DELINEATION OF GROUNDWATER POTENTIAL ZONES IN AURANGABAD, MAHARASHTRA USING REMOTE SENSING, GIS, AND MIF TECHNIQUES

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ABSTRACT:
This article discusses the use of remote sensing and geographic information systems to manipulate and analyse each layer of spatial control data in Aurangabad, Maharashtra, to determine groundwater potential zones. Due to climatic trends, topographical factors, and aquifer characteristics, groundwater occurrence in drought-prone areas varies through time and place. Because of this, precise delineation of Groundwater Potential Zones (GWPZs) is crucial for the sustainable management of water resources in these settings. The goal of the current study is to identify and evaluate GWPZs in drought-prone areas by combining remote sensing (RS), geographic information systems (GIS), and analytical hierarchy process (AHP). Seven thematic layers were created in the following categories: Rainfall, LULC, Geomorphology, Soil Classification, Lineament Density, Drainage Density, Slope. This study concludes that the AHP model will be more accurate in determining the GWP. The stack holders would gain from any groundwater management projects done out in this advantageous area. The present study divide Aurangabad district based on the result in the four different category i.e, Poor (6.3%), moderate (35.2%) , and Good (56.6), Excellent (1.9).

1.0 INTRODUCTION

One of the most valuable natural resources, groundwater makes up around 34% of the world's freshwater resources **(Shekhar and Pandey, 2015)**. In India, 50% of urban residents and 90% of rural residents rely on groundwater for domestic water use. About 70% of India's groundwater is used for agriculture. Several variables, including geomorphology, lithology, topography, slope, precipitation, soil, drainage pattern, land use/land cover (LULC), and hydrological conditions of an area, affect groundwater, a dynamic resource **(Pradhan, 2009)**. One billion people in Asia alone are directly dependent on groundwater, which is one of the most precious natural resources on the planet and supports ecological diversity, economic growth, and human health **(Foster 1995)**. Due to the whims of the monsoon and the shortage of surface water, groundwater dependence has significantly increased in India's arid and semi-arid regions. 97% of fresh water comes from groundwater, with the remaining 3% coming from surface water in the form of streams, rivers, etc **(Zektser 1998)**. With only 4% of the world's fresh water supply, India sustains more than 16% of the world's population, which suggests that the country's water sector is severely stressed **(Rawat et al 2022)**.

Surface and subsurface water quality have declined due to growing population and its needs **(Niwate et al 2022)**. Due to its inherent advantages over surface water, groundwater, also known as subsurface water, is the primary source of fresh water used for domestic, industrial, and agricultural purposes in most of the world **(Kaushik et al 2022)**. This water is obtained from municipal well fields and many private bore holes **(Ragunath 1987)**. Now, groundwater resources provide almost one-fifth of the water utilised worldwide **(Ragunath 2009)**.

According to **Palanisamy et al. (2007)**, the groundwater is found below the surface of the ground in the pore spaces of the soil and in the rock or lithologic formation's fissures. Due of its inherent availability and to fulfil overall. The first step in any water resources management project is to estimate groundwater reserves and define potential zones. At this point, accurate calculations of the inputs (recharge) and outputs (discharge) are essential. According to **Chowdhury (2007)**, the proper utilization and management of this precious but diminishing natural resource necessitate systematic planning of groundwater exploitation made use of modern methods. Traditional methods like geological, geophysical, geostatistical, and numerical modelling are costly, time-consuming, and laborious. The rapid development of space technology has been crucial to groundwater research. The geographic information system (GIS) and remote sensing (RS) are promising methods for effective planning and management of groundwater resources. One of the pioneers in using the integrated study of RS and GIS to define an area's potential for groundwater recharge in India. The use of RS and GIS is extensive in India, for the mapping and monitoring of groundwater potential zones and locating suitable locations for the artificial groundwater recharge **(Giri et al 2020)**. Geospatial technologies provide cost-effective solutions for the management of aquifers and the integration of multi-thematic data sets at a uniform scale. In recent times, when assigning weight to thematic layers, GIS methods are combined with multi-criteria decision-making (MCDM) technology, such as the analytic hierarchy process (AHP). Structure, suitability, and precision can all be successfully integrated into decisions using these methods. Environmental problem-solving and management now frequently incorporate AHP methods **(Kudnar et al 2022)**. Several researchers have utilized AHP in solid waste management and environmental impact assessments. The most common and successful application of AHP technology is groundwater potential mapping and the search for artificial recharge-friendly locations. A crucial element of the hydrological system that is found in the subsurface geological formations is groundwater (aquifers). The existence and accessibility of groundwater are influenced by the recharge process, which is governed by several variables, including physiographic, lithological composition, drainage pattern, use, and land cover, as well as climatic variables like precipitation, temperature, evapotranspiration, etc. and geological setting features like fractures and lineament features. Therefore, even within the same aquifer, groundwater potential meaningfully changes in time and geography, sometimes by a few metres. This supports the disparity in groundwater potential discovered in different locations.

2.0 Study Area

Between North Latitude 19° 15' and 20° 40' and East Longitude 74° 37' and 75° 52', the Aurangabad district is in the north-central part of Maharashtra portions of the Survey of India Toposheet No. 46 L & P and 47 I & M. The district is bordered in the north by Jalgaon, in the west by Nashik, in the south by Ahmednagar and Beed, and in the east by Parbhani and Buldhana.

Aurangabad City serves as the district's administrative center. The district has been divided into nine talukas, which are as follows: There are talukas in Aurangabad, Kannad, Soygaon, Sillod, Phulambri, Khuldabad, Vaijapur, Gangapur, and Paithan. The district covers 10,107 square kilometers. In 2010, net area sown was 6540 sq. km, while cultivable area is 8135.57 sq. km and forest cover 726 sq. km. The primary occupation of the rural population is agriculture. Since 1985–1986, the district has engaged in various phases of ground water investigation. The Deccan Trap Basalt and isolated alluvial patches-occupied hard rock locations have been the sites of the ground water exploration. Except for the south-west monsoon season, which runs from June to September while October and November make up the post monsoon season, the district's climate is characterised by a scorching summer and a general dryness throughout the year. When temperatures start to significantly drop at the end of November, the winter season officially begins. With a mean high temperature of 28.9° C and a mean minimum temperature of 10.3°C, December is the coldest month of the year. The daily temperature has been steadily rising since the beginning of March.

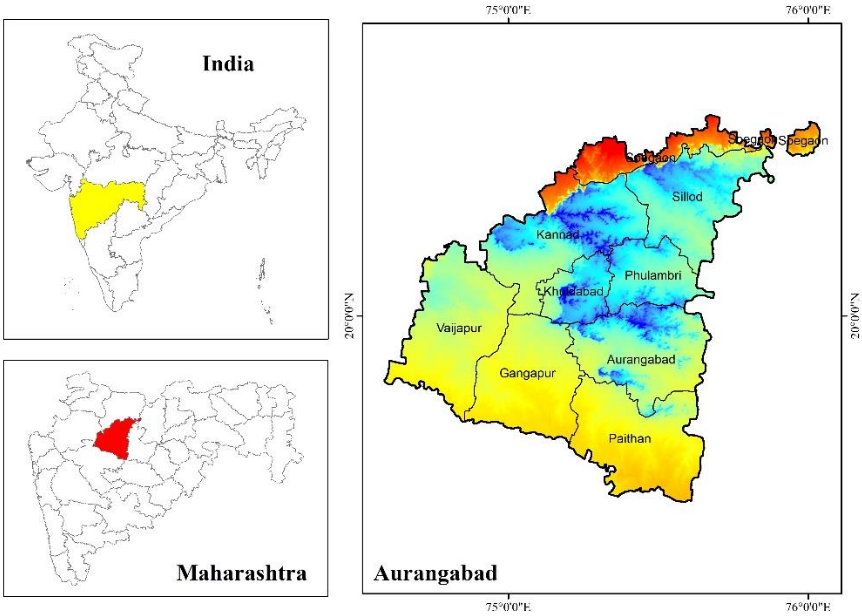

Figure 1- Location Map of Study area

With a mean high temperature of 39.8°C and a mean minimum temperature of 24.6°C, May is the hottest month of the year. By around the second week of June, the south-west monsoon arrives, causing a noticeable drop in temperature. The air over the district is mostly dry, with the exception of during the southwest monsoon season, when the relative humidity is high. When the relative humidity is typically between 20 and 25% in the afternoon during the summer, that is when it is the driest. The majority of the time, winds are mild to moderate, but they can become brisker during the monsoon season and the second half of the hot season. During the hot season, the winds are primarily from the west and the north. During the southwest monsoon season, they are primarily from the southwest to northwest. For the remainder of the day, they primarily blow in directions between northeast and southeast during the rest of the year becoming south-westerly to north westerly in January and February. The average annual rainfall of the district for the period 2002 to 2011 is 705 mm.

3.0 Methodology

In the present study the base map of the Aurangabad district was created using topographic maps from the Survey of India that were scaled to 1:50,000. The drainage network for the research area was digitalized using the ArcGIS 10.2 platform after being scanned from Survey of India (SOI) toposheets. The ArcGIS Spatial Analyst module was used to create the slope map from SRTM DEM data. The rainfall distribution map was then created using spatial interpolation utilising the Inverse Distance Weighted (IDW) approach. The delineation of thematic layers such Rainfall, LULC, Geomorphology, Soil Classification, Lineament Density, Drainage Density, Slope. Before being included to a GIS system, these thematic layers were transformed into a raster format (30 m resolution). Using the spatial analysis tool in ArcGIS 10.2, the groundwater potential zones were created by weighted overlaying all the theme maps.

Weights were allocated for each characteristic of each thematic map during the weighted over lay analysis in accordance with the multiinfluencing factor (MIF) of that specific feature on the hydro geological environment of the research area **(Shaban et al., 2006).**

To define the groundwater potential zones, seven contributing elements, including lithology, slope, land use, lineament, drainage, soil, and rainfall, have been identified. Fig. 3 illustrates the interactions between these variables and how they have an impact. Each connection is given a weight based on how strong it is. The total weights from each component make up the representational weight of a factor in the potential zone. On groundwater potential zones, a component with a higher weight value has a greater impact, and a factor with a lower weight value has a smaller impact. Using weighted overlay analysis in ArcGIS, these factors are combined with any potential weights.

4.0 Result and Discussion

The AHP is a component of the multi-criteria decision-making process, which entails the analysis and decision-making process related to several objectives **(Wang et al. 2009; Uyan & Cay 2013)**. The rates of the various classes in each stratum are defined using the GIS-based multi-criteria assessment. Each thematic layer's weights are distributed based on how it may affect groundwater potential and by taking Saaty's AHP technique into account **(Saaty 1980)**. When using MCDA, each influencing factor's weighting is assigned based on its practical importance in each area **(Agarwal & Garg 2016; Murmu et al. 2019).**

The AHP is a subjective technique, and **Saaty's(1980)** proposed appropriate decision-making strategy is used to compare various criteria before choosing which subunits receive what weights. The AHP method is used to determine weighting from a preference matrix that represents map layers. The comparison of pertinent criteria based on preference variables determines the weighting. The method is well-liked among many GIS methods since it can manage a sizable quantity of heterogeneous data for the needed weightage, even for sizable data, in an easy way **(Chen et al. 2010; Khan &Jhariya 2019)**.

Table 1: Relative weight of various thematic layers and their corresponding classes.

Influencing factors	Category (Classes)	Potentiality for groundwater storage	Rating (High = 5; Low = 1)
Geomorphology	Alluvial plain	Very good	4
	Valley fill buried pediplain	Good	3
	Pediment	Moderate	2
Geology	Alluvium	Very good	4
	Laterite	Good	3
	Sandstone, calcareous rock	Moderate	2
	Shale	Poor	1
Lineament buffer	0–50 meter	Very good	4
	50–100 meter	Good	3
	100–150 meter	Moderate	2
	150–200 meter	Poor	1
Slope	0–1%	Very good	4
	1–3%	Good	3
	3–5%	Poor	2
Rainfall	1,209.92–1,267.84 mm	Very good	4
	1,151.99–1,209.92 mm	Good	3
	1,094.07–1,151.11 mm	Moderate	2
	1,036.15–1,094.07 mm	Poor	1
LULC	Lake	Very good	4
	Drainage	Very good	4
	Cultivation	Good	3
	Vegetation	Good	3
	Open land	Moderate	2
	Settlement	Poor	1
	Road	Poor	1
	Industry	Poor	1
Drainage density	1.43–2.24	Very good	4
	2.34–3.12	Good	3
	3.16–4.12	Moderate	2
	4.12–4.89	Poor	1
Soil texture	Sandy clay loam	Very good	4
	Sandy loam	Good	3
	Clay loam	Moderate	2
	Clay	Poor	1

4.1 Rainfall

The main source of recharge for aquifer units is rainfall **(Zghibi et al 2020)**. Therefore, when the distribution of rainfall varies, the likelihood of GWPZs increases. The research area experienced rainfall that varied from 583 to 905mm. The places with the most rainfall have more GWPZ. The regions that experienced rainfall between 583 to 905mm were given a high weighting. When the MIF and AHP methods were used to determine the rainfall factor.

The highest levels of yearly rainfall are found in the northeast region, and there is a gradient that moves eastward. In this investigation, four rainfall zones were identified. The variability of the rainfall shown by Fig.2.

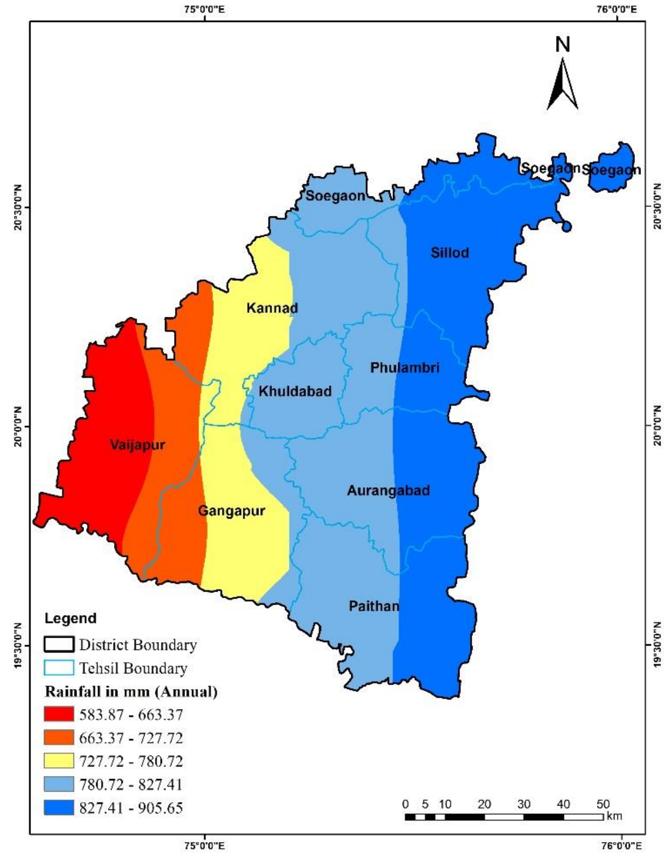

Fig.2- Rainfall map of Aurangabad District

4.2 Lineament Density

Remote sensing can be used to find Lineament, which are a form of underground geological feature (fractures or structures). Lineaments intersecting drainage networks might result in higher groundwater yields than other locations. Thus, lineaments aid in the identification of groundwater zones in hydrogeological investigations and provide information regarding groundwater movement and storage. There are five categories of lineament density in the research area, ranging from very low to high. According to Table 1, when the lineament factor was estimated using the MIF and AHP techniques, respectively. The lineament density in the area shown by fig.4 and area wise distribution given in table 2.

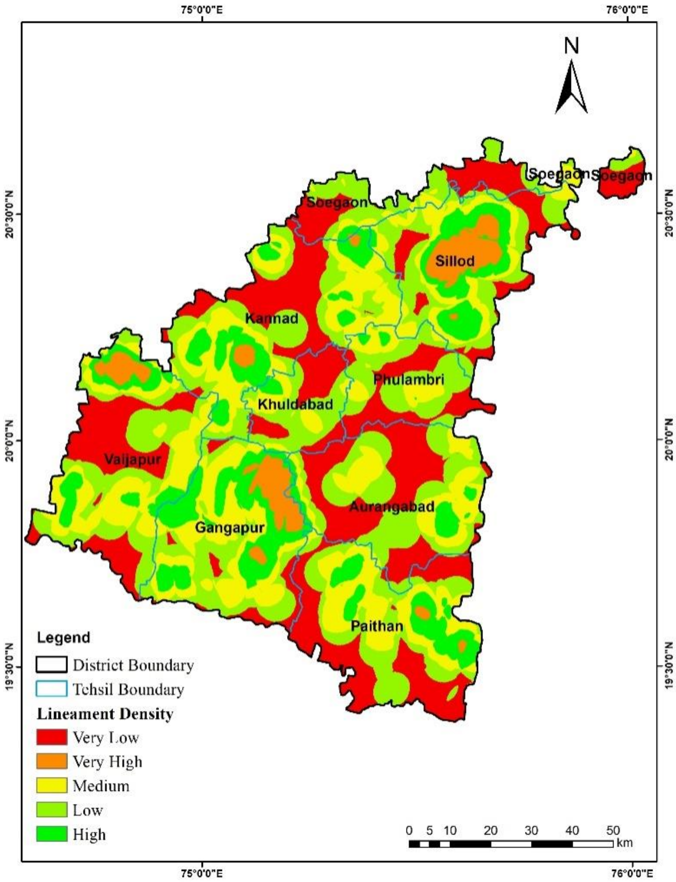

Fig.3- Lineament density map of Aurangabad District

Table 2- Percentage wise distribution of Lineament Density in Aurangabad District.

	Class	Area (Ha)	Percentage
Lineament Density	**Very Low**	271314.18	27.43
	Low	297336.24	30.06
	Medium	247136.67	24.98
	High	129631.5	13.10
	Very High	43592.31	4.40

4.3 Soil

The district resource map provided additional information that was used to create the soil map, which was created using IRS-ID LISS III data. The research region contains two different types of soil: Clay Soil and Sandy Loam. The distribution of soil is given in Fig.4 and percentage wise statistics given in table 3.

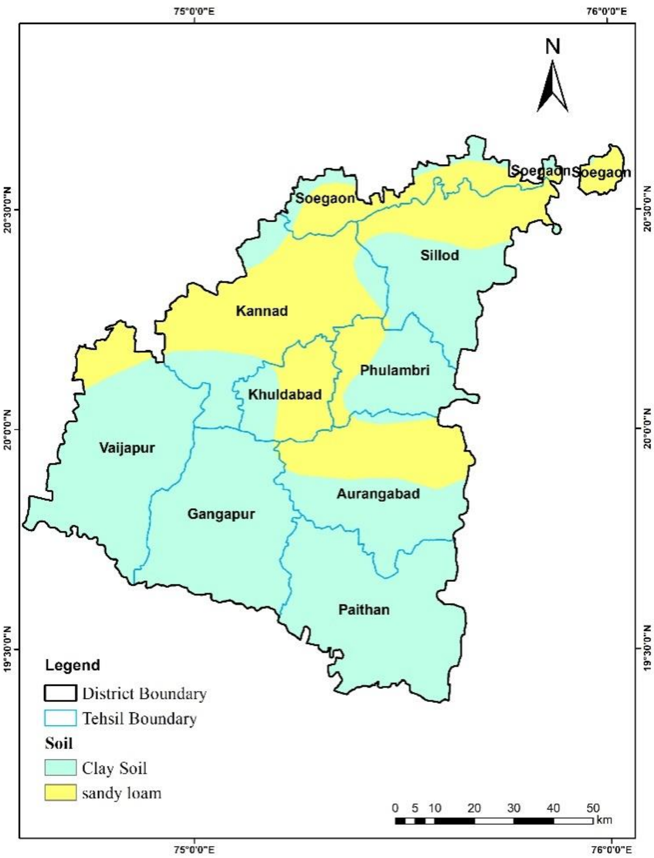

Fig.4- Soil Map of Aurangabad District.

Table 3- Percentage wise distribution of Soil in Aurangabad District

	Soil_type	**Area(Ha)**	**Percentage**
	Clay Soil	678667.95	66.33936
Soil	sandy loam	344356.56	33.66064

4.4 Slope

One of the elements that controls how much water permeates into the subsurface is an area's is slope. Infiltration of surface water does not always take place in the same location. Surface water runoff is weak and infiltration is considerable in places with smooth slopes. The slope in the area shown by fig.5 and area wise distribution given in table 5.

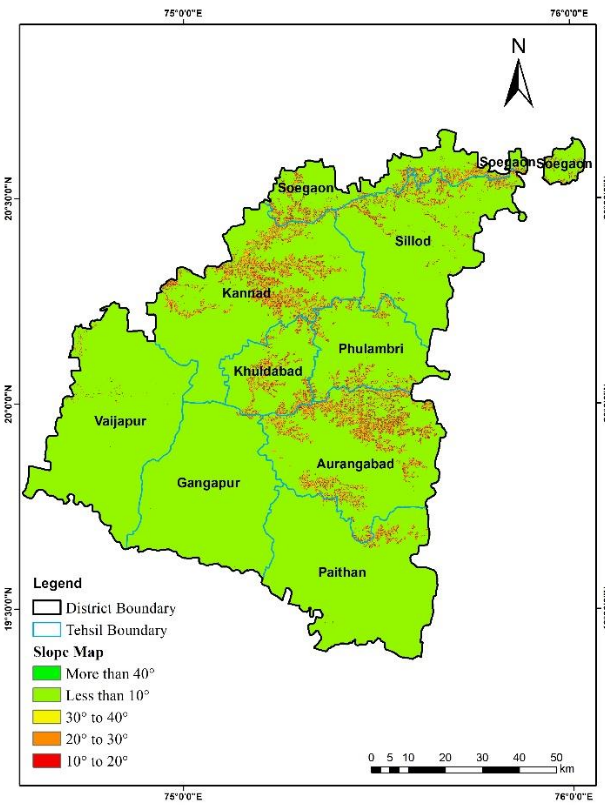

Fig.5-Slope map of Aurangabad District

Table 4- Percentage wise distribution of Slope in Aurangabad District.

Slope	Class	Area(Ha)	Percentage
	Less than 10°	960927.03	93.81373
	10° to 20°	38417.04	3.750593
	20°to 30°	17172.27	1.676501
	30° to 40°	6087.42	0.594305
	More than 40°	1688.76	0.164871

4.5 Geomorphology

Water Body, Plateau, Alluvial Plain, Denudational Hill, Structural Hills, Habitant, Flood Plain were the geomorphology features of the study area. Due to the significant quantity of infiltration, the floodplain area was given the highest priority for GWPZ. The MIF and AHP techniques yielded scores for the geomorphology factor. The lineament density in the area shown by fig.6 and area wise distribution given in table 5.

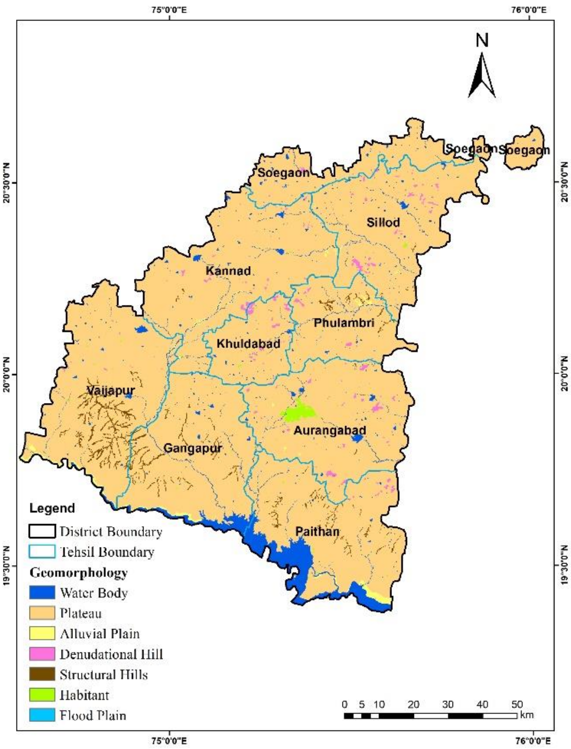

Fig.6- Geomorphology map of Aurangabad District

Table 5- Percentage wise distribution of Geomorphology in Aurangabad District.

	Class	**Area (Ha)**	**Percentage**
Geomorphology	Water Body	44631.61	4.512707094
	Plateau	913764.15	92.39
	Alluvial Plain	6727.95	0.68
	Denudational Hill	7350.88	0.74
	Structural Hills	12246.82	1.23
	Habitant	4292.26	0.43
	Flood Plain	7.09	0.00071

4.6 Drainage Density

Because high drainage densities result in poor infiltration rates, there is a negative correlation between a region's drainage densities and groundwater recharge. Most of the research area has low to moderate drainage densities, which has a positive impact on the potential for groundwater. The lineament density in the area shown by fig.7 and area wise distribution given in table 6.

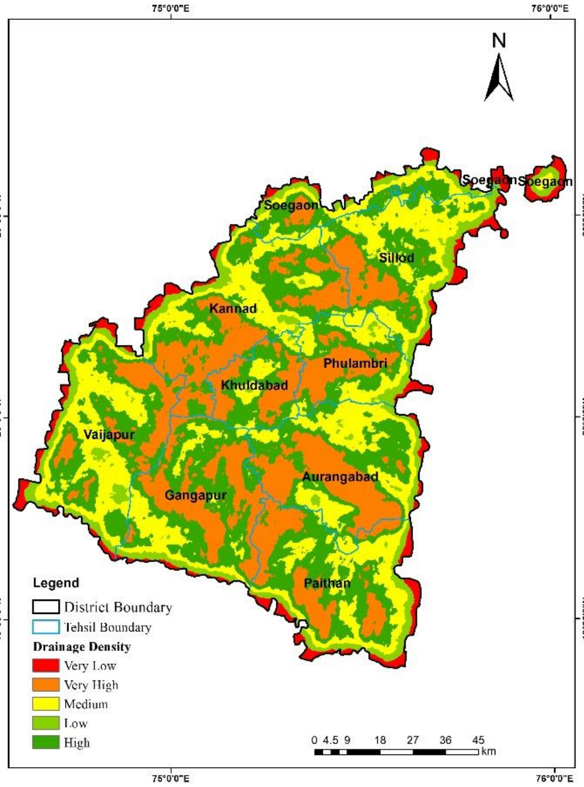

Fig.7- Drainage density map of Aurangabad District

Table 6- Percentage wise distribution of Drainage density in Aurangabad District.

	Class	Area(Ha)	Percentage
Drainage density	Very Low	52340.94	5.11
	Low	87902.82	8.59
	Medium	277827.57	27.15
	High	344282.76	33.65
	Very High	260670.33	25.48

4.7 LULC

The LULC pattern in the area shown by fig.8 and area wise distribution given in table 7.

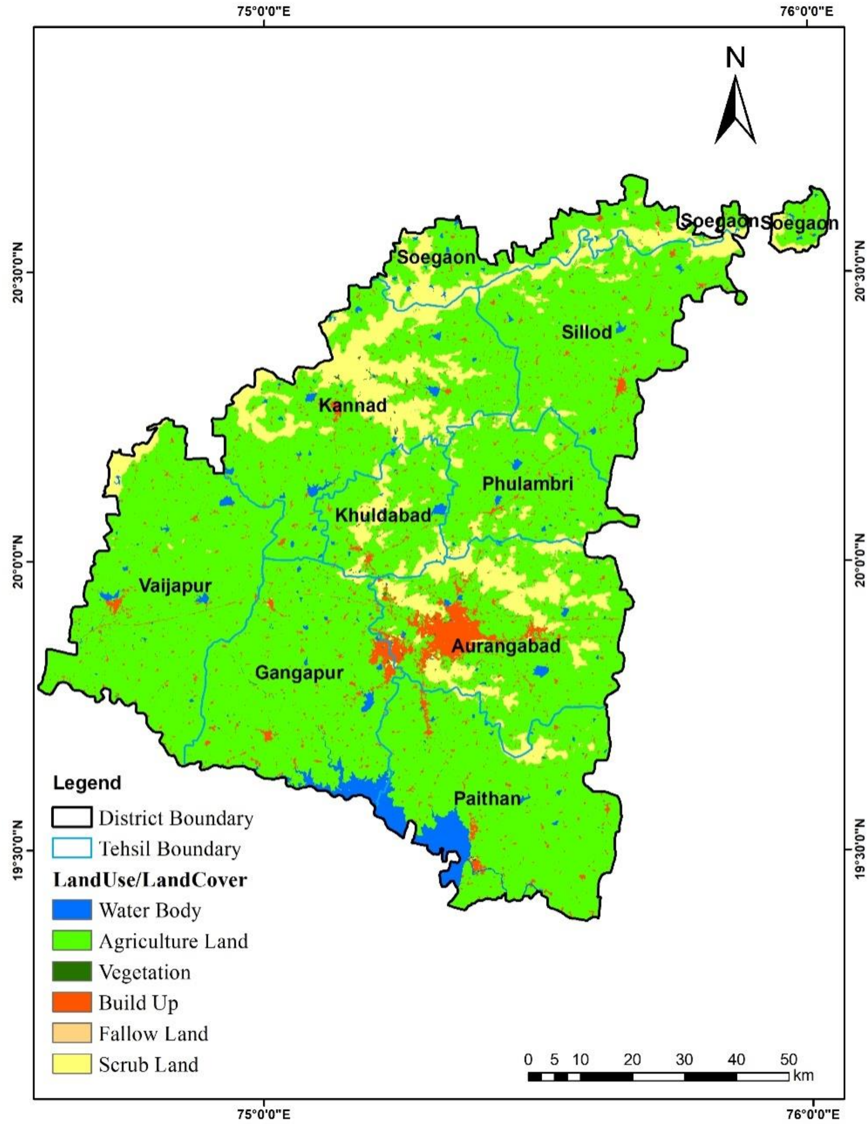

Fig.8- LULC of the Aurangabad district.

Table 7- Percentage wise distribution of LULC classes in Aurangabad District.

	Class	Area (Ha)	Percentage
LULC	**Water Body**	29254.98	2.85
	Agriculture Land	816724.3	79.83
	Vegetation	782.7	0.076
	Build Up	43931.76	4.29
	Fallow Land	52.64	0.0051
	Scrub Land	132279.66	12.93

4.8 Groundwater Potential Zonation

The GIS-based MIF, AHP, and overlay analyses of the variables identified as significant groundwater predictors in our literature analysis were used to construct the GWPZ map of the research area. To start, the weight values of the components and the score values for each sub-class were determined using the MIF and AHP procedures. Each factor's score and weight were multiplied and assigned to the corresponding raster file. The distribution of groundwater potential zone in the Aurangabad district shown by Fig. 9 and table 8.

The GWPZ of the study area was categorised using the AHP technique as follows: Poor, Moderate, good and Excellent. According to some researchers, the GWPZ map created using the AHP method is more effective than the one created using the MIF method. Others have discovered that the MIF methodology is more effective than the AHP technique. In this study, we discovered that the thematic layers employed, as well as the influence and weights supplied by experts, affect the quality of a GWPZ map produced using the AHP and MIF approaches. The results can be significantly impacted by even little adjustments to the methodology and layer weightings. The significance of the thematic layers and how they define the GWPZ should therefore take precedence over the methodology. In MCDA, the outcome of the models is influenced by the scientists' subjective judgement when determining the weights and influence of specific components. To properly analyse the weightings of these parameters in accordance with site conditions, detailed examination of predictive factors is necessary. Furthermore, each factor's weights must be exact. Weight figures can be found in earlier research that looked at regions with comparable climatic circumstances. Outliers, illogical factors, and factor weights used by some authors should all be disregarded by the researcher.

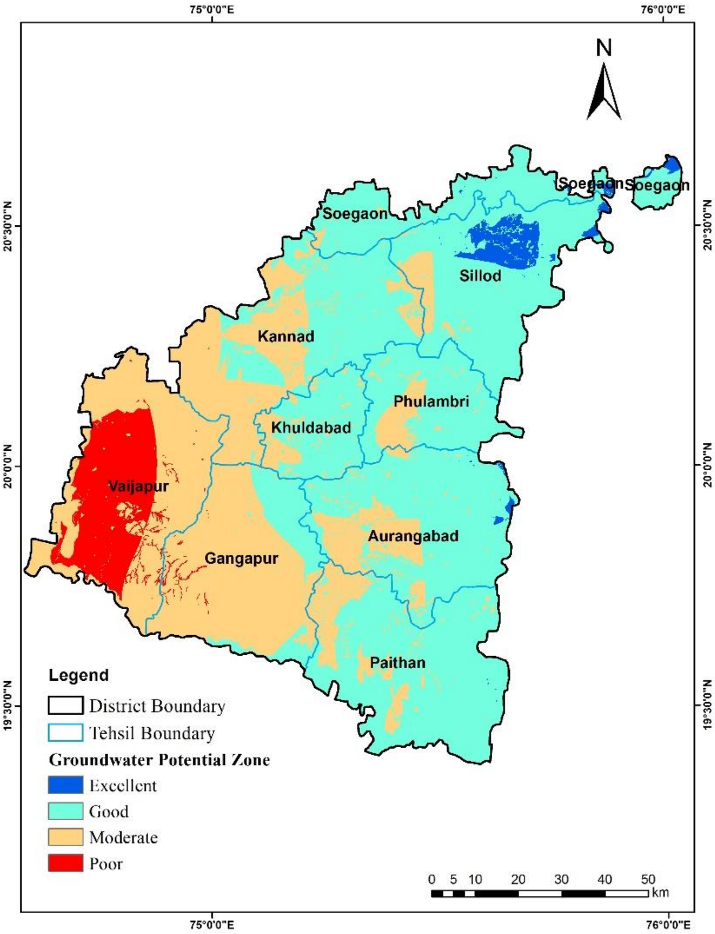

Fig.9- Groundwater Potential zone of Aurangabad District

Table 8- Percentage wise distribution of Groundwater Potential Zone in Aurangabad District.

GWPZ	Class	Area (Ha)	Percentage
	Poor	64540.8	6.3

	Moderate	359776.1	35.2
	Good	577504.9	56.6
	Excellent	19095.8	1.9

5.0 Conclusion

In the Aurangabad District of India, where groundwater is being over-exploited to fulfil the demand from agriculture, industry, and domestic users, this study was carried out to map the groundwater potential zones. Seven thematic layers—rainfall, LULC, geomorphology, soil classification, lineament density, drainage density, and slope—were combined using a weighted overlay approach to create a map of groundwater potential zones. Within this region, the demarcated zones were divided into four categories: Poor, moderate, Good and Excellent groundwater potential zones.

The strategy outlined in this research must be further validated by conducting groundwater well discharge, groundwater depth level data, and step-drawdown pumping well tests at various places throughout the watershed to assess the precise yield of groundwater wells in various GWPZ. The site's sustainable groundwater can be drawn out in this manner. However, the proposed methodology might be utilised as a primary estimate of the groundwater prospect in the absence of recharge and groundwater head data and rigorous validation, and the indicated possible zones for the drilling of water wells should be chosen.

Engineers, hydrologists, decision-makers, and regional planners can use the present study's understanding of the potential of groundwater areas in the watershed under study as the basic framework for replenishing this priceless life-sustaining resource. Since the methodology used in this study was founded on rational considerations and general traits, it may be used, with or without necessary adjustments, to other semi-arid and arid locations of the world. A coordinated approach is also needed, especially by ministries, government agencies, non-governmental organisations (NGOs), and individuals, about creating efficient rules and processes for the responsible use and exploration of groundwater resources. Future research will use artificial neural networks, fuzzy topics, and other cutting-edge AI techniques to investigate the potential of groundwater.

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