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IDENTIFICATION OF GROUND WATER POTENTIAL ZONE USING GIS AND AHP IN LATUR REGION

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Abstract:-Groundwater is essential in many arid and semi-arid areas, providing for almost all human requirements. Thirty percent is groundwater and seventy percent is surface water on Earth. Every day, around 3 billion people depend on groundwater. 80–90% of the water used for residential use, 50% for urban and industrial use, and 50% for irrigation is supplied by groundwater. Since agriculture is the main business in many areas, more irrigation is required for growth. Determining groundwater zones is so essential. Even if they work well, traditional techniques like test drilling have drawbacks such as high prices, labour intensity, long processing times, and the necessity for trained personnel, especially in developing nations like India.

On the other hand, quick data patterns impacted by land use, drainage density, slope, flow direction, lineament density, rainfall, and pre- and post-monsoon aquifer data are provided by GIS-based detection, which supports geological studies. Using GIS and the Analytical Hierarchy Process (AHP), this research describes the groundwater potential in Latur, Maharashtra (latitude 18.4088 N, longitude 76.5604 E). Groundwater potential was calculated by coordinating several factors and weighing their relative relevance in themed maps created with ArcGIS software. The groundwater potential zone mapping and final comparison were made easier by the weighted overlay approach.

The groundwater potential zones in Latur can be reliably visualized thanks to the thematic maps created with GIS software. By analysing all of the geological data that is currently known about the Latur region, the weighted overlay approach provides an understanding of groundwater potential zones by assigning weights based on a thorough examination of literature from several sources. The region is categorized as poor (0.81%), moderate (36.14%), good (58.96%), and exceptional (4.0%) in the final result. In order to prioritize groundwater extraction and conservation and ensure water security in the area, this map is essential.

Keywords: Weighted overlay analysis (WOA), Analytical Hierarchy Process, (AHP), Digital Elevation Model (Dem) , ArcGIS Pro .

1. INTRODUCTION

On our planet Earth freshwater is only 3% of the total amount of water on Earth. 30% are readily available to humans as groundwater, which is necessary for drinking, sanitation, habitats, and power production (Noori & Singh, 2021c). Around 3 billion people world wide depend on groundwater sources to fulfil

their water needs . In dry and semi-arid regions, groundwater resources are more susceptible to over exploitation, and the declining quality of groundwater resources is also a major problem (Singh & Noori, 2022b). Groundwater provides 80-90% of domestic water supply in rural areas; 50% of urban and industrial demand; and more than 50% of the irrigation (Central ground water Board,2014).
The primary industry in these areas are agricultural, which also plays a significant role in maintaining population stability. Increasing the irrigated surface area and well flow are only two aspects of region development; the primary goal is raising agricultural yield. The best way to guarantee groundwater quality and availability in a region is to conduct test drilling at the anticipated locations. Unfortunately, this method's high cost, lengthy processing time, and need for trained labour limit it’s use, particularly in developing nations with limited resources like India. Conversely, remote sensing combined with GIS skills provides an effective tool to manage these kinds of spatially-dimensional difficulties. With the benefits of being available in terms of space, spectrum, and time, remotely sensed data offers quick access to baseline information on various factors that either directly or indirectly affect the occurrence and movement of ground water, such as slope, drainage density , rainfall, lineament density ,flow direction , land use/cover. (Todd, 1980; Meijerink, 1996; Jha and Peiffer, 2006).

For long-term resource management, it is essential to be able to locate the groundwater potential zone. It helps planners, decision-makers, and policymakers ensure that the groundwater resource is protected from factors affecting both quantity and quality. One of the most popular methods for multi-criteria decision-making is the analytical hierarchy process (AHP). analytical hierarchy process(AHP) can be used to divide groundwater potential zones since it is an easy, quick, dependable, and efficient procedure (Eyasu Tafese 2022).

This study aims to prepare groundwater potential zone map for Latur, Maharashtra (latitude 18.4088 N, longitude 76.5604 E) using Geographic Information System “GIS”; and the Analytical Hierarchy Process (AHP) technique. This approach integrates different statistical and geospatial methods to evaluate and identify areas with high groundwater potential. The present study used ArcGIS Pro software, a powerful spatial analysis and mapping tool, to prepare a map of the potential groundwater area for Latur, Maharashtra. ArcGIS Pro's advanced features enable seamless integration and processing of diverse geospatial datasets, facilitating comprehensive analysis of a region's hydrogeological characteristics. By leveraging this software, we can effectively manage and visualize the subject layers required for our research, ensuring the accuracy and precision of our results. The study used a weighted overlay procedure, a technique that combines multiple layers of data to identify areas with the highest groundwater potential. This process involves assigning specific weights to each thematic class based on its relative importance in influencing groundwater recharge. The analytic hierarchy process (AHP) was used to systematically determine these weights. AHP is a structured decision-making method that uses pairwise comparisons to prioritize factors affecting groundwater potential, ensuring rationality and consistency.

Several key parameters are considered in this analysis, including slope, stream density, drainage density, rainfall, land cover, land use, and pre-monsoon and post-monsoon data .These parameters are essential for understanding the hydrological dynamics of the region.The weights for each parameter are assigned using a standard AHP weighting Excel table, ensuring that the relative importance of each factor is accurately reflected in the final analysis.This meticulous approach allowed us to create a detailed and reliable map of groundwater potential, which can provide a valuable resource for effective water resources planning and management in Latur district or suffer from drought.

2. AIM

Determination Of Ground water Potential Zone Using GIS Software And Analytical hierarchy Process(AHP)

3. OBJECTIVES

1. Generation of thematic data layers and their spatial analysis using GIS Software.

2. To utilize open-data resources (SRTM Data) available and carry out research work using GIS software.

3. To Study Ground Water Potential Zones

4. To visualize and publish the results in the form of maps which will help in identifying Ground Water Potential areas with the help of GIS software.

4. COMPONENTS AND TOOLS

While evaluating groundwater potential in Latur area, many advance tools and method were used to understand the ground water situation in Latur. One of them that we use ArcGIS PRO for determining ground water potential. ArcGIS Pro, a powerful geographic information system, or "GIS," is the primary tool utilized. Several geospatial data sets can be processed and integrated using the software. Several layers of data, including rainfall, slope, drainage density, land cover/land use, flow direction, previous water level, post-monsoon, and line density, can be combined using this software to do weighted overlay analysis. Furthermore, geographical data have been gathered by remote sensing techniques, offering insight into the surface and subsurface characteristics that affect groundwater movement.

The analytic hierarchy process (AHP) was used to determine the weight of each parameter and their classes for identifying ground water potential zone, a process guided by comprehensive analysis of the literature.

Data and case studies: - the combination of GIS , Remote sensing , AHP has provided strong framework for precisely mapping potential groundwater areas, allowing for efficient planning and resource management.

5. METHODOLOGY

Latur is one of the drought-prone districts of Maharashtra State in India. It is situated between north latitudes 17°55′00″ and 18°50′00″ and east longitude 76°15′00″ and 77°15′00″. The district has a geographical area of 7157 km2. The normal annual rainfall over the district varies from 600 to 800 mm and mean annual rainfall is 724 mm. (Navane, Vishal & Sahoo, Sanat.2020). Temperatures in Latur range from 13 to 41°C (55 to 106 °F), The highest temperature ever recorded was 45.6 °C (114.1°F). The lowest recorded temperature was 2.2 °C (36.0 °F). The Marathwada region lacks rainfall due to its poor geographical condition and the Sahyadri range and the ground condition of the Deccan plateau does not let the water to recharge the groundwater table. Lack of watershed management practices leads to unnecessary wastage of water which leads to water scarcity in summers.(Varun Kumar, Vishal Mishra Dr. Pallavi Kharat,2020)

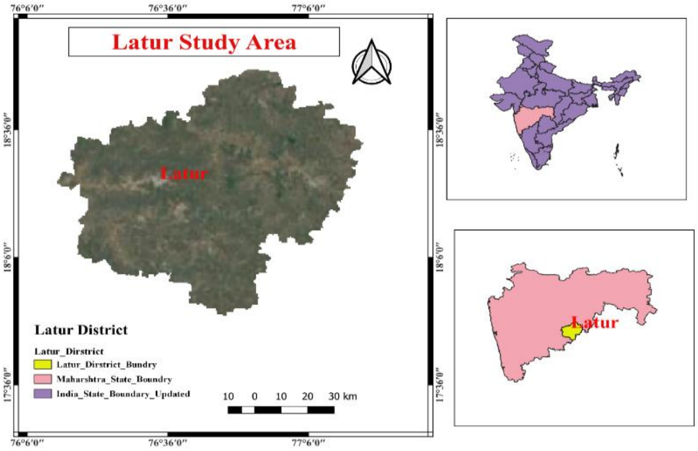


Fig 3.1: Study area

The study area is severely facing water scarcity problem which resulted in frequent droughts. This problem may become severe in future because of unsustainable groundwater use practices and expected climate change. Therefore, there is a need for the scientific study of groundwater management and development

3.1 Data used

Table 3 lists the various data used in the approach for the study.1Slope map, Drainage Densitymap, and Lineament Density map were created from data consisting of DEM of 30m resolutionretrieved from (https://earthexplorer.usgs.gov) is WGS 84, Geo-Tiff format Digital elevation model.

Thematic layer	Description	Source
Latur Boundary	Vector data of India Administrative boundaries	Survey of India onlinemaps.surveyofindia.gov.in
DEM	30m resolution raster data	USGS https://earthexplorer.usgs.gov/
LULC	10m resolution raster data	Esri Landuse 2021 https://livingatlas.arcgis.com/
Normalized Difference Water Index	Re-categorized to raster data in to the 30-m resolution.	Landsat 8/9 data- USGS Earth Explorer- https://earthexplorer.usgs.gov/
Rainfall	The rainfall measurements for 2011-2021	CHRS Portal- https://chrsdata.eng.uci.edu/
Drainage Density	Downloaded and listed in to the 30-m raster data resolution.	Bhukosh-Geological Survey ofIndia https://bhukosh.gsi.gov.in/
Lineament Density	Downloaded and listed in to the 30-m raster data resolution.	Bhukosh-Geological Survey of India https://bhukosh.gsi.gov.in/
Pre-Monsoon and Post Monsoon Ground water Depth	Minimum, maximum ground water level	Central Ground Water Board - https://cgwb.gov.in/sites/default/files/2022-11/latur_f_compressed.pdf

Table 3.1: Thematic layer used and their Sources

3.2: Analytical Hierarchy Process (AHP)

The Analytical Hierarchical Method (AHP) can assist the decision-maker in setting goals thatlead to the right option. In order to choose the best course of action, the AHP takes into accounta variety of factors and options. By adding the major eigenvector of the pairwise relationship of the square reciprocal matrix between the two variables, Satty's method calculates the weightsof the parameters. The continuous ranking scale of Satty's analytical hierarchical method was utilised to allocate weights for pairwise contrast. The

AHP assesses a variety of options, including the optimum decision to be made, along with a set of evaluation parameters. It lessens difficulty a variety of pairwise differentiation decisions. Because it transforms decision makers'inputs into figures, the AHP is analytical.

These were the steps that were taken:

- In the beginning, criteria for the analysis of solar potential were chosen.
- Following the pairwise comparison, weight was assigned. (Banerjee et al., 2020):
-

Parameters	**A1**	**A2**	**A3**
A1	a11=1	a12	a13
A2	a21=1/ x12	a22=1	a23
A3	a31=1/ x13	a32=1/ x23	a33=1

Table 3.2: Pairwise Comparison Matrix

- Take into account the 'n' compared items A1, A2, A3,... A which create a comparison matrix A= aij of order n with the restrictions such that aij= 1/aji where i-j and aij =1 where i=j.
- • A 3x3 pairwise comparison matrix. The inclusion of items from A denotes the significance of i in comparison to j.

Intensity Importance	**Linguistic value**
1	A1 and A2 have exactly equal importance
3	A1 is slightly more important than A2
5	A1 is much more important than A2
7	A1 is highly important than A2
9	A1 is exceptionally more important than A2
Where 2,4,6,8 lying between two adjacent judgements	

Table 3.3: Scales for Pairwise Comparison Matrix with AHP described

- If xij=1, then i and j are both equally significant.
- If xij>1, i will be more powerful than j.
-

- If xij>1, j will be more dominating than i.

Each column's sum in matrix A was determined using the following formula:

Sj =∑xji(1<j<n)

The weights were then calculated from the pairwise comparison of the parameters as the meanof the normalized values of each row.

Consistency index (CI): The formula for CI is ((λmax-n)/(n-1), where n stands for the size ofthe matrix and (λmax is the average eigenvalue of the matrix. (Al-Djazouli et al., 2021)

CI = (λmax-n)/(n-1)

Random Index (RI): The order of the matrix affects the average random index.

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 3.4: Index of Random Consistency (Satty's AHP, 1980)

Consistency ratio (CR): It is characterized as the consistency index to random index ratio.(Al-Djazouli et al., 2021)

CR= CI/RI

Only if the CR is less than 0.1 will the pairwise comparison matrix pass the consistency test.The formula shown below is used to compute " λmax":

AB = λmax * B

where B is the matrix of criteria weighting.

Saaty asserts that the comparison matrix is flawlessly consistent if λmax = n. The decision maker must review his choices if the consistency ratio is higher than 0.1. A straightforwardtechnique can be used to determine consistency:

For the mapping of groundwater potential zones in Delhi, India, seven factors were used in total. These parameters are crucial for the distribution of groundwater. Groundwater potentialzones were mapped using thematic maps created with the aid of remote sensing and GIS techniques for the research region. All of the theme maps in the GIS environment were spatially organized while maintaining the same resolution and projected coordinate system. Each thematic map was classed in a GIS framework using knowledge-based rankings and weights.

thematic map was classed in a GIS framework using knowledge-based rankings and weights.The mapping of groundwater potential zones is done using overlay analysis within the GIS software's Spatial Analyst function. Each relationship is given a weight based on how powerfulit is. The methods employed is shown in Fig. 3.2.

Consistency ratio (C.R.) = 0.009 < 0.1

Therefore, the current study takes this tactic into account. The representative weights of a givenfactor in the potential zone are the sum weights from each component.. Factors with higher weight values have a greater impact on groundwater potential zones than those with lower weightage. These parameters, along with weights, are assimilated using weighted overlay in ArcGIS. (Saha et al., 2017)

3.2 Method used: Flow chart

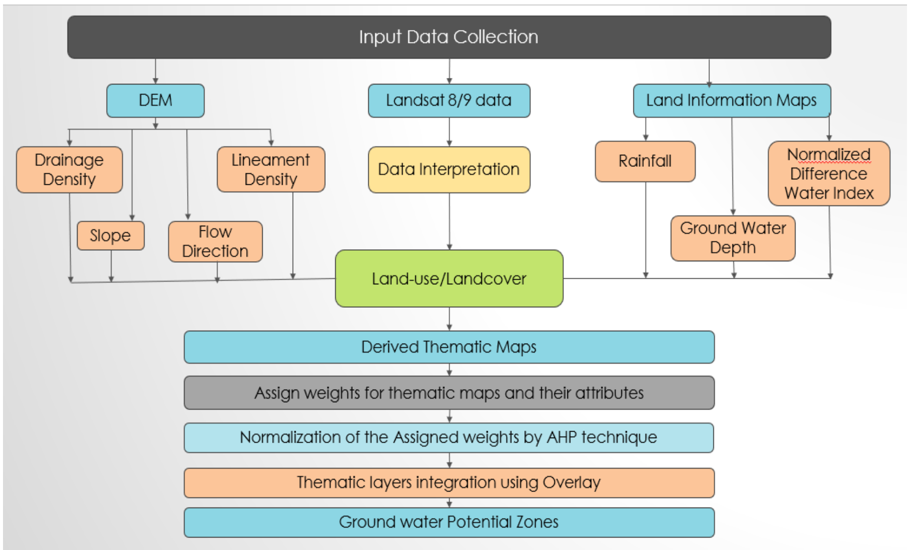


Fig 3.2: Flow chart for ground water potential zone mapping

6. Discussion

DEM:-

DEM provides a detailed and accurate description of the elevation of the terrain at various geographic locations. DEM data is widely used in a variety of academic fields, such as geography, geology, cartography, urban planning, and environmental science. Several popular techniques for obtaining DEM data include satellite photography, radar interferometry, aerial photogrammetry, and LiDAR (Light Detection and Ranging).

These methods measure the distance between the sensor and the Earth's surface to get elevation data, which allows for the creation of an exact and accurate image of the terrain. Input data used was a USGS DEM model with a 30 m resolution. Study area has maximum elevation of 733 meters and minimum is 409 meters. Details of elevation are shown in Figure

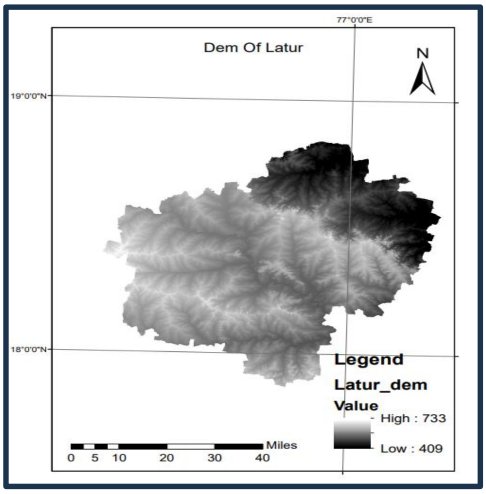


Fig 4.1 : Digital Elevation Model(DEM) map of Latur, India.

Lineament Density:-

lineaments are recognized as geologic or geomorphic formations. These might be faults, fractures, dykes, joints, or other linear structures. By dividing the total length of lineaments in a particular region by the area itself, one may calculate the density of lineaments. The length of lineaments per unit area is displayed on the resulting graph in either meters per hectare (m/ha) .

According to satellite imagery, lineaments are the outward manifestation of linear or curvilinear features on the surface of the earth that are aligned manifestations of an underlying lithological structure, such as a fault, fractures, or cleavages. Which is given in range from 1 mile/hector, 1-2 mile/hector, 2-3 mile/hector, 3-4 mile/hector, 4-5 mile/hector.

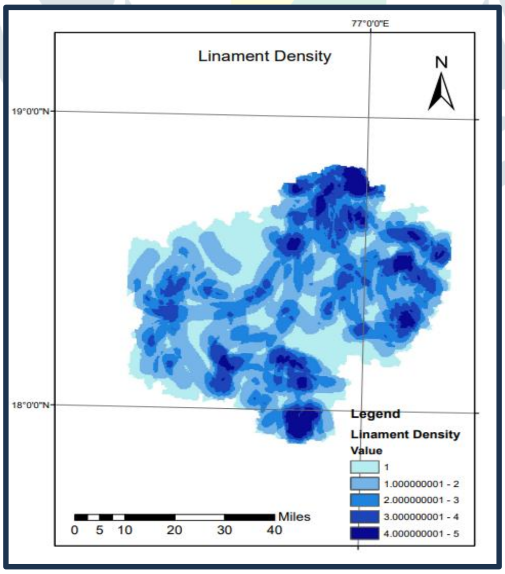


Fig 4.2 : Lineament Density map of Latur, India.

Drainage Density :-

Drainage density provides information on the hydrological system features of a terrain. It is influenced by several factors such as climate, geology, slope, plant cover, and land usage. The Drainage Density for the current research has been determined using the DEM. Arc hydro tools in a GIS environment are used to quantify drainage density. The higher drainage density there is, the more groundwater is available as infiltration grows. Latur's drainage density map was split up into five smaller categories. 10-41m/ha,41-73m/ha,73-104m/ha,104-135m/ha.

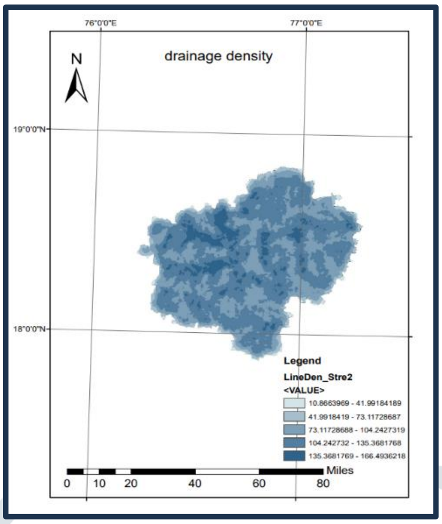


Fig 4.3 : Drainage Density map of Latur, India.

Land Use/Land Cover:-

Land use and land cover (LULC) are important factors in understanding and managing groundwater resources. Analysis of LULC data provides information on hydrological processes such as flow, evapotranspiration and infiltration, which are essential for assessing groundwater potential. In Latur district, the LULC map classifies the area into six categories: water bodies, non-agricultural land, agricultural land, barren land, mainland and built-up areas. Each type affects the amount of groundwater differently, highlighting the importance of LULC analysis in identifying potential groundwater bodies. Agricultural soils and vegetated zones are especially important in groundwater research because of their impact on soil properties and infiltration rates.

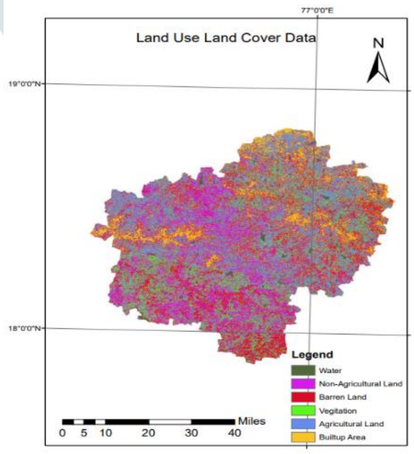


Fig 4.4 : Land Use and Land Cover map of Latur, India.

Slope :-

The research area's topography steepness will be analyzed using the slope map in Figure, which was produced in a GIS environment using a USGS DEM with a 30m resolution. The highest rate of value change from that cell to its neighbors is ascertained via the slope tool. In essence, the largest elevation change across the distance between the cell and its neighbors determines the sharpest descent from the cell. A high slope region contributes less groundwater because it generates more runoff and less infiltration than a low slope zone. The research region is mostly composed of gently sloping, rather flat terrain.1-2m,2-3m,3-4m,4-5m.

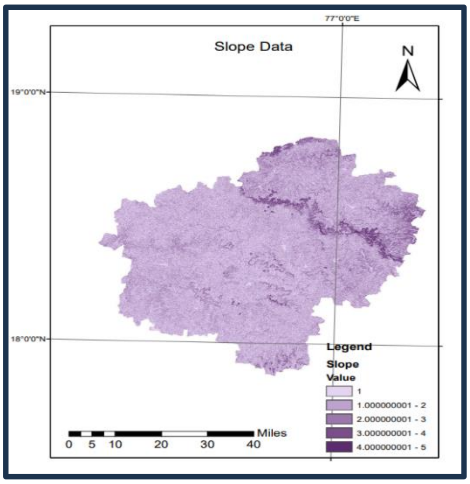


Fig 4.5: Slope map of Latur, India.

Rainfall:-

Latur is a drought-prone region in Maharashtra, India, which has been facing severe water shortage problems for many years. Groundwater levels in the region are gradually decreasing due to overexploitation and insufficient replenishment, exacerbated by erratic and often insufficient rainfall. This persistent water shortage has had a severe impact on agriculture, daily life and overall socio-economic conditions in Latur, making effective water planning and management essential for sustainable development. regional sustainability. To address these issues, we analyzed the annual rainfall data of the Latur region.1-1.8mm,1.8-2.6mm,2.6-

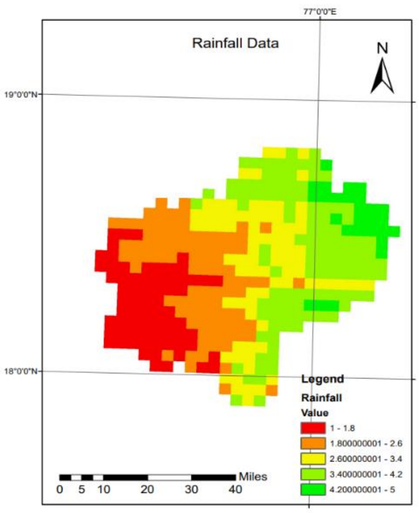


Fig 4.6 : Rainfall map of Latur, India.

The average annual rainfall in Latur is about 800 mm, which is relatively low and unevenly distributed throughout the year. For our analysis, we collected rainfall data from the CHRS (Centre for Hydrometeorology and Remote Sensing) portal, covering the period from 2010 to 2021.

AHP Calculations and Procedure :-

The Analytic Hierarchy Process (AHP), which integrates factors such as slope, Land use/land cover, rainfall, flow direction, pre monsoon and post monsoon data, lineament density, drainage density. is essential for locating groundwater potential zones. This approach guarantees a thorough evaluation by methodically assessing and ranking these elements. AHP supports sustainable water extraction, well location optimization, and the prioritization of high recharge regions. In this way, it encourages conservation and sustainability by supporting well-informed decision-making in the management of water resources.

Using Saaty's AHP, we compare variables such as topography, soil type, rainfall, land use, and geological formations to determine weightages for GIS weighted overlay. By systematically evaluating each factor's significance, groundwater potential zones may be accurately mapped. As so, it improves techniques for the management of water resources.

Matrix		Rainfall 1	Lineament density 2	Slope 3	Drainage density 4	LULC 5	flow direction 6	PreMonsoon 7	PostMonsoon 8	0 9	0 10	normalized principal Eigenvector
Rainfall	1	1	3	3	5	5	5	1	1	-	-	27.31%
Lineament density	2	1/3	1	3	3	5	5	1	1	-	-	19.07%
Slope	3	1/3	1/3	1	1	3	3	1	1	-	-	10.61%
Drainage density	4	1/5	1/3	1	1	1	2	1	1	-	-	8.09%
LULC	5	1/5	1/5	1/3	1	1	1	1	1	-	-	6.34%
flow direction	6	1/5	1/5	1/3	1/2	1	1	1	1	-	-	5.88%
PreMonsoon	7	1	1	1	1	1	1	1	1	-	-	11.35%
PostMonsoon	8	1	1	1	1	1	1	1	1	-	-	11.35%
0	9	-	-	-	-	-	-	-	-	1	-	0.00%
0	10	-	-	-	-	-	-	-	-	-	1	0.00%

	Criterion	Comment	Weights (%)
1	Rainfall		27.3
2	Water Index		19.1
3	Slope		10.6
4	Drainage density		8.1
5	LULC		6.3
6	flow direction		5.9
7	PreMonsoon		11.3
8	PostMonsoon		11.3

4.7 Weight Comparison Matrix 4.8 Assignment For Weighted Overly

Using Saaty's AHP, we compare variables such as topography, soil type, rainfall, land use, and geological formations to determine weightages for GIS weighted overlay. By systematically evaluating each factor's significance, groundwater potential zones may be accurately mapped. As so, it improves techniques for the management of water resources.

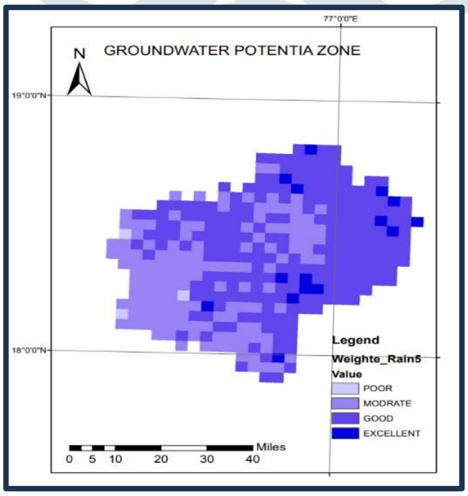
Weighted overlay :- Groundwater potential zones are identified by applying percentage values to several criteria such as slope, Land use/land cover, rainfall, flow direction, pre monsoon and post monsoon data, lineament density, drainage density using Saaty's AHP for a weighted overlay in GIS. A thorough map of groundwater potential is produced by superimposing these weighted layers in a GIS. Each factor's weight indicates its relative relevance. Sustainable water resource management is aided by this accurate evaluation.

Sr.No.	criterion	class	reclass
1	RAINFALLL	678.168-74.63174	1
		746.179-782.572	2
		782.573-817.054	3
		817.055 -856.326	4
		856.327 - 922.417	5
2	LULC	147212	1
		2114364	2
		1726031	3
		1686505	4
		1418263	5
		912271	6
3	LINEAMENT DENSITY	8667	4
		13844	5
		11452	3
		6374	2
		2060	1
4	DRAINAGE DENSITY	134	5
		750	4
		1554	3
		2296	2
		34524	1
5	SLOPE	3012827	2
		3257916	1
		1416377	3
		232797	4
		61596	5
6	FLOW DIRECTION	1 TO 2	5
		2 TO 8	4
		8 TO 32	3
		32 TO 64	2
		64 TO 128	1
7	PRE MONSOON	1318907	5
		3074317	4
		2529332	3
		912302	2
		169925	1
8	POST MONSOON	388533	5
		2739717	4
		3147137	3
		1362116	2
		367280	1

4.9 Weights assigned to the parameters from Weighted overlay matrix

Final Result

Our study's map categorizes groundwater potential in the Latur region into four categories: poor, moderate, good, and exceptional. This classification gives a clear and complete representation of the area's groundwater resources. According to our findings, 0.81% of the area falls into the "Poor" category, indicating a lack of groundwater availability. A considerable proportion, 36.14%, is classed as "Average," indicating moderate groundwater potential. The bulk of the region, 58.96%, is classified as "Good," suggesting a high level of groundwater availability. Finally, 4.07% of the territory is rated as "Excellent," indicating the areas with the best groundwater possibilities. This classified map is a critical tool for good groundwater management and planning, helping to prioritize regions for conservation and sustainable use in



4.10 Final result data

5. CONCLUSION

From the results obtained from the analysis of various thematic parameters .It is conformed that the various criteria used in Arc GIS software with help of AHP has successfully given us the potential groundwater area in percentage in Latur region area. Through the careful waight assignment of 8 critical parameters which includes rainfall, slope, drainage density, land cover land use, flow direction pre-post monsoon water level, and line density our analysis ha provided us with the reliable information ground water potential .
Utilizing the weighted overlay method in Arc GIS Pro this study classifies the ground water potential into four distinct categories which are Poor, Moderate, Good and Excellent . this distribution of the categories are spread across the Latur region reveals the significant portion of the area that exhibits the excellent ground water potential which is approximately 58.96%. This finding suggests promising prospects for sustainable groundwater utilization in these regions. Conversely only 0.81% of the area of latur region falls into the poor category which indicates that this area is in need of careful management to Prevent overexploitation of the resources and the depletion of the groundwater

The decrease of groundwater potential zones in Latur serves as a valuable tool for guiding the water resource planning and management efforts in the Latur region. By giving the priority the area with the excellent potential of the groundwater and conservation initiatives policymakers and stakeholders can then ensure the suitable utilization of the groundwater resource that us mitigating the risk associated with the water safety operations. Their clear and classified map that are determined in the above paper gives the idea about the strategic decision-making processes aimed at promoting water security and socio economical stability in the Latur region

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