Delineation of ground water potential zone in Sweta sub-watershed using remote sensing and GIS in parts of Perambalur district of Southern India

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Abstract: Perambalur district has been declared as one of the over exploited regions in Tamil Nadu by the Central Groundwater Board. Therefore, it is very important to delineate potential for groundwater development and management. Perambalur district is partially and ephemerally drained by Sweta sub-watershed which extends over an area of 730 km^2. The study area exhibits dendritic and sub dendritic drainage patterns with maximum of 6th order drainage. In the present study, groundwater potential zones have been delineated with the help of Remote Sensing (RS) and Geographic Information System (GIS) techniques. In this study, a standard weight and rank method is adopted to identify groundwater potential zone using integration of RS and GIS techniques. The parameters considered for identifying the groundwater potential zone are geology, geomorphology, slope, drainage density, lineament density and land use / land cover which are generated using the satellite data and survey of India (SOI) toposheets at the scale of 1:50000. They are then integrated based on rank and weightage method in GIS platform and classified into five categories such as very poor, poor, moderate, good and excellent. Rank and weightage has been assigned based on the interpreter's prior knowledge. The integrated analysis showed that about 41% of the area falls in the category of excellent and good; rest are in other categories. This groundwater potential information will be useful for effective identification of suitable locations for extraction of groundwater for drinking and agricultural purpose.

Keywords: Groundwater, Remote sensing, GIS

1. Introduction

Perambalur district in Tamil Nadu faces severe water scarcity since last decade in all sectors, especially in domestic and agricultural. It is mainly due low annual rain fall, monsoon failure and over exploitation of ground water. Water is an important constituent of all forms of life and is required in sufficient quantity and quality to meet the ever increasing demand for various sectors. Exploitation of groundwater in uncontrolled manner led to decrease in groundwater potential, lowering of groundwater level and deterioration in groundwater quality. It is therefore necessary to develop sustainable groundwater management scheme for proper utilization of this natural resource, which in turn requires delineation of groundwater potential zones. Remote sensing (RS) is one of the best tools for delineating groundwater potential zone because of it facilitates identifying and demarcating various parameters that may serve either as direct or indirect indicators for groundwater availability. Geographic Information System (GIS) is being used for various purposes such as feasibility study of recharge sites, finding contaminated sites etc. The main objective of the present study is to locate the favourable groundwater zone using weight and rank method with the help RS and GIS.

Many geoscientists and hydrogeologists like Murthy (2000), Naga Rajani et al. (2006), Preed Kumar (2009), Nagaraju et al., (2011) and Waiker and Nilawar (2014) have used RS and GIS techniques for groundwater exploration and identification of artificial recharge sites. Ravi and Mishra (1993), Jaiswal et al. (2003), Jothiprakash et al. (2003), Prasad et al. (2008), Chowdhury et al. (2009) have utilised RS and GIS techniques to delineate groundwater potential zones. GIS has also been considered for multi-criteria analysis in resource evaluation. Boutt et al. (2001) and Elkadi et al. (1994) have carried out groundwater modelling through the application of GIS. In the present study Landsat satellite data acquired on March 2013 has been used for preparation of various thematic maps such as base, drainage, geology, lineament, geomorphology, drainage-density and land use/land cover. Aster DEM has been used for slope calculations.

2. Study area

The study area lies between 78°30'- 11°32' and 78°58'- 11°15' of Perambalur district, Indian state of Tamil Nadu and is situated about 60 km from Tiruchirappalli in southern direction. Study area covers about 730 km^2, which comprises of numerous villages and drought prone areas of Perambalur district. The entire area is drained by a small stream Sweta, which flows west to east. The basin is characterized by poor soil cover, erratic rainfall and lack of soil moisture for most part of the year (Fig. 1). Frequent drought coupled with over exploitation results in decline in groundwater levels. In order to manage and develop sustainable development, it is essential to delineate the groundwater potential zones in this watershed.

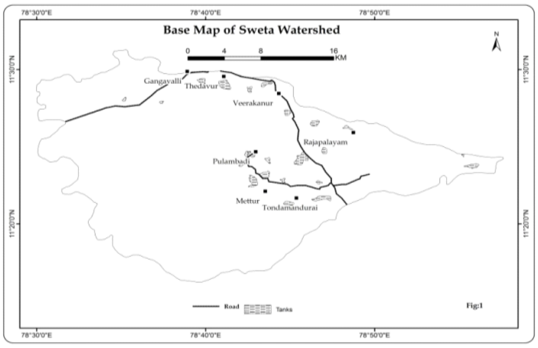

Figure 1: Base map of Sweta watershed

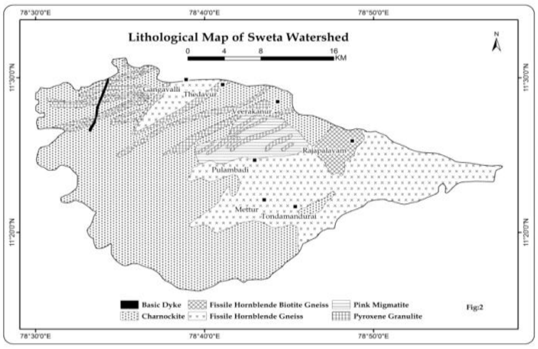

Figure 2: Lithology map of Sweta watershed

3. Methodology

There are six important indicators namely, (i) Geology, (ii) slope, (iii) geomorphology, (iv) land use / cover, (v) drainage and (vi) lineament for groundwater prospects. Preparation of maps for these themes (except slope) based on image characteristics such as tone, texture, shape, colour and association are standardised. Slope is derived from ASTER DEM 30m resolution (www.jspacesystems.or.jp /ersdac/ GDEM/E/2.html). Thematic maps of the study area were prepared.

To get wholistic view of the above mentioned indicators, overlay analysis is required. Assignment of rank to an individual class was based on influence of these themes as reported in literature (Krishnamurthty et al., 1996; Saraf and Chowdhary, 1998). Rank and weight based thematic layers were integrated through GIS to find out the resultant groundwater potential zones. Overlay analysis was carried out from the derived multi thematic layers in a GIS environment. ARCGIS software was used for the same.

4. Result and discussion

4.1 Geology

The study area comprises Archaean to late Proterozoic rocks which include Pyroxene granulite, Migmatite, fissile Hornblende gneiss, fissile Hornblende biotite gneiss, Charnockite and intrusive basic dyke. Western part of the hill exposes massive charnockite whereas the eastern part of plain area is covered by fissile hornblende gneiss rocks. Youngest litho unit observed in this area is basic dyke which is trending NNE-SSW direction (Fig. 2). The trend of the dyke is akin to the Attur – Gangavalli shear zone. Lithological distribution in the study area is given in table 1. Charnockite is the major rock type exposed in the study area covered over an area of 398.78 km^2(54.57%) followed by fissile hornblende gneiss about 219.02 $km^2$and rest of the rock types covered small portion of the study area.

Table 1: Area coverage for lithological units

Sr. No	Description of Lithology	Area (km^2)	Area (%)
1	Fissile Hornblende Biotite Gneiss	19.33	2.65
2	Fissile Hornblende Gneiss	219.02	29.97
3	Pink Migmatite	34.26	4.69
4	Pyroxene Granulite	57.71	7.90
5	Charnockite	398.78	54.57
6	Basic Dyke	1.62	0.22

4.2 Slope

The slope is one of the important factors for controlling the residence time of runoff water and thereby the infiltration of groundwater into the subsurface of any terrain. Hence, it is also one of the indicators for the suitability for groundwater prospect. Surface runoff is slow where the slope is gentle and also allows more time for rain water to percolate which leads to more infiltration. Slope of the area varies from 0 to 58.45 degree which is derived from ASTER DEM 30m resolution (www.jspacesystems.or.jp /ersdac/ GDEM/E/2.html) and is shown in figure 3. The slope of the area is classified into five classes based on the method given by Patil and Mohite(2014).

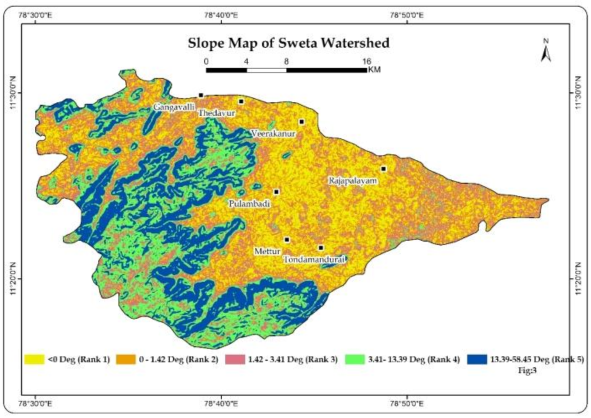

Figure 3: Slope map of Sweta watershed

4.3 Geomorphology

Geomorphological units are very important for the identification and characterization of various landforms and structural features in the study area for groundwater development and management activities. Geomorphologic units are delineated based on image characteristics such as tone, texture, shape, colour and association of features. Structural hills and Inselbergs are observed on western part of the study area, which mostly act as runoff zones due to their sloping topography. This results in poor potential for groundwater occurrence and recharge. Shallow pediments, which have considerable slope with less thickness of sediments indicate moderate occurrences of groundwater. Valleys are low lying depressions formed longitudinally along the streams or amongst the ridge portions, which show excellent potential for groundwater occurrence and recharge. Colluvial fills also have high potentiality of groundwater (Fig. 4). By extraction of various classes of geomorphology, a thematic map for geomorphology is generated (Fig. 4). The ranks and weight were assigned to the individual landform, according to their respective influence of groundwater occurrence, holding and recharge, as given in table 2. In the study area, structural hill covered over an area of 246.42 km^{2}followed by shallow pediment 189.02 km^2, colluvial fill 117.97 km^2, valley fill etc.

Table 2: Area coverage for geomorphological units

Sr. No.	Geomorphological Units	Area (km^2)	Area (%)
1	Colluvial Fill	117.97	16.23
2	Valley Fill	104.28	14.34
3	Plateau Dissected	58.49	8.05
4	Bajada	10.90	1.50
5	Shallow Pediment	189.02	26.00
6	Structural Hill	246.42	33.89
7	Inselberg	4.16	0.57

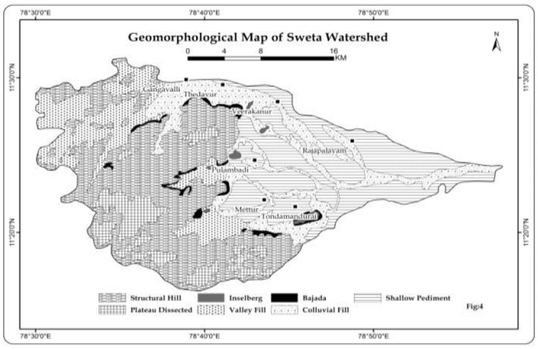

Figure 4: Geomorphological map of Sweta watershed

4.4 Landuse / landcover

Baseline information about occurrences of surface and groundwater can be directly or indirectly obtained using landuse / landcover information of that particular area. RS and GIS tools play a vital role in mapping of land use / land cover pattern of any terrain (Fig. 5). The effect of land use / land cover is manifested either by reducing runoff and facilitating, or by trapping water on their leaf. Land use / land cover distribution in percentage as well as in km^2 is listed in table 3. Majority of the study area is crop land covered over an area of 395.77 km^2, followed by forest area, fallow land etc.

Table 3: Area coverage for land use /land cover units

Sr. No.	Categories	Area (km^2)	Area (%)
1	Crop Land	395.77	54.12
2	Plantation	4.59	0.63
3	Salt Affected Land	8.39	1.15
4	City/Town	1.09	0.15
5	Barren Rock	8.59	1.18
6	Land with Scrub	16.88	2.31
7	Forest	237.75	32.51
8	Tanks	7.98	1.09
9	Gullied/Ravenous Land	7.84	1.07
10	Fallow Land	42.45	5.80

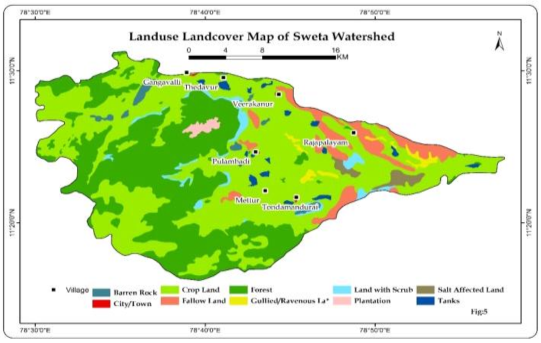

Figure 5: Land use/ land cover map of Sweta watershed

4.5 Drainage

The drainage of the study area shows dendritic to sub dendritic pattern, the drainage is highly dense in hilly region with steep slope noticed on the western part. Moderate to low density observed is on eastern side part where the slope is gentle. Seasonal streams are noticed in this area which are flowing from west to east towards the Sweta river (Fig. 6). By extraction of drainage density features, a thematic map is generated. It is classified into five zones according to their respective drainage density as shown in figure 7.

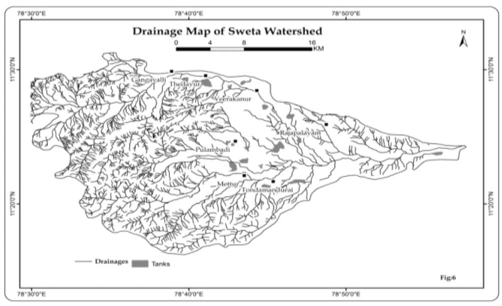

Figure 6: Drainage map of Sweta watershed

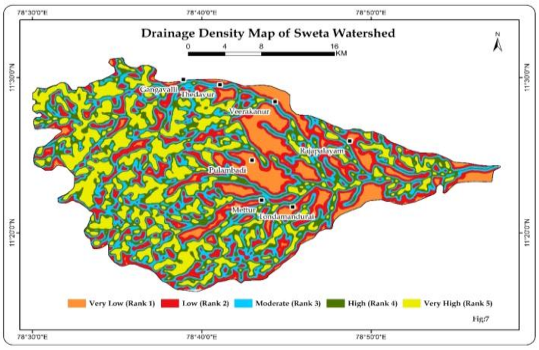

Figure 7: Drainage density map of Sweta watershed

4.6 Lineament

Lineaments are the surface manifestation of subsurface weakness or structural displacement and deformations. It represents deep seated faults, fractures and joints sets, drainage lines and different litho-contacts. In hard rock terrains, lineaments are represented by areas and zones of faulting and fracturing which results in increased secondary porosity and permeability. Lineaments are linear and curvilinear feature that are significant for groundwater, mineral and metal explorations and exploitations. Lineament map (Fig. 8) is prepared from satellite imagery and the lineament density is derived from the lineament map (Fig. 9). High density zone represents the maximum intersection of lineaments and favourable zone for any kind of mineral and groundwater exploration activities. The lineament analysis provides important information on subsurface fractures that may control the movement and storage of groundwater.

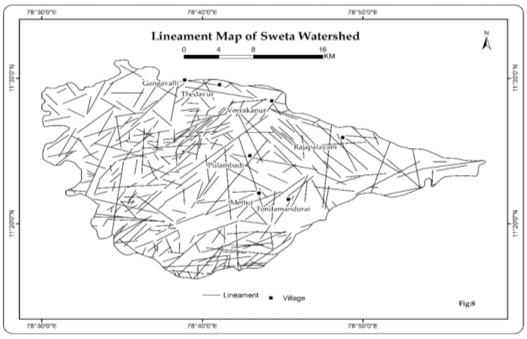

Figure 8: Lineament map of Sweta watershed

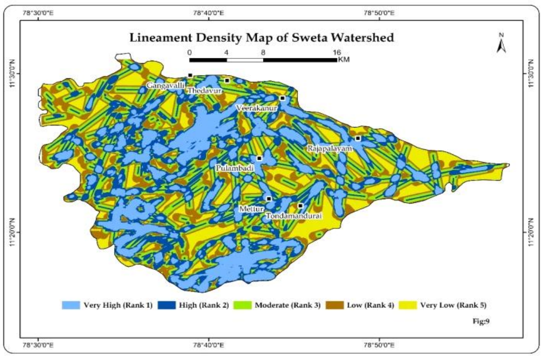

Figure 9: Lineament density map of Sweta watershed

4.7 Assigning of rank and weights

Overlay analysis has been carried out from the available multi thematic layers with the help of assignment of rank to the individual class and assigning weights to the individual features by considering their influence over the occurrence and movement of ground water. The weights and rank have been taken considering the work carried out by researchers such as Krishnamurthty et al. (1996) and Saraf and Chowdhary(1998). In this method, all the thematic layers were converted into raster format. Rank and weight based thematic layers were integrated through GIS to find out the groundwater potential zones. The ARCGIS software has been used for preparation of thematic maps, integration analysis /overlay analysis in GIS environment. The rank and weight assigned for the features are given in table 4.

Table 4: Ranks and weights of parameters for groundwater recharge potential zones

Parameter	Classes	GW Prospect	Wt %	Rank
Geomorphology	Colluvial Fill	Very Good	20	1
	Valley Fill	Very Good		1
	Plateau Dissected	Good		2
	Bajada	Good		2
	Shallow Pediment	Moderate		3
	Structural Hill	Poor		4
	Inselberg	Very Poor		5
Slope	< 0	Very good	25	1
	0 - 1.42	Good		2
	1.43 - 3.41	Moderate		3
	3.42 - 13.49	Poor		4
	13.40 - 58.45	Very Poor		5
Drainage Density	<0.00	Very Good	5	1
	0 - 1.02	Good		2
	1.02 - 2.01	Moderate		3
	2.01 - 3.09	Poor		4
	3.09 - 7.66	Very Poor		5
Lineament Density	<0.00	Very Good	20	1
	0 - 0.94	Good		2
	0.94 - 1.26	Moderate		3
	1.26 - 2.10	Poor		4
	2.10-5.83	Very Poor		5
Land use Land cover	Crop Land	Very Good	25	1
	Plantations	Good		2
	Tanks	Good		2
	Forest	Moderate		3
	Fallow Land	Moderate		3
	Gullied/Ravenous Land	Moderate		3
	Land with Scrub	Poor		4
	Salt affected Land	Poor		4
	Barren Rock	Very Poor		5
	City/Town	Very Poor		5
Lithology	Fissile Horn. Bio- Gneiss	Very Good	5	1
	Fissile Horn. Gneiss	Good		2
	Charnockite	Moderate		3
	Pyroxene Granulite	Poor		4
	Pink Migmatite	Poor		4
	Basic Dyke	Very Poor		5

4.8 Discussion

The present study has resulted in identifying various groundwater potential zones based on geologic, geomorphic and hydrologic parameters such as geomorphology, lithology, slope, land use / land cover, drainage density and lineament density. During the weighted overlay analysis, the ranks have been given for each individual parameter of each thematic map and the weight is assigned according to the influence of the different parameters. The weights and rank have been taken by considering researchers' knowledge about the area (Krishnamurthty et al., 1996; Saraf and Chowdhary, 1998). Based on these analysis, groundwater potential zones were demarcated. This map has been categorized into five classes such as very poor, poor, moderate, good and excellent. The detail of the area covered is given in table 5. In this study, it is observed that the good and excellent area covers almost 41% of the study area (Fig. 10).

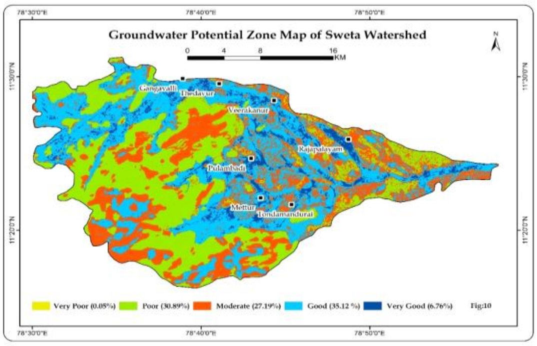

Figure 10: Groundwater potential zone map

Table 5: Area distribution for groundwater potential zones

Sr.No	Potential Zones	Area (km^2)	Area (%)
1	Very Poor	0.33	0.05
2	Poor	225.98	30.89
3	Moderate	198.96	27.19
4	Good	256.91	35.12
5	Excellent	49.44	6.76

The groundwater potential zone categories good and moderate are falling in the plain area of Gangavalli, Thedavur, Veerakanur, Rajapalayam, Pulambadi, Mettur and Thondamandurai. Most of these areas are coming under the over exploitation block of Vepanthattai in Perambalur district. Therefore, the state and central groundwater board can concentrate on these resulted zone of good and moderate categories for drilling new bore wells. In addition, along the Gangavalli shear zone also groundwater potential zones were delineated. Hence, this area can be considered for future drilling programme for groundwater exploration. However, resolution of satellite imagery and its geometric correction procedure, ASTER DEM data resolution are having some limitations in this approach that should be considered before proceeding to drilling activity.

5. Conclusion

The present study carried out for groundwater exploration has brought to light few important zones for ground water extraction for drinking as well as irrigation purpose. The study area is a hard rock terrain, therefore the availability of groundwater is mainly based on the structural porosity and permeability. The integrated groundwater potential zone map for the study area is categorized into five qualitative classes which are very poor, poor, moderate, good and excellent. Most of the good and excellent areas are located in the NW of Attur - Gangavalli shear zones and Eastern part where most of the excellent parts fall all along the colluvial fills. Among 730 km^2, 306 km^2 falls under the good and excellent categories.

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References

Boutt, D.F., D.W. Hyndman, B.C. Pijanowski and D.T. Long (2001). Identifying potential land use-derived solute sources to stream base flow using ground water models and GIS. Groundwater, 39(1): 24–34.

Chowdhury, A., M.K. Jha, B.C. Mal and V.M. Chowdary (2009). Delineation of groundwater prospect zones using remote sensing and geographical information system techniques: A case study. Proceedings of the International Conference WEES - 2009, New Delhi, Conducted by NIH, (1): 1975–1981.

Nagaraju, D. C. Papanna, S. Iddalingamurthy, Lakshmamma, Mohammad Subhan lone, P.C. Nagesh, G. Mahadevaswamy and Krishna Rao (2011). Identification of groundwater potential zones through remote sensing and GIS techniques in Kollegal taluk, Chamarajnagar district, Karnataka, India. International Journal of Earth Sciences and Engineering, Vol. 04, No. 04, 651-658.

Elkadi, A.I., A.A. Oloufa, A.A. Eltahan and H.U. Malik (1994). Use of a geographic information system in site specific groundwater modelling. Groundwater, 32(4), 617–625.

Jaiswal, R.K., S. Mukherjee, J. Krishnamurthy and R. Saxena (2003). Role of remote sensing and GIS techniques for generation of groundwater prospect zones towards rural development–An approach. International Journal of Remote Sensing, 24(5): 993–1008.

Jothiprakash, V., G. Marimuthu, R. Muralidharan and N. Senthil Kumar (2003). Delineation of potential zones for the artificial recharge using geographical information system. Journal of the Indian Society of Remote Sensing, 31(1): 37–47.

Patil, S.G. and N.M. Mohite (2014). Identification of groundwater recharge potential zones for a watershed using remote sensing and GIS. International Journal of Geomatics and Geosciences, 4 (3), 485 – 498.

Pradeep Kumar, G.N., (2009). Demarcation of groundwater prospect zones through RS and GIS techniques in a basin. Indian Geotechnical Society (IGC), 819 - 822.

Saraf, A. and P.R. Choudhary (1998). Integrated remote sensing and GIS for ground water exploration and identification of artificial recharge site. Int. J. RemoteSensing 19, 1825–1841.

Krishnamurthy, J., K.N. Venkatesan, V.Jayaraman and M. Manivel (1996). Anapproach to demarcate groundwater potential zones through remote sensing and geographic information system. Int. Journal of Remote Sensing 17, 1867-1884.

Waikar, M.L. and A.P. Nilawar (2014). Identification of groundwater potential zone using remote sensing and GIS technique. International Journal of Innovative Research in Science, Vol. 3, Issue 5, 12163-12174.