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Assessment Of Groundwater Potential Zones Using Gis Based Ahp ,In Bangalore Region, India

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Abstract

Groundwater resources can be expected to be increasingly relied upon shortly due to rapidly growing population and global environmental and climatic changes. Groundwater is a vital resource contributing significantly in the annual supply of water for domestic, industrial, and irrigation sectors. This paper aims to groundwater prospect zones and their spatial distribution and couples this information with pollution parameters for groundwater prioritization. The study is carried out in the Bangalore region of Karnataka state, which is geographically located between 12.40° N to 13.20° N latitudes and 77.30° E to 78.00° E longitudes and covers an area of 1617.12 sq. km. Groundwater prioritization is one of the most important aspects of watershed management. Groundwater potential zones are optimized in the study by using the GIS based Analytical Hierarchy Process (AHP). Five groundwater prospect zones have been identified in the present study, ranging from a very good prospect zone to a very low prospect zone. The study area has only 7% of very good zones, about 19% of good prospect zones, and 36% moderate zones. This cautions the decision-makers and concerned departments to promote the scientific and sustainable use of groundwater for future needs and initiate the appropriate measures to develop groundwater resources.

Key words: Remote Sensing, GIS, Groundwater Potential Zone, Analytical hierarchical process.

Introduction

Remote Sensing(RS) and Geographic Information System (GIS) techniques are used to determine groundwater potential zones(Gumma & Pavelic, 2013). This paper proposes a standard methodology for determining groundwater potential using RS and GIS techniques (Machiwal, Jha, & Mal, 2011). Satellite data and Survey of India (SOI) topo sheets of scale 1:50000 are used to generate accurate information for obtaining parameters which help in deriving groundwater potential zone. The main themes used are geology, Geomorphology, slope, drainage density, and lineament density. In ArcGIS, it is then combined with a weighted overlay. For each of these factors, appropriate ranks are allocated.

Groundwater prioritization is one of the most important aspects of watershed management(Choudhari, Nigam, Singh, & Thakur, 2018). This study identifies the potential groundwater zones of Bangalore, which covers Devanahalli, Hoskote, Bangalore East, and Anekal Taluks, using RS, GIS, and Saaty’s AHP model. IRS-LISS IV satellite data was combined with IRS-P5, Cartosat-1 imagery in ArcGIS software to analyze the spatial charecteristucs of the study and to prepare groundwater zones map using a weighted overlay technique. The major themes influencing groundwater such as geomorphology, geology, drainage, lineaments, slope, LULC, and soil are spatially mapped and analyzed in the GIS domain(Nithya, Srinivas, Magesh, & Kaliraj, 2019).

This paper focusses on the quantitative mapping of groundwater prospect zones, and their spatial distribution and couples this information with pollution parameters for groundwater prioritization.

Study Area

The region chosen for this investigation is Bangalore which covers Devanahalli, Hoskote, Bangalore East and Anekal Taluks **(Figure 1)** and is situated between 12.40°N–13.20°N latitudes and 77.30°E–78.00°E longitudes, falling in the Karnataka state in the center of the Mysore Plateau at an average elevation of 922 m to 980 m above sea level. The topography of the area is undulating with a central elevation running 'NNE-SSW'.

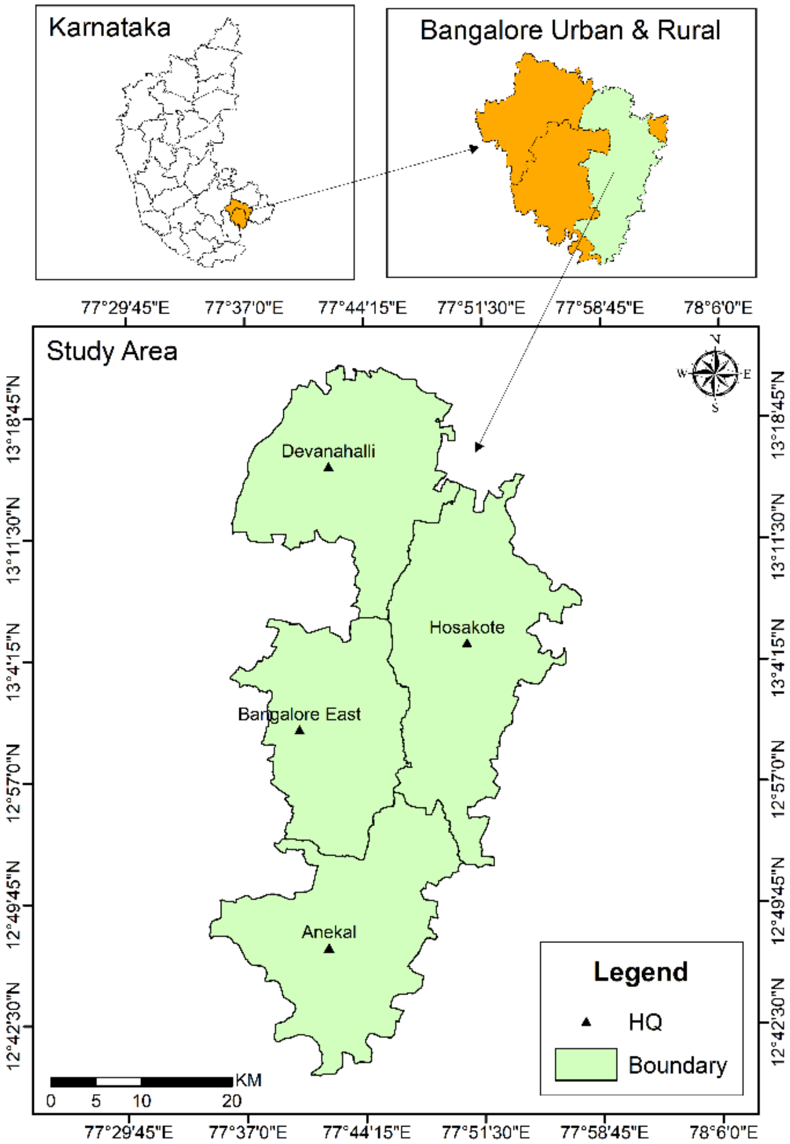


Figure 1.Location map of study the area

Methodology

Preparation of Thematic Maps

In the present study, the different thematic layers like geomorphology, geology, land-use/landcover, lineament, soil, slope, Drainage, and were prepared using digital image processing & visual interpretation techniques. Satellite images acquired from the National Remote Sensing Centre, Survey of India (SOI) topographical maps, secondary map resources & GPS-aided field survey data have been extensively utilized for the purpose. Drainage map, structural map, and LULC (Landuse/Landcover) map were prepared using the LISS-IV image of Resource sat-1 (spatial resolution of 5.8 m). Web Map Service (WMS) of Bhuvan Geoportal developed by Indian Space Research Organization (ISRO) was also used for validation and field inputs. With the application of the digital elevation model (DEM) Slope map was prepared, developed from IRS-P5 CartoDEM satellite product having a spatial resolution of 10 m. The ERDAS imagine software was used to carry out the image preprocessing, image enhancement, mosaicking, and study area extraction.

Further, ArcGIS software was used to generate the different thematic layers, including editing, topology creation, attribute generation, and density mapping. Based on the signification of each theme towards groundwater, all the layers of their features and weights were assigned, and their corresponding normalized weightages were derived based on the Arithmetic Hierarchy Process (AHP) model(Sahoo, Jha, Kumar, & Chowdary, 2015). Finally, using weighted overlay analysis, the thematic layers were superimposed to produce a groundwater prospect zone map for the study area.

Saaty's AHP Model

Saaty's AHP Model (1980), is an efficient technique for multicriteria decision analysis and is used to compute weights and ranks for thematic layers(T. Kumar, Gautam, & Kumar, 2014). Different classes under each theme were assigned weights based on their influence on groundwater existence. Saaty`s AHP model was used to construct a matrix and assign the normalized weights. The groundwater prospect zones map was generated by delineating the study area into five categories: Cumulative Score Index (CSI) was calculated by multiplying the weight (x), and normalized weight (w) of each theme. The equation is given below

CSI = Σ (Geomorphology xi x wj + Geology xi x wj + Lineament Density xi x wj + Soil xi x wj +Slope xi x wj + Drainage Density xi x wj + Land use/Land cover xi x wj)

$$CSI = \int_{i=1}^{n} \int_{j=1}^{m} w_j x_i$$

In the above equation wj corresponds to the normalized weight of j[th] theme, x_i is the rank of the i[th] class/feature of thematic layers. m corresponds to the number of thematic layers; and n belongs to the total number of components in teach t hematic layer (Navane & Sahoo, 2020).

Results And Discussion

The results and inferences of the study are discussed under different headings as follows.

Geology

The geology of the Bangalore region contains mainly the Archaean crystalline formation comprising of peninsular gneissic complex(Meert & Pandit, 2015). Laterites are mostly restricted for Devanahalli and Hosakote taluks. In Laterite, groundwater occurs under phreatic conditions. Pink Granulite is the third litho unit in the study area, but its presence is minimal. The geology map and weight/rank details are furnished in **(Figure 2a)** and **(Table 1)**, respectively.

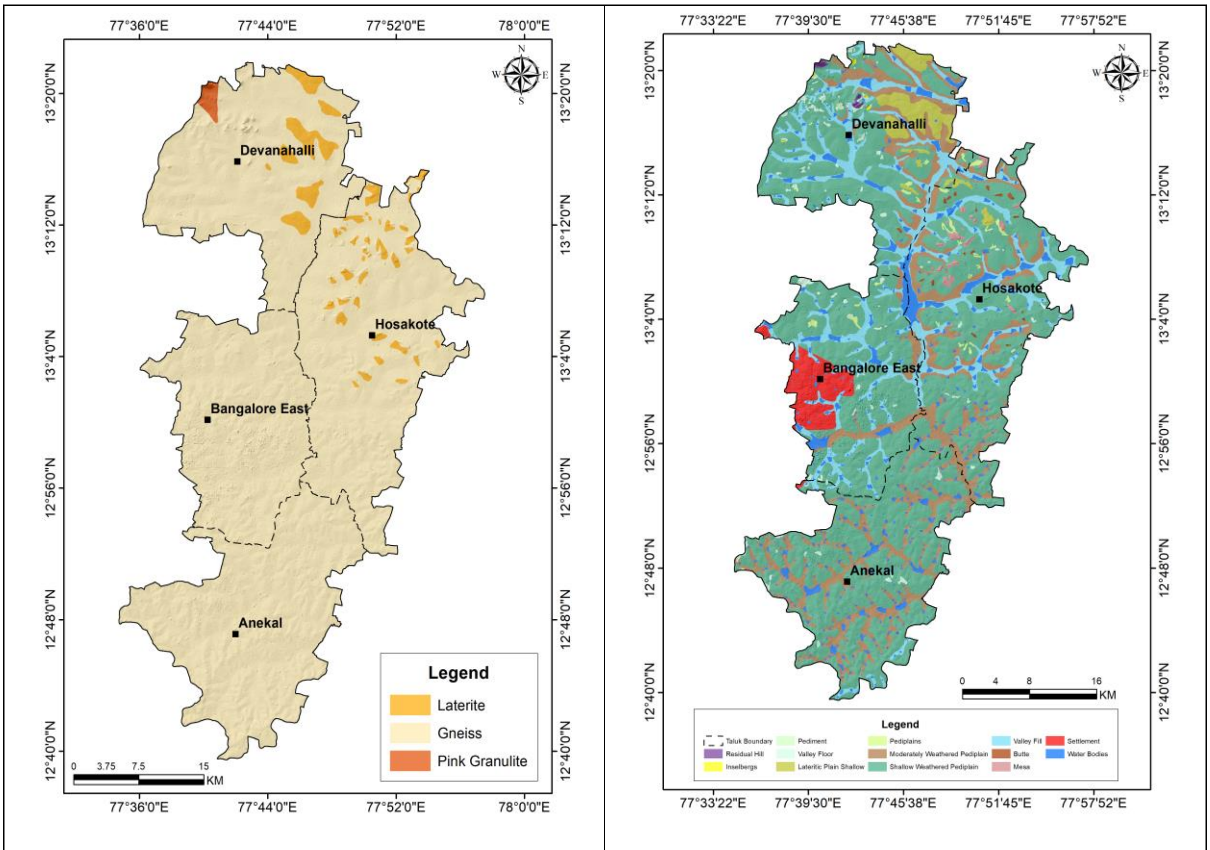
Table 1: Geology classes and their weights/ranks

Geology		
Class	**Weight**	**Rank**
Laterite	8	7
Pink Granulite	8	3
Gneiss	8	3

Geomorphology

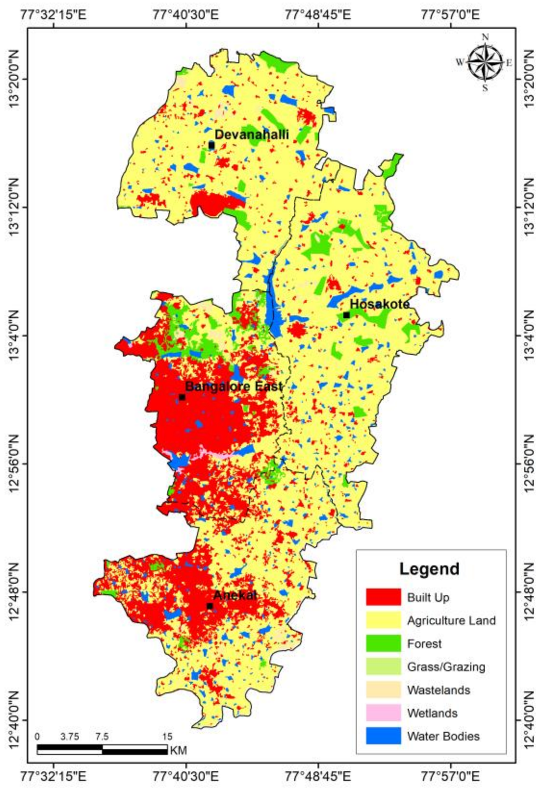
Mapping the geomorphic units is very important for the identification of groundwater potential. Important erosional and depositional geomorphic units such as residual hills, pediplains, inselbergs, pediments, valley fills, water bodies have been mapped with the help of satellite images and extensive field surveys(Gopinathan et al., 2020).

Shallow weathered pediplain and moderately weathered pediplains are the major geomorphic units in the study area. Groundwater pediplains contribute significantly to groundwater potential, depending on the thickness of the weathered region(Singh, Thakur, & Kumar, 2013). The valley fills differ in composition and texture depending on the parent rock(Prokofyeva, Martynenko, & Ivannikov, 2011). Usually, they are covered with sandy, clayey soils red, gravel, brown to coarse black soil. The valley fills are uniformly distributed throughout the study area. Because of the geological composition of highly porous materials, groundwater prospects in valley fills are good to excellent. Subsurface water potential is also good to excellent in the valley fills (Krishnamurthy, Venkatesa Kumar, Jayaraman, & Manivel, 1996). The study area also exhibits lateritic plains, especially in the northern parts. The geomorphplogy map and weight/rank details are furnished in **(Figure 2b) and (Table 2),** respectively.

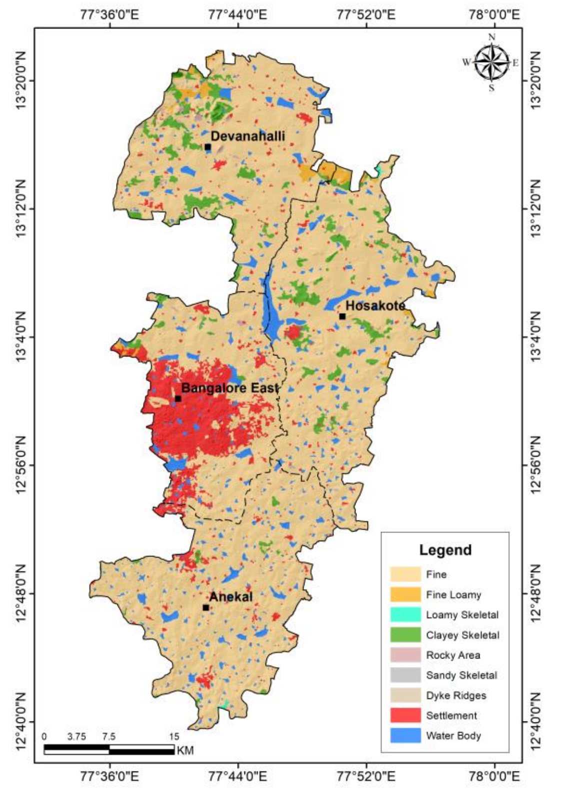


(a)

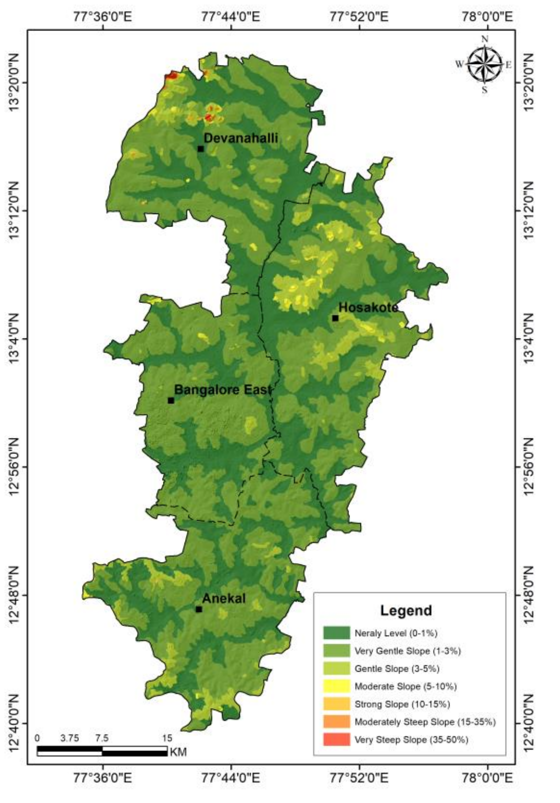
(b)

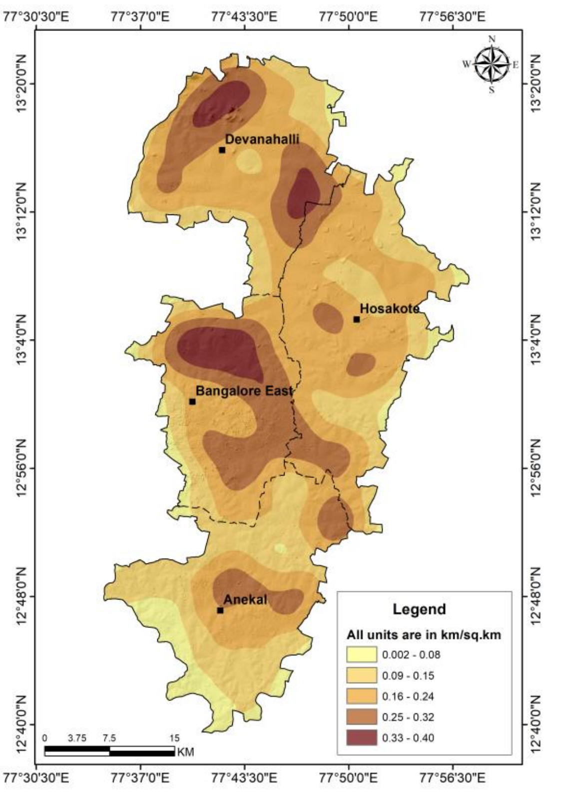

Devanahalli
Hosakote
Bangalore East
Anekal
Legend
Built Up
Agriculture Land
Forest
Grass/Grazing
Wastelands
Wetlands
Water Bodies
0 3.75 7.5 15 KM

(c)


Devanahalli
Hosakote
Bangalore East
Anekal
Legend
Fine
Fine Loamy
Loamy Skeletal
Clayey Skeletal
Rocky Area
Sandy Skeletal
Dyke Ridges
Settlement
Water Body
0 3.75 7.5 15 KM

(d)


Devanahalli
Hosakote
Bangalore East
Anekal
Legend
Neraly Level (0-1%)
Very Gentle Slope (1-3%)
Gentle Slope (3-5%)
Moderate Slope (5-10%)
Strong Slope (10-15%)
Moderately Steep Slope (15-35%)
Very Steep Slope (35-50%)
0 3.75 7.5 15 KM


Devanahalli
Hosakote
Bangalore East
Anekal
Legend
All units are in km/sq.km
0.002 - 0.08
0.09 - 0.15
0.16 - 0.24
0.25 - 0.32
0.33 - 0.40
0 3.75 7.5 15 KM

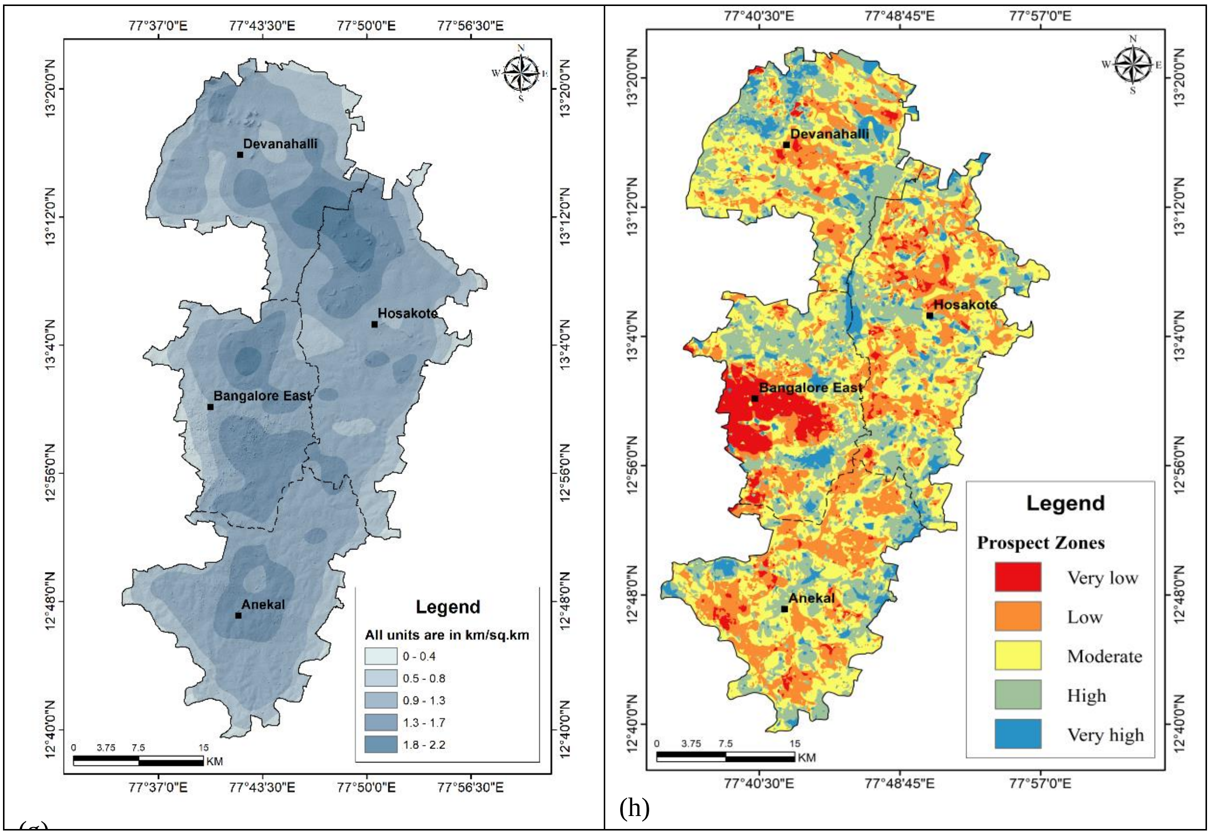


Figure 2 .Spatial distribution maps for the DRASTIC model in the study area: a) "Geology" b)" Geomorphology" c) "Landuse/landcover" d) "Soil map" e) "Slope map" f) "Lineament density" and g) "Drainage density" h) "Groundwater prospect zones"

Table 2: Geomorphology classes and their weights/ranks

Geomorphology		
Class	Weight	Rank
Butte	7	5
Isenberg	7	5
Lateritic plain shallow	7	9
Mesa	7	5
Moderately weathered/ moderately buried Pedi plain	7	9
Pediment - Isenberg Complex	7	9
Pediment/ Valley Floor	7	9
Pedi plain Eroded	7	9
Residual Hill	7	3
Settlement	7	5
Shallow weathered/ shallow buried Pedi plain	7	9
Valley Fill/ filled-in valley	7	9
Water Body	7	9

Land Use/Land Cover (LULC)

The study area exhibits a variety of landcover/land use categories, including agricultural land, built-up land, forest, grassland, wasteland, waterbodies, and wetlands. It is found that agriculture plantation is the major land cover in the study area, covering more than 60% km of the total area. The next mainland cover is built-up land. The agriculture plantation a key parameter for groundwater prospect studies. The LULC provides vital information on groundwater, surface water, infiltration, and soil moisture(Arulbalaji, Padmalal, & Sreelash, 2019).

The forest and agriculture hold a significantly high quantity of water than the built-up land, land without scrub, and rocky surfaces. The increased weight is assigned for the water bodies, wetlands, agricultural land, forest, and grasslands(Mwanjalolo et al., 2018). Similarly, settlement areas have a poor scope for groundwater recharging due to built-up land's waterproof nature. The low weight is assigned for the built-up land and wastelands. The LULC classes like the water bodies and wetlands are very useful in improving the groundwater aquifer(Patra, Sahoo, Mishra, & Mahapatra, 2018). The LULC map and weight/rank details are furnished in **(Figure 2c) and (Table 3),** respectively.

Table 3: Landuse/landcover classes and their weights/ranks

Land use/Land cover (LULC)		
Class	**Weight**	**Rank**
Agricultural land	6	5
Built-up land	6	2
Forest	6	5
Grassland / Grazing land	6	6
Wastelands	6	2
Water Bodies	6	9
Wetlands	6	8

Soils

The soils of the Bengaluru region are mainly of the soil orders Alfisols, Inceptisols, Entisols and in a small area Vertisols(Pal, Wani, Sahrawat, & Srivastava, 2014). The soil order Alfisols are deep to very deep, at places moderately deep, well-drained to somewhat excessively drained, clayey and at places gravelly clay, with surface crusting, occurring on very gently sloping to undulating lands and at places of undulating lands with moderate erosion(Dregne, 2011). Soils of the soil order Inceptisols are deep to very deep and at places shallow, moderately well drained to well-drained, gravelly clay to clay, occurring on undulating interfluves and ridges with moderate erosion. Soils of the soil order Entisols are deep at places shallow, well-drained to somewhat excessively drained and at locations moderately well-drained, clayey, gravelly in the subsurface at locations, occurring on gently sloping to rolling lands with moderate erosion. In contrast, soils of the soil order Vertisols are very deep, moderately well drained, calcareous clayey soils in valleys with moderate erosion. Texture-wise the study area is mainly covered by fine soil. As the infiltration is poor, this class has been given lower rank in the present study. The highest rank is given to sandy skeletal; however, the area covered under such category is below 1 sq km. The soil map and weight/rank details are furnished in **(Figure 2d) and (Table 4),** respectively.

Table 4: Soil classes and their weights/ranks

Soil		
Class	Weight	Rank

Clayey Skeletal	6	6
Fine	6	4
Fine Loamy	6	4
Loamy Skeletal	6	6
Sandy Skeletal	6	8

Slope

The geologic and geodynamic processes operate at a regional scale, where slope plays a vital role in providing valuable information(Dregne, 2011). Slope is the major theme influencing the infiltration of groundwater into deeper layers. The higher weight is assigned to nearly level, very gentle slope, and gentle slope. The lower weight is assigned for a strong slope and a very steep slope. The slope categories of the main range from nearly level to gentle. Steep slopes are restricted to the northern parts of Devanahalli taluk. The slope map and weight/rank details are furnished in **(Figure 2e) and (Table 5),** respectively.

Table 5: Slope classes and their weights/ranks

Slope		
Class	**Weight**	**Rank**
Gentle Slope	5	6
Moderate Slope	5	4
Moderately Steep Slope	5	3
Nearly Level	5	8
Strong Slope	5	2
Very Gentle Slope	5	5
Very steep slope	5	1

Lineament density

Lineament controls groundwater movement and storage. In demarcating groundwater prospect zones, the lineaments also play a vital role(Jaiswal, Mukherjee, Krishnamurthy, & Saxena, 2003). The lineaments have been extracted by using LISS-IV satellite imagery, geological maps, and ISRO`s Web Map Service of the Bhuvan portal through the visual interpretation technique. Lineament density is derived from the kernel density, which calculates the frequency of the lineaments per unit area(Thannoun, 2013). Areas with high lineaments densities are good for groundwater prospect zones(Gupta & Srivastava, 2010). The density of the lineaments is more in the in Bangalore East and Devanahalli Taluks. The zones with very high lineaments density have been classified as high groundwater prospects and assigned a higher weightage. Similarly, the zones with very low lineaments density are poor zones for groundwater prospect, hence assigned a lower weightage. The Lineament density map and weight/rank details are furnished in **(Figure 2f) and (Table 6),** respectively.

Table 6: Lineament density classes and their weights/ranks

Lineament Density

Class	Weight	Rank
0.002 - 0.08	6	2
0.09 - 0.15	6	4
0.16 - 0.24	6	6
0.25 - 0.32	6	8
0.33 - 0.40	6	9

Drainage Density

Drainage density helps in understanding the characteristics of groundwater infiltration and runoff. Drainage density values have calculated using the natural break method (Shekhar & Pandey, 2015). The zones with low to moderate drainage density are considered excellent groundwater prospect zones and were assigned a higher weightage. High drainage density is an unfavorable zone for groundwater occurrence, moderate drainage density has reasonable groundwater potential, and low drainage density is a high groundwater prospect zone(T. Kumar et al., 2014). The higher weight is assigned to the low drainage density categories. The lower weight is assigned to high drainage density classes. In the study area, drainage densities range from 0 to 0 2.2 km/sq km. The Drainage density map and weight/rank details are furnished in **(Figure 2g) and (Table 7),** respectively.

Table 7: Drainage density classes and their weights/ranks

Drainage Density		
Class	**Weight**	**Rank**
0 - 0.4	5	8
0.5 - 0.8	5	6
0.9 - 1.3	5	4
1.3 - 1.7	5	3
1.8 - 2.2	5	2

Groundwater Potential Zones Map

By integrating the themes in the GIS domain, the groundwater prospect zones map has been derived as discussed in the methodology section. The resulted map shows the distribution of groundwater potential zones across the study area. It os observed that 113.03 km2 (7%) of the area falls under very high category, 405.95 km2 (25.14%) of the area falls under the high category, and 586.35 km2 (36.31%) of the area is covered under moderate category.

Table 8: Details of the groundwater prospect zones

Class	**Pixel Count**	**Area (km^2)**	**Area under Prospect zone in %**
Very low	248060	99.22	6.14
Low	1026201	410.48	25.42

Moderate	1465865	586.35	36.31
High	1014887	405.95	25.14
Very high	282570	113.03	7.00
Total		**1615.03**	**100**

It can be noted that 410.48 km2 (25.42%) of the area belongs to low, and the remaining 99.22 km2 (6.14%) area falls under the very low category. All the classes are evenly distributed throughout the study area. However, a significant portion of Bangalore East taluk falls under very low and low categories. This could be due to intensive urbanization in this region. Geological structures play a vital role in groundwater movement and accumulation in the surface and subsurface layers(Elmahdy & Mohamed, 2014). The regions with high lineament density fall under potential zones. Generally, lateritic zones are potential zones of groundwater availability(Arulbalaji et al., 2019). The land-use/landcover classes such as water bodies and agricultural lands are good for improving the groundwater and groundwater development is difficult on fallow land(Pundir & Garg, 2020). Forest and agricultural lands hold significantly high quantities of water compared to built-up lands and barren rocky surfaces(Arulbalaji et al., 2019). Low potential zones are associated with the upper parts of the pediments, impervious built-up lands, and high relief hilly zones(A. Kumar & Pandey, 2016). In the study area, hill categories like residual hills and steep slope areas belong to the high runoff zones. The Drainage density map and weight/rank details are furnished in **(Figure 2h) and (Table 8),** respectively.

Conclusion

The study reveals that RS and GIS techniques play a crucial role in assessing groundwater prospect zones. To identify the groundwater prospect zones, seven spatial themes have been considered for weighted overlay analysis, including geology, lineament, geomorphology, landuse/landcover, soil, slope, and drainage. Weights/ranks to the classes of the different themes are assigned based on the specific characteristics of individual class and its significance towards groundwater occurrence. The weights and their corresponding normalized weights have been calculated using the analytical hierarchy process in GIS domain.

Five groundwater prospect zones have been identified in the present study, ranging from a very good prospect zone to a very low prospect zone. The study area has only 7% of very good zones, about 19% of good prospect zones, and 36% moderate zones. This cautions the decision-makers and concerned departments to promote the scientific and sustainable use of groundwater for future needs and initiate the appropriate measures to develop groundwater resources. It is vital to begin constructing water harvesting and storage structures at the proper sites for efficient rechargeand tapping of groundwater. It is suggested to carry out an integrated study by using advanced technologies and other convention mtehods to identify feasible sites for building checkdams and other structures to improve groundwater availability.

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