Cloud Publications
International Journal of Advanced Remote Sensing and GIS
2017, Volume 6, Issue 3, pp. 2080-2087
ISSN 2320 - 0243 doi: 10.23953/cloud.ijarsg.70

Research Article

Open Access

Potential Groundwater Accumulations Assessment in Drought Prone Area using Remote Sensing and GIS Technology

Jothibasu, A.[1], Venkatesan, A.[2], Gunasekaran, S.[1]

[1]Centre for Geoinformatics and Planetary Studies, Department of Geology, Periyar University, Salem
[2]Department of Geology, Periyar University College of Arts and Sciences, Mettur Dam, Salem

Publication Date: 25 March 2017

DOI: https://doi.org/10.23953/cloud.ijarsg.70

Abstract Water plays a crucial role in the socio-economic development of India. Safe drinking water is required for the very large and growing population. Water has also become a major factor for the growth of the agricultural and industrial sectors. In the present study, the application of remote sensing and GIS techniques is applied for delineation of potential groundwater zone. The failure of monsoon and extensive groundwater usage lead to frequently drought condition. This has been visually observed during the field visit most of the dry wells extended to the depth of more than 50 m depth which is in unusual conditions in hard rock terrain. Similarly bore wells are using for extraction of groundwater with an average depth of 150 m (bgl). The study area annual average rainfall is 628 mm. In the present study the potential groundwater zones were demarcated through analysis of hydrogeology, geomorphology and lineaments with the help of IRS P6 LISS III satellite data and field investigation. The thematic maps like geology, geomorphology, lineament density, drainage density, land use and land cover and soil were reclassified and integrated for generation of groundwater potential map through GIS technique. Reclassification of thematic maps, ranking and weights assignment and were done through subjective and field experience. The final result is obtained through GIS overlay analysis. The groundwater condition in the major formations such as hornblende biotite gneiss, charnockite in the study area is controlled by secondary porosities like joints and fractures. The lineaments and associated fractures and buried pediments are important zones for potential groundwater accumulations and suitable for groundwater development for agriculture.
Keywords *Groundwater; Potential Zones; GIS; Remote Sensing; Index Overlay Method*

1. Introduction

Groundwater is one of the most valuable natural resources, immensely important and dependable source of water supply in all climatic region of all over the world (Todds and Mays, 2005). Although it is more dynamic renewable natural resource yet availability with good quality and quantity in appropriate time and space is more important (Chaudhary et al., 1996). The GIS technique is not only useful in mapping groundwater potential zones through spatial integration but also provides the controlling terrain parameter. GIS and remote sensing tools are widely used for the management of various natural resources (Krishna Kumar et al., 2011; Magesh et al., 2011). Remote sensing has become a vital tool for groundwater targeting, because the topographic expression and terrain characteristics have a direct relation to the characteristics of rocks and subsurface geological conditions. Integration of remote sensing data in the GIS environment is very useful in delineating various groundwater potential zones in a meaningful way (Agarwal et al., 2004).

The number of studies had attempted to clarify spatial variability of groundwater potential in different terrain conditions using technologies like aerial photography and GIS. Remote sensing from satellite has recently become a valuable tool that provide quick and baseline information on sub-surface water conditions. With this information, one can find out the factors controlling the occurrence potential and movement of groundwater such as geological structures, geomorphology, soil, land use land cover and other related characteristics of the area (Anbazhagan, 2002). This data can be spatially integrated by means of geographic information system and finally groundwater potential zones can be delineated. In this field attempts have already been made in different parts of the country by various authors like, Chaudhary et al. (1996), Krishnamurthy et al. (1996), Das et al. (1997), Goyal et al. (1999), Pratap et al. (2000), Nag (2005), Vijith et al. (2007), Suja Rose et al. (2009), Kumar Pradeep (2010) etc. Vagaries of monsoon and semi-arid to hot climate further aggravate the situation. Due to limited number of rainy days, natural depressions the study area also remains dry during most of the time of year. In the present study, an attempt has been made to assess the potential groundwater accumulation zones by an integrated approach of remote sensing and GIS technology.

2. Study Area

The Uppar Odai sub-basin is located in the Amaravati River basin in the state of Tamil Nadu, India, and falls between 77°6′36″E–77°32′24″E longitude and 10°26′40″N–10°55′48″N latitude. The aerial coverage of the Uppar Odai sub-basin is 1280 km2. It covers the major part of Tiruppur district and a small area of Coimbatore district (Figure 1). The annual average rainfall in the sub-basin is 625 mm, which is much lower than the state average rainfall (970 mm). A subtropical climate prevails throughout the region. The maximum temperature ranges from 27 to 35°C and minimum temperature varies from 17 to 23°C. There are four distinct seasons, namely southwest monsoon, northeast monsoon, winter season and hot weather period, prevailing in the study area. The rainfall pattern, as recorded at the rainfall stations, indicates that the precipitation is mostly uncertain, uneven or unequally distributed. It is slightly higher in the central and western parts and decreases in the northern and eastern parts of the sub-basin. The highest average annual rainfall of 738 mm is observed in the central part and the lowest amount of rainfall is 573 mm received in the northern part of the sub-basin.

3. Materials and Methods

The IRS P6 LISS III satellite data are visually interpreted for the preparation of lineament density, geomorphology and land use/land cover. The thematic layers and their corresponding categories are assigned a knowledge base ranking from 1 to 5 depending on their suitability to hold groundwater. The maximum value is given to the feature with highest groundwater potentiality and minimum being to the lowest potential feature. Based on these ranks their weightage are calculated and added to each layer (Sitender & Rajeshwari, 2011).

From the various methods available for determining interclass dependency, a probability weighted approach has been adopted that allow a linear combination of probability weights of each thematic map and different categories of derived thematic maps by assessing their importance in groundwater occurrence (Sitender & Rajeshwari, 2011). This process involves raster overlay analysis which is called multi-criteria evaluation techniques (MCE). The ‘Raster Calculator’ option of spatial analyst extension in Arc GIS 9.3 is used to prepare the integrated final groundwater potential map of the study area. This map indicates the potentiality of groundwater occurrence in the study area which is then classified into three categories based on the mean and standard deviation values namely high, moderate and low.

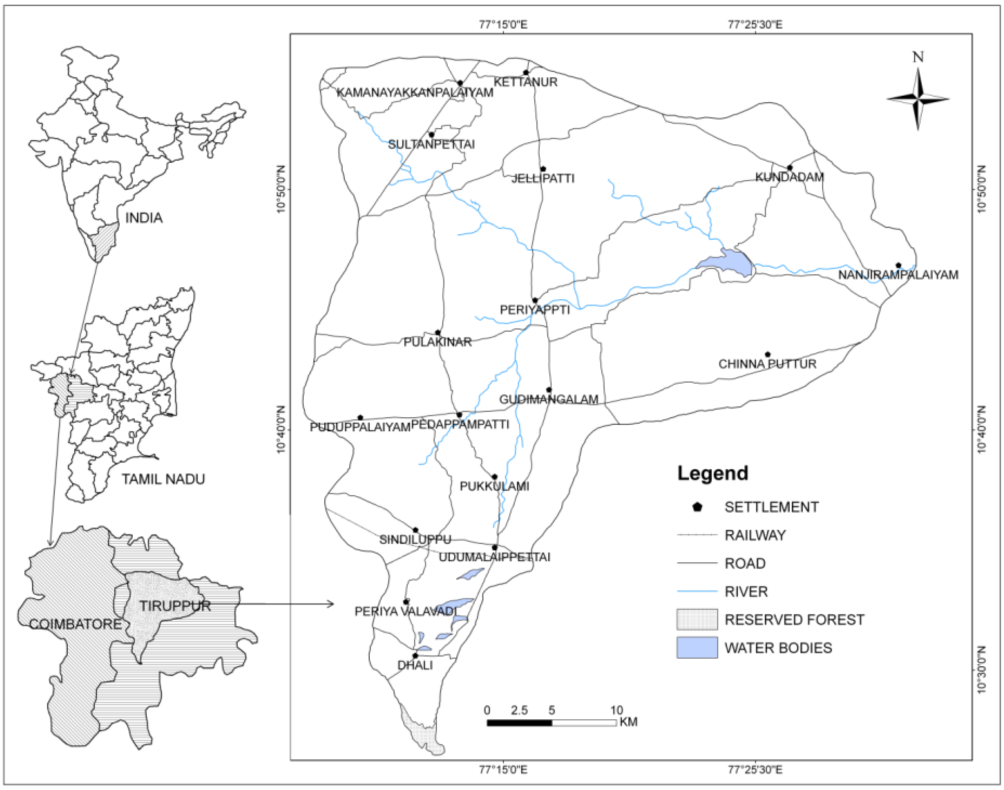

Figure 1: *Location map of the study area*

3.1. Geology Map

The study area is covered by the Precambrian age of crystalline rocks. The recent formation is marked by river alluvium and soil. Geological map of the study area was generated from Geology map of Tamil Nadu published by GSI (1969). The study area is characterized by outcrops of hornblende biotite gneiss, limestone and calcareous sandstone, charnockite, pink migmatite gneiss, felsic porphyry, pyroxene granulites and ultra-basic complex. Overall classified the geology ranked to seven, all the classes were merged together to form single class to weightage given by based on knowledge to one to five.

3.2. Drainage Density

In order to generate drainage density for the study area, the entire basin was divided into square grids of equal area of 1 km x 1 km. In each square grid the total length of streams of all order is measured. This was done for all grids and then points of equal drainage density were contoured. The drainage density for the study area is found to from zero to 4500 m per square kilometer. On the basis of drainage density the entire basin was divided into three zones like High, Medium and Low then rank and weightage given based on knowledge.

3.3. Lineaments Density

Lineament is defined as mappable, simple or composite linear feature on the surface whose parts is aligned in a rectilinear or slightly curvilinear relationship and differs distinctly from adjacent feature due to its distinct trend. Lineaments were delineated from FCC and PCA. Lineaments are of great importance in groundwater studies as they are considered to zones of maximum infiltration. They are considered to be surface manifestations of joints, fractures, faults and dykes. Dykes act as except for the central and S-E zone where land form is almost a plain. Major lineaments and intersection were delineated separately as it is an important factor in finding potential zones groundwater (Sitender and Rajeshwari, 2011). High lineament density is considered to be highly favourable location for potential groundwater zones.

3.4. Geomorphology

The regional geomorphological units were delineated based on the IRS P6 LISS III image characteristics like tone, texture, shape, colour, associations, background and also with considerations from the unsupervised classification, geology map and toposheets and visual interpretation was carried out. The units identified are linear, narrow and generally barren (Sitender and Rajeshwari, 2011). Structurally may be strike controlled feature and is of structural origin. Groundwater prospect is poor in this region. Structural Hills are mostly linear to arcuate hills showing definite trends associated with folding and faulting. Hills other than that of structural control are formed due to differential weathering and erosion.

Normally barren lands with sparse vegetation and poor groundwater potential. Valleys that are mostly fracture controlled and are of fluvial origin. Narrow valleys filled with unconsolidated sediments which are deposited by streams and rivers. Depending on to thickness of the fill, the groundwater prospects vary from very good to good.

3.5. Land Use /Land Cover

Land use/land cover plays important role in the occurrence and development of groundwater. Agricultural land, forest cover and settlement are the prominent land use types in the study area. The main land use/land cover units in the study area are agriculture land, settlement or built up areas. Water bodies, scrub land, outcrop area, forest, mudflat and salt affected areas. Of these various units, agricultural land and forest cover occupies maximum aerial extent.

3.6. Soil

Development planning of problematic lands particularly on watershed basis requires through knowledge of soil resources. The soil resource inventory provides information of various attributes e.g. texture, depth, slope, erosion, extent of salinity, water logging etc. Major portion of the study area is covered by Mixed Red and Black soil and also it covers maximum area in this region and small southern part of the study is covered by red sandy soil. These two soil types were classified fourth ranking and weightage given based on knowledge. All six thematic maps are shown in Figure 2.

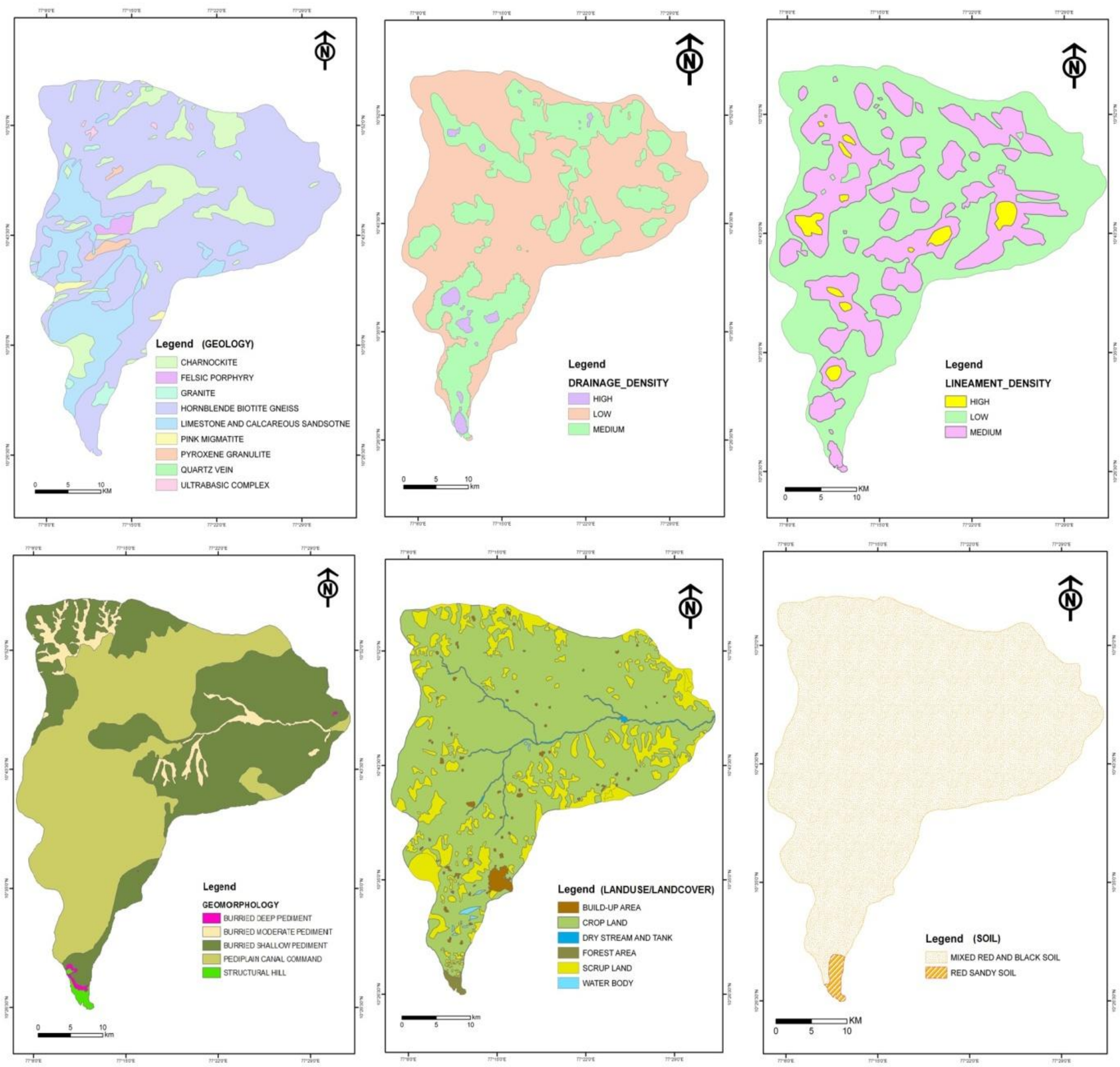

Figure 2: *Different parameters selected for groundwater accumulation in the study area*

4. Results and Discussion

The normalized weights of different features of the six themes were obtained in the similar manner as presented in Table 1. After deriving the normal weights of all the thematic layers and each feature under individual themes, all the thematic layers were integrated with one another using MapInfo GIS software in order to demarcate groundwater potential zones in the study area. In the first step, the geomorphology layer was integrated with the geology layer. The weight of each polygon of the integrated layer was derived by adding the weights of polygons of the original two layers and the process was continued for the remaining five themes to obtain a final integrated layer. The final weights of each polygon in the final integrated layer were derived by summing up the weights of polygons from individual layers and the highest derived sum of the weights in the final integrated layer was divided into three equal classes, i.e. 'high', 'moderate' and 'low', in order to delineate groundwater potential zones (Figure 3). The delineation of groundwater potential zones was done by grouping the polygons in the final integrated layer having weights of any of the three classes.

Groundwater potential map clearly indicate that alluvial plain which is composed of sand, silt and clay with nearly level slope and very low drainage density has excellent potentiality. Piedmont plain with gentle slope and low drainage density poses good to very good potential while plain with coarse to fine sand has good to moderate potential due to less water holding capacity. Structural hills and linear ridges with steep slope and high drainage density but due to presence of high lineament density offer poor to moderate potential. Structural hills with low lineament density, very steep slope and very high drainage density lie in very poor potential zones (Sitender and Rajeshwari, 2011). Thus the generated groundwater potential map serves as a base line for future exploration.

Table 1: *Thematic features, ranking and weights*

Thematic Maps	Classes Within Each Maps	Overall Ranking	Weights	Total Weights
Lineament Density	High	10	2	20
	Medium		4	40
	Low		2	20
Drainage Density	High	9	1	9
	Medium		4	36
	Low		5	45
Geology Map	Charnockite	7	2	14
	Felsic porphyry		3	21
	Granite		4	28
	Limestone and Sandstone		4	28
	Pink Migmatite		3	21
	Pyroxene Granulite		2	14
	Quartz vein		2	14
	Ultrabasic complex		2	14
	Hornblende Biotite Gneiss		4	28
Land use/Land cover	Build-up land	6	3	18
	Crop land		5	30
	River		1	6
	Reserved Forest		2	12
	Scrub land		4	24
	Tank		2	12
Geomorphology	Buried shallow pediment	5	2	10
	Buried deep pediment		4	20
	Pediplain canal command		1	5
	Structural Hill		5	25
	Buried Moderate pediment		3	15
Soil Map	Mixed Red and Black soil	4	3	20
	Red sandy soil		5	8

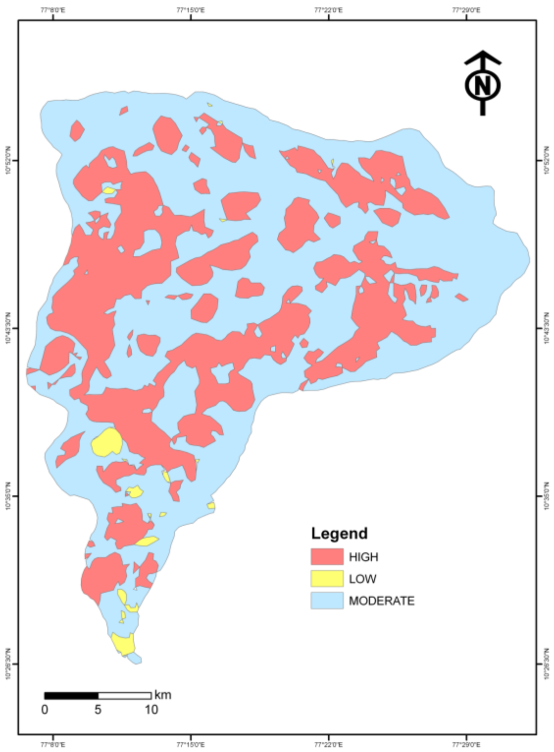

Figure 3: *Potential groundwater accumulations of the study area*

5. Conclusion

In the present study, multi-criteria evaluation technique using raster based GIS analysis is attempted to delineate the groundwater potential zones. Remote sensing and GIS have proved as vital tools in delineating groundwater potential zones based on the integration of various thematic maps. Occurrence of groundwater has a direct relationship with the geomorphology and slope of the area. In hard rock area potentiality for groundwater occurrence is influenced by the presence of lineaments. The groundwater condition in the major rocks such as Hornblende Biotite Gneiss, Charnockite in the study area is controlled by secondary porosities like joints and fractures. The lineaments and associated fractures and buried pediments are important zones which have potential groundwater and suitable for groundwater development for agriculture.

References

Anbazhagan, S. (2002). Remote Sensing and GIS Based Hydrological Studies in Kinzig Basin, Germany. Geomatics 2002, Conference on IT Enabled Spatial Data Services September 18-20, Centre for Remote sensing, Bharathidasan University Tiruchirappalli. 218-222.

Chaudhary, B.S., Manoj Kumar, Roy, A.K., & Ruhal, D.S. (1996). Application of Remote Sensing and Geographic Information Systems in Groundwater Investigations in Sohna Block, Gurgaon District, Haryana (INDIA). *International Archives of Photogrammetry and Remote Sensing, XXXI*(Part B6), 18-23.

Das, S., Behra, S.C., Kar, A., Narendra, P., & Guha, N.S. (1997). Hydrogeomorphological Mapping in Groundwater Exploration using Remotely Sensed Data – Case Study in Keonjhar District in Orissa. *Journal of Indian Society of Remote Sensing, 25*(4), 247-259.

Goyal, S., Bhardwaj, R.S., & Jugran, D.K. (1999). *Multi-criteria Analysis using GIS for Groundwater Resource Evaluation in Rawasen and Pilli Watershed, Uttar Pradesh.* Retrieved from http://www.gisdevelopment.net.

Krishnamurthy, J., Kumar, N.V., Jayaraman, V., & Manivel, M. (1996). An Approach to Demarcate Groundwater Potential Zones through Remote Sensing and Geographical Information System. *International Journal of Remote Sensing, 17*(10), 1867-1884.

Nag, S.K. (2005). Application of Lineament Density and Hydrogeomorphology to Delineate Groundwater Potential Zones of Bagmundi Block in Purulia District, West Bengal. *Journal of the Indian Society of Remote Sensing, 33*(4), 521-529.

Pratap, K., Ravindran, K.V., & Prabakaran, B. (2000). Groundwater Prospects Zoning using Remote Sensing and Geographical Information System: A Case Study in Dala-Renukoot Area, Sonbhadra District, Uttar Pradesh. *Journal of the Indian Society of Remote Sensing, 28*(4), 249-263.

Sitender & Rajeshwari. (2011). Delineation of groundwater potential zones in Mewat District, Haryana, India. *International Journal of Geomatics and Geosciences, 2*(1), 270-281.

Suja Rose, R.S., & Krishnan, N. (2009). Spatial Analysis of Groundwater Potential using Remote Sensing and GIS in the Kanyakumari and Nambiyar Basins, India. *Journal of the Indian Society of Remote Sensing*, 37(4), 681-692.

Todd, D.K. (1980). *Groundwater Hydrology*. Second Edition. New York: John Wiley and Sons Inc. 556.

Vijith, H. (2007). Groundwater Potential in the Hard Rock Terrain of Western Ghats: A Case Study from Kottayam District, Kerala using Resourcesat (IRS-P6) data and GIS Techniques. *Journal of the Indian Society of Remote Sensing, 35*(2), 163-171.