REMOTE SENSING AND GIS TECHNIQUE WERE USED TO EVOLUTION THE GROUNDWATER POTENTIAL ZONE IN BULDANA TALUKA, MAHARASHTRA, INDIA

Abstract

Groundwater exploration using remote sensing data and a geographic information system (GIS) has become a breakthrough in the field of groundwater research, assisting in the assessment, monitoring, and conservation of groundwater resources. Groundwater is a valuable natural resource and one of the most basic requirements for human survival. Overexploitation, on the other hand, has severely reduced groundwater supplies. The ability to assess the potential zone of groundwater is critical for effective groundwater management. In this work, groundwater potential zones were assessed using remote sensing and Geographic Information System (GIS) techniques, and a composite groundwater potential map of the research region was created. This methodology was proved in the current study for a specific research region in Maharashtra.

Slope, land use, drainage density, geomorphology, and lineament density were all hierarchically used and merged with weighted overlay in ArcGIS by assigning appropriate ranks to each category of these factors. Based on a knowledge-driven methodology, the weighting factor for each category is determined based on its predicted capabilities in terms of groundwater potential. The resulting groundwater potential zones were categorised into five categories: very poor, poor, moderate, good, and very good, which were validated to some extent with the CGWB field / ground database, with encouraging findings.

Keywords: Remote sensing, GIS, Weighted overlay, Thematic map.

Author

Ranjana R. Gawande
Ph.D Associate Professor
Deogiri College, Aurangabad
Maharashtra
drrrgawande@gmail.com

I. INTRODUCTION

Groundwater is an important natural resource that contributes to human health, economic prosperity, and biological diversity. It has become an extremely significant and dependable supply of water in all climatic regions, including both urban and rural areas of developed and emerging countries, due to its many natural features. Groundwater is a type of water that fills all of the spaces in a geological layer. Water-bearing strata in the earth's crust serve as transmission conduits and storage reservoirs. The establishment of porosity determines the presence of groundwater in a geological formation and the extent to which it can be exploited.

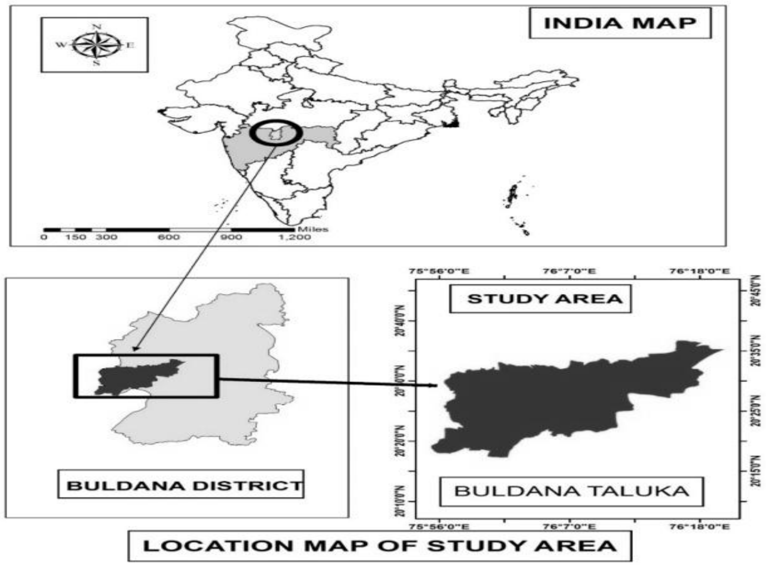
The increasing importance of groundwater as a result of increased demand has led to improper groundwater mining, resulting in a water stress situation. This perilous condition necessitates the development of a low-cost, quick-to-implement method for assessing groundwater resources and developing management strategies. Groundwater potential zones can be identified using several hydrological themes, but remote sensing and Geographic Information System (GIS) tools can offer up new avenues in water resource studies. The indirect examination of directly observable terrain aspects such as geological structure, geomorphology, and associated hydrologic characteristics is used to identify groundwater occurrence using remote sensing data.

The use of remote sensing and GIS tools to extract detailed drainage, slope, and geomorphic features (1-9) in parts of the study region, which suggests appropriate approaches for demarcation of groundwater potential zone and morphometric analysis in drainage parameter investigations. In recent years, morphometric analysis employing remote sensing and GIS techniques has developed as a strong tool. Drainage basins are the primary units for understanding morphometric aspects of fluvial landscapes, such as stream network geology and drainage texture pattern form and relief features. Morphometric analysis is a useful tool for assessing and comprehending the behaviour of hydrological systems.

The hydrological character of the rock exposed within the watershed can be determined using a quantitative morphometric examination of the watershed. A basin drainage map is a good indicator of rock permeability and the relationship between rock type, structure, and hydrological parameters.

1. **Groundwater's Importance:** Water is essential for people's survival and livelihood. Many people in many parts of the world do not have access to clean, drinkable water. Groundwater, unlike other natural resources or raw commodities, is found all around the planet. Due to varying rainfall circumstances and distribution in relation to aquifers, the concept's possibilities vary drastically from place to location (rocks, sandy layers and so on, in whose pore spaces the groundwater sites vary). Groundwater is often renewable just for a portion of each year's season, yet it must be abstracted all year because its occurrence is limited. The availability of groundwater, which is an important and vital aspect of the hydrological cycle, is dependent on rainfall and recharge conditions. Until recently, it was thought to be a reliable source of uncontaminated water.

2. **Location and Study Area:** Buldhana district is located in Maharashtra's Amravati division in western India. Buldhana District is located between 20° 32' north latitude and 76° 14' east longitude. It is 500 kilometres from the state capital, Mumbai, and is located on the westernmost frontier of Maharashtra's Vidarbha area. It is bordered on the north by Madhya Pradesh, on the east by Akola, Washim, and Amravati districts, on the south by Jalna district, and on the west by Jalgaon and Aurangabad districts. Buldhana is significant religiously since it is home to the Shri Gajanan Maharaj shrine at Shegaon. Shegaon, Khamgaon, Lonar, Mehkar, and Dongaon are some of the towns and cities in the district.



Map No. 1: Study area location map

3. **Objects and Goals:** The goal of this study is to understand the evolution of the groundwater zone in the Godavari Sub-Basin by analysing remotely sensed data on a GIS platform. The drainage network for the entire District was retrieved from a 30 m SRTM DEM acquired from the USGS website to achieve this goal. The study's goals are as follows:

4. **Using Landsat OLI and SRTM data to do image processing.**

- To integrate remotely sensed data to create various thematic maps for the study area's groundwater potentiality, such as a drainage map, an aspect map, a soil map, a mini-micro watershed map, a geomorphological map, a slope map, a land-use/land-cover map, a lineament map, and a groundwater potential map.

- Using remote sensing and GIS, investigate the geomorphological characteristics and geological investigations of Buldhana taluka.

- Recommend, if possible, corrective steps for water resource conservation and management in the research region.

- Using remotely sensed data, the groundwater potential zone of Buldhana taluka was assessed.

5. The following were involved in the research:

- LANDSAT OLI data image processing

- 30 m SRTM DEM obtained from the USGS website was processed.

- Slope, Aspect, and Hillshade Preparation The research area's contour map.

- Drainage network extraction from DEM.

- Drainage density map creation.

- The area's geomorphological and lineament map is being prepared.

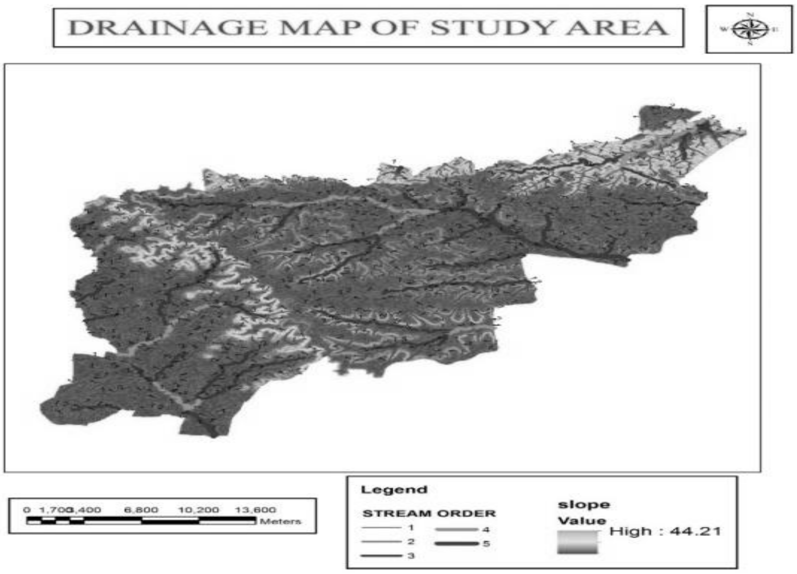
- Weighted overlay analysis in ARCGIS allows for the integration of influencing parameters such as slope, drainage density, lineament density, and geomorphology.

6. Rainfall and Climate: The district's climate is characterised by a scorching summer and general dryness throughout the year, with the exception of the south west monsoon season, which runs from June to September, and the post monsoon season, which runs from October to November.

The start of the winter season is towards the end of November, when temperatures start to drop fast. The coldest month is December, with a mean high temperature of 28.9° C and a mean minimum temperature of 10.3° C. The daily temperature has been steadily rising since the beginning of March. With a mean high temperature of 39.8°C and a mean minimum temperature of 24.6° C, May is the hottest month. By the second week of June, the south-west monsoon has arrived, and the temperature has dropped significantly.

The air is normally dry over the area, except during the southwest monsoon season, when relative humidity is high. Summer months are the driest, with relative humidity ranging from 20 to 25 percent in the afternoon.

7. Drainage: Climate, precipitation, isolation, cloudiness, wind direction, humidity, rock types, vegetation, soil, human activity, and other elements all contribute to the region's drainage. The drainage system is an important component of the physical environment that has direct and indirect effects on agriculture. In clean weather, ground water influent creates the basic flow that keeps streams flowing. When we talk about surface water, we're talking about stream flow, regardless of where it comes from. Buldhana district has a poorly developed drainage pattern. Purna and Penganga are the district's two major rivers. The tributaries of this river have been dispersed over the region.



Map No. 2: Study area drainage map

8. **Soil:** In general, soil refers to the earth's loose surface as opposed to solid rock. Soil is a thin layer of mineral particles created by the breakdown of rocks, decomposed organic materials, living organisms, water, and air that cover the earth's surface. Soil is generated under specific natural conditions, and each element of the natural environment contributes to this complicated process, known as pedagenesis by soil scientists.

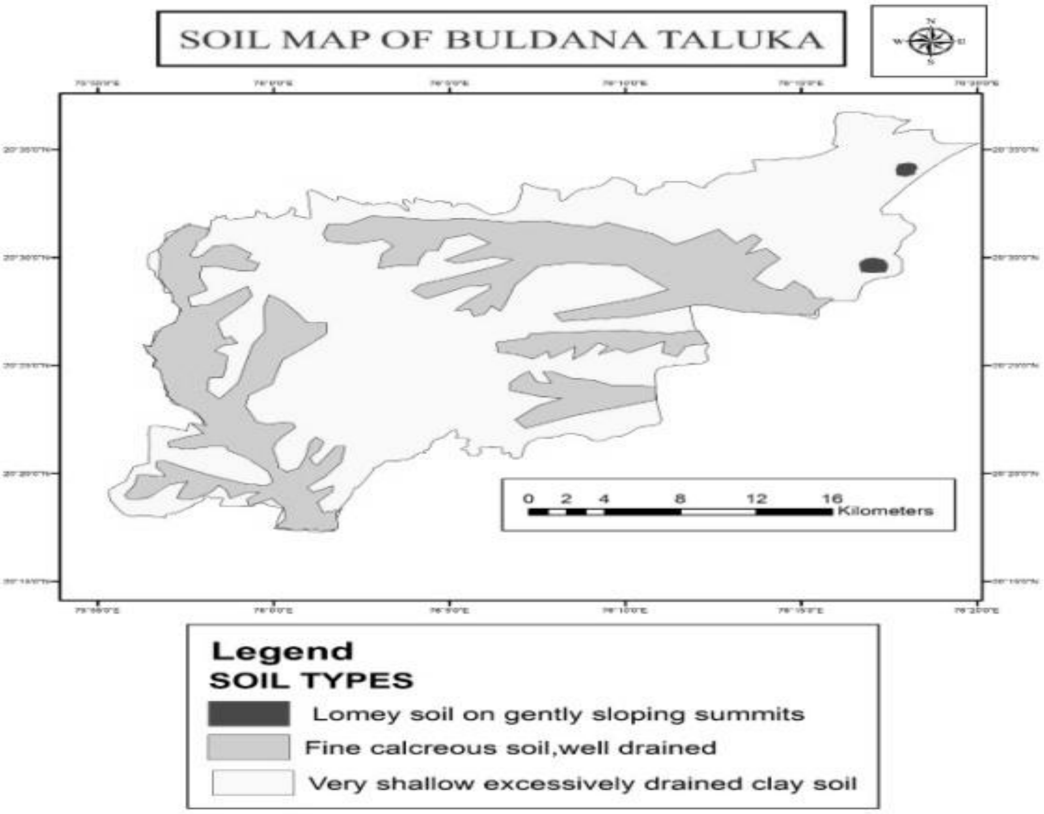
Soil is an extremely valuable natural resource. Because agricultural productivity is largely dependent on soil fertility. The parent rock composition, surface relief, climate, and natural vegetation all play a role in soil formation. It is a natural body of dirt that allows plants to grow and farms to thrive. The fertility and productivity of soils typically determine the standard of living of people who rely on agriculture.

Farming is a business, and a farmer's stock in trade is healthy soil. Good soils are only good to the extent that man uses them wisely. Great civilizations have virtually always thrived on fertile soils, particularly alluvium. Ratzel made a declaration of significant relevance and in sight even at the start of his work on political geography: "Jederstaalistein stuck moncheite." As a result, no student of civilization can afford to overlook the critical relevance of soils even for a moment. These are the sources of almost all of a man's food, clothing, and an ever-growing list of other requirements.

So much so that man derives nearly all of his nourishment from the soils, with fish accounting for less than 1% of his diet. The most essential aspects of human life are productive soils and water, which are among nature's many gifts to man. Even today, farmers account for roughly 66 percent of the world population, with 62 percent of their income coming straight from the land. Agricultural geographers place a high value on geographical investigations of soil characteristics. Soil characteristics, particularly physical qualities, assist us in determining crop distribution and soil selection for specific crops: this is referred to as the ‘selective' rather than the ‘prohibitive' influence of soils.

It can be split into three categories based on the physical features of the soil in the district.

- Soil that is coarse and shallow.
- Soil of a medium dark colour
- Soil with a deep black colour



Map No. 3: Study area soil map

The study area's geological setting is as follows:

9. **Geology of the Regions:** The Deccan Trap basaltic lava flows cover the district in a consistent pattern. Because of the step-like or terraced look of the lava flows' outcrops, they're dubbed traps. The lava flows indicate that there has been a lot of volcanic activity. The end of the Cretaceous epoch in India was marked by a massive eruption of volcanic activity in the form of a series of massive cracks. The eruptions did not occur in a continuous pattern, but rather at intervals separated by lengthy or short sequence periods. The Deccan Trap flows cover an area of around 5,00,000 square kilometres, encompassing parts of Maharashtra, Gujarat, Madhya Pradesh, Andhra Pradesh, and Mysore states. These fluxes have been grouped into the three categories below. (See Table)

Deccan Trap Classification (10-14)

Divisions	Distributions	Characters
Upper Traps (450m)	NW Peninsula	Lavaflows with ash beds and intertrappeans.
Middle Traps (1200)	Maharashtra and Madhya Pradesh	Lavaflows with ash beds.Intertrappeans are rare.
Lower Traps (150m)	Madhya Pradesh and Eastern areas	Lavaflows with many Intertrappeans.Ash beds are rare.

Deccan traps are a large pile of basaltic flows arranged horizontally and with a composition that appears to be more or less homogeneous. Each individual flow is a typical segment, with a porous worn base, a huge middle unit, and gradually vesicular top. The Deccan Trap's basaltic lava flows are the only important geological formation in the district; the lava flows are horizontal and each flow comprises two separate units. The topmost layers are made up of vesicular and amygdule zeolitic basalt, with massive basalt at the bottom. The middle traps occupy the Aurangabad district. The traps in the middle of two large divides. The district's geological sequence is as follows:

Alluvium is a type of soil that is rich in minerals. The term "recent" refers to something that happened recently or recently.

- **Cretaceous-Eocene Deccan Trap**

  - **The Study Area's Geology:** Geology is the study of the Earth, its materials, the structure of those components, and the processes that affect them. It encompasses the study of species that have lived on our planet in the past. The study of how Earth's materials, structures, processes, and species have changed over time is an essential element of geology. The Deccan volcanic, which date from the Cretaceous to the Eocene, cover the majority of the area, with a few alluvium patches from the Purna and Penganga basins. Fine to coarse-grained, dark grey to greenish-black basalts of vesicular and massive forms make up the trap rocks.

    The hard compact massive flows, such as the Melghat portion, are found on the hill summits, whilst the softer and amygdule variants are found on the slopes of the hill or valley floors. Weathering in the traps is characterised by spheroidal exfoliation. Columnar jointing, in addition to vertical and inclined jointing, is common in more substantial varieties. The vesicular and non-vesicular flows are divided by thin beds of ash or scoriae in some locations, but there are no typical inter-trappean sedimentary rocks in the area. Secondary minerals like as zeolites (mainly heulandite), calcite, and chalcedony are found in the amygdule variations of flows. In the district where a lava pile of about 800 metres has been preserved, no dykes linked with the trap flows have been discovered.

- **Methodology and Materials**

  - **Material:** The current research is based on a quantitative examination of geomorphic indices extracted from the SRTM DEM (30 M resolution). ArcGIS software was used to georeferenced all of the topographical maps and satellite pictures.

    The images are georeferenced before being corrected and projected using the Universal Transverse Mercator (UTM) projection WGS 1984, Zone 43 North.

  - **Processing of Information:** For data normalisation, SRTM DEM and Landsat data are rectified for data defects and noise using certain pre-processing utilities.

    The SRTM DEM was filled to remove sinks and data values that were not included in the dataset. For removing sinks, the ArcGIS Spatial Analyst tool has a fill option under hydrology. After that, a flow direction raster displaying eight different flow directions is created. The study's area of interest is represented by a subset raster produced from an SRTM DEM.

    A flow accumulation raster is created for drainage extraction. Following the creation of the flow accumulation raster, a conditional statement is given, stating that any flow accumulation bigger than 500 pixels should be evaluated for further processing. Strahler's approach was used to separate the extracted drainage into several groups. Using the stream to feature tool, the stream raster is finally turned into a feature (line feature).

    Basin tool under hydrology tools was used to design drainage basins. Pour points, or locations where water flows out of a region, were used to define the basin. The retrieved basin (raster) was then turned into a feature (vector) polygon using the raster to polygon conversion tool. Flow accumulation has been taken into account based on the direction of flow of each cell in order to construct a drainage network.

  - **Information that was used:** Digital Elevation Model (DEM) - 30 M resolution data from the Shuttle Radar Topography Mission (SRTM) was downloaded from http://edc.usgs.gov. LANDSAT OLI photos of the project area were retrieved from the USGS website. https://www.edc.usgs.gov/ 46 and 146 are the row and path numbers respectively. Information about the bands – there are 11 of them.

    Blue, Green, Red, Near Infrared (NIR), SWIR 1, SWIR 2 spectral areas are represented by seven bands (1, 2, 3, 4, 5, 6, and 7) with a resolution of 30 m. The resolution of Band 1 (Coastal aerosol), Band 8 (Panchromatic), Band 10 (Thermal Infrared 1), and Band 11 (Thermal Infrared 2), respectively, is 30 m, 15 m, 100*(30 m), and 100*(30 m). TIRbands are acquired at a resolution of 100 metres, however the given data output is resampled to 30 metres.

Table 1: Characteristics of the OLI data

	BANDS	**WAVELENGTH**	**RESOLUTION**
LANDSAT 8 OPERATIONAL LAND IMAGER (OLI) THERMAL INFRARED SENSOR (TIRS) LAUNCHED FEB 11, 203	Band 1 – coastal aerosol	0.43- 0.45	30
	Band 2- Blue	0.45- 0.51	30
	Band 3- Green	0.53- 0.59	30
	Band 4 – Red	0.64- 0.67	30
	Band 5 – Near infrared (NIR)	0.85- 0.88	30
	Band 6 – SWIR 1	1.57- 1.65	30
	Band 7 – SWIR 2	2.11- 2.29	30
	Band 8 – Panchromatic	0.50- 0.68	15
	Band 9 – Cirrus	1.36- 1.38	30
	Band 10 –Thermal Infrared (TIRS)1	10.60- 11.19	100* (30)
	Band 11 – Thermal Infrared (TIRS)2	11.50- 12.51	100* (30)

The nine spectral bands in the Landsat 8 OLI and TIR images have a spatial resolution of 30 metres for Bands 1 to 7 and 9. With a spectral range of 0.43-0.45, Band 1 (ultra-blue) is useful for coastal and aerosol research. Three visible bands between 0.45-0.67 m, one near infrared (NIR) band between 0.85 - 0.88 m, and two Short Wave Infrared (SWIR 1 and SWIR 2) bands between 1.57-2.29 m make up Bands 2, 3, and 4. With a spectral range of 1.36-1.38, Band 9 is effective for detecting cirrus clouds. Band 8 (panchromatic) has a resolution of 15 metres and a spectral range of 0.50-0.68 m. Thermal bands 10 and 11, which have a spectral range of 10.60-12.51 m and are gathered at 100 metres, are effective for delivering more accurate surface temperatures. TIR bands (10 and 11) are acquired at 100 metre resolution, but the provided data output is resampled to 30 metres.

Here's an overview of some popular Landsat 8 band combinations, [15], represented as a Red, Green, Blue (RGB) chart:

Applicable Software The project's objective goal is achieved with the help of Arc GIS software. ArcGIS software was used to do the DEM-based analysis and image interpretation. The spatial analyst tool, 3D Analyst tool, Conversion tool, and other tools were used for the majority of the job.

- 1-Surface tool: This tool was used to prepare the slope, aspect, contour map, and so on.
- 2-Hydrology tool: This tool was used to do a drainage analysis in the area.
- 3- Extraction tool: This tool was used to extract all information relevant to or restricted to the study region exclusively.

Table 2: Combination of bands

APPLICATION	RGB
Natural color	4 3 2
False color (urban)	7 6 4
Color Infrared (vegetation)	5 4 3
Agriculture	6 5 2
Atmospheric Penetration	7 6 5
Healthy Vegetation	5 6 2
Land / Water	5 6 4
Natural with Atmospheric Removal	7 5 3
Shortwave Infrared	7 5 4
Vegetation Analysis	6 5 4

II. INTERPRETATION AND INTEGRATION

There are two terms that are often used interchangeably

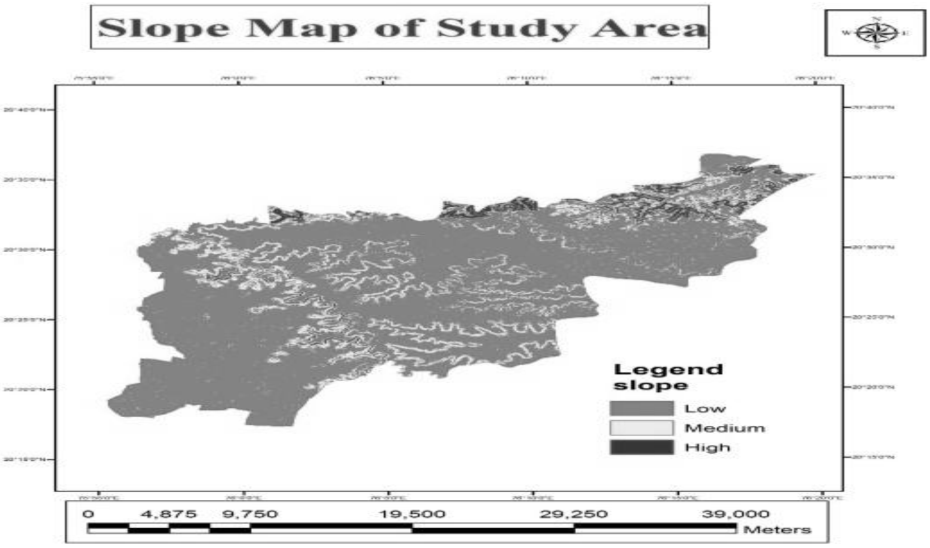
The interpretation and processing of remotely sensed data (16-17), together with GIS analysis, is a powerful tool for determining a region's ground water potential.

For analysing the ground water potential of an area, several thematic aspects impacting the ground water potential of an area must be taken into account. Slope, Geomorphology, Drainage Density, and Lineament Density are four topic parameters studied in this study. Where to consider arriving at the research area's ground water potential based on its projected influence on topographical characteristics. The following chapter delves into these four thematic characteristics in further depth:

Slope The area's freely available 30m resolution SRTM DEM was obtained and processed to produce a derivative-like slope map. The resulting map was divided into five discrete divisions based on slope characteristics: 0- 20 Nearly flat slope, 20-60 extremely soft slope, 60-120 gentle slope, 130-200 moderate slope, 21-470 high slope.

Table 3: Slope gradient and area distribution per category

Class	Degree	Area %	Slope Category	Ground Water Potential
1	0- 2	45	Nearly flat	Very good
2	2 - 6	39	Very gentle	Good
3	6 - 12	9	Gentle	Moderate
4	13 - 20	5	Moderate	Poor
5	21-47	2	Steep	Very Poor



Map No. 4: Slope Map of the Study Area

In general, the slope map of the area portrays flat to very mild slopes in the majority of the territory. Steeper slopes can be found on the northern and north eastern parts of the territory, while mild escarpment slopes can be seen in the western border.

Geomorphology Based on terrain characteristics, the current study area, which is part of the Deccan Basalt Provenance, has been geomorphologically divided into five separate geomorphological categories.

Table No. 4 : Geomorphological categories

Class	Class Name	Category
1	Escarpment Slope	Very Poor
2	Mesa	Poor
3	Moderately Dissected Plateau	Moderate
4	Weathered Plateau	Good
5	Plateau Slightly Dissected	Very Good

Different classes were identified in the study region and are displayed below and introduced in fig.Different classes were identified in the study region and are depicted below, such as 1) PlateauSlightly Dissected 2) Weathered Plateau 3) Moderately Dissected Plateau 4)Mesa 5)Escarpment Slope. Because Highly Dissected plateaus have more Runoff than Low Dissected plateaus, they were given the lowest weighting. Because there is no runoff and water are absorbed by the ground, the LowDissected Plateau was assigned the maximum weighting.

- **Dissected Plateau:** A dissected plateau is a region of a plateau that has been badly eroded, resulting in sharp relief. Although dissected plateaus are mountainous, they differ from orogenic mountain belts in that they lack the folding, metamorphism, widespread faulting, and magmatic activity associated with orogeny.

- **MESA:** A mesa is a small, flat-topped hill or mountain with steep sides that is separated from the rest of the world.

- **Escarpment :-** An escarpment is a steep slope or long cliff that divides two relatively levelled areas with varied elevations as a result of faulting or erosion.

Table 5: Area and Category of Geomorphology

Class	Class Name	Area %	Ground water Potential
1	Escarpment slope	8.9	Very Poor
2	Mesa	1.55	Poor
3	High Dissected Plateau	9.22	Moderate
4	Weathered Plateau	29.28	Good
5	Low Dissected Plateau	50.93	Very Good

- **Zone of Potential Groundwater:** Fig. depicts the very high ground water potential zone, which is restricted to the north part of the area and is dominated by the Low dissected Plateau geomorphic unit, which has high to moderate lineament density, low to very low drainage density, land that is mostly used for agriculture, and a flat to gentle slope.

  The research area's high ground water potential zone is dominated by Weathered plateau geomorphic units with very high to moderate lineament density, high to moderate drainage density, land mostly used for water bodies, and a very soft to nearly flat slope.

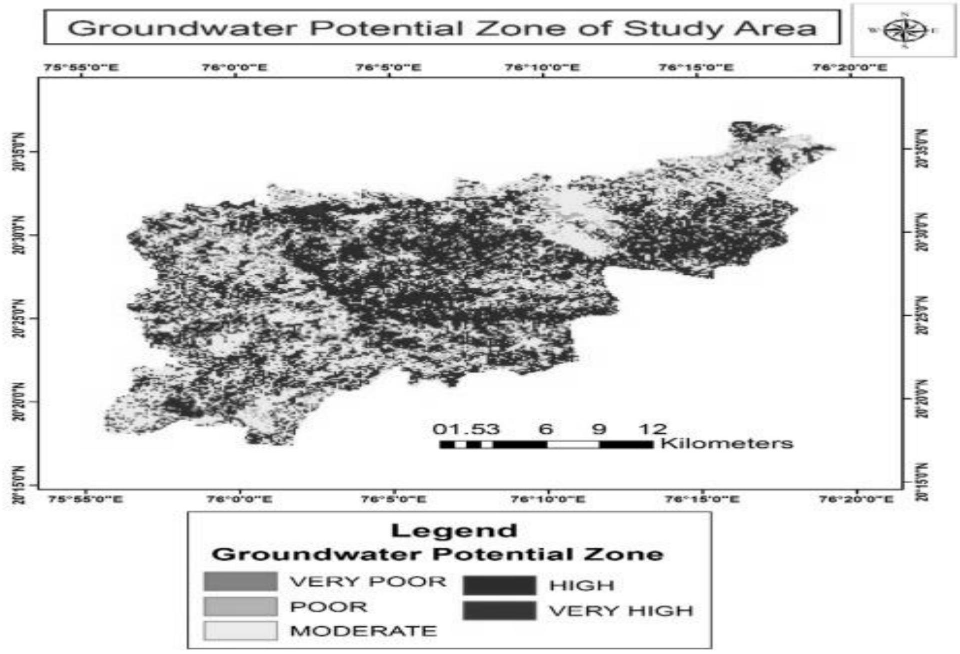
  The research region's moderate ground water potential zone is typified by highly dissected plateau geomorphic units with moderate to low lineament density, high to very high drainage density, land use for Forest area, and a very soft to nearly flat slope.

  The research area's weak ground water potential zone is dominated by mesa geomorphic units with extremely low to low lineament density, very high to high drainage density, land uses for built up area, and a very mild to nearly flat slope.

  The very poor ground water potential zone can be found in occasional locations in the north-eastern and south-western regions of the research region, which is dominated by an escarpment slope geomorphic unit with low lineament density, very high drainage density, and a steep slope.

Table 6: Category X: Groundwater Potential Zone

Class	Area %	Ground water potential zone
1	0.02	Very poor
2	5.15	Poor
3	45.69	Moderate
4	48.98	Good
5	0.16	Very good



Map No. 5: Groundwater Potential Zone Map of the Study Area

III. CONCLUSION

The use of a geographic information system and remote sensing to determine an area's groundwater potential has shown to be a strong and cost-effective strategy. The ground water potential of the area was calculated using five influencing thematic maps: slope, geomorphology, drainage density, land use/land cover, and lineament density. This type of research can provide first-hand knowledge to local governments and planners regarding whether sites are suitable from a groundwater perspective.

With the use of remote sensing data and GIS technology, the current study on the ground water potential of Buldhana Taluka proved to be a significant input in analysing the role and significance of various influencing aspects attributing to the ground water potential of the area. Various Deccan basalt flows make up the research area. In general, groundwater in the Deccan Basalt topography occurs in phreatic conditions in exposed basaltic rocks and under semi-confined conditions in deeper flows. Primary porosity in the form of vesicles and secondary porosity in the form of fractures, joints, and other structures control ground water on such terrain.

Slope, geomorphology, drainage density, land use/land cover, and lineament density were researched in depth, and the study area was divided into five groundwater potential zones: very good, good, moderate, poor, and very poor (Map.no.15). In terms of slope (Tables XI and X), it can be seen those areas with a slope less than 20 over the Low Dissected Plateau geomorphic unit, drainage density less than 0.1, agriculture area of land use, and lineament density greater than 114 falls into the very good groundwater potential zone, covering 0.16 km2. The good groundwater potential zone, which covers an area of 48.98 km2, has slopes ranging from 20 to 60 with drainage density of 1.5 to 2.98, water body area of land use, and lineament density of 85 to 113. The moderate groundwater potential zone, which covers an area of 45.69 km2 and is covered by Highly Dissected plateau with drainage density of 2.99 to 4.48 and land use for Forest area and lineament density of 56.7 to 84.9, has been classified. Mesa has identified an area of 5.15 km2 as a poor groundwater potential zone with a slope ranging from 130 to 220, drainage density of 4.49 to 5.97, land uses for Built up area, and lineament density of 28.4 to 56.6. Escarpment slopes with drainage density more than 5.98 cover areas with slopes greater than 220. Its land uses are primarily for Barren land, and lineament density less than 28.3 has been categorised as a very poor groundwater potential zone, encompassing 0.02 km2.

This groundwater potential information will be useful for effectively identifying suitable locations for future water resource exploitation, and the methodology used in this study can serve as a guideline for future research work, with significant ground / field inputs, in order to improve the credibility of the results obtained from the above applied laboratory-based study.

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