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Modelling of Groundwater Potential Zone of Hard Rock Dominated South-Western Hyderabad Using Multi-Criteria Based Geospatial Approach

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Abstract

Groundwater is under extreme strain due to global urbanization and population growth. In addition to impeding rainwater's ability to seep beneath the surface of the earth, it has incited overuse of groundwater. In the semi-arid regions dominated by hard rock, the issue of water scarcity and a significant decrease in groundwater height were caused by the unpredictability of rainfall and excessive use of groundwater. The aim of the current study is to detect the GWPZ (Groundwater Potential Zone) in the hard-rock terrain-controlled southwestern Hyderabad city of Telangana with GIS data and remote sensing in line with the knowledge-driven statistical method of the AHP (Analytical Hierarchy Process). Ten groundwater controlling factors— curvature, lineament density, TWI (Topographical Wetness Index), soil, rainfall, Drainage Density (DD), LULC (Land Use Land Cover), slope, geomorphology, and geology were compiled to create the GWPZ map. LULC map is prepared using Support Vector Machine(SVM) algorithm and Sentinel data in Google Earth Engine Platform. The overall accuracy and kappa coefficient of LULC map are 89.6% and 0.86 respectively. The analysis revealed that there are only moderate and good GWPZ, accounting for 63% and 37% of the study area, respectively. The findings are evaluated using the ROC (Receiver Operation Characteristics) and AUC (Area Under Curve) techniques with groundwater level data, and this value (0.721) also demonstrated the dependability of the study. The study's conclusions can help planners, engineers, and legislators make informed decisions about how best to use, assess, and manage groundwater in this region to ensure sustainable development.

Keywords: LULC, Google Earth Engine, SVM, Groundwater, AHP, ROC-AUC

Introduction

Groundwater is utilized in agriculture, industry, and residential settings. Because of its protection and purification from the earth's vadose zone, it is regarded as the most suitable water source compared to surface water (Rao et al., 2017). Groundwater is becoming more and more important because of factors like population growth worldwide, rising water demands for agriculture, climate change, and rapid urbanization. Furthermore, overexploitation is another issue that has severely strained groundwater supplies (Biswas et al., 2020). Worldwide, approximately 27%, 36%, and 42% of total groundwater extraction are attributed to industrial, domestic, as well as agricultural uses, respectively (Shao et al., 2020). Furthermore, it is projected that 2.5 billion people worldwide get their drinking water from groundwater (Achu et al., 2020). According to Kolanuvada et al. (2019), Indian groundwater supplies more than 60 percent of the country's irrigation requirements and 86 percent of its drinking water needs. Reduced groundwater depth and deteriorating water quality are examples of aquifer-stress syndromes that have been reported because of unplanned and uncontrolled groundwater extraction in the country (Patra et al., 2018). Identification and assessment of critical parameters are required to properly plan for this resource and predict groundwater potential (Arulbalaji et al., 2019). Groundwater is a hidden natural resource that can be challenging to locate, making it difficult to identify and explore. Drilling, hydrogeological, geological, and geophysical techniques have historically been the mainstays of groundwater exploration; however, these methods are time-consuming and costly (Jha et al., 2010). More significantly, Oh et al. (2011) state that this survey technique might not always take into account the different factors affecting occurrence and groundwater movement. Numerous scholars have employed various methodologies, such as logistic regression, random forest, support vector machine, and frequency ratio (Rizeei et al., 2018; Norouzi & Moghaddam, 2020; Pourghasemi et al., 2020; Das & Pardeshi, 2018). However, these approaches rely on multivariate statistical methods and bivariate, which have limitations in terms of the sensitivity of the results and the assumptions made before investigations (Thapa et al., 2017). Groundwater exploration using GIS and RS-integrated methods has become more common recently due to their cost-efficiency and time-saving benefits (Arulbalaji et al., 2019a, 2019b). The delineation of groundwater potential zones has been accomplished by researchers worldwide in recent decades through the extensive application of geospatial techniques, as demonstrated by the works of Mohammadi-Behzad et al. (2019) in the Arabian Peninsula, Ahmad et al. (2020) in Africa, and Abijith et al. (2020) in Southwest Asia others. As per Dar et al. (2020), the AHP (Analytical Hierarchy Process) is a generally utilized MCDM model for determining potential groundwater zones because it is a dependable, uncomplicated, economical, transparent, and easy approach. Integrating AHP and GIS is an affordable method of managing spatial data (Shekhar & Pandey, 2014). To identify GWPZ in a semi-arid area of eastern India, Mukherjee and Singh (2020a) used GIS-AHP techniques. In Kancheepuram District, Tamil Nadu, India, GWPZ mapping was carried out by Saravanan and Saranya (2020) utilizing the GIS-AHP method. Molwalefhe and Lentswe (2020) have determined potential groundwater recharge zones in eastern Botswana through the application of GIS-AHP techniques. The groundwater potential regions in India were mapped by Doke et al. (2021) with a GIS-based MCDA-AHP technique. To determine the GWPZ in the Valley of the Ethiopian Rift, Legesse Kura et al. (2021) employed integrated geospatial methods on the basis of AHP methods. When identifying the GWPZ, these methods take less time to compute and yield more accurate results than traditional field methods. (Zolekar & Bhagat, 2015). The GWPZ and flood susceptibility of the Saroor Nagar Urban Watershed in India were determined by Vaddiraju and Talari (2022, 2023) using a GIS-based AHP process. Moreover, since the study area depends on the Srisailam, Nagarjuna Sagar, and Kaleswaram dams for its water supply, excess water in the rainy season could be redirected into the watershed's GWPZ, increasing the amount of water available because of unpredictable monsoon as well as summertime freshwater scarcity. Most of the study area now consists of agricultural areas, and the area has been under a protected zone for the last few decades, whereas now the area is made open to development, which might post water resources below in the future due to an increase in urbanization. The current study's methodology, approaches, and conclusions might help make sure that there is enough groundwater available for daily requirements.

Study Area

Shamshabad, Rajendra Nagar, Gandipet, and Moinabad mandals of Ranga Reddy district, which are adjacent to Hyderabad city, are selected as the research area. It is observed that these mandals are experiencing rapid urbanization due to their access to international airports and information technology hubs. The study area holds significant geographical importance as it consists of two major reservoirs on the Musi River, i.e., Osman Sagar and Himayat Sagar, which provide drinking water supply to adjoining regions. The study area is spread over 593 sq. km. The advancement of the research area ranges between 415m to 563m above average sea level. The study area experiences a distinct climatic pattern, characterised by using monsoon season from June to September. The study area and digital elevation model map are presented in Figure 1.

Methodology

Groundwater potential zones were mapped using ten thematic layers that were gathered from different data sources. The study area's hydrological conditions can be more precisely predicted with the aid of these thematic layers. Nevertheless, producing thematic maps needs several tasks, including digitizing pre-existing maps, extracting pertinent information from field data, and digital image processing. The GIS study in the current study was performed with ArcGIS 10.7. Geological Study of India data on geomorphology, geology, and lineaments were obtained from https:// bhuko sh.gsi.gov.in/Bhukosh/MapViewer.aspx. The Palsar DEM ("Digital Elevation Model") with a resolution of 10 m was applied to generate the slope, drainage, and curvature maps. The soil map is downloaded from the FAO database. The distance to water map is prepared with the Euclidean distance tool in ArcMap 10.7. LULC map is prepared using SVM classifier in Google Earth Engine platform.The spatial study tool in ArcGIS 10.7 was utilized to reclassify the thematic layers into 4 classes. The generated map showed the many ways in which the potential for groundwater recharge was altered by the influencing variables in each subclass.

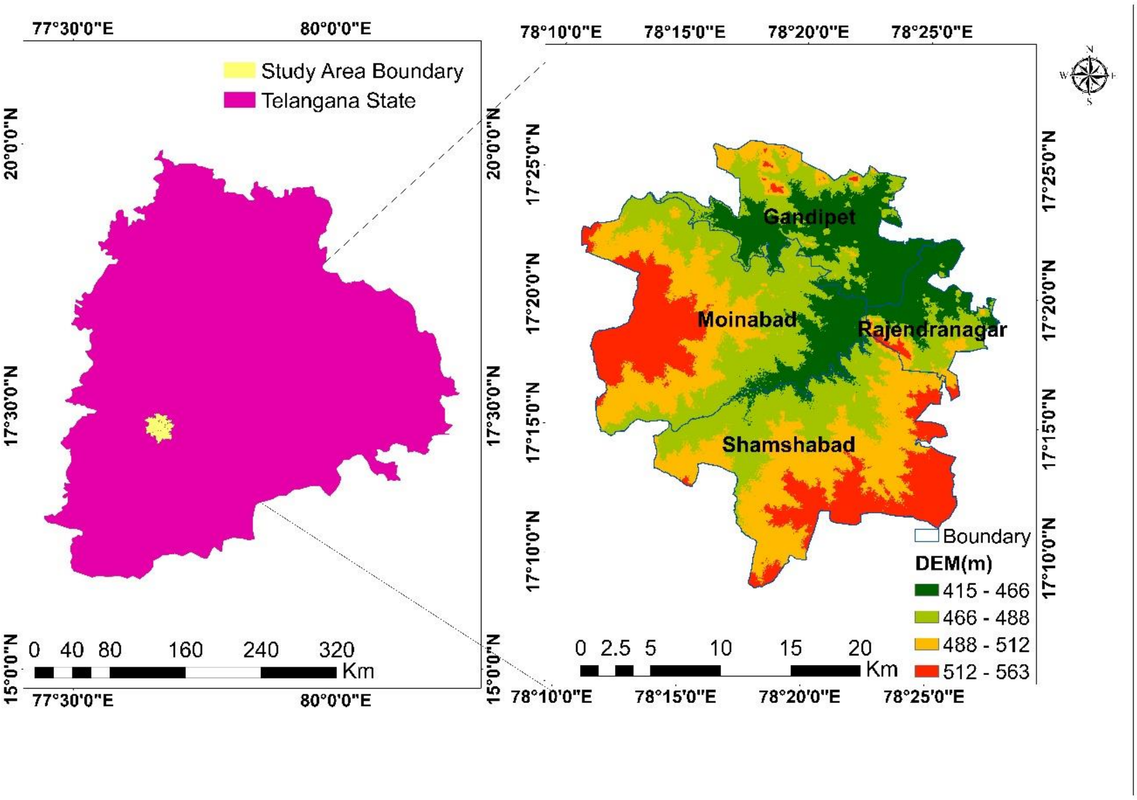


Figure 1: Location and Digital Elevation Model of the Study Area

Assignment of weight using AHP

The weighting of every class is the most important step in an integrated study because it has a significant impact on the outcome (Muralitharan & Palanivel, 2015). Weights are assigned in this study using the Multi-Criteria Decision Analysis method on the basis of AHP. The final weights allocated to different thematic layers and their corresponding features are decided upon using this technique (Sener et al., 2005). The AHP was created by Tomas Saaty in 1980 (Saaty, 1980) as a productive tool for structuring and resolving difficult groundwater decision-making problems. Weight assignment, weight normalization, pairwise comparison matrix as well as consistency evaluation are the four phases of the AHP model (Benjmel et al., 2020). Using a decision hierarchy as a starting point, this technique determines criteria and sub-criteria based on how they affect groundwater potential. One advantage of hierarchy is that it helps us concentrate our judgment on specific attributes, which is essential for coming to well-informed conclusions (Murmu et al., 2019). A standard Saaty's 1 to 9 scale (Saaty, 1980) was applied to examine the relative significant values of each theme and its corresponding characteristics (Table 1). According to expert advice, literature review, field experience, and groundwater potential impact, each of the ten thematic layers was given a weight (Tiwari et al., 2019). In the present analysis, geomorphology is given the highest weight because it is believed to have a greater impact on groundwater. Curvature, on the other hand, has the lowest weight and has less of an effect on groundwater (Shao et al., 2020). Following the assignment of relative weights to each factor, a pairwise comparison matrix is calculated. In the pairwise comparison matrix, each theme layer was contrasted with the others. The final weights were normalized to 1 (one) using the AHP eigenvector technique. To achieve this, values are added to each column, and each factor is then divided by the total of its corresponding columns.

Pairwise comparison matrix

The relative significance levels are ascertained using Saaty's 1–9 scale. According to Saaty (1980), a score of 1 denotes equal significance for the 2 layers, whereas a score of 9 highlights the exceptional importance of one layer in relation to the other. Table 2 displays Saaty's scale. A pairwise comparison matrix is inferred from thematic maps utilized for a GWPZ outline with Saaty's 9-point significance scale. Potential decision vulnerabilities are identified by the AHP's primary eigenvalue and consistency index (Rahmati et al. 2015).

CR (“Consistency Ratio”) and CI (“Consistency Index”) are computed with eqs 1 and 2, respectively.

$$\mathrm{CI} = \frac{\lambda\mathrm{max} - \mathrm{n}}{\mathrm{n}} - 1 \qquad (1)$$

where λ max indicates the largest eigenvalue of the pairwise comparison matrix and n represents the number of classes.

$$\mathrm{CR} = \mathrm{CI}/\mathrm{RI} \qquad (2)$$

where RI denotes the Random Index, as revealed in Table 2. Table 3 displays the pairwise matrix, and Table 4 displays the weighting and ranking of the thematic levels.

Table 1. Factors of importance on a scale of 1 to 9 (Saaty 1980).

Scale	Importance
1	Equal Importance
2	Equally to Moderately
3	Moderate Importance
4	Moderately to Strong
5	Strong Importance
6	Strongly to very Strong
7	Very Strong Importance
8	Very Strong to Extremely Strong
9	Extreme Importance

Table 2: Saaty's ratio index with varying values of n (Saaty 1980)

N	3	4	5	6	7	8	9	10
RI	0.58	0.89	1.12	1.24	1.32	1.41	1.45	1.49

Table 3: Pairwise comparison matrix

Factors	Assigned Weight	Geom	Geo	LD	Sl	So	LULC	DD	RF	TWI	Curv	Weight
Geom	8	1.00	1.14	0.89	1.33	1.33	1.60	1.60	2.00	2.00	2.67	0.15
Geo	7	0.88	1.17	1.17	1.17	1.17	1.40	1.40	1.75	1.75	2.33	0.13
LD	6	0.75	0.86	1.00	1.00	1.00	1.20	1.20	1.50	1.50	2.00	0.11

Sl	6	0.75	0.86	1.00	1.00	1.00	1.20	1.20	1.50	1.50	2.00	0.11
So	6	0.75	0.86	1.00	1.00	1.00	1.20	1.20	1.50	1.50	2.00	0.11
LULC	5	0.63	0.71	0.83	0.83	0.83	1.00	1.00	1.25	1.25	1.67	0.09
DD	5	0.63	0.71	0.83	0.83	0.83	1.00	1.00	1.25	1.25	1.67	0.09
RF	4	0.50	0.57	0.67	0.67	0.67	0.80	0.80	1.00	1.00	1.33	0.07
TWI	4	0.50	0.57	0.67	0.67	0.67	0.80	0.80	1.00	1.00	1.33	0.07
Curv	3	0.38	0.43	0.50	0.50	0.50	0.60	0.60	0.75	0.75	1.00	0.06

Note: Geom- Geomorphology, Curv- Curvature, LULC-Land Use Land Cover, TWI-Topographic Wetness Index, RF-Rainfall, DD-Drainage Density, So-Soil, Sl- Slope, LD-Lineament Density, Geo-Geology

Delineation of GWPZ

The map of the zone is created using equation 3 as shown below:

$$\mathrm{GWPZ} = \mathrm{GwGr} + \mathrm{GMwGMr} + \mathrm{TWIwTWIr} + \mathrm{CwCr} + \mathrm{SLwSLr} + \mathrm{DDwDDr} + \mathrm{DWwDWr} + \mathrm{SwSr} + \mathrm{RwRr} + \mathrm{LUwLUr} \tag{3}$$

Here G_w represents the Geology weight and G_r signifies its rank; GM_w presents the Geomorphology weight and GM_r indicates its rank; TWI_w presents the Topographic Wetness Index weight and TWI_r signifies its rank; C_w presents the Curvature weight and C_r represents its rank; SL_w signifies the Slope weight and SL_r indicates its rank; DD_w represents the Drainage density weight and DD_r signifies its rank; DW_w indicates the weight of distance to the waterbody and DW_r presents its rank; S_w signifies the soil weight and S_r represents its rank; R_w indicates rainfall weight and R_r indicates its rank; LU_w presents the LULC weight and LU_r indicates its rank.

Table 4: Weightages of different parameters under consideration

Parameter	Class	Rating	Weight
Geology	Deccan Traps	1	0.13
	Gneiss	1	
TWI	3.15-7.14	1	0.07
	7.14-9.91	2	
	9.91-13.2	3	
	13.2-23.9	4	
Geomorphology	Active Quarry	3	0.15
	Waterbody	4	
	Pediment Pedi plain Complex	4	
Slope	0-4.5	4	0.11
	4.5-9.0	3	
	9.0-16.0	2	
	16.0-82.8	1	
Drainage Density	0-0.42	4	0.09
	0.42-0.90	3	
	0.90-1.42	2	
	1.42-2.91	1	

Lineament Density	0-0.10	1	0.11
	0.10-0.31	2	
	0.31-0.50	3	
	0.50-0.77	4	
Rainfall	821-891	1	0.07
	891-943	2	
	943-1003	3	
	1003-1078	4	
LULC	Agriculture	3	0.09
	Barren	2	
	Built-up	1	
	Vegetation	3	
	Waterbody	4	
Soil	Clayskeltal	3	0.11
	Clay	1	
	Loam	2	
Curvature	Concave	3	0.06
	Convex	2	
	Flat	4	

Results and Discussions

An efficient method of mapping groundwater zones is demonstrated by the combination of GIS, RS, and AHP methods. AHP's multi-criteria assessment makes it possible to include various factors that affect the occurrence of groundwater, and RS and GIS make it possible to examine and visualize the results spatially. The research's conclusions support sustainable groundwater resource use and well-informed decision-making (Pande et al., 2021). These maps are useful for water resource managers, hydrogeologists, and decision-makers in identifying suitable groundwater extraction locations, prioritizing recharge plans, and implementing sustainable water management practices.

Geomorphology

Given its capacity to shed light on a particular region's topography and landforms, geomorphology is crucial in evaluating areas with substantial groundwater potential. It provides helpful information on the distribution of landform features and processes such as fluctuations in temperature, patterns of water flow, geochemical reactions, and the dynamics of freezing and thawing (Grozavu 2017). The geomorphological landforms are categorized into pediment pediplain complex, waterbody, active quarry, older flood plain, low and medium dissected denudation valleys and hills, and low dissected structural valleys and hills, where pediment pediplain is dominant, covering 87.6% of the total area, followed by waterbody covering 11% of the area, and other landforms constitute 1.4% of the total area. Groundwater recharge is best suited for the denudational pediment pediplain complex due to its gently undulating plains and weathered material (Murmu et al., 2019). The geomorphological map is presented in Figure 2.

Geology

Groundwater occurrence, movement, and storage are all influenced by geology. The amount of water that can be held in and how easily it can pass through various rock types and geologic structures depends on their porosity and permeability (Lee et al., 2012). Geology understanding of a region is therefore essential for managing and safeguarding the region's groundwater resources as well as for locating possible groundwater sources. To detect and demarcate the various geological units determined in the current study area, the Geological Survey of India's geological map was used in this investigation. The study area is primarily covered by Gneiss, covering 96% of the study area, and only 4 percent of the area is covered by Deccan Traps. These are rocks that are crystalline and have very little to no porosity within their compact structure. Seenipandi et al. (2019) state that this form of hard rock does, however, have moderate to high groundwater content based on the degree of secondary porosity found in places like faults, fractures, and lineaments. Figure 3 displays the study area's geological map.

Lineament Density

The visible expressions of underlying geological structures, like fractures and faults, are known as geological lineaments, which can show either a significant displacement of the fractures or no displacement at all. These lineaments support the growth of secondary permeability and porosity, both of which are essential for groundwater flow (Choudhary et al., 2022). Lineament data is attained from the Geological Survey of India, and a lineament density map is generated with the line density tool in ArcGIS 10.7. The lineament density is categorized into 0-0.10 km/km, 0.10-0.31 km/km, 0.31-0.50 km/km, and 0.50-0.77 km/km. 89% of the study area has a low lineament density of 0.10 km/km, and only 5% of the study area has a lineament density greater than 0.5km/km. Figure 4 displays the lineament density map.

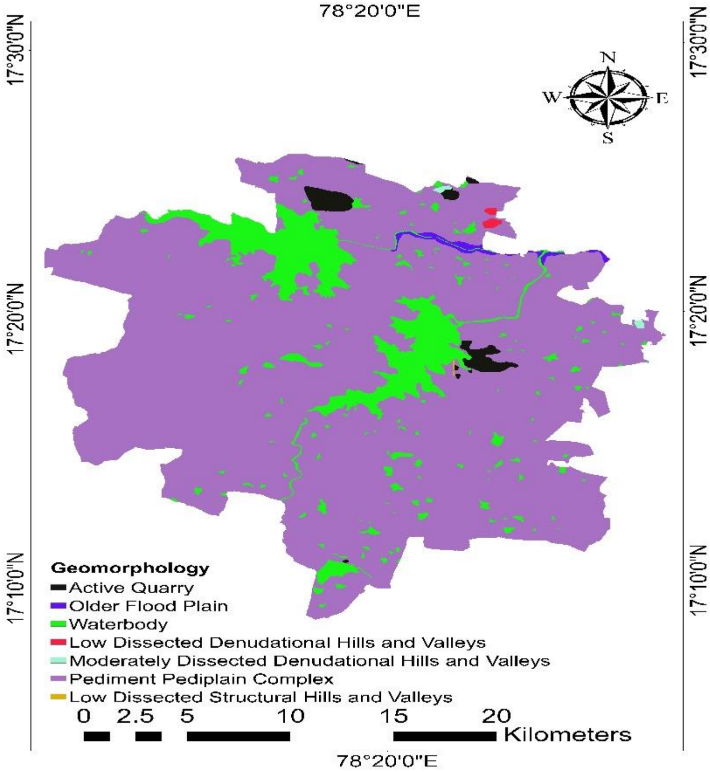


Figure 2: Geomorphological map of study area

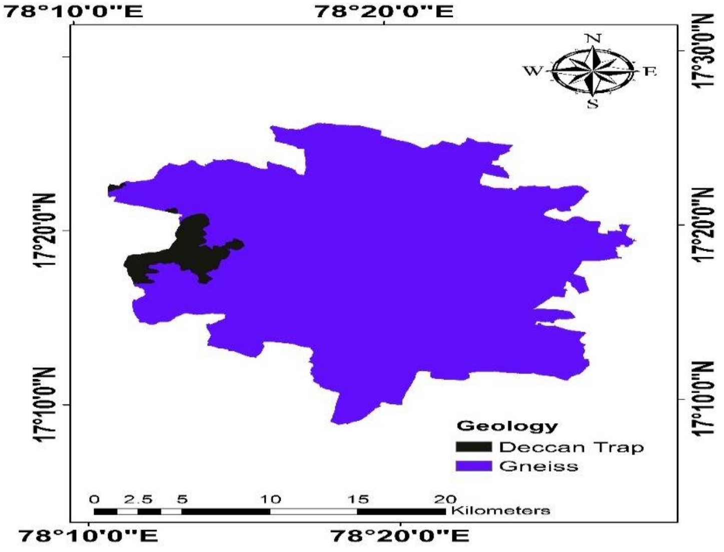


Figure 3: Geological map of the study area

Drainage Density

One important indicator for detecting possible groundwater zones is DD, which is the precisely defined total of the lengths of the rivers in a drainage area divided by the basin's entire area. Since it is inversely correlated with permeability, it is an important parameter for evaluating groundwater potential (Rizeei et al. 2019). Reduced infiltration rates are implied by higher drainage densities, which are detrimental to groundwater potential. In contrast, low drainage density suggests a higher rate of infiltration, which raises the possibility of groundwater availability (Ben Mammou and Chenini 2010). The drainage density data is classified into four categories: 0-0.42, 0.42-0.90, 0.90-1.42, and 1.42-2.91 km/km^2. 32.4% of the study area has a DD of less than 0.42 km/km^2, 29.4% of the area falls under the category of 0.42-0.90 km/km^2 drainage density, 25.5% of the study area is between 0.90-1.42 km/km^2, and only 12.7% of the study area has a drainage density greater than 1.42 km/km^2. Figure 5 displays the drainage density map.

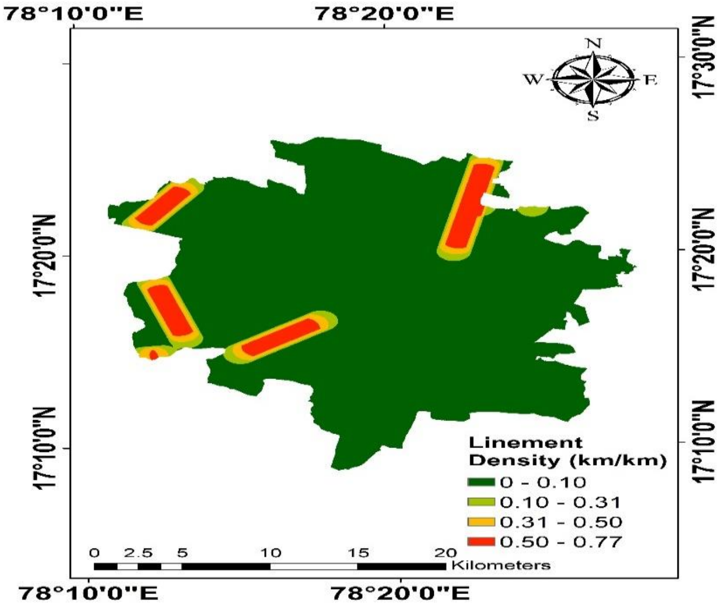


Figure 4: Lineament Density map of the study area

Rainfall

Rainfall directly affects the distribution and accumulation of groundwater in any given area because it allows rain-bearing water to percolate, infiltrate into the subsurface, and store as groundwater. An infiltration high rate and a runoff low rate are represented by prolonged and less intense rainfall, and vice versa. The rainfall map is prepared with IDW ("Inverse Distance Weighted") method by considering the rainfall data of four individual mandals in ArcGIS 10.7. The rainfall map is divided into four categories: 829-891mm, 891-943mm, 943-1003mm, and 1003-1078mm. 28.3% of the study area received rainfall of 829-891mm; 34.8% of the area received rainfall of 891-943mm, 25.4% of the area received a rainfall of 943-1003mm, and only 11.5% of the study area received rainfall of 1003-1078mm. Figure 6 displays the rainfall map.

Slope

Topography is a significant factor to consider when analyzing the properties of the land surface. It offers important details regarding the regionally significant geological and geodynamic processes that shape the terrain. The infiltration rate and surface runoff are significantly impacted by this. Additionally, it can offer insightful information about the general direction of groundwater flow. As water from precipitation runs off the slope quickly, steep slopes typically produce less recharge. As a result, the groundwater system is not sufficiently occupied for water to seep in and replenish (Akhtar et al. 2020). The study area's slope is divided into four groups: 0-4.5%, 4.5%-9.0%, 9.0-16.2%, and 16.2-82.8%. Good prospects for groundwater recharge are indicated by the fact that 53.8% of the area has a slope of below 4.5%. A total of 35.3% of the study area is categorized as having a slope between 4.5% and 9.0%, 9.5% as falling under the 9.0–16.2% category, and 1.4% as having a slope exceeding 16.2%. Figure 7 shows the slope map of the research area.

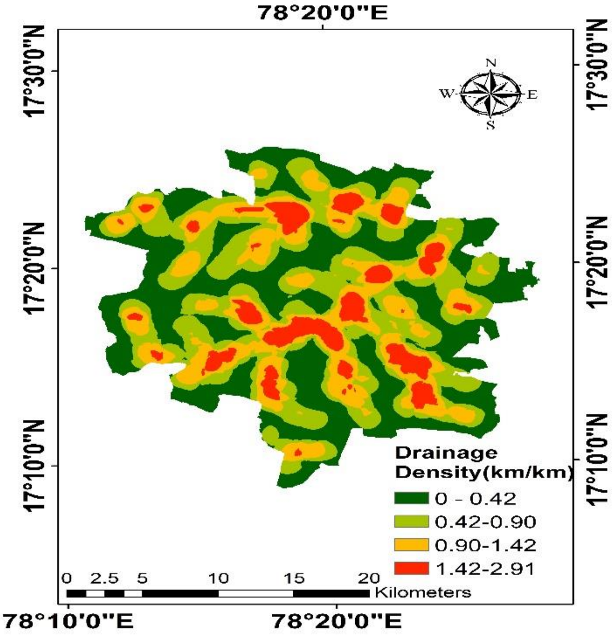


Figure 5: Drainage Density map of the study area

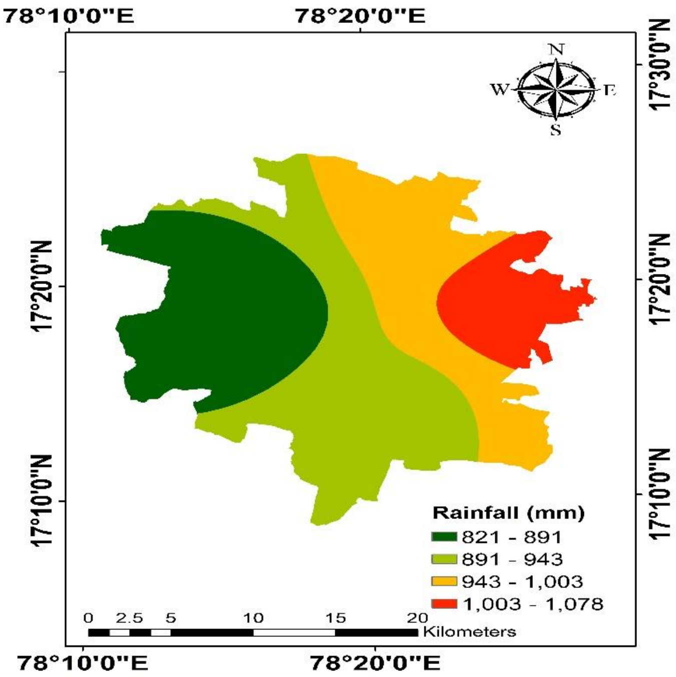


Figure 6: Rainfall map of the study area

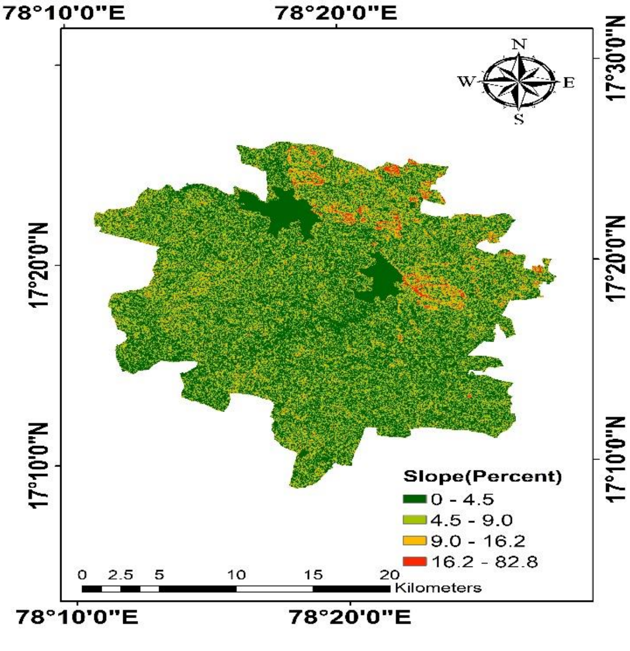


Figure 7: Slope map of the study area

Topographic Wetness Index

It is a widely used method to calculate how topography affects hydrological processes, such as groundwater infiltration (Sørensen et al., 2006). The gravitational attraction and water accumulation tendency to move water downward is measured by this index. According to Chaudhry et al. (2019), low-lying areas and depressed landscapes have higher index values and can store more water. In regions with a high rate of flow accumulation, the aquifer can be refilled (Msabi & Makonyo, 2021). Consequently, TWI is a useful indicator for identifying areas that may contain groundwater (Mukherjee & Singh, 2020a). Numerous studies demonstrate that the TWI has a vital impact on the mapping of groundwater zones (Msabi & Makonyo, 2021; Pal et al., 2020). TWI of the study area is categorized into four classes:3.15-7.14, 7.14-9.91, 9.91-13.1, 13.1-23.9. The TWI map of the study area is presented in Figure 8.

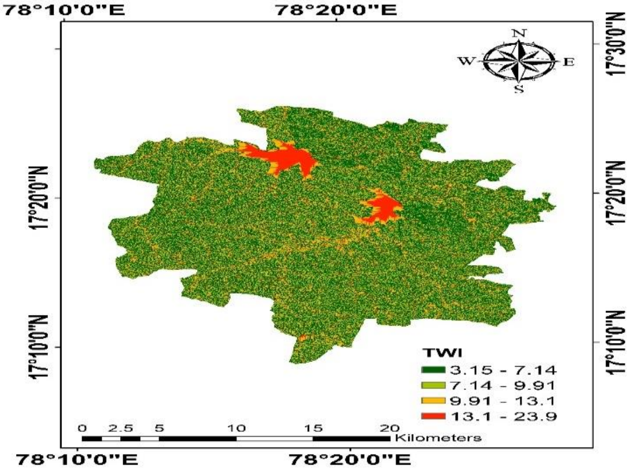


Figure 8: TWI map of the study area

Soil

Soils are critical for groundwater movement in the unsaturated area (Machiwal et al., 2010). When estimating the infiltration rates, the two main factors considered are the soil texture and hydraulic characteristics. In general, infiltration rates are influenced by soil type, permeability, and water retention capacity (Gupta et al., 2018). The study area has three different types of soil textures: clayskeltal, clay, and loam. 57.7% of the study area is covered with clayskeltal soil, followed by clay soil at 35%, and loam soil covering 7.3% of the study area. Figure 9 displays the soil map of the research area.

Curvature

Depending on the profile's type, a surface profile's curvature may be convex or concave upward. (Arunbose & Associates, 2021). Al-Abadi et al. (2016) state that a surface with positive curvature is convex, while a surface with negative curvature is concave. A surface with a value of zero is completely flat. According to Bera et al. (2020), soils on concave slopes are thicker as compared on convex slopes. Soils in these kinds of locations usually maintain more water as compared to soils on convex slopes as a result. In general, convex slopes release more surface runoff than concave slopes. The research area is composed of 33.8 percent concave curvature, 32.3 percent flat area, and the rest fraction convex in shape. Figure 10 displays the research area's curvature map.

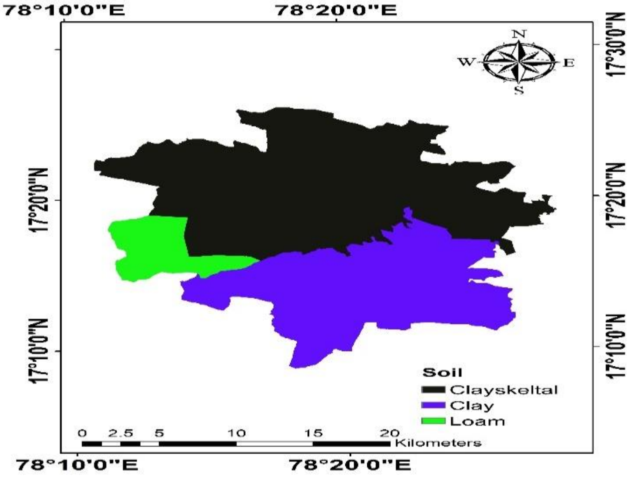


Figure 9: Soil map of the study area

LULC

Several factors, including surface water, infiltration, groundwater, soil moisture, and determining groundwater requirements, depend on LULC (Khadri 2013; Worku and Mohamed 2020; Pande et al. 2022; Kumar et al. 2022; Kumar et al. 2023). The LULC map is prepared by using Sentinel data and Support Vector Machine algorithm in Google Earth Engine platform. The study area's LULC contains agriculture, vegetation, barren land, built-up, and waterbody classes. Agriculture constitutes 42.8% of the study area, followed by built-up area at 31.8%, barren land at 15.8%, waterbody at 8.24%, and vegetation layer at 1.36%. The LULC map is then validated using overall accuracy and kappa coefficient. The overall accuracy is 89.6% and the kappa coefficient is 0.86, which indicates the classification of LULC is as per standards. The validation statistics are presented in Table 5.The snapshot of Google Earth Engine based classification of LULC is presented in Figure 11, and the LULC map is presented in Figure 12.

Groundwater Potential Zones (GWPZ)

The term GWPZ describes the potential groundwater areas in any given region in the future. It was determined in semi-arid & arid regions, particularly for groundwater in areas with limited water resources, to help define potential areas. Even though groundwater is a renewable resource, over-pumping for drinking and agricultural purposes, concretization because of increasing urbanization, intense population pressure, etc., have all contributed to a sharp decline in groundwater levels in recent decades. Given that groundwater is a valuable resource for humans, it is important to identify its prospective zone and protect future generations from the declining groundwater level. The ten distinct groundwater controlling variables— curvature, topographic wetness index, rainfall, LULC, drainage density, slope, lineament density, slope, geomorphology, and geology—have been compiled with GIS and remote sensing methods to create the GWPZ for the study area. The weighting of the thematic layers on the basis of their groundwater potential has been determined by applying the AHP technique. Each thematic layer is categorized into 4 zones: low, moderate, good, as well as very good. As per the analysis, the study area has only moderate to good potential zones. For groundwater recharge, 37% of the study region has good potential, whereas 63% of the research area has intermediate potential. The GWPZ map is presented in Figure 13.

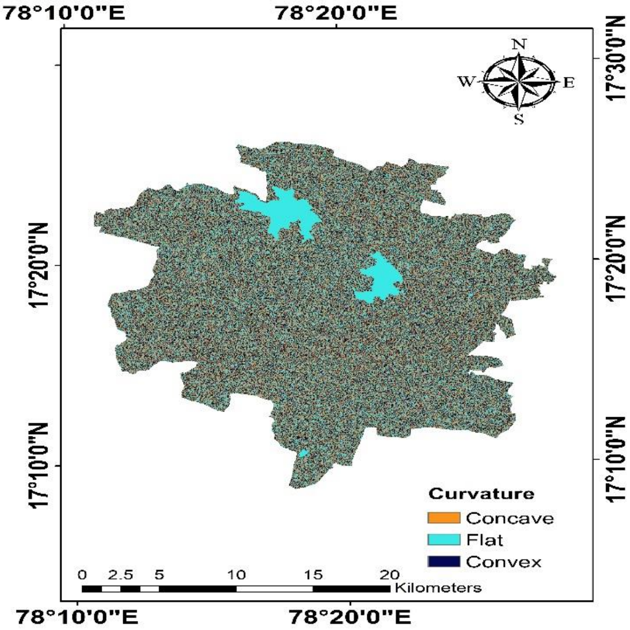
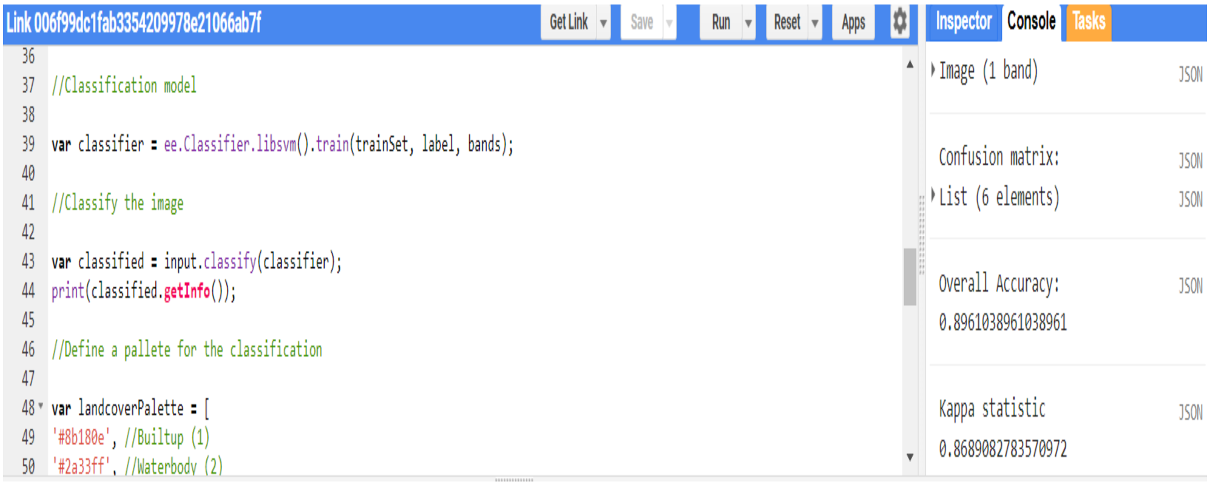


Figure 10: Curvature map of the study area



```

//Classification model

var classifier = ee.Classifier.libsvm().train(trainSet, label, bands);

//Classify the image

var classified = input.classify(classifier);
print(classified.getInfo());

//Define a pallete for the classification

var landcoverPalette = [
'#8b180e', //Builtup (1)
'#2a33ff', //Waterbody (2)
```

```
Image (1 band)                  JSON

Confusion matrix:               JSON
List (6 elements)               JSON

Overall Accuracy:               JSON
0.8961038961038961

Kappa statistic                 JSON
0.8689082783570972
```

Figure 11: Google Earth Engine Snapshot of LULC classification

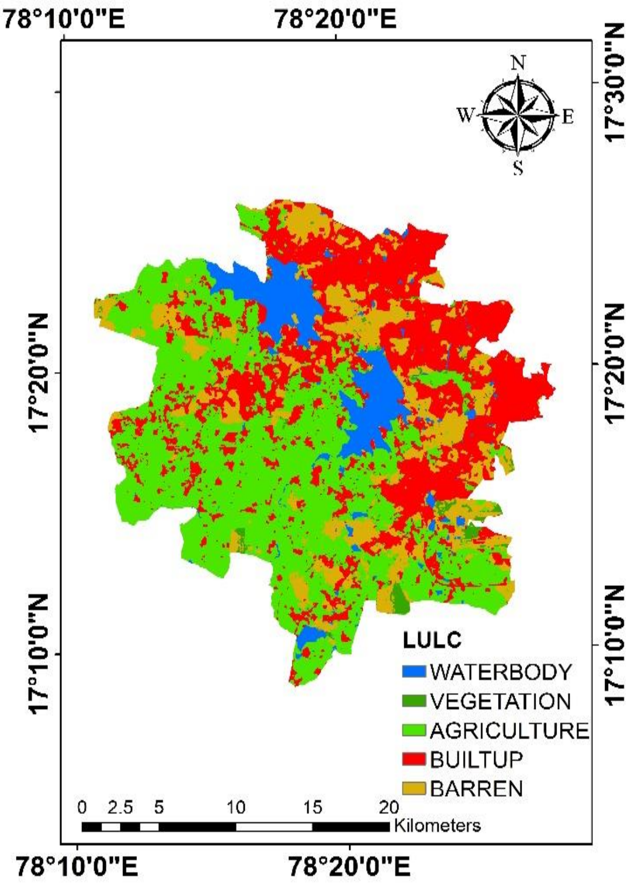


Figure 12: LULC map of the study area

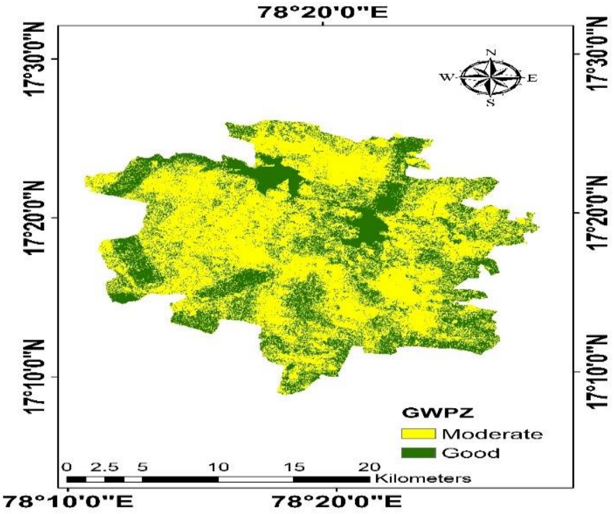


Figure 13 : Groundwater Potential Zone Map of the Study Area

Table 5 : LULC Validation Details

LULC	Producer Accuracy	User Accuracy	Overall Accuracy	Kappa coefficient
Built-up	1	0.83	0.896	0.86
Waterbody	0.94	1		
Vegetation	0.77	0.89		
Agriculture	0.85	0.75		
Barren Land	1	1		

Validation of GWPZ

The GWPZ map generated using the AHP-based geomatic approach is validated with the ROC-AUC method. The ROC curve is a graphical plot that validates the dataset's sensitivity. The ROC curve was plotted at different threshold layouts with TPR ("True Positive Rate") vs. FPR ("False Positive Rate"). The ROC was used to validate the result after preparing the GWPZ map of the study area. The ROC curve is plotted using water level data taken from the Groundwater Department Telangana. The groundwater level map is presented in Figure 14, and the ROC-AUC plot is presented in Figure 15. The ROC value measured is 0.721, which means 72.1% of the area falls AUC. In terms of the quality of the test results, an AUC value between 70 and 80% is typically regarded as good.

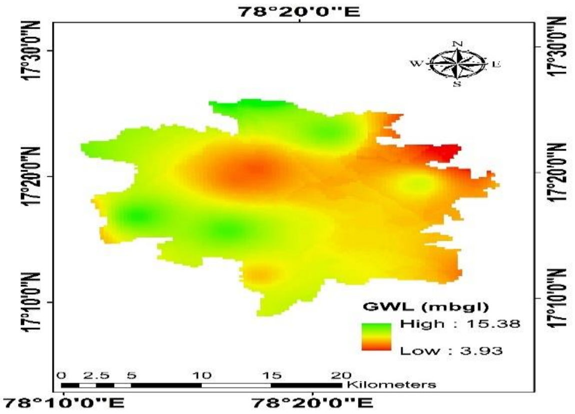


Figure 14: Groundwater Level Map of the Study Area

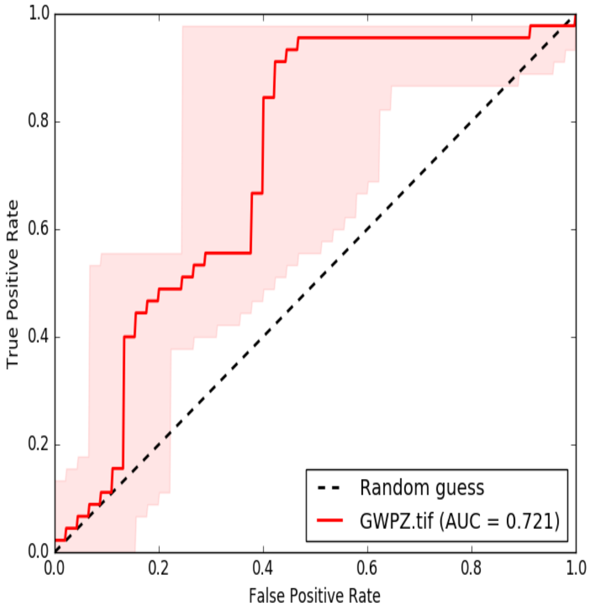


Figure 15 : ROC-AUC Curve of the Study

Conclusions

The aim of the current research was to assess the GWPZ in the basin area, which is located in south-western Hyderabad city in Telangana state, India. An analysis of ten thematic layers was done to accomplish this goal. By combining and assessing these layers, a thorough grasp of the groundwater potential was attained. The results showed that there is a great deal of potential for sustainable groundwater use in the study area. The analysis area was categorized as good or moderate, meaning that groundwater availability was likely to be favourable. 37% of the study area had good groundwater potential, followed by the moderate potential in 63%, according to the results. According to these results, a sizable section of the study area may have good groundwater potential, offering promising chances for sustainable groundwater use. By comparing the results with the area's known groundwater prospects, the accuracy of the methodology was confirmed, thereby confirming the dependability of the results. The method's overall accuracy of about 72% was discovered, demonstrating how useful it is for determining groundwater potential. The results of the present research have important ramifications for those in charge of strategic planning and efficient groundwater resource management, especially for agricultural and urban applications.

Author Contributions

All authors, Shiva Chandra Vaddiraju, Sandhya Rani, Kameswara Rao, and Manjunath collaboratively contributed to the design and execution of the work. All authors prepared, read, and approved the manuscript.

Data availability: The authors certify that the information contained in the paper supports the study's findings.

Declarations

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Consent to Participate: Not applicable

Consent for Publication: Not applicable

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