Remote Sensing and GIS-Based Analysis for Identifying Groundwater Potential in Chhatrapati Sambhajinagar Tehsil

Dr. Shubhada koranne[1], D.A.Nagkirti[2]

[1]Assistant Professor & HOD of Civil Engineering Department GECA Chh.Sambhajinagar MH India
[2]MTech Student of Water Resources Engineering Department GECA Chh.Sambhajinagar MH India

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Abstract - *Groundwater is a crucial renewable natural resource that supports domestic, agricultural, and industrial needs, especially in semi-arid regions such as Chhatrapati Sambhajinagar tehsil in Maharashtra. Increasing population, growing water demand, and erratic rainfall patterns have intensified the need for identifying viable groundwater zones to ensure sustainable resource management. This study employs Remote Sensing (RS) and Geographic Information System (GIS) techniques to delineate groundwater potential zones (GWPZ) across the tehsil. The methodology involved generating multiple thematic layers—including geology, geomorphology, slope, soil type, drainage density, lineament density, and land use/land cover (LULC)—from satellite imagery and existing datasets. These layers were assigned weights using the Analytical Hierarchy Process (AHP), reflecting each factor's influence on groundwater recharge. A weighted overlay analysis in GIS was then performed to integrate the layers and assess groundwater potential across the region. The final output classified the area into five categories: very good, good, moderate, poor, and very poor potential zones. The findings highlight that RS and GIS provide a reliable, cost-effective, and comprehensive approach for evaluating groundwater availability in data-scarce and water-stressed regions. This spatial analysis serves as a scientific foundation for groundwater planning, helping decision-makers implement appropriate conservation strategies, recharge structures, and land use interventions. The study also opens up opportunities for replicating the approach in other semi-arid landscapes facing similar hydrological challenges.*

***Key Words*: Groundwater Potential Zones, Remote Sensing, GIS, Analytical Hierarchy Process, Weighted Overlay, Chhatrapati Sambhajinagar, Thematic Layers**

1.INTRODUCTION

1.1 Importance of Groundwater in India

Groundwater is a key water source for drinking, agriculture, and industry throughout India. It is particularly vital in rural areas, where it supports irrigation and underpins food security. Around 60% of agricultural irrigation and 85% of household water needs in India are fulfilled by groundwater.

1.2 Challenges in Groundwater Management

Despite its vital role, groundwater in India faces intense pressure due to excessive withdrawal, lack of regulation, and growing pollution. Falling water tables and unpredictable monsoon patterns further worsen the situation. This necessitates adopting scientific approaches for sustainable groundwater assessment and management.

1.3 Significance of Chhatrapati Sambhajinagar Tehsil

Situated in Maharashtra, Chhatrapati Sambhajinagar tehsil lies in a semi-arid zone with limited surface water and irregular rainfall. The area frequently experiences droughts and water shortages. Groundwater is the main source of water for both farming and domestic use, making its systematic assessment and conservation essential.

1.4 Scope of Remote Sensing and GIS

Technologies like Remote Sensing (RS) and Geographic Information Systems (GIS) are effective in analyzing and mapping natural resources such as groundwater. These tools allow for the creation and combination of thematic layers—like geomorphology, soil, slope, and drainage—across vast regions. When integrated with models like the Analytical Hierarchy Process (AHP), they can accurately identify groundwater potential zones to support better water resource planning.

1.5 Objectives

1. To process Landsat OLI and SRTM satellite data.
2. To derive a drainage network using SRTM DEM.
3. To generate thematic maps for slope, elevation, drainage density, LULC, NDVI, geomorphology, and soil.
4. To identify suitable groundwater potential areas through integrated analysis of all thematic layers.

1.6 Study Area

1.6.1 Geographical Setting

Chhatrapati Sambhajinagar tehsil is located centrally in Maharashtra, between latitudes 19.87° N and longitude 75.34° E, covering an area of approximately 1,292.65 sq. km.

1.6.2 Climate and Rainfall

The tehsil experiences a semi-arid climate characterized by hot summers and mild winters. Annual rainfall averages around 710 mm, with most precipitation occurring during the monsoon season from June to September.

1.6.3 Soil and Drainage

The region predominantly features clayey and loamy soils, which exhibit moderate to low water infiltration. The drainage system is largely dendritic, influenced by seasonal rivers and streams that affect surface runoff and groundwater recharge.

1.6.4 Geology

The geological structure consists mainly of basaltic rocks from the Deccan Traps. These rocks, often fractured and weathered, significantly influence the movement and storage of groundwater in the area.

2. MATERIAL AND METHODOLOGY

2.1 Data Uses

The 30-meter resolution Digital Elevation Model (DEM) data was sourced from the Shuttle Radar Topography Mission (SRTM) via the USGS website (http://edc.usgs.gov). Satellite imagery of the study area, specifically from LANDSAT OLI, was also obtained from the same site.

- The 30 m SRTM DEM data from USGS was processed for further analysis.
- LANDSAT OLI imagery was utilized to develop a Land Use/Land Cover (LULC) map.
- The drainage network was derived from the DEM.
- A drainage density map was generated.
- Geomorphological and lineament maps were created for the study area.
- Parameters such as slope, drainage density, lineament density, LULC, and geomorphology were integrated using weighted overlay analysis in ArcGIS.

The LANDSAT OLI dataset includes 11 bands. Seven of these—bands 1 through 7—cover spectral ranges such as Blue, Green, Red, Near Infrared (NIR), SWIR 1, and SWIR 2 at a 30 m resolution.

Other bands include Band 1 (Coastal aerosol), Band 8 (Panchromatic at 15 m), and Bands 10 and 11 (Thermal Infrared 1 and 2) which are acquired at 100 m resolution but resampled to 30 m in the final data product.

2.2 Data Processing

SRTM DEM and Landsat imagery were pre-processed to remove errors and normalize the data. The DEM was corrected for sinks using the Fill tool in ArcGIS's Spatial Analyst extension. Flow direction rasters were then created to indicate the direction of water movement. A subset raster focusing on the area of interest was generated from the DEM. Flow accumulation was computed to identify stream paths, and a threshold of 500 pixels was set to define drainage lines. These drainage lines were then ordered using Strahler's method.

Stream rasters were converted into vector line features via the Stream to Feature tool. Drainage basins were outlined using the Basin tool, and pour points (where water exits the basin) were used to finalize basin delineation. The raster basin map was then converted into a polygon feature for further spatial analysis.

To form a complete drainage network, flow direction and accumulation rasters were used to trace water flow across each cell in the DEM.

2.3 Software Used

QGIS software was employed to meet the objectives of the project.

- **Saga Tool**: Utilized for conducting drainage analysis.
- **Extract by Mask Tool**: Used to limit the extracted data to the defined study area.

I) Slope Map

Slope refers to the steepest gradient or change in elevation over distance. Slope mapping is crucial to understand variations in terrain, detect geological disturbances, and identify features like fault scarps or tilted strata. It was created using the Surface Tool available under Spatial Analyst in QGIS via the sequence: QGIS > Raster > Analysis > Slope.

II) Drainage Delineation

To create a drainage map in QGIS, the DEM was first loaded and processed to fill depressions using GRASS or SAGA tools. A flow direction raster was then generated to model how water moves across the terrain. Flow accumulation was calculated to identify areas where water would collect, and these were used to define stream channels based on a set threshold.
The resulting stream rasters were converted into vector layers, and stream orders were assigned using systems like Strahler's. Optional watershed boundaries were defined by setting pour points and using watershed tools. This process

produced both a drainage network and watershed maps for hydrological and watershed management purposes.

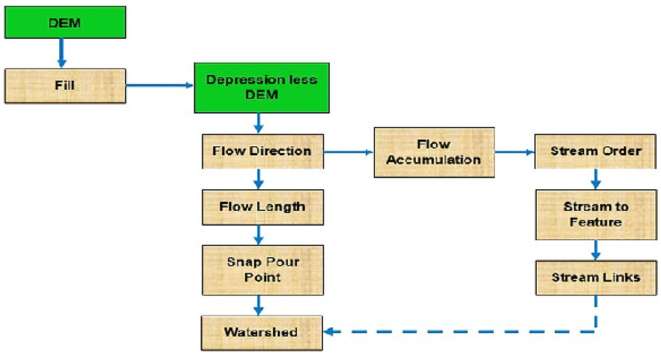

Fig 1: Steps involved in delineation of watershed

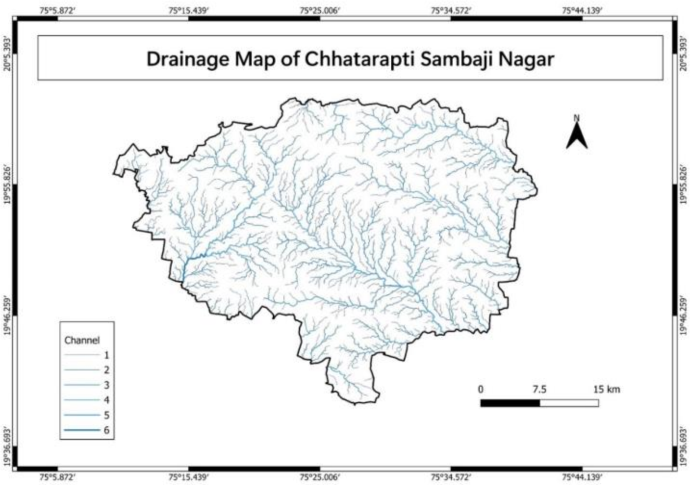

Fig 2: Drainage Map of Study Area

3. INTERPRETATION AND INTEGRATION

Interpretation of remotely sensed data integrated with GIS techniques provides an effective approach for assessing groundwater potential. In this study, six key thematic layers—Rainfall, Slope, Geomorphology, Drainage Density, Lineament Density, and Land Use/Land Cover (LULC)—were analyzed based on their influence on groundwater occurrence in the study area. These layers were examined and integrated to delineate potential groundwater zones.

3.1 Elevation

Areas below 590 meters exhibit very high groundwater potential due to flat terrain and enhanced infiltration, whereas regions above 844 meters show poor potential due to steep slopes and runoff.

Table 1: Elevation and category wise area distribution

Class	Elevation	Ground water potential
1	<= 590	Very High
2	591-674	High
3	674-759	Moderate
4	760-844	Low
5	>844	Very poor

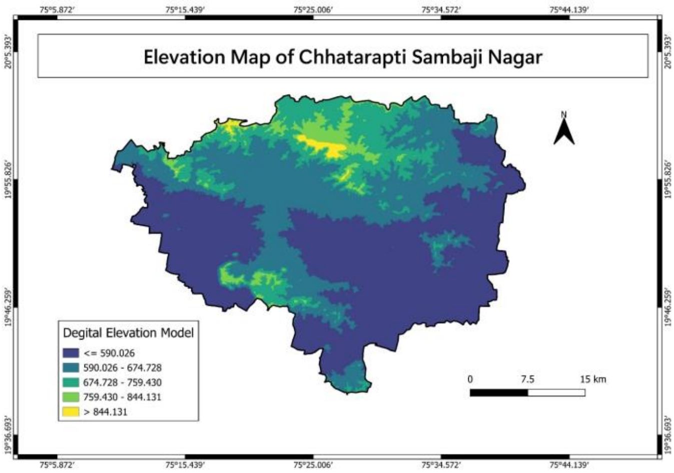

Fig 3 : No Rainfall Map of Chhatrapati Sambhajinagar District

3.2 Slope

Nearly flat to very gentle slopes support better infiltration and thus higher groundwater potential. Steeper slopes correspond to reduced recharge.

Table 2: Slope gradient and category wise area distribution

Class	Slope (Degree)	Slope Category	Ground water potential
1	<21.21	Nearly flat	Very good
2	21.21-42.42	Very gentle	Good
3	42.42-63.3	Gentle	Moderate
4	63.63-84.85	Moderate	Poor
5	>84.85	Steep	Very Poor

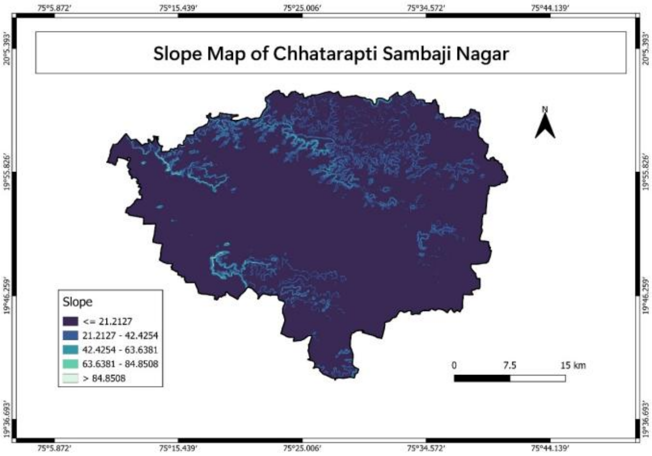

Fig 4 : Slope Map of Study area

The slope map of the area depicts in general flat to very gentle slope in most part of the area. Steeper slope are encountered in the northern part of the area whereas moderate escarpment slope has been represented in eastern fringe of the area. Some moderate gentle slope has been noted in the central and eastern extremity of the study area.

3.3 Geomorphology: -

Valley fills, pediplains, and shallow weathered pediplains emerged as highly favorable zones for groundwater accumulation, while hilly terrains and structural hills were less suitable.

Table 3: Geomorphology Category

Class	Class Name	Category
1	Pediment Pediplain Complex	Very High
2	Pond, River, WatBod Lake, Dam and Reservoir	Very High
3	Low Dissected Structural Lower Plateau	moderate
4	Low Dissected Structural Upper Plateau	moderate
5	Moderately Dissected Structural Lower Plateau	poor
6	Moderately Dissected Structural Upper Plateau	poor
7	Abandoned Quarry	Very poor

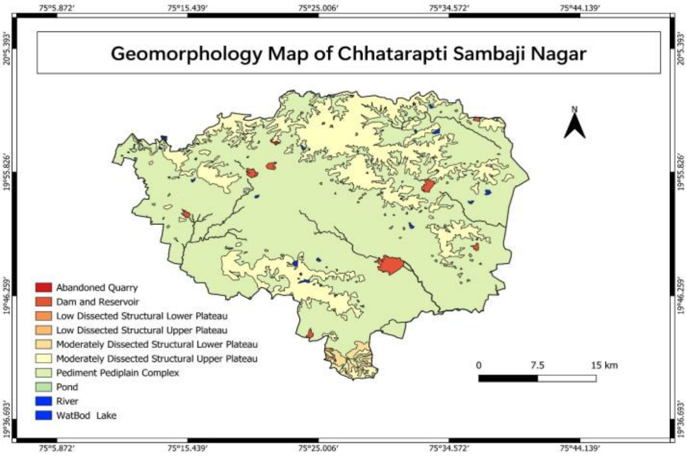

Fig. 5: Geomorphological Map of Study Area

3.4 Drainage Density

Areas with low to moderate drainage density supported higher infiltration. High drainage density indicated higher runoff and thus lower recharge potential.

Table 4: Drainage Density Category

Class	Drainage Density km/km2	Ground water potential
1	0.023-0.45	Very Good
2	0.45 – 0.62	Good
3	0.62 – 0.75	Moderate
4	0.75- 0.90	poor
5	0.90- 1.23	Very poor

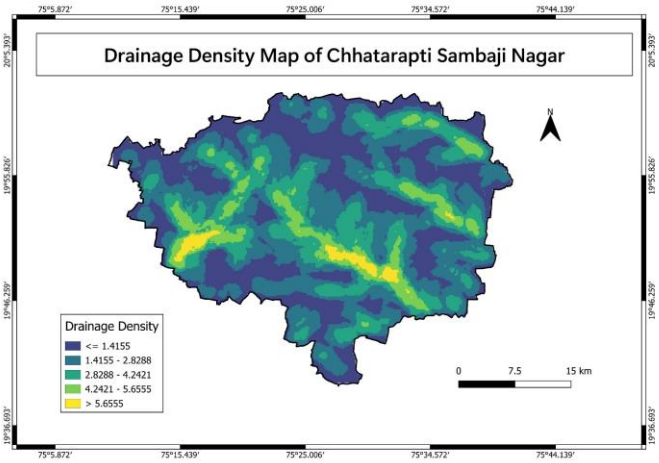

Fig.6 : Drainage Density Map of Study Area

3.5 NDVI

Normalized Difference Vegetation Index (NDVI) helps analyze vegetation cover. High NDVI values correlate with dense vegetation and higher infiltration, while low NDVI implies less cover and limited recharge.

Table 5: NDVI Range Table

Sr. No	NDVI Range	Ground water potential
1	<= 0.0320	Very Poor
2	0.0320 – 0.1414	Poor
3	0.1414-0.3148	Moderate
4	0.3148-0.4882	Good
5	>0.4882	Very good

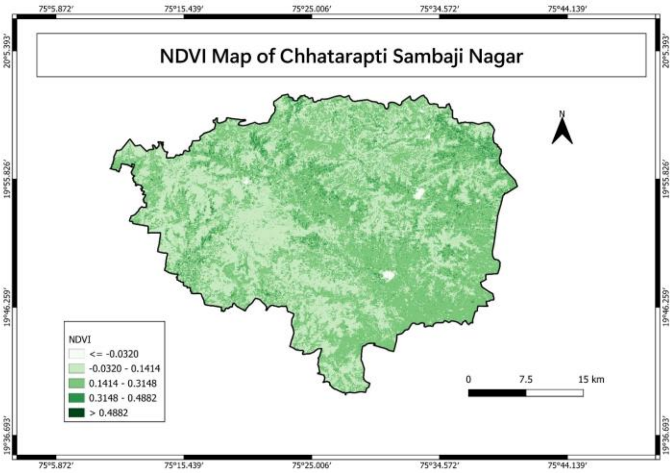

Fig.7 : NDVI Map of Study Area

3.6 Land Use Land Cover

Agricultural and forested areas show high recharge potential due to greater perviousness. Built-up and barren land impede percolation, leading to lower potential.

Table 6: Land Use Category

Class	LULC	Ground water potential
1	Water	Very Good
2	Trees	Good
4	Flooded vegetation	Good
5	Crops	Good
6	Built up area	Poor
7	Bare Ground	Very Poor
8	Rangeland	Moderate

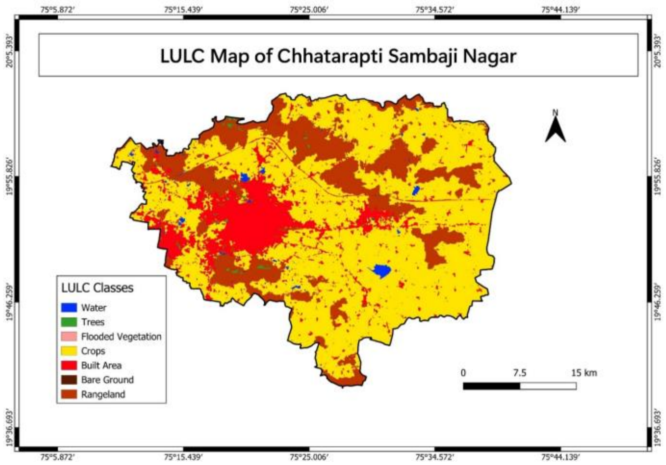

Fig.8 : Land use Land Cover Map of Study Area

3.7 Soil Map

Soil types significantly influence recharge. Loamy and sandy soils allow better infiltration, while clayey soils restrict water movement, reducing groundwater availability.

Table 7: Soil type Category

Sr. No	Soil type	Ground water potential
1	Clay Loam	High
2	Clay	Very poor

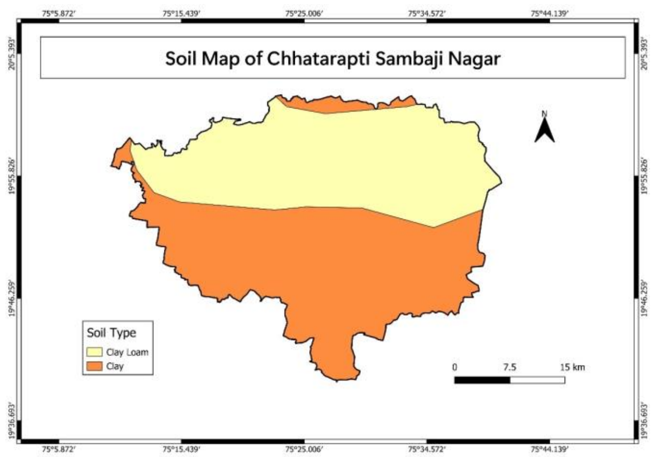

Fig.9 : Soil Map of Study Area

4. Integration (Assigning Rank and Weight)

The various factors influencing the groundwater potential of the area, as previously discussed, were assessed using knowledge-based weightages and rankings specific to the study region. These inputs were applied in a weighted average overlay analysis using raster tools to determine the groundwater potential zones. The parameters used in the analysis, along with their assigned weights and ranks, are presented in Table–8.

Table 8 : showing Ranking and Weightage Used for Ground water Potential Zone

Parameter	Class	Ground water Prospect	Weight (%)	Rank
Elevation (m)	<= 590	Very good	27	1
	591-674	Good		2
	674-759	Moderate		3
	760-844	Poor		4
	>844	Very poor		5
Geomorphology	Fluvial Origin	Very good	23	5
	Water Bodies	Good		4
	Structural origin	Moderate		3
	Anthropogenic origin	Poor		2
	Denudational origin	Very Poor		1
NDVI	<= 0.0320	Very Poor	18	1
	0.0320 – 0.1414	Poor		2
	0.1414-0.3148	Moderate		3
	0.3148-0.4882	Good		4
	>0.4882	Very good		5
Drainage Density Km/km2	0.0233 – 0.4598	Very good	12	5
	0.4599 – 0.6211	Good		4
	0.6212 – 0.7586	Moderate		3
	0.7587 – 0.9057	Poor		2
	0.9058 – 1.233	Very Poor		1
Slope (Degrees)	Nearly level < 1.4	Very good	11	5
	Very gently sloping 1.41-3.19	Good		4
	Gently Sloping 3.2 -6.38	Moderate		3
	Moderately Sloping 6.39-12.2	Poor		2
	Steeply Sloping 12.3 – 50.8	Very Poor		1
LULC	Water	Very good	5	
	Trees	Good		
	Flooded vegetation	Good		
	Crops	Moderate		
	Built up area	Poor		
	Bare Ground	Very Poor		
	Rangeland	Very Poor		
Soil Map	Clay Loam	High	4	4
	Clay	Very Poor		1

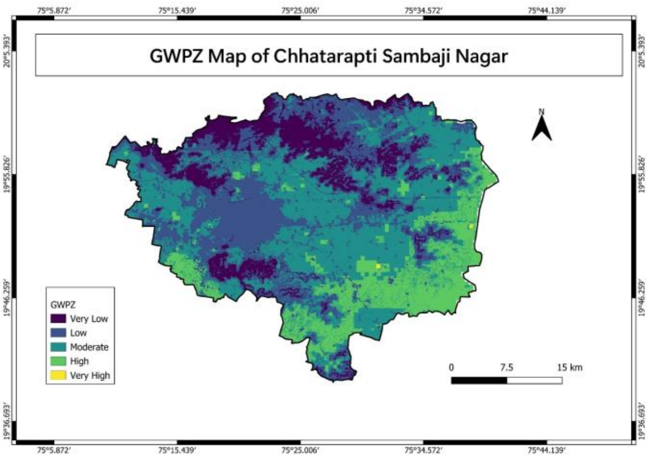

Fig.10 : Ground water Potential Zone Map

Table 9: Ground water potential zone Area

Class	Area in Sq. Km	Area (%)	Groundwater Potential Zone
1	186.6078	14.15975	Very Poor
2	419.8644	31.85921	Poor
3	494.8578	37.54969	Moderate
4	215.9676	16.38757	Good
5	0.5769	0.043775	Very Good

Groundwater potential zones in Chhatrapati Sambhaji Nagar district were delineated using a weighted overlay analysis of various thematic layers such as Elevation, Geomorphology, NDVI, Drainage Density, Slope, LULC, and Soil. Each layer was assigned specific weights and ranks based on its impact on groundwater recharge.

Elevation, carrying the highest weight (27%), revealed that lower elevations (≤ 590 m) were more conducive to recharge, while higher elevations (> 844 m) were less favorable. Geomorphology (23%) indicated that fluvial features and water bodies provided high potential, whereas denudational and man-made landscapes had limited recharge capacity. NDVI values also influenced potential—areas with dense vegetation (NDVI > 0.4882) promoted infiltration, while barren zones (NDVI ≤ 0.0320) were least favorable.

Areas with low drainage density (< 0.4598 km/km^2) and gentle slopes (< 1.4°) supported recharge, unlike regions with high drainage density and steep slopes (> 12.3°), which hindered it. Land Use/Land Cover analysis rated forests and water bodies as having good to very good potential, agricultural land as moderate, and built-up and barren land as poor. Soil type played a role too—clay loam allowed better infiltration, whereas clayey soils were less permeable.

Based on these inputs, the district was categorized into five groundwater potential zones, ranging from Very Poor to Very Good. The majority of the area falls under moderate to poor zones, with only select low-lying regions exhibiting very good potential due to favorable conditions. This comprehensive methodology provides a reliable framework for sustainable groundwater resource planning.

5. CONCLUSIONS

- Remote sensing and GIS techniques were found to be efficient tools for identifying groundwater potential zones in Chhatrapati Sambhaji Nagar district.
- A weighted overlay analysis was used to integrate multiple thematic layers including elevation, geomorphology, NDVI, drainage density, slope, LULC, and soil.
- Elevation and geomorphology emerged as key factors influencing the region's groundwater recharge potential.
- A significant portion of the district is categorized under moderate to poor potential zones, suggesting a risk of groundwater shortage.
- High groundwater potential is mostly confined to low-lying areas where surface and subsurface conditions are favorable.
- The findings highlight the importance of focused groundwater management initiatives, such as implementing artificial recharge systems and promoting watershed development.
- This approach can be replicated in other semi-arid regions to support sustainable groundwater resource planning.
- Future studies may incorporate field verification and water quality analysis to improve the reliability of groundwater potential mapping.

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