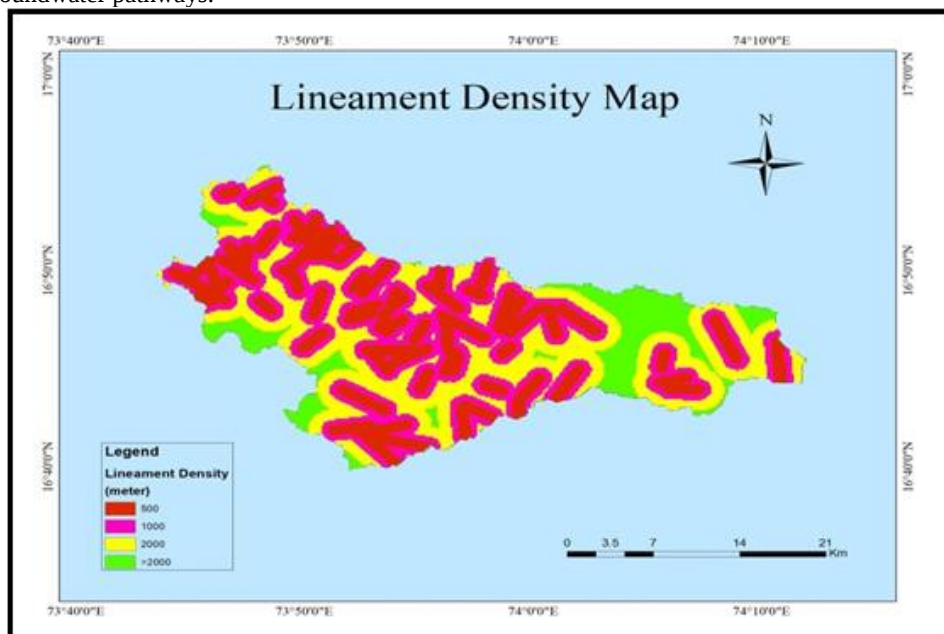


Fig. No. 7: Lineament Density Map of Kasari Basin

Rainfall

Rainfall is the main source of recharge for groundwater and also for all hydrological processes. The Rainfall maps were categorized into five rainfall zones. Zones that which provide gives low rainfall may not be useful for groundwater zones (Manap et al., 2013). Rainfall is a source of groundwater (Musa et al. 2000).

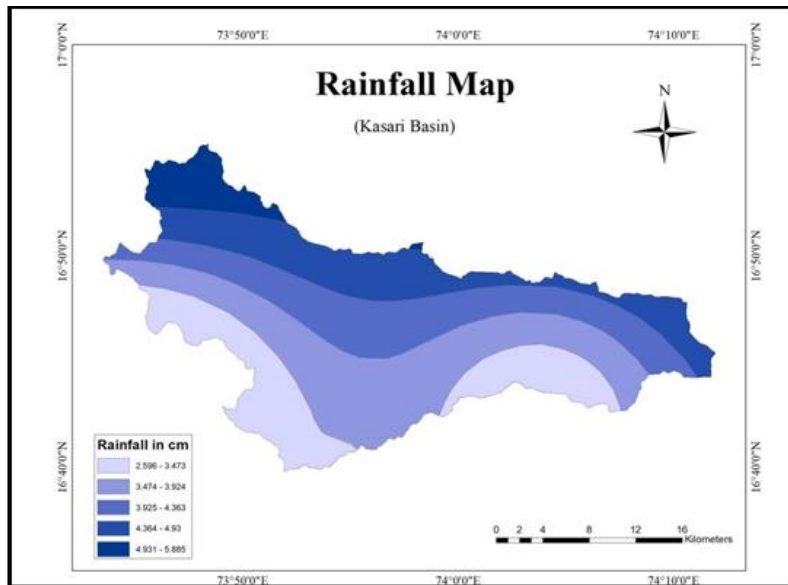


Fig. No. 8: Rainfall Map of Kasari River Basin

The Monthly rainfall data were collected from different rain gauge stations over a period of 24 years using the Global Swat website. From the rainfall map, it was concluded that the annual rainfall in the elevation regions was higher than that in the low elevation regions. Rainfall is a major source of groundwater. If the rainfall is higher than groundwater, it is available; if the rainfall is less than groundwater, it will be less. Rainfall can vary from one region to another. Annual rainfall data were taken from the rain gauge stations for the past 24 years, and an interpolation method was used to determine the amount of rainfall that appeared in the study area.

Elevation

Elevation plays a significant role in the groundwater availability. At higher elevations, the runoff is greater, and at lower elevations, more water can be percolate more. In the study area on the eastern side, the elevation was very low; therefore, there was a greater chance of groundwater.

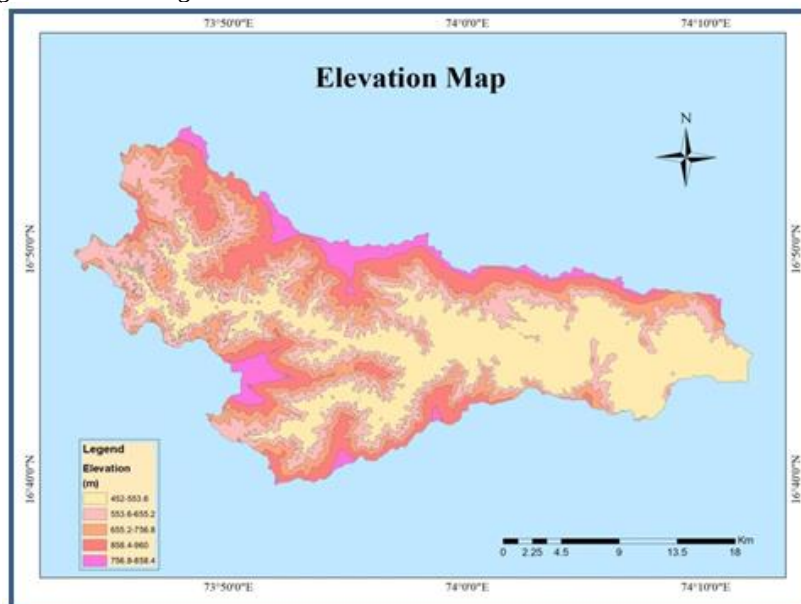


Fig. No 9: Elevation Map of Kasari River Basin

Geology

Geology is also the important for the occurrence of groundwater. Geologically, the Kasari River study area is covered by Deccan Volcanic Basaltic (DVB) lava flows from the late Cretaceous to early Eocene. In some places, these flows are separated by red bole beds, as observed in the hills, valley exposures, and well sections. This area is typically formed with igneous rocks. The rocks available in the area with groundwater quality were Basalt and Laterite. Geological mapping has already been conducted by the Geological Survey of India (GSI). Two types of basaltic rocks occur in the basin: compact basalt (simple aa) and vesicular-amygdaloidal (compound pahoehoe). A large part of the area is covered with black cotton soil, which is important for agricultural purposes. The hilltop was covered by laterites of the Pleistocene age. Based on lithostratigraphy, the present study area is under the Mahabaleshwar Formation of the Upper Deccan Traps in India⁹. In DVB The availability of groundwater is limited extent. It occurs in the fractures/joints of the basaltic rocks. In the present study

area, the watersheds showed well-developed dendritic to sub-dendritic drainage patterns. It is an indication of a regional slope, homogeneous lithology, and relief.

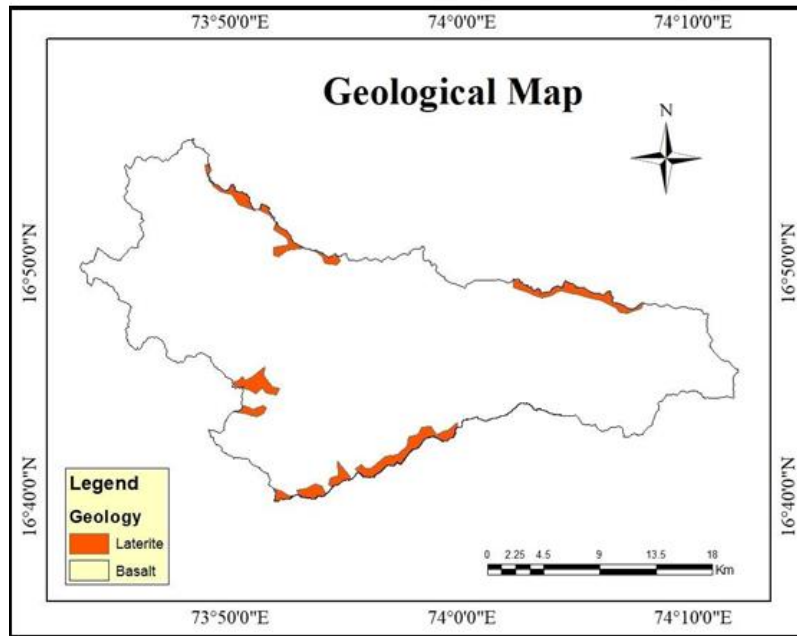


Fig. No. 10: Geological Map of Kasari River Basin

AHP Analysis for Ground Water Potential Zone

The main objective of this project was to use GIS and Remote sensing techniques to generate thematic layers that influence groundwater potential zones in the Kasari River Basin. Ground water potential zone maps were prepared using eight thematic maps by using the AHP method. The occurrence and movement of groundwater in an area is controlled by different factors, and the influence of all factors in a given area need not be the same. Hence, each parameter was assigned a weighting according to its effect on groundwater movement and storage, and rainfall was more important than geomorphology. Therefore, Rainfall, Lineament, and Drainage Density layers provided higher weightages; however, when there is comparatively less influence of geomorphology and land use land cover in the area, these themes are given lower weights. Influence we have given 100%, then it depends on us to give weights. If any parameter is important for the groundwater potential zone, then we must give more influence to that particular parameter. Various layers were prepared using remote sensing and GIS techniques, equipment, and other applications to define the possible groundwater zones. Geomorphology, Lineament density, Slope, Land use and land cover, Elevation, Rainfall, Geology and Drainage Density were the layers considered for the suitability study.

Table No.1: AHP calculation of LULC layer

Variable	Sr. No.	Sub Criteria	1	2	3	4	5
LULC	1	Waterbody	1	2	3	4	5
	2	Agriculture Land	0.5	1	2	3	4
	3	Forest Area	0.33	0.5	1	2	4
	4	Settlement	0.25	0.3	0.50	1	4
	5	Open Scrub/pasture	0.20	0.3	0.3	0.25	1
	Sum		2.28	4.08	6.75	10.25	18.00
	Sum*Avg		0.932	1.041	1.126	1.199	0.957
	L Max		5.255				
	CI		0.064				
	CR		0.057				

Table No.2: AHP calculation of Slope layer

Variable	Sr. No.	Sub Criteria	1	2	3	4	5
Slope	1	<5.2	1	2	3	4	5
	2	5.21-10.6	0.5	1	2	3	5
	3	10.7-16.6	0.33	0.5	1	2	4
	4	16.7-23.5	0.25	0.3	0.50	1	2
	5	>23.5	0.20	0.2	0.3	0.50	1
	Sum		2.28	4.03	6.75	10.50	17.00
	Sum*Avg		0.938	1.083	1.139	1.006	0.954
	L Max		5.121				
	CI		0.030				
	CR		0.027				

Table No.3: AHP calculation of Drainage Density layer

Variable	Sr. No.	Sub Criteria	1	2	3	Row Total
DrainageDensity	1	1400-1900	1	2	3	6.0
	2	690-1300	0.5	1	3	4.5
	3	63-680	0.33333	0.33333	1	1.7
	Sum		2	3.3333	7.00	12.167
	Sum*Avg		1.0	1.1	1.0	
	L Max		3.065			
	CI		0.033			
	CR		0.056			

Table No.4: AHP calculation of Geomorphology layer

Variable	Sr. No.	Sub Criteria	1	2	3	4
Geomorphology	1	Waterbody	1	2	4	5
	2	Denudational Origin	0.5	1	2	3
	3	Structural Origin	0.25	0.5	1	3
	4	Anthropogenic Origin	0.20	0.3	0.33	1
	Sum		1.95	3.83	7.33	12.00
	Sum*Avg		0.973	0.997	1.183	0.955
	L Max		4.107			
	CI		0.036			
	CR		0.040			

Table No.5: AHP calculation of Lineament Density

Variable	Sr. No.	Sub Criteria	1	2	3	4
ineamentDensity	1	<500	1	2	4	3
	2	500-1000	0.5	1	2	2
	3	1000-2000	0.25	0.5	1	1
	4	>2000	0.33	0.5	1.00	1
	Sum		2.08	4.00	8.00	7.00
	Sum*Avg		0.994	1.026	1.026	0.968
	L Max		4.013			
	CI		0.004			
	CR		0.005			

Table No.6: AHP calculation of Geology layer

Variable	Sr. No.	Sub Criteria	1	2
Geology	1	Basalt	1	2
	2	Laterite	0.5	1
	Sum		1.50	3.00
	Sum*Avg		1.000	1.000
	L Max	2.000		
	CI	0.000		
	CR	0.000		

Table No.7: AHP calculation of Rainfall layer

Variable	Sr. No.	Sub Criteria	1	2	3	4	5
Rainfall	1	4.931-5.885	1	2	3	4	5
	2	4.931-4.364	0.5	1	2	3	5
	3	4.363-3.925	0.33	0.5	1	2	4
	4	3.924-3.474	0.25	0.3	0.50	1	3
	5	3.473-2.596	0.20	0.2	0.3	0.33	1
	Sum		2.28	4.03	6.75	10.33	18.00
	Sum*Avg		0.933	1.074	1.126	1.095	0.943
	L Max	5.171					
	CI	0.043					
	CR	0.038					

Table No.8: AHP calculation of Elevation layer

Variable	Sr. No.	Sub Criteria	1	2	3	4	5
Elevation	1	452-553.6	1	2	3	4	5
	2	553.6-655.2	0.5	1	2	3	5
	3	655.2-756.8	0.33	0.5	1	2	4
	4	756.8-858.4	0.25	0.3	0.50	1	2
	5	>858.4	0.20	0.2	0.3	0.50	1
	Sum		2.28	4.03	6.75	10.50	17.00
	Sum*Avg		0.938	1.083	1.139	1.006	0.954
	L Max	5.121					
	CI	0.030					
	CR	0.027					

Final Groundwater Potential Zone Map and Calculation

With the application of GIS, the integration of various thematic maps describing favorable groundwater zones was developed as a single groundwater potential area map.

Table No. 9 - AHP calculation of Groundwater Potential Zone

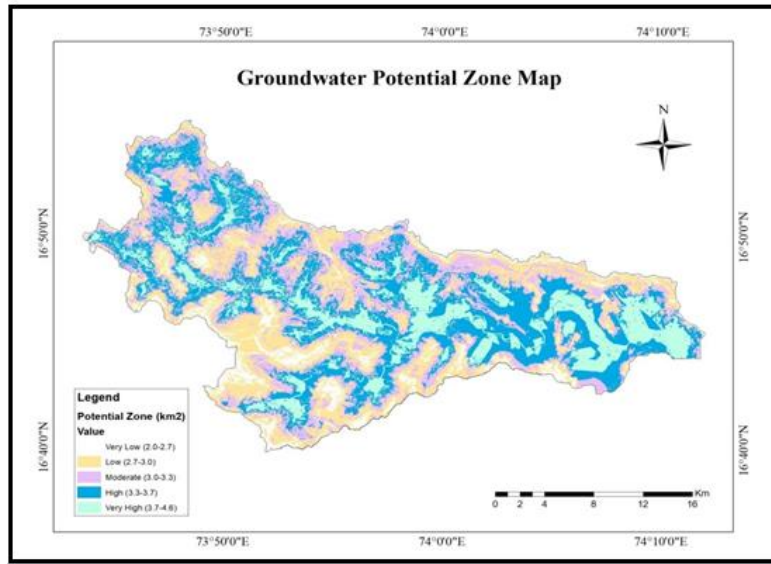


Fig. No.11 - Groundwater Potential zone Map of Kasari River Basin

Variable	Sr. No.	Sub Criteria	1	2	3	4	5	6	7	8	Row Total	Eigen Vector
AHP	1	Geomorphology	1	0.5	0.33	0.2	0.2	0.17	0.14	0.13	2.668	0.024
	2	LULC	2	1	0.5	0.5	0.33	0.25	0.2	0.17	4.950	0.045
	3	Geology	3	2	1	0.5	0.5	0.33	0.33	0.33	8.000	0.072
	4	Lineament Density	5	2	2	1	0.5	0.5	0.5	0.33	11.833	0.107
	5	Elevation	5	3	2	2	1	0.5	0.5	0.5	14.500	0.131
	6	Slope	6	4	3	2	2	1	0.5	0.5	19.000	0.172
	7	Drainage Density	7	5	3	2	2	2	1	0.5	22.500	0.204
	8	Rainfall	8	6	3	3	2	2	2	1	27.000	0.244
	Sum		37	23	14.83	11.20	8.53	6.75	5.18	3.5	110.451	1
	Sum*Avg		0.927	0.99	1.01	1.078	1.08	1.13	1.07	0.93		
	L Max		8.213									
	CI		0.030									
	CR		0.022									

Table No. 11- Groundwater Potential zone Area in Percentage

Sr. No.	Potential Zones	Area in (%)
1	Very low potential	24.47
2	low potential	34.12
3	Moderately Potential	14.51
4	Highly Potential	18.42
5	Very High Potential	8.46

The table categorizes the study area into five groundwater potential zones based on an integrated GIS and remote sensing analysis. The 'Low Potential' zone occupies the largest area, accounting for 34.12%, indicating that a significant portion of the region has limited groundwater availability. This is followed by the 'Very Low Potential' zone, covering 24.47% of the area, suggesting that nearly one-fourth of the study region is unsuitable or has poor conditions for groundwater extraction. The 'Moderately Potential' zone constitutes 14.51%, representing areas with average groundwater prospects. Meanwhile, 'Highly Potential' zones cover 18.42%, highlighting areas where groundwater development could be promising. Finally, only 8.46% of the area falls under the Very High Potential zone, indicating limited regions with excellent groundwater availability.

Conclusion:

The final groundwater potential zone map was generated using the Analytical Hierarchy Process (AHP) method, which effectively integrates remote sensing and GIS techniques. This approach has proven to be a powerful and cost-effective tool for identifying potential groundwater areas within the Kasari River Basin in the Kolhapur district. This study classified the area into five distinct groundwater potential zones: Very Low, Low, Moderate, High, and Very High. Based on the

analysis, 24.47% of the area falls under the Very Low Potential zone, 34.12% under the Low Potential zone, 14.51% under the Moderate Potential zone, 18.42% under the High Potential zone, and 8.46% under the Very High Potential zone. This classification provides valuable insights into sustainable groundwater resource planning and management in this region.

Acknowledgment

The authors express their sincere gratitude to the Department of Geography, Shivaji University, Kolhapur, for providing the necessary facilities and academic support throughout the course of this research. We are thankful to the United States Geological Survey (USGS), Indian Space Research Organisation (ISRO–Bhuvan), and Global SWAT database for providing open-access satellite data crucial to our analysis. We extend our appreciation to the Central Ground Water Board (CGWB) and Geological Survey of India (GSI) for their valuable reference data and geological insights.

Financial support and sponsorship

Nil.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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