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Identification of Groundwater Potential Zones in Moalleman, Iran by Remote Sensing and Index Overlay Technique in GIS

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Abstract

Water plays a vital role in the development of activities in an area. The surface water resources are inadequate to fulfill the water demand. Productivity through groundwater is quite high as compared to surface water, but groundwater resources have not yet been properly exploited. Keeping this view, the present study attempts to select and delineate various groundwater potential zones for the assessment of groundwater availability in Moalleman, using the remote sensing and GIS technique. Satellite images such as Landsat 8, Aster and SRTM DEM data have been used in the present study to prepare various thematic maps for the study area, such as geology, geomorphology, soil hydrological group, land use/land cover, and drainage maps. According to the relative contribution of each of these maps towards groundwater potential, the weight of each thematic map has been selected. Furthermore, within each thematic map ranking has been made for each of the features. All the thematic maps have been registered with one another through integrated step-by-step using the normalized aggregation method in GIS for computing groundwater potential index. Based on this final weight and ranking, the groundwater potential zones have been delineated. Thus from the present study it has been observed that an integrated approach involving remote sensing and GIS technique can be successfully used in identifying potential groundwater zones in the study area. Five categories of groundwater potential zones: excellent, very good, good, moderate and poor have been demarcated. Major portions of the study area have "good" or "moderate" prospects, while a few scattered areas have poor prospects. The excellent potential areas are mainly concentrated along the shore line. This groundwater potential information is useful to effectively identify suitable locations to extract water. Lastly, the final map has been overlaid with the map of springs and qanats for comparison and rolling as a checkpoint.

Keywords: *Groundwater Potential Map, GIS, Remote Sensing, Weigh Overlay, Landsat8, Aster & STR DEM*

1. Introduction

Water is one of the most essential natural commodities that supports human needs and economic development, and the largest available source of fresh water lays underground (Ravindran 2012). Tremendous increase in agricultural, industrial, and domestic activities in recent years has increased the demand for good quality water to meet the growing needs. Groundwater is mostly preferred to meet this growing demand because of its lower level of contamination and wider distribution.

The occurrence of groundwater at any place on the earth is not a matter of chance but a consequence of the interaction of the climatic, geological, hydrological, physiographical, and ecological factors. Groundwater exploration operation is essentially a hydrogeological and geophysical inference operation, and is dependent on the correct interpretation of the hydrological indicators and evidences (Arkoprovo et al. 2012). The movement of groundwater is controlled mainly by porosity and permeability of the surface and underlying lithology. The same lithology forming different geomorphic units will have variable porosity and permeability thereby causing changes in potential the groundwater. This is also true for same geomorphic units with variable lithology. The surface hydrological features like topography, geomorphology, drainage, surface water bodies, etc. play an important role in groundwater replenishment. High relief and steep slopes impart higher runoff, while the topographical depressions help in increased infiltration. An area of high drainage density also increases surface runoff compared to a low drainage density area. Surface water bodies like rivers, ponds, etc. can act as recharge zones enhancing the groundwater potential in the vicinity. Hence, identification and quantization of these features are important in generating a groundwater potential model of a particular area (Khan and Moharana 2002).

Remote sensing is an excellent tool for hydrologists and geologists in understanding the "perplexing" problems of groundwater exploration. In recent years, satellite remote sensing data has been widely used in locating groundwater potential zones (Jensen 1986). Satellite remote sensing data is not only cost effective, reliable and timely, but also meets the essential

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requirements of data in the geographical information system (GIS) domain, which are "current, sufficiently accurate, comprehensive and available to a uniform standard" (Musa et al. 2000). Integration of the information on the controlling parameters is best achieved through GIS, which is an effective tool for storage, management, and retrieval of spatial and non-spatial data as well as for integration and analysis of this information for meaningful solutions. The technique of integration of remote sensing and GIS has proven to be extremely useful for groundwater studies (Nath et al. 2000; Waikar and Nilawar 2014). Satellite remote sensing provides an opportunity for better observation and more systematic analysis of various geomorphic units/landforms/lineaments due to the synoptic and multi-spectral coverage of a terrain. Investigations of remotely sensed data for the drainage map and geological, geomorphological, and lineament characteristics of terrain in an integrated way facilitate effective evaluation of groundwater potential zones. Similar attempts have been made in the generation of different thematic maps for the delineation of groundwater potential zones in many case studies.

2. Study area

The study area (Moalleman) is near Damqan city located in Semnan Province, north of Iran. The geographical extension of the study area is latitude 35º00´N to 35º30´N and longitude 54º30´E to 55º00´E. (Fig 1). The 1:100000 Moalleman geological sheet is in the area and is located on northern part of the 1:250000 Troud geological map. The topography of the study area varies and is high in the NW part of the area and nearly smooth in the SE parts.

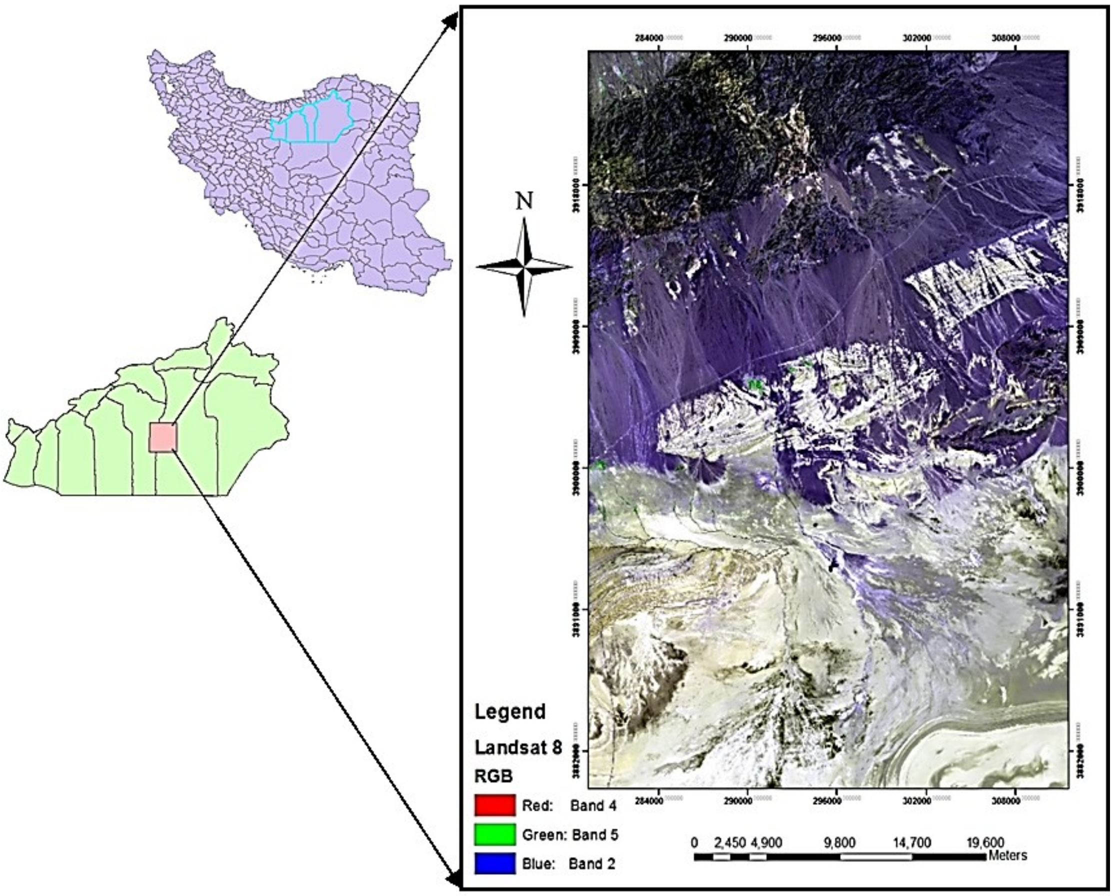

Fig 1. Location map of the study area

3. Geology

Moalleman district in the geological structure view is in the north of Iran central field. In the Nogole Sadat (1993) this field is underlain by tectonic-sediments of the central Iran and central Magmatic unit. Houshmandzadeh et al. (1975) named the north part of the area Toroud-Chah Shirin unit and is located on the Torud and Anjilo major fault zones and the northern edge of the Great Desert. The area can be separated under the structural zone:

3.1. Toroud-Chah Shirin subzone

Thin string or the Torud-Chah Shirin subzone that contains outcrops of metamorphic rocks of Paleozoic and Mesozoic and igneous early Tertiary sedimentary (Paleogene) deposits is formed entirely in the northern part of the sheet.

3.2. Neogene low depth subzone

This zone contains some parts of the Jandaq Sedimentary basin and is located on the south part of the geologic sheet. In this unit, low depth marine sediments that have evaporative with the recent to sub recent age.

4. Geomorphology

The area of Moalleman is located in the northern part of Jandaq Desert and at the beginning of the desert road of Jandaq, so it is known as Sar-Kavir (meaning the "start of the desert" in Persian). There are uneven terrains in the Moalleman area and some fields have mostly high lands. The highest mountain is Kahovan with a high of 1009 meters. The lowest plain is Moalleman-Khor Playa and is located in the south with a high of 798 meters. Moalleman-Toroud alluvial zone has low to middle steep topography to the south and some evidence of young tectonic activity is seen in the alluvial deposits. Many of the valleys and watersheds in the Toroud-Chah Shirin subzone are in accordance with the fractures and faults where the influence of the dyke can be observed.

5. Hydrogeology

Contrasting water bearing properties of different geological formations usually plays an important role in the occurrence and movement of groundwater. Alluvial plains or areas, known as Kooh Zar-Maabad plain is located in the north, Toroud-Moalleman in the middle and mud flat (Moalleman-Khor Playa) in the south. Some of the important seasonal rivers of the area such as Hafez, Chah Alla, Shourchai, Hasan Amrou (Zook), Chalou, Kam Anjir, Jodar, and Moalleman have catchment to the south and join the Jandagh-Khor mud flat plain. North waterways and rivers pour into Haj Gholo Khan Desert (Chah Jam Plain). In the area, because of the variety of geologic units and non-uniform resistance against the phenomenon of tectonic and erosional, there are valleys with different shapes, but most are V-shaped created. Drainage networks also have different shapes and circles. Hydrogeologically the weathered and fractured zones of the crystalline and the porous alluvium constitute the main repository of groundwater in the district.

6. Methodology

The proposed methodology of the study involved various activities such as base map preparation, Digitization and image processing using software and interpretation of the outputs. GIS and remote sensing technology has been applied to prepare various thematic maps with reference to groundwater like drainage density and contour, and stream length. The study has been conducted based on the secondary data that have been collected from the relevant department. The study has considered eight parameters for the groundwater level assessment as mentioned in the introduction. The elevation data has been downloaded from *ASTER GDEM* and this has been used as a base to create the elevation and slope maps. Then using the elevation data, the drainage network has been created. The Landsat 8 satellite data downloaded from "earthexplorer.usgs.gov" has been used to identify the land use and land cover pattern of the study area. The spatial data such as soil, dykes, geology, and geomorphology were collected from the Department of Mines and Geology of Iran, "NGDIR.com". The slope map was extracted from Aster GDEM and for the lineaments map two methods were used. The collected rainfall and temperature data contained information about the particular rain gauge station so the method Inverse Distance Weightage (IDW) in ArcGIS was used to determine overall rainfall variation in the study area (Fig 2). Once the error reification of each parameter was complete, the Satty's analytical hierarchical process was used to rank the weight of each parameter (See: Table 1). The detailed report of the analytical procedure is given in Fig 3.

7. Results and discussion

As mentioned in the Methodology section, the selected nine parameters have been created using GIS techniques and it has been ranked based on the Satty's analytical hierarchical process. The detailed discussion of each parameters followings.

7.1. Drainage and Drainage density

The study of drainage is one of the practical approaches to understand the structural and lithological control of land form evolution. The density of drainage is one of the factors that plays a major role in a potential groundwater map (GPM). The water runoff will be high if the density of drainage is high, so the infiltration of water into the groundwould be less; whereas the low drainage density area's surface-water runoff will be less, so the infiltration of surface water into the ground will be high. For the present study, the stream data have been created from the aster DEM and the data have been compared with the stream data, which were collected from the Department of Mines and Geology. The corrected streams data have been used to find out the drainage density of the study area.

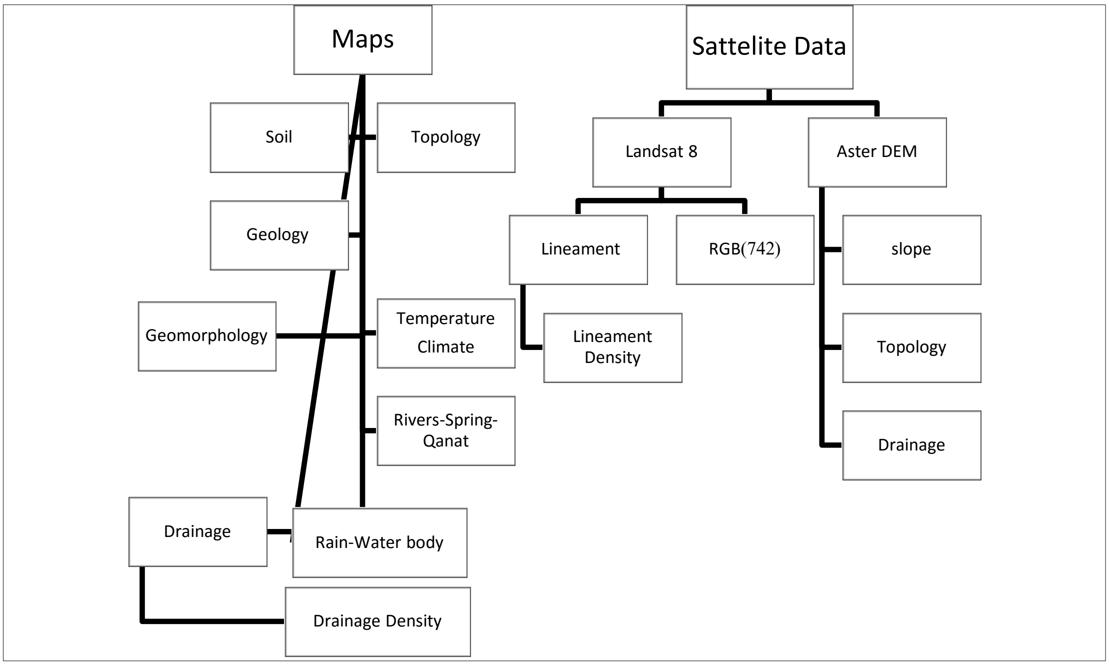

Fig 2. Flow chart depicting broad methodology

Table 1. Drainage density classification

Groundwater Potentiality	Km/Km2	Rank
Poor	0.49-1.86	1
Moderate	1.86-3.71	2
Good	3.71-5.57	3
Very good	5.57-7.43	4
Excellent	7.43-9.28	5

There are several methods that have been used by a number of researchers to determine drainage density, notably Magesh et al. (2012) and Sajikumar and Pulikkottil (2013) used the line density method and Godebo (2005) used IDW. Therefore, for the present study, we have usedthe IDW and line density method for the drainage density and we have found these two methods are not suitable for drainage density analysis because the line density method calculates a magnitude per unit area from polyline features that fall within a radius around each cell (ESRI). The density of drainage does not calculated by the radius; rather it is calculated by the square area and so it is not suitable for the drainage density analysis. The method IDW uses the measured values surrounding the prediction location to predict a value for any unsampled location (ESRI). Therefore, the IDW technique is not suitable for drainage density analysis because this technique does not produce the valuebased on the square area, rather it produces it based on the distance of two sample locations. Drainage density can provide higher accuracy than previous methods. This method is based on pour points and then compared with drainage network detection. This method is used to determine the drainage density. Drainage density was estimated by following the methodology adopted for calculating lineament density. Drainage pattern reflects the characteristic of the surface as well as subsurface formation. Drainage density (in terms of km/km^2) indicates closeness of spacing of channels as well as the nature of surface material. The more the drainage density, the higher would be runoff. Thus, the drainage density characterizes the runoff in an area or in other words, the quantum of relative rainwater that could have infiltrated. Hence, the lesser the drainage density, the higher is the probability of recharge or potential groundwater zone. The drainage density in the area has been calculated after digitization of the entire drainage pattern (Fig 4). The high drainage density area indicates low-infiltration rate whereas the low-density areas are favorable for high infiltration rate. The obtained drainage density values were reclassified to prepare a drainage density map and categorized into five categories: excellent, very good, good, moderate, poor.

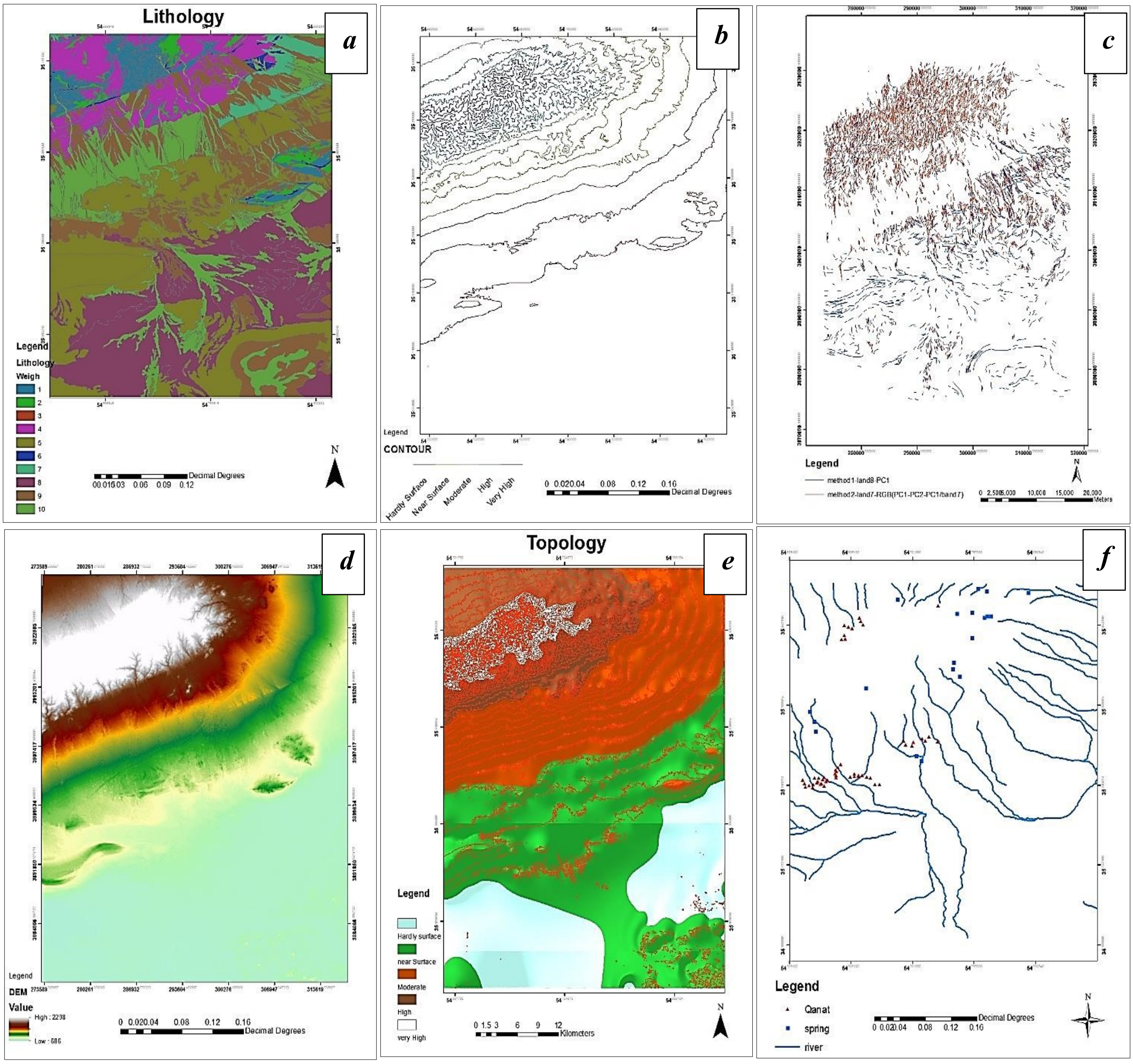

Fig 3. Selected parameters for identification of potential groundwater zones
(a) Lithology (b) topology sheet (c) lineaments (d) evaluation (e) satellite topology (f) river, spring, qanat

7.2. Elevation

Water tends to store at lower topography rather than higher topography. The higher the elevation, the lesser the groundwater potential and vice versa (Godebo 2005), for the present study elevation data having a 100 meter spatial resolution have been created based on the ASTER DEM. The study area's elevation ranges between 686 to 2298 meters from the mean sea level, these values have been classified equally into five classes and weightage for each class have been assigned.

7.3. Soil

Soil is the one of the primary factors that determines the amount of groundwater, the study of soil helps determine types and as properties. The movement of groundwater and infiltration of surface water into the ground is based on the porosity and permeability of soil. Therefore, the study of soil is important to determine the amount of groundwater of any place. The base data for the soil classification of the present study has been obtained from the National Bureau of Soil Survey and Land Use Planning, Bangalore. The result of soil classification found that the study area has three types of major soils. The movement and infiltration of water in these three types of soil is not the same, so based on its property the weightages have been assigned.

The soil present in the study area was studied and classified up to the sub group level according to the Soil Taxonomy (1961), by "the Soil Department of Irrigation Bongah, Ministry of Agriculture, and the Food and Agriculture Organization of the United Nations". The prepared soil map of the study area is shown in Fig 3. The map has been digitized and the distribution of the different soil sub groups are as follows:

i) Calcareous lithosols- Desert and Sierozem Soils
ii) Sierozem Soils
iii) Desert Soils – Seirozem Soils- Solonchak soils
iv) Solonchak and solonetz Soils

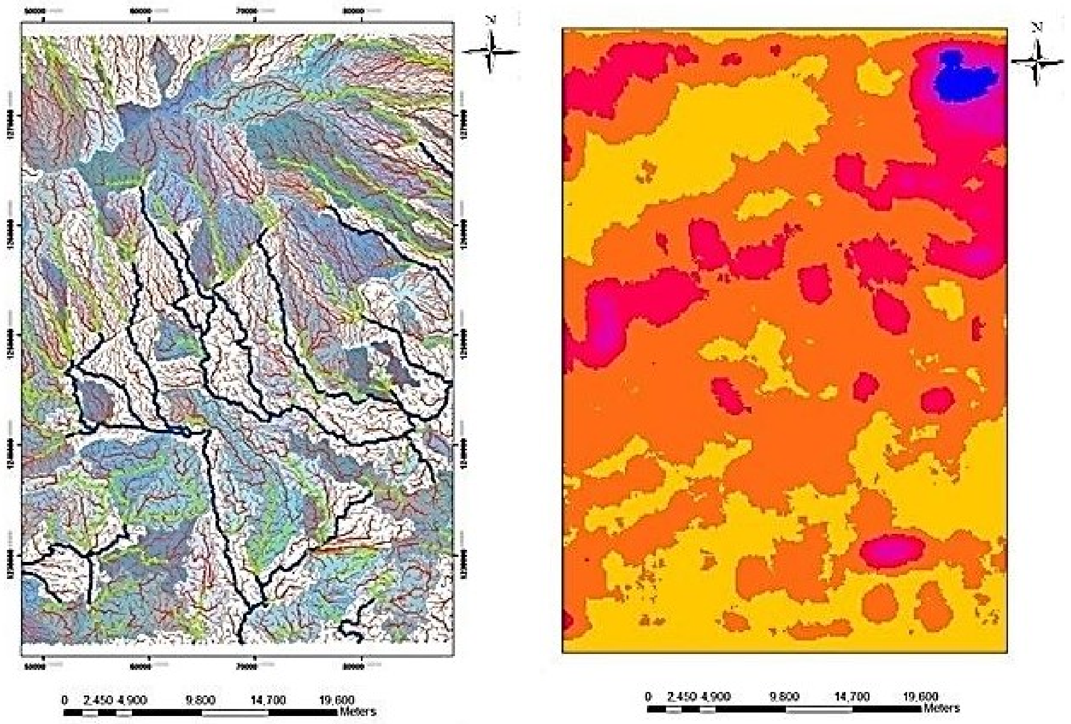

Fig 4. Drainage and drainage density of the study area

7.4. Slope Map

Slope is an important terrain parameter that is explained by horizontal spacing of the contours. Slope determines the rate of infiltration and runoff of surface water. The flat surface areas can hold and drain the water inside of the ground, increasing the groundwater recharge; whereas, the steep slopes increase the runoff and decrease the infiltration of surface water into the ground. In general, in the vector form, closely spaced contours represent steeper slopes and sparse contours exhibit gentle slopes; whereas, in the elevation output raster every cell has a slope value. The slope of the study area has been calculated in degrees based on the DEM model, which was based on the ASTER data.

A slope map was prepared according to the following class interval, and the slope was classified into five classes (Fig 3) and for each class weightage was assigned. The slope values are calculated either in percentage or in degrees. The slope amount derived from digitized contours and spot heights show that elevation decreases from the northern part to the southern part with a slope of 0º to 10º in flat and mountainous areas respectively. In the nearly level slope area (0º -3º), the surface runoff is slow allowing more time for rainwater to percolate, and so it is considered a good groundwater potential zone. Whereas the strong slope area (30º-74º) facilitates high runoff, allowing less residence time for rainwater; hence, there is comparatively less infiltration and poor groundwater potential. The entire slope map is divided into five categories as in Table 2 and each class weightage has been assigned.

Table 2. Slope gradient and category

Groundwater Potentiality	Degree	Rank
Nearly level	0-0.3	1
Very gently sloping	0.3-6.23	2
Gently sloping	6.23 – 14.10	3
Moderately sloping	14.10 – 31.22	4
Strongly sloping	21.22 – 74.80	5

7.5. Geology

According to the Chambers dictionary, the definition of geomorphology is “the scientific study of the nature and history of the landforms on the surface of the earth and other planets, and of the processes that create them”. Geology is one of the major factors playing an important role in the distribution and occurrence of groundwater. Ingenious and sedimentary rocks generally form this study area.

7.6. Geomorphology

Geomorphology is a study of earth structures and depicts the various landforms relating to the groundwater potential zones and structural features. Geomorphology of an area depends upon the structural evolution of geological formation. Based on the importance for geomorphological features the weightage was assigned.

7.7. Land use and Land cover (LU/LC)

Due to anthropogenic activities, the land surface has been modified enormously in recent years. The surface has been covered by vegetation like forests and agriculture traps and holds the water in the root of plants; whereas the built-up and rocky land use affects the recharge of groundwater by increasing runoff during the rain, so it is necessary to study what kind of features are covered in the study area’s land surface. Landsat 8 satellite image has been used for the study to determine the land use and land cover of the study area. Also, the supervised classification and NDVI method has been used. The result of the study found that the land cover elements in this study area are not covered much and do not affect groundwater potential.

7.8. Lineaments and dykes

Lineaments are straight linear elements visible at the Earth's surface as significant “lines of landscape” (Hobbs 1904). These are primarily a reflection of discontinuities on the Earth’s surface caused by geological or geomorphic processes Clark and Wilson (1994) and can be indicators of subsurface faults and fractures influencing the occurrence of groundwater acting as canals and reservoirs. Geological features that give rise to lineaments include faults, shear zones, fractures, dykes and veins as well as bedding planes and stratigraphic contacts. Geomorphic features appear as lineaments on the maps, aerial photographs and satellite images include streams, linear valleys and ridgelines. Lineament studies have vast applications in different disciplines of geosciences for example identification of tectonic features, recognition of folds and faults, exploration of mineral deposits, petroleum prospects, and groundwater, etc. Remote sensing data i.e., satellite images of an area are useful for map lineaments. For better interpretation of lineaments, the images have been digitally processed using image processing software.

The dykes act as a conductor based on intensity of faults and fracturing. The lengths of the dykes are most important in controlling regional subsurface water flow. Lineament density of an area can ultimately expose the groundwater potential because the presence of lineaments usually signifies a permeable zone. Areas with high lineament density are good for groundwater potential zones (Haridas et al. 1998). Hence, the lineaments and dykes play a major role in groundwater potential zoning. The process in this study contains two method: *PCA band ratio* and *RGB (PC1, PC2, PC1/band7)* of Landsat8 image. Results have been comprised and the best lineaments and dykes with suitable weightage have beenspecified based on the infiltration of groundwater (Table 3).

7.9. Rainfall, Temperature, Evaporation

Rainfall is one of the major sources for groundwater availability through the water cycle. The amount of rainfall is not the same everywhere and it varies based on the environment conditions of the place. The possibility of groundwater is high if the rainfall is high and it is low if rainfall is low.

The rainfall not only varies spatially, it also varies temporally; hence, to determine the influence of rainfall in any region a long-term study period is necessary. The temperature and evaporation are deferent; lower amounts have more values. These three items have been mapped and based on their influence weighted. The final map shows the value of 10%, which has been summed with other layers.

Table 3. Lineament density classification

Lineament Density	Km/Km^2	Rank
Very low	0 – 0.33	1
Low	0.33 – 0.8	2
Moderate	0.8 – 1.39	3
High	1.39 – 2.18	4
Very High	2.18 – 4.24	5

8. SATTY'S Analytical Hierarchical Process (AHP)

This process introduced by Thomas Sayty in 1980 is an effective tool for dealing with complex decision making, and can aid the decision maker to set priorities and to make optimal decisions. The AHP considers a set of evaluation criteria and a set of alternative options, among which the best decision is made. The AHP generates a weight for each evaluation criterion according to the decision maker's pairwise comparisons of the criteria; the higher the weight, the more important the corresponding criterion. Next, for a fixed criterion, the AHP assigns a score to each option according to the decision maker's pairwise comparisons of the options based on that criterion; the higher the score, the better the performance of the option with respect to the considered criterion.

Determination of the groundwater potential value for a given area involves multiplying each scale value of the reclassified layer (parameter) by its weight (or percent influence). The resulting cell values are added to produce the final output raster that represents potential groundwater areas. Higher sum values represent a greater potential for groundwater. For a particular area being evaluated, the parameter classes were scaled on an evaluated scale according to their importance to other classes in the layer. The values were assigned in terms of their importance with respect to groundwater occurrences. Once each parameter has been assigned a suitable scale value it is weighted. Weight values from 1 to 100 express the relative importance of the parameter with respect to each other to groundwater occurrences. The formula of the GPM is shown below **[9-10]**:

$$GPM = LD_sLD_w + DD_sDD_w + SS_sDD_w + TE_sTE_w + GF_sGF_{w+\ldots}$$

Where

W: Importance weight for the factor (1% - 100%),
S: Scale value of area being evaluated (1 - 9),
LD: Lineament length-density,
DD: Drainage length-density,
TE: Topography elevation,
SS: Slope steepness,
GF: Geological formations.

This formula was modified by Musa et al., (2000) from the DRASTIC model, which is used to assess groundwater pollution vulnerability by the Environmental Protection Agency of the United State of America. Table 1 shows the scaled values and weights assigned to different classes for different parameters; each of these parameters was represented by a single GIS layer. These layers were manipulated spatially to produce the GPM map. Figure 5 shows these layers along with their scaled values based on Table 2.

9. Integration of Thematic Layers and Modeling through GIS:

9.1. Weighted Index Overlay Model

Depending on the groundwater potentiality, each class of the main eight thematic layers (geomorphology, lithology, slope, drainage density, lineament density and surface water body) are qualitatively placed into one of the following categories: excellent, very good, good, moderate, poor. Suitable weightage on a scale of 9 has been given to each class of a particular thematic layer based on their contribution towards groundwater potentiality. The rank of each thematic map is scaled by the weight of that theme. All the thematic maps are then registered with one another through ground control points and integrated step-by-step using the normalized aggregation method in GIS for computing the groundwater potential index of each feature. The weight assigned to the different classes of all the thematic layers and rank of each features are given in Table 1. All the thematic maps have been integrated using the GWPI formula in GIS. A final groundwater potential map (Fig 5) is prepared based on the above technique.

In the present study, the groundwater potential zones have been categorized into five types: excellent, very good, good, moderate, and poor. Table 2 gives the upper and lower limits of the weights considered for demarcating these five types of groundwater prospective areas.

Table 4. Rank and weight for different parameters of the groundwater potential zone

Parameter	Classes	Groundwater prospect	Weight (%)	Rank
Slope	0-0.3	Nearly level	15 %	9
	0.3-6.23	Very gently sloping		7
	6.23 – 14.10	Gently sloping		5
	14.10 – 31.22	Moderately sloping		3
	21.22 – 74.80	Strongly sloping		1
Lineament density	0 – 0.33	Very low	15 %	9
	0.33 – 0.8	Low		7
	0.8 – 1.39	Moderate		5
	1.39 – 2.18	High		3
	2.18 – 4.24	Very High		1
Geomorphology	Salt crust	Very low	15 %	8
	Salt domes and Layer	Low		7
	Hills, plateaus and Badlands	Moderate		6
	Plain surfaces between 500 and 1000 m.	High		4
	Mountain with an altitude of 500 meters.	Very High		1
Topography	Surface	Very good	15 %	9
	Near surface	Good		8
	moderate	Moderate		5
	High	Poor		4
Soil	Semi-moist Litosell soils	Good	15%	8
	Desert soils.			
	Salty Soils	Moderate		4
		Poor		3
Surface	Excellent	Excellent	10 %	9
	Very good	Very good		7
	Good	Good		5
	Moderate	Moderate		3
	poor	poor		1

9.2. Assigning Rank and Weight

The groundwater potential zones have been obtained by overlaying all the thematic maps in terms of the weighted overlay method using the spatial analysis tool in ArcGIS 10.1. During the weighted overlay analysis, the ranks have been given for each individual parameter of each thematic map and the weight was assigned according to the influence of the different parameters. The weights and rank have been taken considering the tasks carried out by researchers such as (Krishnamurthy et al. 1996; Saraf and Choudhury 1998). All the thematic maps have been converted into raster format and superimposed by the weighted overlay method (rank and weight wise thematic maps and integrated with one another through GIS .For assigning the weight, the slope and geomorphology were assigned a higher weight, whereas the lineament density and drainage density were assigned a lower weight. After assigning weights to different parameters, individual ranks were given for the sub variable. In this process, the GIS layer on lineament density, geomorphology, and slope and drainage density were analyzed carefully and ranks were assigned to their sub variable (Butler et al. 2002; Asadi et al. 2007; Yammani 2007). The maximum value was given to the feature with the highest groundwater potentiality and the minimum given to the lowest potential feature. The landforms such as moderately dissected plateau were given the highest rank and lower value was assigned for the Pedi plain. As far as slope is concerned, the highest rank value was assigned for gentle slope and low rank value was assigned to the higher slope. The higher rank factors were assigned to low drainage density because the low drainage density factor favors more infiltration than surface runoff. Lower value has been followed by higher drainage density. Among the various lineament density classes the very high lineament density category was assigned a higher rank value as this category has a greater chance for groundwater infiltration. Lower value was assigned for very low lineament density. The overall analysis is tabulated in Table 5.

Table 5. Groundwater potential zones of the study area

Area (%)	*Area (km^2)*	*Potential*	*Rank*
0.07	0.047	Poor	1
5.5	137.70	Moderate	2
18.9	472.10	Good	3
47.5	1188.61	Very Good	4
27.98	698.74	Excellent	5

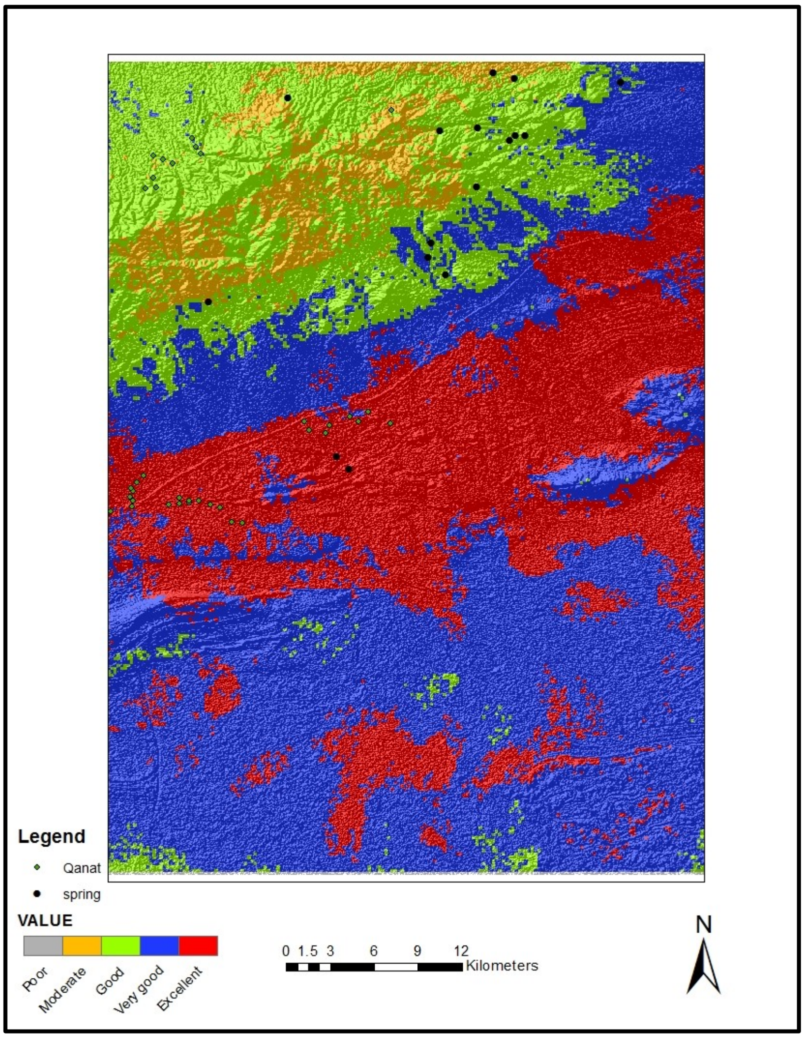

Fig 5. Groundwater potential map

10. Conclusions

The remote sensing and geographic information system (GIS) approach is very constructive because this integrates various geospatial information especially for groundwater potential zone mapping and has proved to be a powerful and cost effective method for determining groundwater potential in the study area. Further, it is felt that the present methodology can be used as a guideline for further research.

This Study has focused on the effectiveness of remote sensing and GIS in the identification and delineation of groundwater potential zones of the study area. All the thematic maps were converted into grid (raster format) and superimposed by weighted overlay method (rank and weightage wise thematic maps). From the analysis, the groundwater potential zones with excellent, very good, good, moderate, and poor prospects cover the area. To validate the result of the present study the locations of springs and qanats of the area have been prepaid and collected, then these data have been correlated with the result of the study. The result of correlation between the study result and water source map data has 90% accuracy. Therefore, based on the result and accuracy of the study, these methods would be suitable for exploring potential groundwater zones.

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