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# Identification of Groundwater Potential Zone of Chhatrapati Sambhajinagar Tehsil Using Remote Sensing and GIS Technique

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**_Abstract_**

*Groundwater is one of the most vital and renewable natural resources, playing a key role in sustaining domestic, agricultural, and industrial activities, particularly in semi-arid regions like Chhatrapati Sambhajinagar tehsil in Maharashtra. The growing population, rising water demand, and irregular rainfall patterns have resulted in a pressing need to locate potential groundwater zones for sustainable water management. This research employs Remote Sensing (RS) and Geographic Information System (GIS) techniques to assess and map groundwater potential zones (GWPZ). Key thematic layers, such as geology, geomorphology, slope, soil type, drainage density, lineament density, and land use/land cover (LULC), were generated using satellite imagery and supplementary data sources. These layers were assigned relative importance through the Analytical Hierarchy Process (AHP) and combined using GIS-based overlay methods. The study area was subsequently classified into five categories of groundwater potential: very high, high, moderate, low, and very low. The findings highlight the value of integrating RS and GIS approaches for identifying suitable areas for groundwater development, particularly in semi-arid environments.*

**Keywords:** Groundwater potential zones, remote sensing, GIS, analytical hierarchy process, weighted overlay, Chhatrapati Sambhajinagar, thematic layers

## INTRODUCTION

### Importance of Groundwater in India

Groundwater is a crucial resource in India, extensively used for drinking, irrigation, and industrial activities. In rural areas, particularly, it plays a crucial role in sustaining livelihoods by supporting irrigation, which in turn drives food security. It is estimated that nearly 60% of irrigation and 85% of domestic water requirements in India are met through groundwater [1–7].

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### Challenges in Groundwater Management

Although groundwater is vital, it is increasingly threatened by excessive withdrawal, lack of regulation, and rising pollution levels. In many regions, falling water tables and unpredictable monsoon patterns are worsening the crisis. This calls for scientific methods to evaluate and manage groundwater resources sustainably.

### Significance of Chhatrapati Sambhajinagar Tehsil

Chhatrapati Sambhajinagar tehsil, located in Maharashtra, falls in a semi-arid region with limited surface water resources and erratic rainfall patterns. The region is vulnerable to frequent droughts and water scarcity. Groundwater is the primary source of water for agriculture and domestic use here, making its systematic exploration and management critically important [8].

**Scope of Remote Sensing and GIS**

Advanced technologies such as Remote Sensing (RS) and Geographic Information Systems (GIS) provide effective means for investigating, analyzing, and mapping natural resources, particularly groundwater. These tools help in the generation and integration of multiple thematic layers, such as geomorphology, soil, slope, and drainage patterns, over large areas. When coupled with decision-making models like the Analytical Hierarchy Process (AHP), they can effectively delineate groundwater potential zones, aiding in better water resource planning and conservation [9].

## OBJECTIVES

1. Carrying out image processing of Landsat OLI and SRTM data.
2. Carrying out SRTM DEM based drainage network.
3. Generation of thematic layers such as Slope, Elevation, Drainage Density, LULC, NDVI Geomorphology, and Soil map.
4. To find out the suitable areas for the Groundwater Potential zone by integration of all thematic layers [10].

## STUDY AREA

### Geographical Setting

The study area, Chhatrapati Sambhajinagar tehsil, is located in the central region of Maharashtra. It lies between 19.87°N latitude and 75.34°E longitude and covers an area of approximately 1,292.65 $km^2$.

### Climate and Rainfall

The region experiences a semi-arid climate with hot summers and mild winters. The average annual rainfall is about 710 mm, most of which is received during the monsoon months (June to September).

### Soil and Drainage

The predominant soil types found in the region are clayey and loamy, which have moderate to low infiltration capacities. The drainage pattern is mostly dendritic, with seasonal rivers and streams that influence the runoff and groundwater recharge dynamics [11].

### Geology

Geologically, the area is characterized by basaltic formations of the Deccan Traps. These formations, often fractured and weathered, play a significant role in controlling groundwater movement and storage [12].

## MATERIAL AND METHODOLOGY

### Data Uses

#### *Digital Elevation Model (DEM)*

The Shuttle Radar Topography Mission (SRTM) data of 30 m resolution was downloaded from http://edc.usgs.gov.

#### *Satellite Images*

LANDSAT OLI images of project area were downloaded from the site USGS. http://edc.usgs.gov [13].

- Processing of 30 m SRTM DEM downloaded from USGS website.
- Image processing of LANDSAT OLI data to prepare Land use/Land Cover Map.
- Extraction of drainage network from DEM.
- Generation of drainage density map.

 

- Preparation of geomorphological and lineament map of the area.
- Integration of influencing parameters like Slope, Drainage density, Lineament density, LULC and Geomorphology using weighted overlay analysis in ARCGIS.

***Band Information***

11 bands: Seven bands (1, 2, 3, 4, 5, 6, and 7) including Blue, Green, Red, Near Infrared (NIR), SWIR 1, SWIR 2 spectral regions at a resolution of 30 m [14].

Band 1 (Coastal aerosol), Band 8 (Panchromatic), Band 10 (Thermal Infrared 1), and Band 11 (Thermal Infrared 2) have spatial resolutions of 30, 15, 100, and 100 m, respectively. Although the thermal infrared (TIR) bands are originally captured at a 100-m resolution, they are resampled to 30 m in the final data products provided [14].

**Data Processing**

SRTM DEM and Landsat data are corrected for data errors and noise using some pre-processing utilities for data normalization. SRTM DEM was filled to remove sinks or no data values in the dataset. ArcGIS Spatial Analyst tool provides fill tool under hydrology for removing sinks. Then flow direction raster depicting eight flows direction is generated. Subset raster is created from SRTM DEM representing the area of interest for the study. For drainage extraction, flow accumulation raster is generated. After creating flow accumulation raster, conditional statement is given in which the flow accumulation greater than 500 pixels was considered for further processing. The extracted drainage was divided into different orders using Strahler's method. Finally, stream raster is converted into feature (line feature) by using stream to feature tool. The drainage basins were created using basin tool under hydrology tools. The basin was defined by specifying pour points, which represent locations where water exits a particular area. The resulting basin raster was then transformed into a vector polygon using the raster-to-polygon conversion tool. To create the drainage network, flow accumulation was analyzed by considering the flow direction of individual cells [15, 16].

**Software Used**

QGIS software is used for successful accomplishment of the desired aim of this project.

- *Saga tool:* This tool has been used for carrying out drainage analysis of the area.
- *Extract by mask tool:* This tool has been used for the extraction of all the details pertaining to or restricted to the study area only.

***Slope Map***

Slope represents the steepest rate of elevation change over a given distance. Creating a slope map allows for the analysis of terrain variation at both local and regional scales, which is useful in identifying structural features such as fault scarps and tilted rock layers. In GIS, slope maps can be generated using tools available in spatial analysis functions. For example, in QGIS, the slope map can be produced by navigating to: Raster > Analysis > Slope (Figure 1) [17].

***Drainage Delineation***

The process of preparing a drainage map in QGIS begins with the acquisition and loading of a Digital Elevation Model (DEM) into the software. To ensure accurate hydrological analysis, the DEM is first processed to fill any sinks or depressions using tools such as the GRASS r.fill.dir or SAGA Fill sinks, creating a depressionless DEM. Subsequently, the flow direction is generated, indicating the path water would naturally follow across the terrain. This is followed by the calculation of flow accumulation, which highlights potential stream channels by identifying areas where surface runoff would converge. Based on the flow accumulation raster, stream networks are derived by applying a threshold value to define the initiation of streams. These raster streams are then vectorized to create a stream network layer. To provide a hierarchical structure to the drainage network, stream ordering is applied using

 

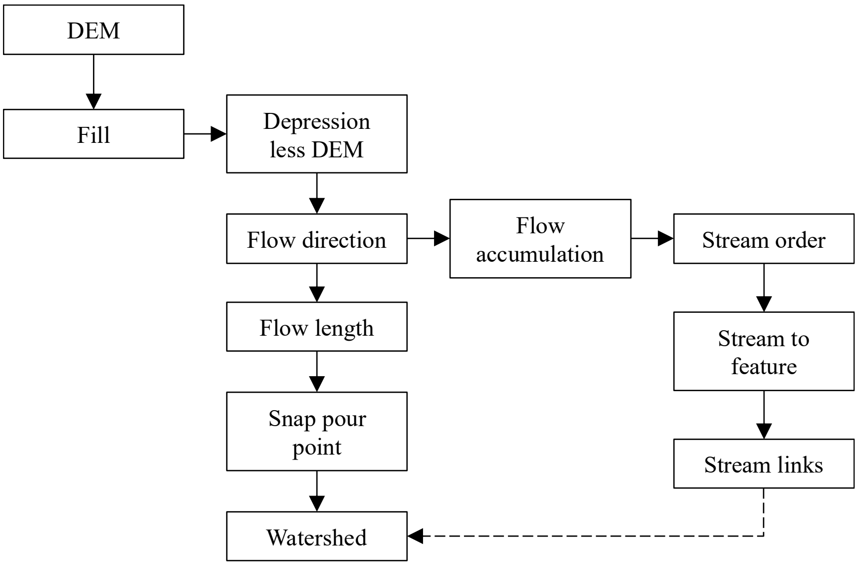


**Figure 1.** Steps involved in delineation of watershed.
*(Source: GIS Resources: A Knowledge Archive)*

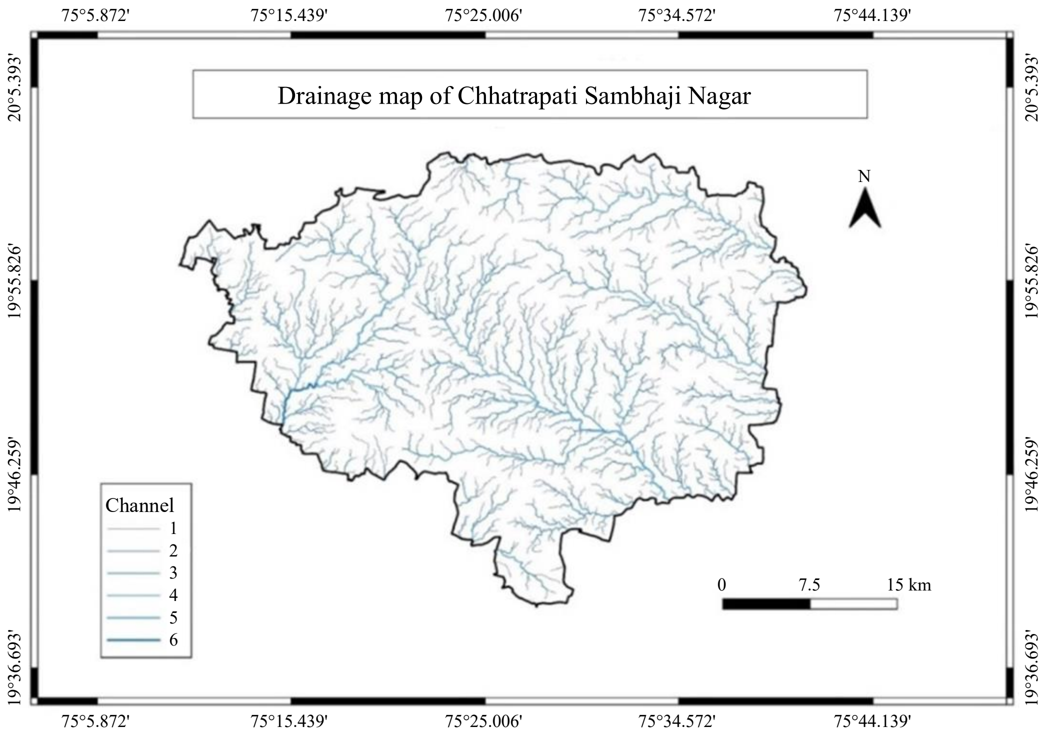


**Figure 2.** Drainage map of study area.

methods like the Strahler system. Optionally, watershed boundaries can also be delineated by defining pour points and running watershed analysis tools. The final outputs include a detailed drainage network and watershed map, essential for hydrological modeling and watershed management studies (Figure 2) [18, 19].

## 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.

## Elevation

Areas below 590 m exhibit very high groundwater potential due to flat terrain and enhanced infiltration, whereas regions above 844 m show poor potential due to steep slopes and runoff (Table 1 and Figure 3) [20, 21].

## Slope

Nearly flat to very gentle slopes support better infiltration and thus higher groundwater potential. Steeper slopes correspond to reduced recharge (Table 2 and Figure 4).

**Table 1.** Elevation and category wise area distribution.

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

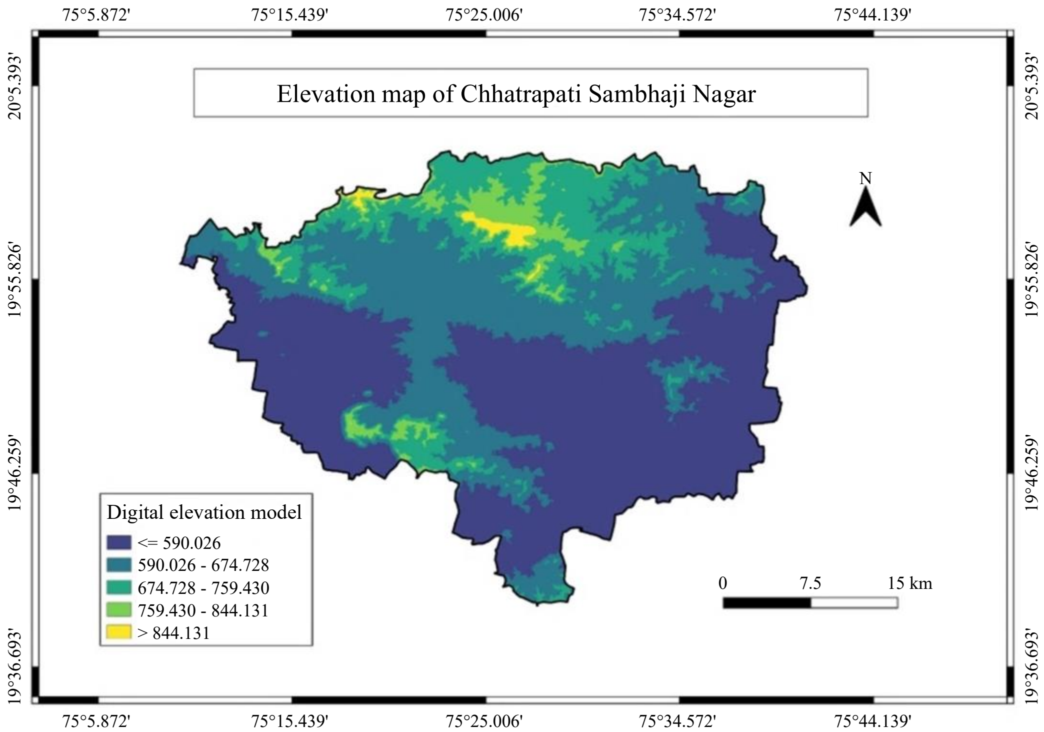


**Figure 3.** No rainfall map of Chhatrapati Sambhajinagar District.

**Table 2.** Slope gradient and category wise area distribution.

| Class | Slope (°) | 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 |

 

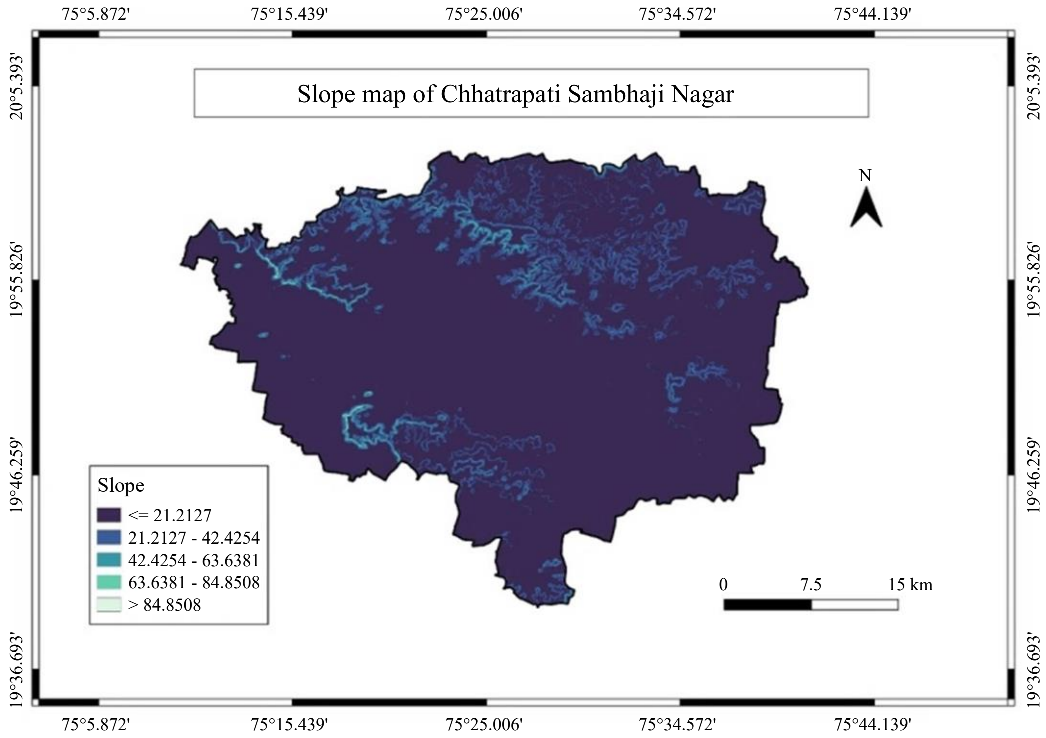


**Figure 4.** Slope map of study area.

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 [22].

**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 and Figure 5) [23].

**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 and Figure 6) [24].

**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 and Figure 7).

**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 |

 

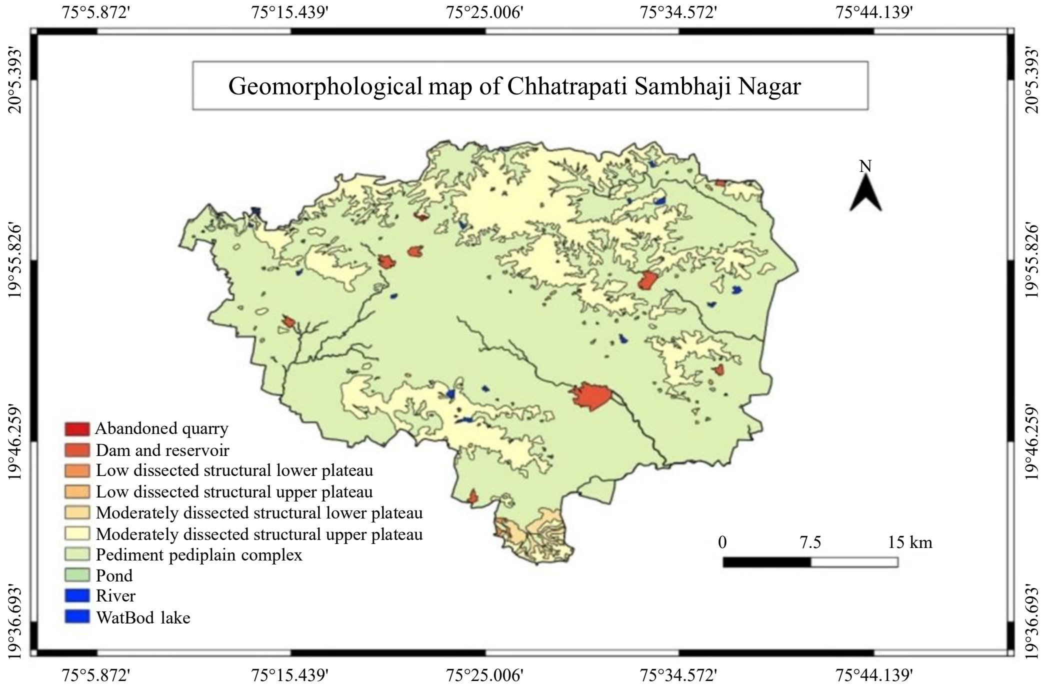


**Figure 5.** Geomorphological map of study area.

**Table 4.** Drainage density category.

| Class | Drainage density (km/km$^2$) | 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 |

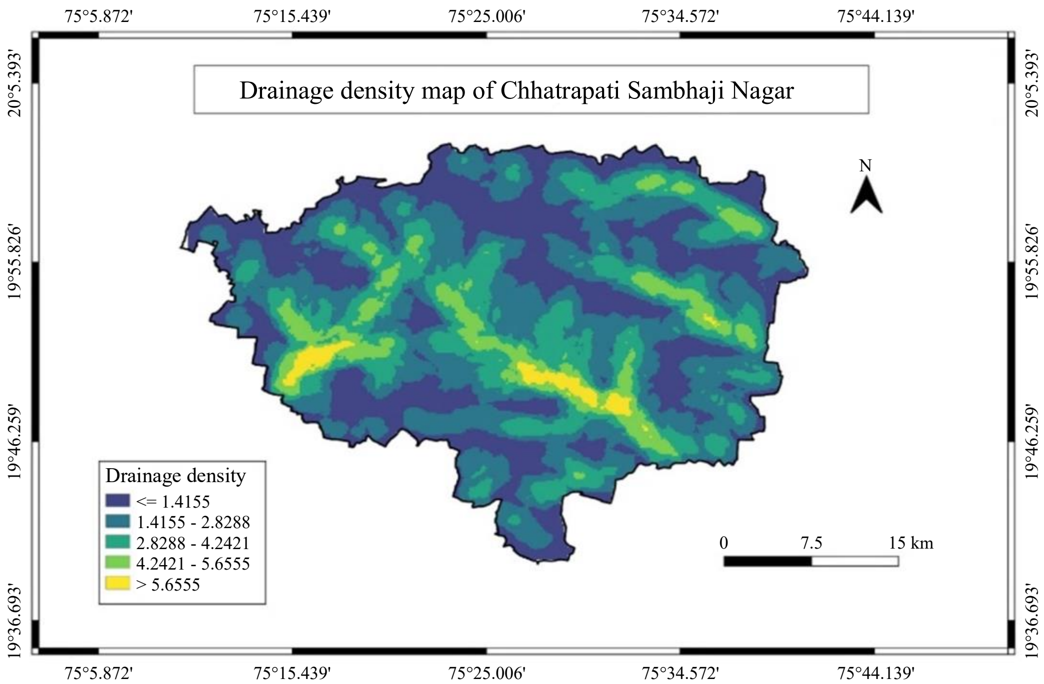


**Figure 6.** Drainage density map of study area.

 

**Table 5.** NDVI range table.

| S.N. | 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 |

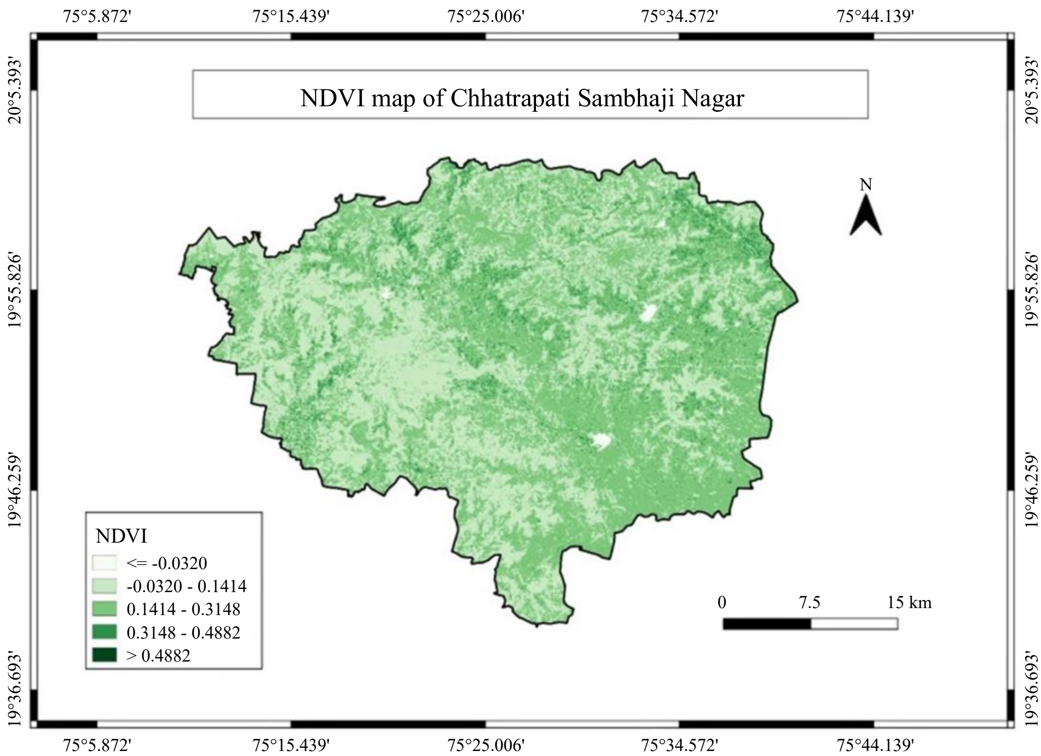


**Figure 7.** NDVI map of study area.

### 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 and Figure 8).

### 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 and Figure 9).

**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 |

 

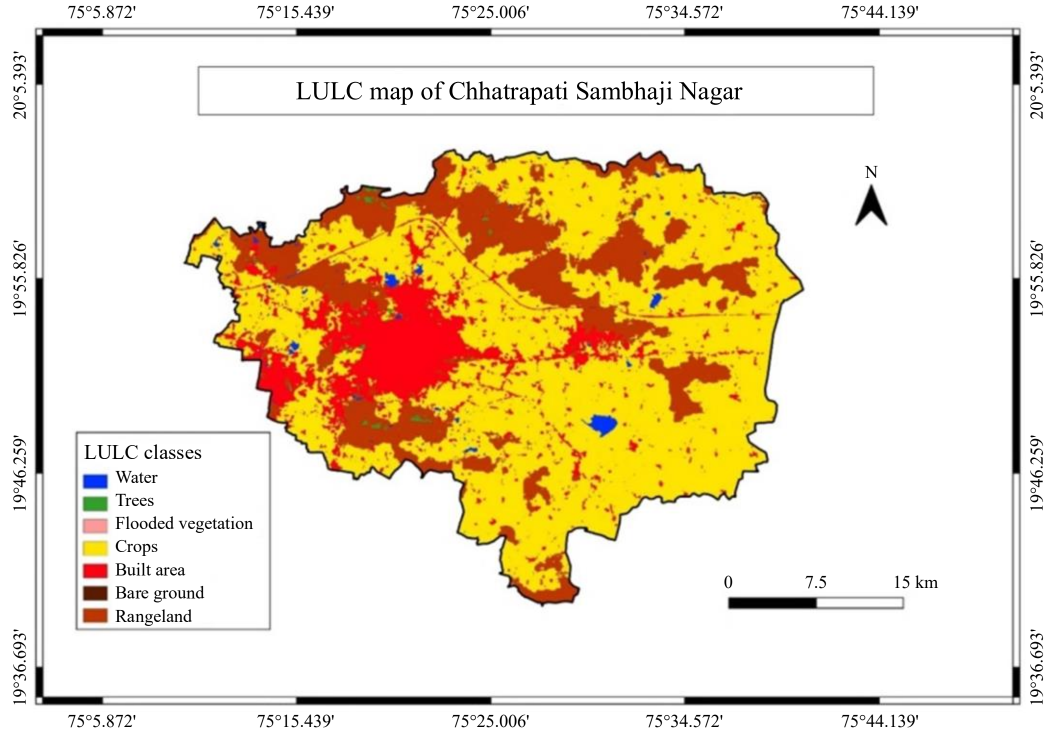


**Figure 8.** Land use land cover map of study area.

**Table 7.** Soil type category.

| S.N. | Soil type | Ground water potential |
|---|---|---|
| 1 | Clay loam | High |
| 2 | Clay | Very poor |

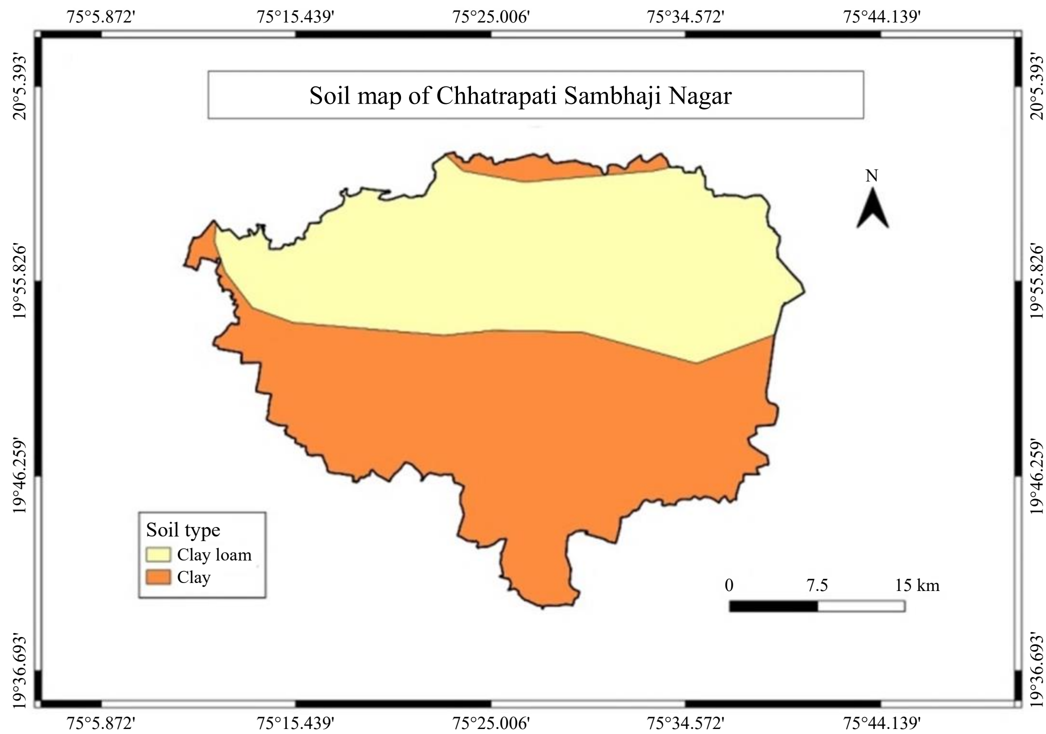


**Figure 9.** Soil map of study area.

## INTEGRATION (ASSIGNING RANK AND WEIGHT)

The various influencing factors towards ground water potential of the area, as discussed above have been considered as per the knowledge driven weightages and ranks for the study area have been utilized in arriving at the ground water potential of the area using the weighted average overlay analysis raster tool. The different parameters considered in this study along with the relevant weightage and ranks applied, have been tabulated in Tables 8 and 9, and Figure 10.

**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/km$^2$) | 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 (°) | 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 |

**Table 9.** Ground water potential zone area.

| Class | Area (km$^2$) | 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 |

 

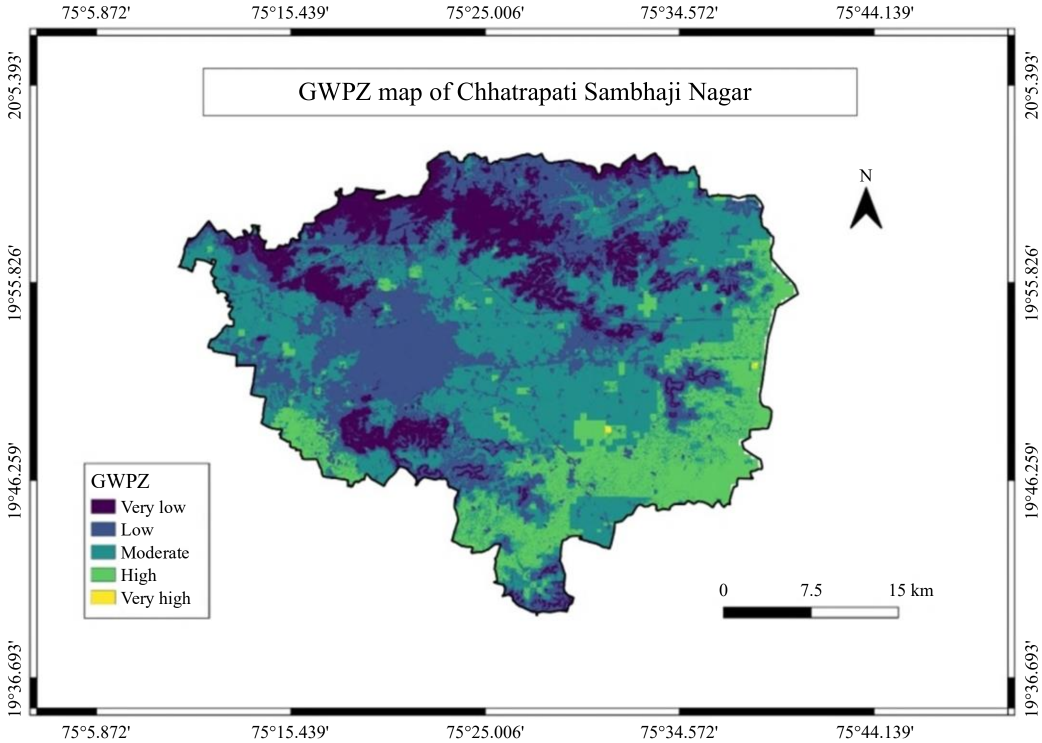


**Figure 10.** Ground water potential zone map.

Groundwater potential zones in Chhatrapati Sambhaji Nagar district were identified using a weighted overlay analysis of thematic layers including Elevation, Geomorphology, NDVI, Drainage Density, Slope, LULC, and Soil. Weights and ranks were assigned based on each parameter's influence on groundwater recharge.

Elevation (27% weight) was a major factor: lower elevations (≤590 m) favored recharge, while higher areas (>844 m) were less suitable. Geomorphology (23%) showed fluvial landforms and water bodies as highly favorable, while denudational and anthropogenic features had poor potential. NDVI indicated better potential in vegetated zones (NDVI>0.4882) due to higher infiltration, while barren areas (NDVI≤0.0320) showed very poor potential.

Low drainage density (<0.4598 km/km²) and gentle slopes (<1.4°) supported infiltration, whereas high drainage density and steep slopes (>12.3°) reduced recharge. LULC analysis rated water bodies and forests as very good to good, agriculture as moderate, and built-up and barren lands as poor. Soil type also influenced recharge: clay loam supported good infiltration, while clayey soils hindered it.

The resulting map classified the district into five zones: Very Poor to Very Good. Most areas fall under moderate and poor categories, while only a few low-lying regions with favorable land use and soil showed very good potential. This integrated approach offers a scientific basis for sustainable groundwater management.

## CONCLUSION

- Remote Sensing and GIS proved effective for delineating groundwater potential zones in Chhatrapati Sambhaji Nagar district.
- Thematic layers (elevation, geomorphology, NDVI, drainage density, slope, LULC, and soil) were integrated using a weighted overlay approach.
- Elevation and geomorphology were found to be the most influential factors in groundwater recharge potential.

 

- A major portion of the district falls under moderate to poor groundwater potential zones, indicating vulnerability to groundwater scarcity.
- Very good groundwater potential is limited to low-lying areas with favorable surface and subsurface conditions.
- The study emphasizes the need for targeted groundwater management strategies, such as artificial recharge structures and watershed development.
- The methodology can be applied to other semi-arid regions for sustainable groundwater planning.
- Future research can include field validation and water quality assessment to enhance the accuracy of groundwater zone mapping.

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