# INVESTIGATION OF GROUNDWATER POTENTIAL ZONES USING RS & GIS IN WESTERN PART OF KRISHNAGIRI DISTRICT

Aenumula Mallikarjun[1], Janaki Vallakeerthi[2] and Tamilanban[3]
[1,2,3]Assistant Professors, TKR Engineering College(R9), Hyderabad, Telangana State

**Abstract**

**Urbanization and ground water potential are interrelated feature in a landscape. With the help of powerful and high-speed computers, technology comprising of RS (Remote Sensing), GIS (Geographic Information System) and GPS (Global Positioning System) are of great significance in identifying ground water potential. The aim of the present study is to delineate the ground water potential zone in Krishnagiri district. The thematic layers considered in present study are Geomorphology, Land slope, Land use, Drainage density, Soil and Surface water body which were prepared using the IRS LISS IV, Topographical sheet and some other conventional data. All these themes and their individual features are then assigned weights according to their relative importance in groundwater occurrence. GIS modeling technique has been used to produce groundwater potential map. The thematic layers finally generated are integrated using ARCGIS software to yield a groundwater potential zone map of the study area. Thus, four different groundwater potential zones have been identified, namely 'Very high', High', 'Moderate' and 'Low'.**

**Keywords: Remote Sensing, GIS, GPS, LISS IV, ArcGIS**

**Introduction:**

In the world scenario, the availability of groundwater is reducing gradually due to over exploitation, and the lack of groundwater management. At present, the worldwide problem is the lack of fresh groundwater resource. Hence, it is necessary to understand the methods and way to approach towards groundwater potential zones and surface water conservation and to improve the groundwater level at the national, regional, and local scale for sustainable livelihood. Groundwater is one of the virtual water resources of planet earth that has been mainly replenished by surface water sources like rivers, lakes, ponds, and by surface and subsurface runoff. Since the eighteenth century onwards, groundwater storage structures like ponds, canals, and reservoirs have been used to store surface water all over India, but it is neither fully scientific nor geographic location based.

In order to circumvent these issues in identifying the groundwater zones, the recent geospatial technologies like remote sensing and GIS could be used with relatively accurate results. It is also possible to demarcate the high potential sites for artificial recharge in both accessible and inaccessible areas. The specific details of water resource systems including drainage pattern, stream order, water storage structures, and their associated geographical features should be incorporated to get credible conclusions for the relative benefits and alternative management policies (Georgakakos and Graham 2008). The hydrologic processes are highly interactive between the vadose zone and groundwater under shallow water table conditions (Xu et al. 2011). Lerner et al. (1990) stated that the tracer techniques can be successfully used to estimate the recharge in arid and semi-arid regions. However, such techniques provide local scale level information and not quantify the recharge over a large area. GIS has been widely used in studies related to pollution, terrain modeling, and groundwater prospecting (Magesh et al. 2011a, b, 2012c, d, Magesh and Chandrasekar 2012, John Wilson et al. 2012). Recent development in remote sensing and GIS techniques allow mapping the spatial distribution of groundwater level and its quality (Brunner et al. 2004, Tweed et al. 2007, Srivastava and Bhattacharya 2006, Krishna Kumar et al. 2011, Magesh and Chandrasekar 2011, Mukherjee et al. 2012, Magesh et al. 2012b, Sarath Prasanth et al. 2012). The results of downscaling analysis of the water resource system and climate change and production of reservoir inflows using statistical method produced significant output for extreme management of water resources (Georgakakos et al. 2011).

Relevant studies on groundwater potential using GIS and numerical modeling have been carried out by different researchers throughout the world (Appleyard 1995, Jyrkama et al. 2002, Lerner 2002, Sankar 2002, De vries and Simmers 2002, Cherkauer 2004; Keese et al. 2005, Nobre et al. 2007, Pradhan 2009, Youssef et al. 2010, Manap et al. 2012a, b, Pourghasemi et al. 2012). However, studies on application of GIS merged with analytical hierarchical process (AHP) in demarcating groundwater potential zones are carried out by few.

AHP technique analyzes the multiple datasets in a pair-wise comparison matrix, which is used to calculate the geometric mean and normalized weight of parameters (Chowdhury et al. 2010). However, Machiwal et al. 2011 have used five parameters in AHP process in their study for the identification of groundwater potential zone but in our study, we have used seven parameters for better results. The evaluation of the spatial parameters such as geological structure, geomorphic features and hydrological characteristics, among them geomorphology, slope and geology of the area have a great role to identify the groundwater zone from the surface runoff (Vijith 2007).

**Study Area:**

Krishnagiri is a district in the state of Tamil Nadu, India. The municipal town of Krishnagiri is the district headquarters. The study area covers two taluks namely- Hosur and Denkanikottai. The area lies between 12 15' 45" N & 12 46' 20"N Latitudes and 77 47' 2.4" & 77 53' 20" E Longitudes. The transportation network is one of the advantages for the development of the District. The prominent geomorphic units identified in the district through interpretation of satellite imagery are structural hills in the southwestern part of the district, denundational land forms like buried pediments in the plains and inselbergs and plateaus represented by conical hills aligned with major lineaments.

Soils have been classified into Black soil, mixed soil, red loamy soil, gravelly and sandy soils. Red loamy and sandy soils are predominant in Hosur taluk. The district receives the rain under the influence of both southwest and northeast monsoons. The normal annual rainfall over the district varies from about 750 to about 900 mm. It is the minimum around Hosur and Rayakottai in the northern and central parts of the district. It gradually increases towards west and east and is the maximum around Denkanikotai in the western part.

**Materials and Methods:**

The multiple parameter analysis for delineating the groundwater potential zones in the study area has been done by GIS-based AHP technique. In this study, 7 spatial parameters such as geology, geomorphology, slope, land use and land cover, NDVI, drainage density and rainfall are analyzed by AHP approach including geometric mean and normalized weight calculation to explore the potential zone for groundwater.

**Data collection and preparation of geospatial database**

Seven spatial parameters have been used for geospatial database preparation. Using GIS tool, the thematic layers namely geology, geomorphology, slope, land use and land cover, lineament density, drainage density and rainfall were prepared from the above data sources and projected with UTM–WGS 84 projection and coordinate system. The geological thematic layer was prepared from the published map of Geological Survey of India using digitizing technique in ArcGIS environment.

**Analytical hierarchical process**

AHP is used to demarcate the potential groundwater zones and this technique was proposed by Saaty (1990). The AHP method allows assessing the geometric mean (Eq. 1), followed by allotting a normalized weight (Eq. 2) to various parameters for finalizing the decision process. In this study, the AHP pair-wise matrix was developed by input values of scale weights of parameters based on direct or indirect relationship. The influence of different parameters towards groundwater potential was integrated with each other to form a cluster of relationships. If a parameter has direct influence towards groundwater potential, then the score was assigned as 1 and for indirect influence the assigned score is 0.5.

**Geometric mean**

In the first step of AHP analysis, the parameters were rated based on a defined score (0.5–1 scale) for calculating the geometric mean. The geometric mean is derived from the total sum of score of a specific parameter known as total scale weight divided by total number of parameter; this is expressed as (after Rhoad et al. (1991)).

$$\text{Geometric mean} = \frac{\text{Total Scale Weight}}{\text{Total number of parameters}} \quad (1)$$

**Normalized weight**

The normalized weight is an indicator of multi-parameter analysis for groundwater potential. In the second step of AHP analysis, the normalized weight was derived from the assigned weight of a parameter feature class divided by the corresponding geometric mean. The formula is represented as (after Yu et al. (2002)):

$$\text{Normalized weight} = \frac{\text{Assigned weight of a parameter}}{\text{Geometric mean}} \quad (2)$$

The normalized weighted map is an indicator of potential groundwater zone that was classified into five classes as very high, high, moderate, low, and unsuitable zone. The class with maximum weight is considered as very high suitable zone and least weighted class is less or unsuitable zone for groundwater.

**Methodology**

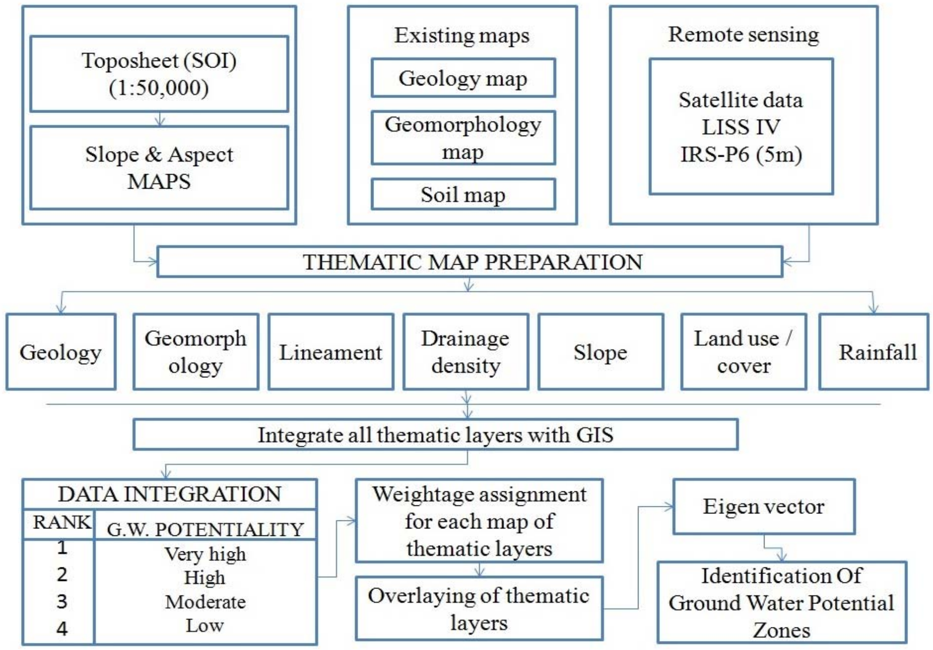


**Fig 2: Flow of Work**

**Results and discussion**

The potential zones for groundwater were explored by analyzing the different parameters such as geology, geomorphology, slope, land use and land cover, NDVI, drainage density and rainfall through integrated AHP method and geospatial technology.

| Theme | GM | GG | SLOPE | SOIL | LU/LC | NDVI | RF | DD | Geometric Mean | Normalized Weight |
|---|---|---|---|---|---|---|---|---|---|---|
| GM | 1 | 9/8 | 9/7 | 9/4 | 9/3 | 9/1 | 9/5 | 9/5 | 2.026 | 0.214 |
| GG | 8/9 | 1 | 8/7 | 8/4 | 8/3 | 8/1 | 8/5 | 8/5 | 1.801 | 0.190 |
| SOIL | 7/9 | 7/8 | 1 | 7/4 | 7/3 | 7/1 | 7/5 | 7/5 | 1.576 | 1.667 |
| SLOPE | 4/9 | 4/8 | 4/7 | 1 | 4/3 | 4/1 | 4/5 | 4/5 | 0.900 | 0.095 |
| LU/LC | 3/9 | 3/8 | 3/7 | 3/4 | 1 | 3/1 | 3/5 | 3/5 | 0.675 | 0.071 |
| NDVI | 1/9 | 1/8 | 1/7 | 1/4 | 1/3 | 1 | 1/5 | 1/5 | 0.225 | 0.023 |
| RF | 5/9 | 5/8 | 5/7 | 5/4 | 5/3 | 5/1 | 1 | 1 | 1.125 | 0.119 |
| DD | 5/9 | 5/8 | 5/7 | 5/4 | 5/3 | 5/1 | 1 | 1 | 1.125 | 0.119 |
| Column Total = | | | | | | | | | 9.453 | 0.997 |

**Table 1:** Weightage given to various factors

Every class in the thematic layers was placed into one of the following categories viz. (i) Good (ii) Good- Moderate (iii) Moderate (iv) Moderate-Poor (v) Poor. Considering their behavior with respect to groundwater control, the different classes are given suitable values, according to their importance relative to other classes

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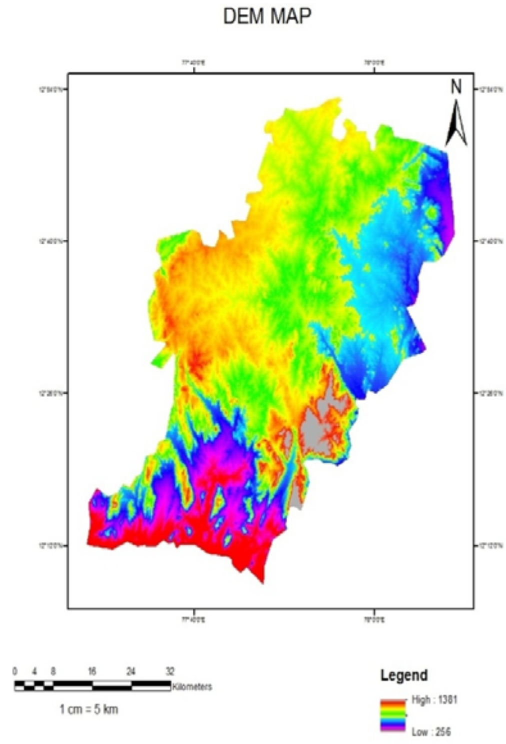


**Fig 3:** Digital Elevation Map

**Slope:**

The slope amount map has been prepared using contours produced from SOI Topographical data and in relation to groundwater flat areas where the slope amount is low are capable of holding rainfall, which in turn facilitates recharge whereas in elevated areas where the slope amount is high, there will be high run-off and low infiltration.

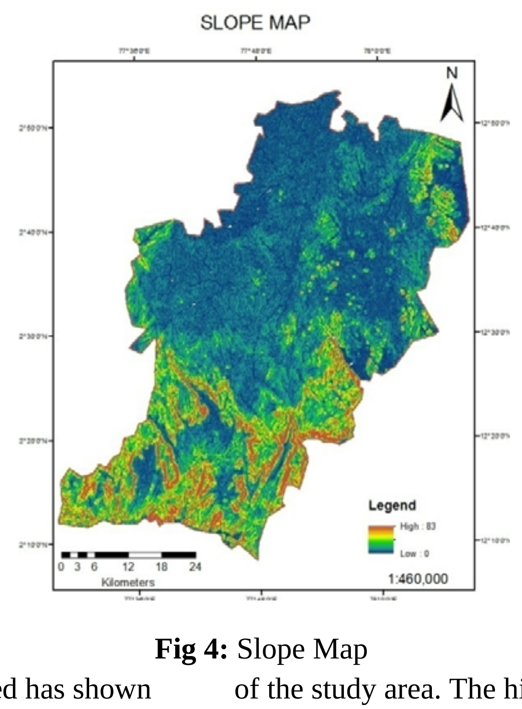


**Fig 4:** Slope Map

The slope amount derived has shown that elevation is low in northern and central part of the study area. The high slopes were found in the southern part ranges from 64% to 83%.

**NDVI:**

NDVI map is shown in fig 5. The results from the map show that higher impact of vegetation is available in the south-east region and normal vegetation in the western and SW regions. Parts of Hosur taluk have normal vegetation

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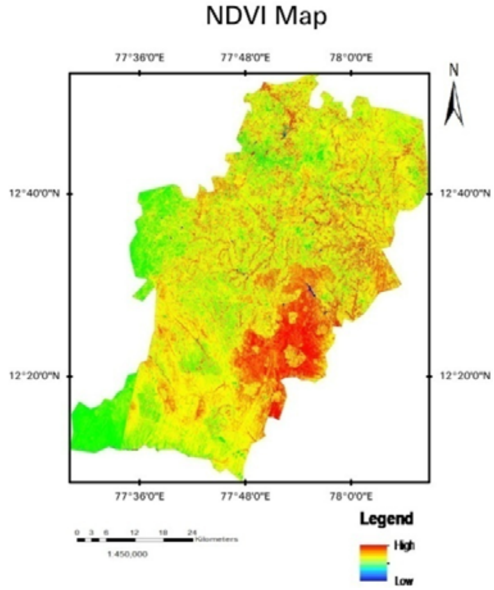


**Fig 5:** NDVI Map

**Landuse and landcover**:

Landuse and landcover map was prepared using geocoded IRS LISS IV data and was visually interpretated based on classification system. Landuse and landcover map is depicted in Fig. 6**.** One of the parameters that influence the occurrence of sub-surface groundwater occurrence is the present condition of landcover and landuse of the area. The effect of landuse/landcover is manifested either by reducing runoff and facilitating, or by trapping water on their leaf. Water droplets trapped in this way go down to recharge groundwater. Classification of landuse/landcover for analysis was done based on their character to infiltrate water in to the ground and to hold water on the ground.

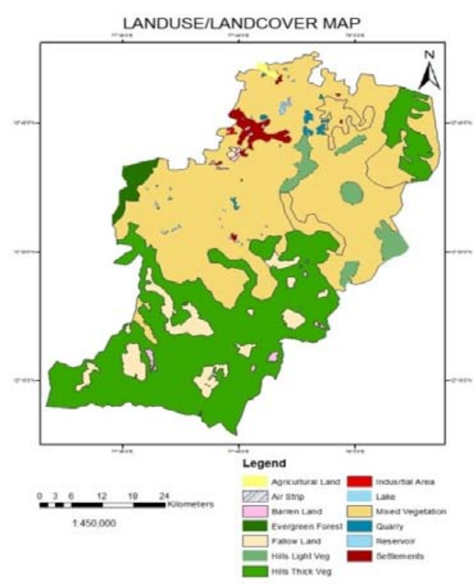


**Fig 6:** Landuse/landcover map

**Aspect:**

The aspect map is shown in the fig 7. Aspect gives the knowledge of low lying steep slopes along the east direction and the steep slopes in the southern region. Due to the slope, runoff will be more in steep slopes.

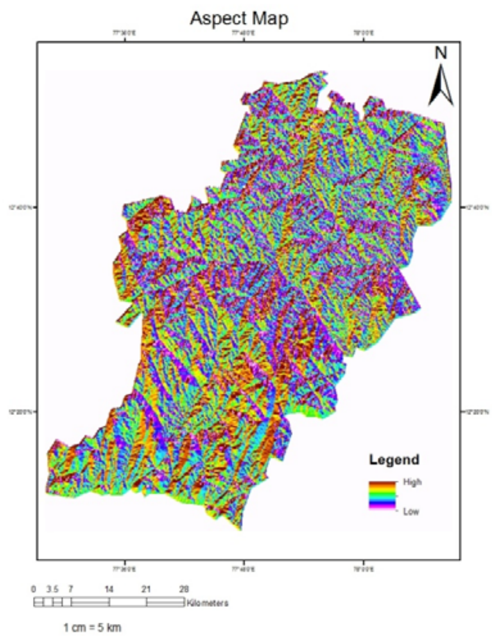


**Fig 7:** Aspect Map

**Drainage Density:**

The drainage network of the project area was derived from on screen digitization from topographic map; also the drainage is denser in southern part. Comparison of the drainage system of the area and structure has shown that the drainage system of the area is structurally controlled following lineaments directions. Dendritic and parallel drainage pattern are recognized, which are indicative of the presence of structures that act as conduits or storage for sub-surface water.

Structurally controlled drainage patterns are observed in western and southern part of the study area. Very high drainage density is found in the southern and southeastern part of the project area whereas high drainage density is found scattered in all parts of the project area.

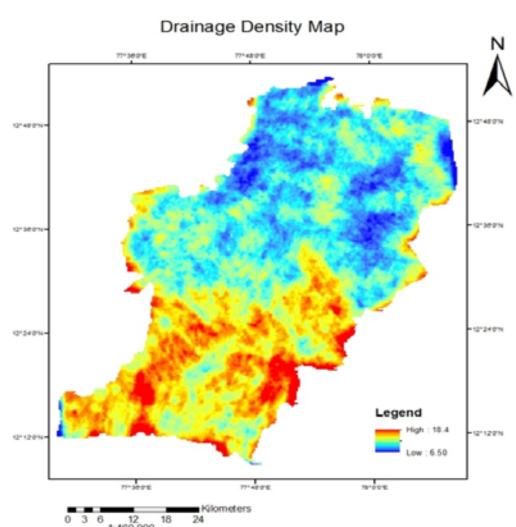


**Fig 8:** Drainage Density Map

**Soil:**

The Soil type ranges from fine loamy, loamy, clayey soils are seen in the study area. Black and loam soil are found in Krishnagiri district. The Soil map is shown in Fig. 9. Soil is one of the significant control factors to determine the infiltration rate of an area. Silt clay loam and sandy clay loam soils are calcareous in nature and they originated from the parent materials of calcium carbonate rocks, whereas loamy sand and loamy fine sand are non calcareous derived from acid rock materials. The areas which have coarse granule, coarse sandy loam, and loamy sand are generally high potential of groundwater infiltration.

**Geomorphology:**

The geomorphologic characteristics are broadly classified into pediments, structural hill, flood plain, shallow pediments upper undulating alluvial plains and Water body mask. The geomorphology map is shown in Fig 10. Floodplain deposits occur mainly along the stream channels in the eastern part of the study area and comprise chiefly poorly sorted to well-sorted clay, silty clay, loam, clayey silt and silt containing scattered granules and pebbles along with moderately to well-stratified loam, sandy loam or fine sand.

**Geology:**

The geological settings of the study area are underlain by sedimentary rocks namely charnockite, Granitoid gneiss, feldspar gneiss, calcareous gritty (sand stone mixed clay), and quartz vein. Granitiod gneiss is a composition of primary lateritic capping, basement crystalline complex, and conglomerate, which are found along the middle part of the river valley. The younger alluvium formations are seen predominantly in the northern part of the study area and are considered as highly permeable. Besides that, the northwest and middle-east part of the study area consist of fluvial–deltaic sediment deposits, which are laid on granitoid gneiss and are considered as good zone for groundwater potential. However, the hard rock materials composed of crystalline charnockite, conglomerate, and quartzite vein present in the southern part of the study area are not suitable for groundwater potential zones. The geology map is shown in the fig. 11.

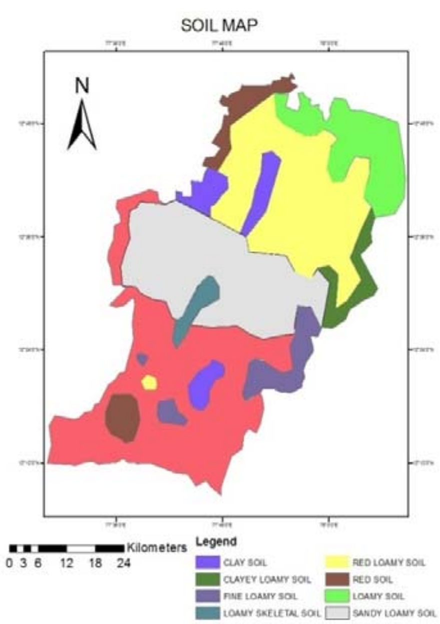


**Fig 9:** Soil map

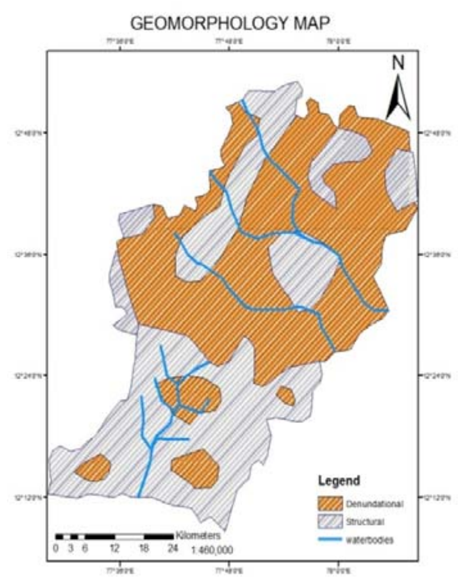


**Fig 10:** Geomorphology map

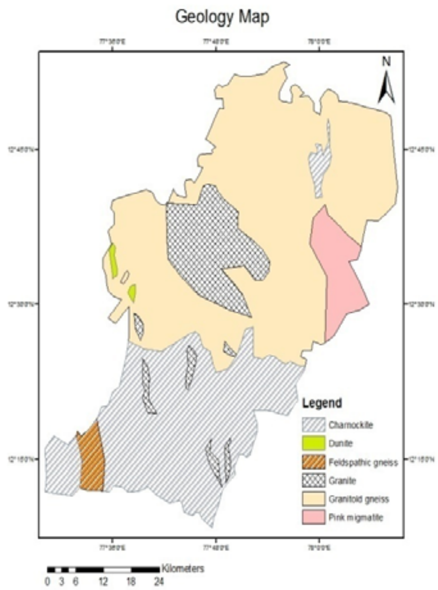


**Fig 11:** Geology Map

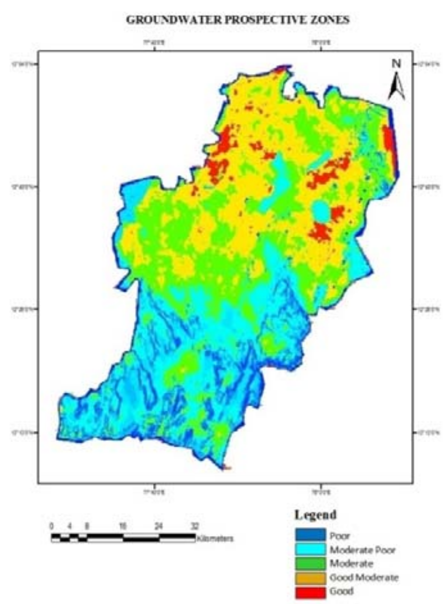


**Fig 12:** Groundwater potential zones of the study area

The map produced has shown that the groundwater potential of the project area is related mainly to lineaments, geology and slope. The groundwater potential zones were identified in the northern part of the study area. Hosur and its surrounding region is having good and average potential of groundwater respectively. So as Hosur, Parts of Shoolagiri and Bagalur also have good potential zone. The hilly regions have the poor groundwater potential zones because of the higher slopes and lower infiltration rate of soils.

### Data validation

The potential groundwater zone for the study area is shown in Fig 12. It is clearly observed that high potential zones are located in the northwestern part of the study area. Spatially the very good and good categories are distributed along areas near to lineaments and less drainage density and where the lithology is affected by secondary structure and having interconnected pore spaces. This highlights importance of lineaments, geology and hydro-geomorphological parameters in the project area. Areas with moderate groundwater prospects are attributed to contributions from combinations of the land use/cover, lithology, slope and landform. The low to poor categories of groundwater potential zones are spatially distributed mainly along ridges where slope class is very high, the lithology is compact/massive and far from lineaments. A cross-validation study has been carried out in this part to ensure the potential zones of groundwater as per field data published by CGWB (2010).

**Conclusions**

The application of integrated geospatial technology and AHP has proven to be a better tool for the identification of potential groundwater zones in western part of Krishnagiri. The present study demarcates the potential zones for groundwater by analyzing the influencing factors. The multi-parametric approach using RS, GIS and AHP techniques can greatly minimize the time, labor and money and thereby enable quick decision-making for efficient water resources management. Despite the inherent limitations of multi-criteria analysis, it is a valuable practical tool for the areas/regions (especially developing nations) where data scarcity (in terms of quantity and quality) is often an obstacle for solving real-world water problems.

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